ANALYSIS OF A NATURAL REGENERATION OF SCOTS PINE FOREST IN THE HIGH CAMPINE AFTER A FIRE.

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Abstract

The study deals with the spontaneous resettlement of a fire area, after destruction of 600 ha Scots Pine forest. The following items have been examined in particular : the composition of the tree species, the duration of the regeneration period, the influence of the parent stand, the exposition, the slope, the treatment, the fire regime and the social differentiation.
The resettlement took place very quickly and over a very short period. Birch and Scots pine take up 95 % of the stem number. The regeneration result is precarious, yet mostly good. The parent stand is favorable both to seed supply and to microclimate, but only over a short distance. The Scots pine prefers more open and dry areas, whereas birch needs more humidity.
Practice has shown that natural regeneration of Scots pine stands is possible. The forest treatment, however, is very important. It determines not only the immediate result of the regeneration, but also the composition and the structure of the future stand.

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1. INTRODUCTION AND PROBLEMS

In former times the High Campine, a region situated in the N-E of Belgium, was covered with an oak-birch forest. This forest, however, was destroyed in the course of time and has been replaced by heather-land. In the last centuries, especially since 1850, these heather-lands have been reafforestated with vast homogeneous scots pine forests.
Due to several reasons, as well of economic as of silvicultural nature, these homogeneous Pine forests must be converted slowly. The objective is to create a mixed forest, with hardwoods and conifers, the former having a cultural significance and the letter, on the other hand, playing a more economic role.

On many places a spontaneous ingrowth of hardwoods occurs in the old pine forest (Lust, 1987). In order to achieve this, a large enough presence of mutter trees is required. In this evolution the red American oak plays an important role, as it regenerates easily under the pine cover on these sites and under the given ecological circumstances.
The natural regeneration can and has to play an important role in the conversion of these pine forests. Nature showed, not only hardwoods, but also the Scots pine themselves are able to regenerate in a natural way. On many places a spontaneous settlement took place after clear cutting or after fire. In this process, the part of birch is also significative. This pioneer species, which is able to regenerate abundantly, protects the regeneration of the other tree species (Fiedler, 1962).

An interesting phenomenon has risen after the great forest fires of 1976 in the commune of Dilsen. That summer, about 600 ha Scots pine forest were destroyed. Yet afterwards, the soil was resettled very quickly, especially with birch and Scots pine.
A study of the mechanism of these natural phenomena can contribute to the future forest treatment. It can indicate the way foresters themselves have to lead the process of regeneration.
In this study, which was carried out 6 years after the fire, special attention was given to the following items : the regeneration result, the influence of several factors, more particularly the situation of the parent stand, the exposition, the slope, the treatment and the fire regime, the duration of the regeneration period and the social differentiation.

2. OBJECT AND METHODOLOGY

The forest region is situated on an altitude of about 60 to 90 m. The soils are dry and sandy and with a little clear humus and/or iron B-horizon, with a thin humous top-soil and with admixture of gravel (Baeyens, 1972). The average annual precipitation amounts to about 800 mm and the average annual temperature is 8,5°C.
Experimental stands were selected dispersed over the fire area. In each of these stands a number of sample plots were established. Their situation, dimension, and their number correspond to the specific circumstances and the preconceived purpose (Fig. 1).

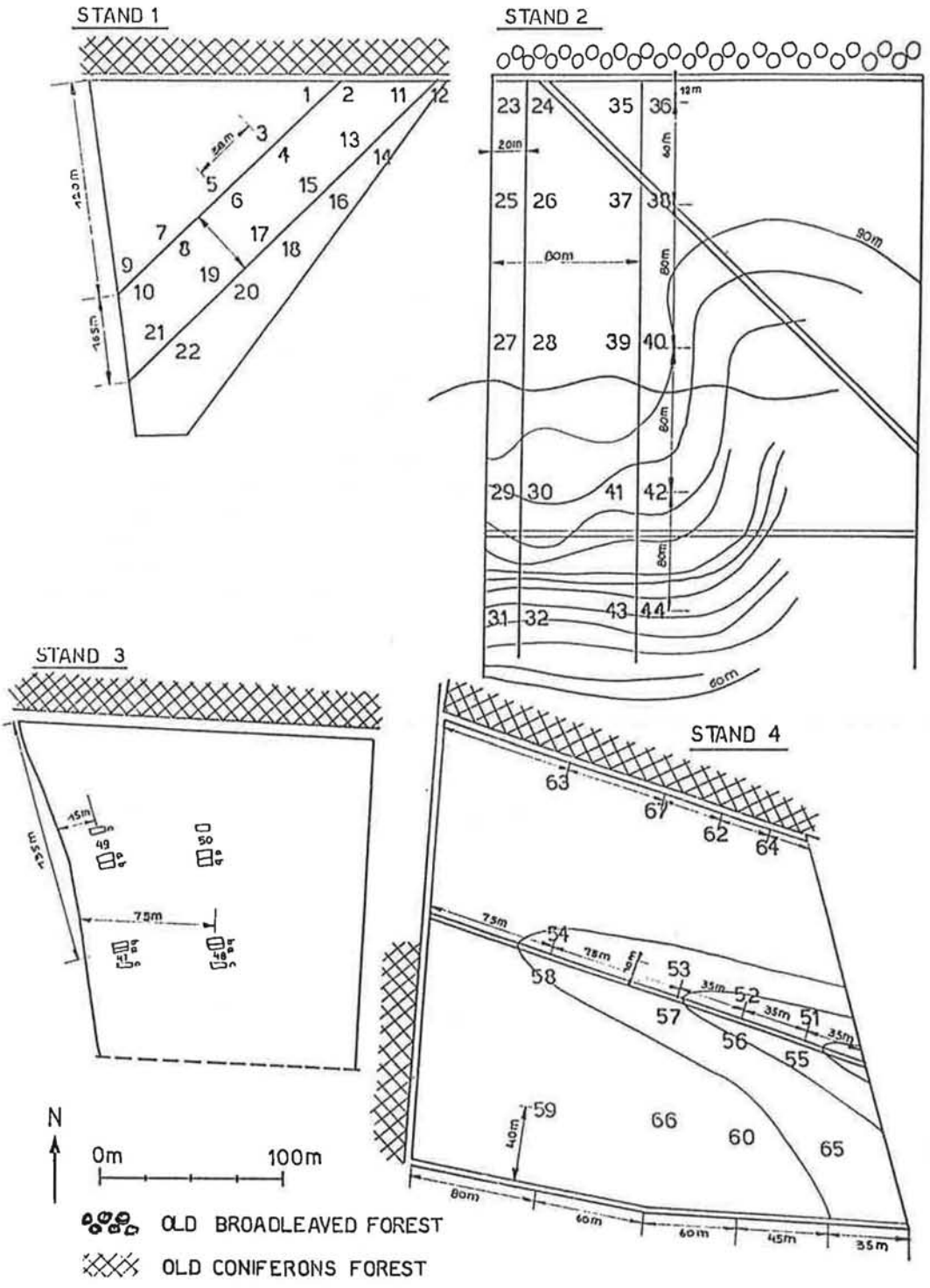

Fig. 1. Situation of the sample plots within the different stands.

- Stand 1 : an old pine forest in the north ; 22 circular sample plots of 25 m² were established on an ever increasing distance to the old conifer forest.

- Stand 2 : an old hardwood forest in the north; this stand was especially chosen in order to examine the influence of the slope and the exposition ; the northern part is float; the southern part, on the contrary has a south exposition with an altitude varying from 60 to 90 m ; 20 circular sample plots of 100 m² were established ; each time 4 plots were laid out on a determined distance to the adjacent hardwood forest.

- Stand 3 : an old pine forest in the north; it was intended to examine the influence of the treatment. The vegetation was mown by strips (with a clapper-mover).
  Four groups of three rectangular plots, each cover 10 m², were laid out. The sample plot a lays on the mowed strip, the plot b borders on a, yet on a not mowed strip, the plot c lays 10 m further in a zone that has not been treated.

- Stand 4 : an old pine forest in the north and partly in the west; characteristic is the south exposition of the northern part and the north exposition of the southern part ; 16 circular sample plots of 25 m² were established in 4 rows, with four plots in each case.

In all these stands the following 4 basic-measurements were carried out : tree species, height, diameter on half height.
In stand 1, a disk of 10 pines and 10 birches was taken in each sample plot, in order to determine the age. The annual shoot length of the pines was also measured, whereas this proved to be rather difficult with the birches; here only the shoot length of the last year could be measured with accuracy.

3. ANALYSIS OF THE NATURAL REGENERATION

3.1. Species, number and variation

Several authors have already pointed out the very heterogeneous character of natural regenerations on fire areas, even when the site could be considered as relatively homogeneous before the fire (Ahlgren, 1960 ; Lust, 1973 ; Jahn 1980).
The differences are caused especially by the thickness of the organic layer before the fire and by the intensity of the fire, both of which can vary very strongly on a short distance. Consequently there great differences were found in the quality of the seedbed.
As a standard for the evaluation of the regeneration result, Rottmann (1981) mentions that 20,000 seedlings per ha are enough to form quality-stands. Based on this, the following classification was made :

- very good regeneration result : N > 200 per are
- good regeneration result : N between 100 and 200 per are
- relatively good regeneration result : N between 50 and 100 per are
- small regeneration result : N between 20 and 50 per are
- bad regeneration result : N between 0 and 20 per are

On the 70 experimental plots, which cover a total area of 3,070 m², 5,696 young trees were measured (Tab. 1). Three points are remarkable :

Table 1. Total number of samplings

Species	absolute number	number/ha	%
Betula spp.	3,352	10,919	58,85
Pinus sylvestris	2,025	6,596	35,55
Salix aurita	136	443	2,39
Quercus rubra	70	228	1,23
Quercus petraea	44	143	0,77
Fagus sylvatica	22	72	0,39
Prunus serotina	21	68	0,37
Populus tremula	16	52	0,28
Rhamnus frangula	6	20	0,10
Castanea sativa	3	10	0,05
Sambucus nigra	1	3	0,02

1. The total number of stems reaches 18,554 per ha, which can be considered as a good result.
2. In all, 11 species occur in the regeneration. Considering the large-scale homogeneous pine forest, on poor sandy soils, this is a very good result.
3. Almost 95 % of the stem number is taken up by two species, birch and Scots pine. The birch is taking up near 60 %, the pine 35 %.

As to stem number and height, birch takes up, as a pioneer tree, a dominant position. The birch is found everywhere in the surroundings, so seed dispersion is not a problem. It germinates and survives on the clear cut area and on the extreme situation of the fire area.
The natural seedling of the Scots pine occurs with more difficulty. The seed density depends on many factors : seed year, seed bank, supply of seed descended from burnt mutter trees or from adjacent stands, fire regime, etc. The seed-bed can differ too.

The nine other species, all hardwood species, represent hardly 5,6 % of the total, namely 1,039 per ha. They can, however, play an important role in the future stand, especially on the cultural level, but also economically speaking. The near-absence of black cherry is remarkable, though this species can play a dominant role on other places in the Campine (Lust, 1987). Is the soils perhaps too poor or too dry ?

The results, however, are not always the same in the different stands(Tab.2).

Table 2. Average stem number of the regeneration in the different stands (per are).

Stand nur.	birch		Scots pine		all spp.	
	$\bar{N}$	s	$\bar{N}$	s	$\bar{N}$	s
1	66	66	197	134	266	178
2	29	32	14	23	52	55
3	460	121	173	106	644	150
4	462	476	114	129	604	498
Total	214	304	122	130	347	354

Besides there is, within the most stands themselves, still a great variation between the different plots. Only in stand 3 this is not the case. Here the regeneration is dense and uniform. The starting situation was relatively homogeneous too.
The variation between the stands is shown by the number of sample plots with the same qualification (Tab. 3).

Table 3. Qualification of the number of sample plots per stand.

Qualification	Stand nr.				Total
	1	2	3	4	
very good	15	1	12	11	39
good	4	3	0	4	11
relatively good	1	1	0	1	3
small	2	11	0	0	13
bad	0	4	0	0	4

Generally speaking, the results are good in the stand 1, 3 and 4. They are insufficient in stand two, which is not surrounded by old pine stands, but only in the north by a hardwood forest. So the presence of a parent stand seems to be important, if not necessary. Nevertheless the question also arises why the regeneration of the birch is carce here too ? It is quite obvious, that there are still other mhenomena determining the parent stand. In stand 1 Scots pine is dominating. On some places the regeneration is insufficient, so that it is necessary to fill in artificially. In the meantime stand 2 was already interplanted with Corsican pine. The result is very good in the stands 3 and 4. In both stads birch is dominating the Scots pine. Stands 3 looks like a homogeneous birch stand. The liberation of the Scots pine is a necessity. In stand 4 Scots pine is not dispersed equally over the area, yet the birch assures a complete occupation.

3.2. Duration of the regeneration period

The beginning and the duration of the regeneration period has been determined by assessing the age of the greatest and the smallest birches.
In each sample plot 5 small and 5 large trees were measured. The age was determined by counting the year-rings. With the Scots pine, the branch whorls were counted too. This method often gave a result which was one year more than the result after counting the year rings.

Therefore with both species 110 small and 110 large trees were measured (Fig. 2). Some points are remarkable.

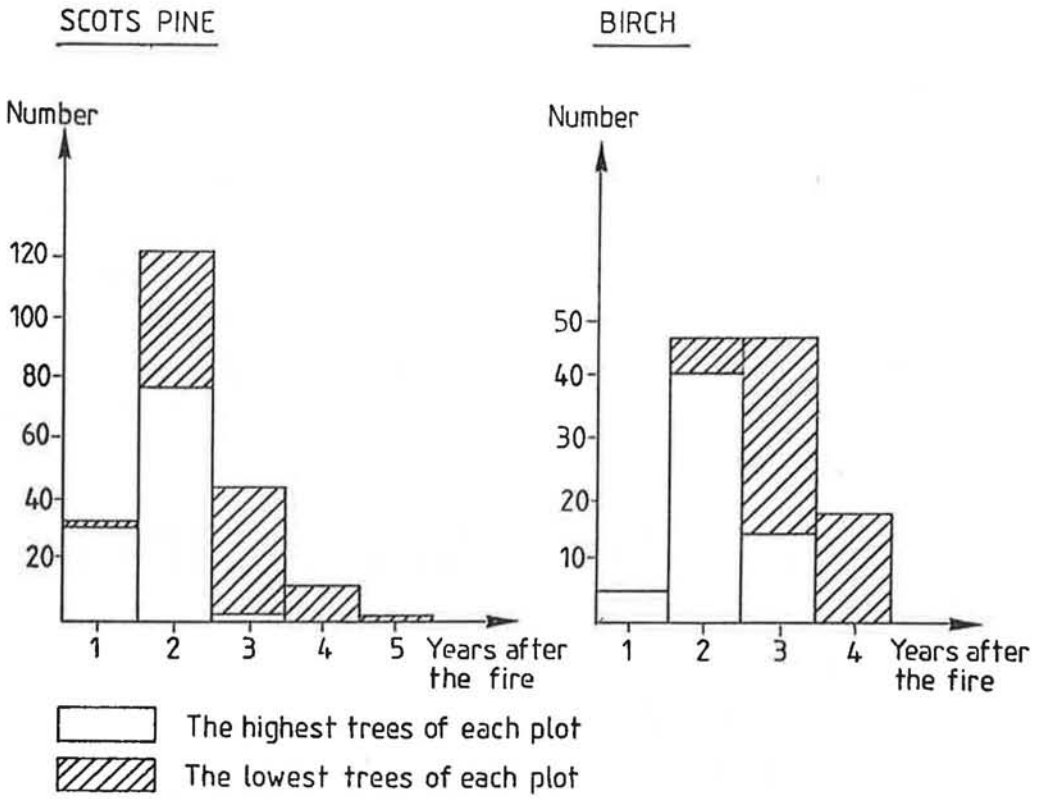

Fig. 2. Course of the settlement of Scots pine and birch.

1. The first year following the fire, regeneration was still very limited, although it was more important with Scots pine than with birch. It is however, not clear why the regeneration does not start immediately : lack of seed (birch), unfavourable climatological circumstances, insufficient decomposition of the litter layer.

2. The regeneration occurs mainly in the second and the third year. With the Scots pine 56 % of the samplings settled during the second year, and another 20 % during the third year. With the birch, the settlement during the third year was as great as during the second year.

3. The fourth yeaf after the regeneration, there was still a certain after-regeneration, especially with the birch. After the fourth year, practically no seedlings have settled anymore. Therefore the regeneration period is very short. It takes hardly 4 years. Twenty five percent of the plants settled during the second and the third year.

4. Though the regeneration period, is relatively short, there is a clear difference in settlement between the largest and the smallest plants.

- With the Scots pine, the greatest plants have settled the first and the second year after the fire. Almost half of the smallest trees settled also during the second year. They kept growing, however, and were soon completely overgrown. An important number of small trees settled also during the third and the fourth year.

- with the birch, which generally have settled a bit later, the highest trees appear also the second year, yet in the third year their number is considerable too. The latter have grown very quickly. With the birch the number of small trees, which settled early, is rather low? The greatest part of the trees, settled in the beginning, are growing quickly.

After only 4 years, the circumstances for regeneration have become very unfavourable. At the same time it is obvious that the upper storey will be built up soon by the oldest trees.

3.3. Factors affecting the regeneration

Regeneration is always determined on one hand by stimulating forces and on the other by limiting factors. Unfortunately,very little is known nowadays about the fundamental phenomena of the natural regeneration. Why a regeneration takes place here and now and not elsewhere ?

It is generally accepted that the situation of the litter layer is very important, yet this is certainly not the only factor. Climatological and ecological circumstances play a role too : the presence of light energy, minerals and water, the temperature-features, and the presence of hindering vegetation, such as heather. Precisely on the involved fire areas also the heather has regenerated very quickly.
Apart from that, it is common knowledge that heather hinders regeneration even makes it impossible.
This process, however, is not examined on the spot. Attention has well been payed to the situation of the parent stand, the exposition, the slope and the treatment.

3.3.1. The situation of the parent stand

The distance and the exposition of the parent stand are important factors. In the present research, all sample plots are situated on less than 200 m from stand that had not been burnt. This is important for the dispersion of the seed.
The parent stand affects also the micro-climate in the surroundings, light energy, air humidity, CO_2-content, wind velocity, temperature characteristics, etc. Generally speaking the parent stand has a favourable influence.

3.3.1.1. Result in stand 2

Stand 2 is bounded on the north by an old hardwood stand (see fig. 1). The twelve most northerly situated sample plots (nrs 23-28 and 35-40) are situated at the same altitude. Therefore the distance to the old forest can be considered here as the only variable. The 8 other sample plots are found on a steep slope. Consequently the differences between the four highest situated plots (29,30,41 and 42) at the one side and the four lowest situated ones at hte other hand can not be explained solely with the distance to the parent stand, but also by the slope.

The distance to the parent stand was only tested for the northern sample plots. For a number of parameters, the relation to the parent stand was examined, viz. : the total stem number, the stem number of Scots pine, the stem number of birch, the ratio birch-pine, the overall average height, the average height of birch and of pine, and the average height of the ten highest trees.

A significant difference was only found for the parameters overall stem number, stem number of birch and average height of the ten highest trees,. For the other parameters no statistically significant relation could be found. Here, the great variation and the limited number of replications play a role.
The distance to the parent stand determines in a significant way the total number of trees. The difference is clearer between the first and the second row, than between the second and the third row. Nevertheless the following linear regression can be computed : $y = 141.9 - 0.93 x$ with $r = 0,84^{+++}$.
Per current meter there is an average decrease of about 1 tree/are.
The decrease of the regeneration has two causes :

- the seed supply by the old stand; this is especially of importance for the trees with heavy seeds ;
- the influence of the micro climate; this is clearly shown by the attitude of the birch. The decrease in density is mainly caused by a more unfavourable microclimate, since the seed supply is everywhere nearly the same.

The above mentioned results, however, must be relativated because of 2 facts :

- the bad regeneration of stand 2 in general ;
- the different reaction of birch and Scots pine.

The stem number of birch decreases significantly as the distance to the parent stand increases. The regression equation is as follows :
$y : 73.0 - 0.51 x$ with $r = -0.77^{++}$. However, significant differences seems to exist only between the first and the second row, but not between the second and the third row. So the favourable effect of the parent stand is rather limited in distance, with a maximum of about 50 m. This is not surprising, taking into account the northern exposition of the old stand.

The general bad regeneration of the birch on these places is imputed to the thickness of the litter layer. This is proven by the appearance of Calluna-heather and by the good regeneration of birch, some tens of meters further, on a south exposed slope, where the litter layer was partly washed away.

For the Scots pine as a whole, over the 12 most northerly sample plots; there is no significant difference between stem number and distance to the parent stand. The situation, however, becomes clearer taking into account all sample plots (tab.4).

Table 4 : The relation stem number of Scots pine - distance to the old forest in stand 2

distance to the old stand	stem number in the different sample plots			
15	91(23)	52(24)	7(35)	9(36)
75	31(25)	28(26)	10(37)	8(38)
155	1(27)	3(28)	16(39)	19(40)
235	1(29)	0(30)	0(41)	0(40)
315	0(31)	0(32)	0(43)	0(44)

- The difference is clear in the rows 1 and 2. Only in the vicinity of the old stand there is still a certain regeneration.
- In rows 3 and 4, on the contrary, regeneration is very limited. Moreover, clear differences can not be found in the upper part.

The absence of seedlings on the slope is not caused by the slope itself. Indeed in other places the pines are growing very well on a south slope. Limited presence of seed and unfavourable germinating and settling circumstances are here the main causes of the bad results.

No significant relation exists between the average height of the trees and the distance to the old forest. On the contrary a good relation was found, taking the ten highest trees per plot : $y = 1{,}25\ c + 352.8$ with $r = 0.90^{+++}$.
Nevertheless one may not conclude trees are growing faster as the distance to the parent stand increases :

- There are many birches near to the old forest, but not so further on. The birches are growing faster than the Scots pine. Consequently the share of the brich with the 10 highest trees per plot is higer in the vicinity of the old stand and therefore also the average height of the 10 tallest trees is higher.

- The higher the number of trees, the greater the chance for finding high trees.

3.3.1.2. Result in stand 4

The situation in stand 4 is rather compoex :

- the stand is surrounded in the north and partly also in the west by an old conifer stand (see fig. 1).

- the northern part has a south exposition, the southern part a north exposition.

- the slope increases from west to east.

For the statistical calculations, three block have been distinghuished.

- block A : includes the first and the second rows (plots 62,63,64 and 67 and 51 to 54) ;

- block B: includes the second and the third rows ;

- block C : includes the third and the fourth rows.

The first and the second rows lie far apart; the second and the third rows lie next to each other, with yet an other exposition, the third and the fourth rows lei again far apart.
In each block the two rows were tested, as well as the four columns.

Especially remarkable is, that only few significant differences were found :

- in block C no significant differences were found.
- in block B the following significant differences were found :
  - the total stem number as compared to that of the colums;
  - the stem number of birch as to columns
- in block A the following significant differences were found :
  - the average height depending on the rows;
  - the proportion of Scots pine according to the rows ;
  - the proportion of birch according to the rows ;

In block A no significant differences in stem number where found neither of Scots pine or of birch. Nevertheless the plots 64 and 51 differ strongly. The existing differences in block A are exclusively due to the situation of the parent stand.

The good results of the birch in the sample plots 55-58 are not coupled with the parent stand, still with the slope (see further). As to the stem number and the share of the Scots pine the following points appear. (Tab. 5).

Table 5. Absolute number and percentage of Scots pine in the different sample plots of stand 4.

N	%	N	%	N	%	N	%
28	23	52	28	316	50	276	73
52	30	44	42	204	70	24	42
448	37	52	6	68	4	8	2
12	1	76	15	32	4	136	11

- The stem numbers of the sample plots 53,54,63 and 67 are relatively low and do not differ much; it is obvious that the distance to the parent stand does not play any role, neither as to seed supply nor as to micro-climate.

- In the sample plots 52,62 and 64 the regeneration result is very good and apparently independent from the parent stand.

- It is not clear why there is such a difference within the rows of block A between the western part and the eastern part.
  It is even not clear why there is in this eastern part still a bad plot (sample 51).

- The best results by far are reached in plot 58 with 448 trees per ha. This is possible due to the vicinity of the old stand. But why are the results again bad in parcel 59, which is situated just as far from the old stand ?

- The variation and the unpredictability of the results appear also from the good growth in sample 65, situated far from the parent stand, on a northern exposition.

- The percentage of the Scots pine is very different :

  - in some cases it reaches only 1 or 2 %; in these cases the regeneration of the Scots pine is very bad too ;

  - the highest share of pine, viz. 73 %, corresponds with a very good regeneration result : the results of birch on the contrary are rather low here ;

- on the two sites, where the overall regeneration is best, the share of the pine attains 37 and 50 % ;
- the pine regeneration is good on plot 65 ; its share, however, equals only 11 %; the regeneration of birch is even better here.

As to average height of Scots pine, significant differences were found for the rows in block A and for the columns in block B. (Table 6) :

Table 6. The average height of the Scots pine in the different sample plots of stand 4 (cm).

75	88	107	120
85	134	136	133
40	55	54	62,5
62,5	32	52	29

- the average height is lower in the vicinity of the cofer of the old stand (row 1).
- the average height is higher on the south exposition than on the north exposition.

In the southern part the average height is still very low. This is in particular due to the dense crown cover, built up by the birch. Fiedler (1962) too indicates, that in most cases it is not necessary to liberate the Scots Pine under birch, yet very high densities of birch can suffocate the pines.

3.3.1.3. Conclusions concerning the influence of the parent stand

The results of the measurements, carried out partly in homogeneous and partly in more complex starting situations show the importance of the parent stand in certain cases :

- the role of seed supplier is necessary for the Scots pine; with birch, however, this does not play a role.
- the favorable influence on the microclimate appears especially with birch; the higher air humidity has a positive effect.

It is, however, quite obvious the vicinity of the parent stand is insufficient to assure a good regeneration result. At the same time several other factors have to be favourable : the thickness of the litter layer, the soil situation, the water supply, the exposition, etc.

3.3.2. The exposition

The ecological differences between a south and a north exposition are sufficiently known. With a forest fire, however, these differences are still accentuated. A forest with a south exposition is drier and more sensitive to fire. The humus layer will burn better too. Consequently better germinating circumstances arise. In a forest with a north exposition, on the contrary, the circumstances are less favourable (West, Shugart & Botkin, 1981).

The influence of the exposition can be examined quite well in stand 4, the northern part of which has a south exposition and the southern part a north exposition. The effect can best be determined here by comparing the two middle rows : the rows are close to each other and the older stands are situated already at a relatively important distance.

The analysis of variance shows that there is a significant difference between :

- the stem number of the birch
- the average height of the pines.

On the contrary no differences were found concerning the stem number of the Scots pine, the average height of the birches and the average height of the highest birches.

The stem number is significantly higer on the northern slope

Table 7. Stem number of birch (per are) as to exposition in stand 4.

S-expos.	116	52	88	16
N-expos.	756	788	1444	328
N/S/ expos.	65	15,2	16,4	20,2

- In all 12 times more birches appear on the northern slope than on the southern slope. Therefore it is evident that the birch has better possibilities on the northern slope.
- The relative differences are the most remarkable by comparing the stands 51 and 55, where the absolute results are the least bood.
- The densities of the birch are on some places very great : nearly 150,000 5 year old plants per ha.

As the exposition causes great differences with the birch, but not with the Scots pine, it is clear there must be a remarkable difference in the growth possibilities of these two species : birch is less resistant to high temperatures and to drought. It could not be examined whether the unfavourable results on the southern slope are the consequence either of a bad germination or of a difficult settlement.
Furthermore it should be mentioned again, that the small height growth of the pines is mainly, if not exclusively, due to the very great densities of the birch. It is, however, well remarkable that the unfavourable settlement circumstances of the birch on a south exposition are not injurious to height growth : the birches are as heigh on the south exposition as on the north exposition.

3.3.3. The slope

The southern part of stand 2 is situated on a steep slope with a south exposition. The 12 most southern sample plots enable us to examine the effect of the slope, for the greater part independent from the old stands. Indeed, the distance to the old stand is minimally 150 m (Tab. 8).

Table 8. Regeneration results of stand 2 on the slope

Other sample plot	distance to the old stand	percentage of the slope	number of birches/are
27	150 m	2	8
28	150 m	2	3
39	150 m	3	4
40	150 m	3	1
29	230 m	12	28
30	270 m	12	17
41	230 m	11	41
42	230 m	11	42
31	320 m	25	39
32	320 m	25	32
43	320	27	43
44	320	27	44

First of all, however, it must be mentioned again that the overall regeneration result in this stand are insufficient.

As the regeneration of the Scots pine is affected for the greater part by the old stand, the results of the pine are not significant here.
The stem number of the birch is increasing from north to south, with increasing slope. The equation below indicates the relation between the stem number of the birch and the percentage of the slope :

$$y = -2.45 + 1.61\,x \quad \text{with } r = 0.900^{+++}$$

The above, however, proves that the birch has not a preference for south exposition. Therefore the better results with increasing slope are not due to more favourable microclimatological circumstances. They are to be explained, because a part of the humus is washed away on the slope, bringing about a better germinating bed.

Such sites are better for pine than for birch. In this case, however, there was not enough seed available, because of the great distance to the parent stand, so that the birch dominated.
So the influence of the slope is not explained here by factors such as radiation temperature, air- and soil humidity, and the like, but by the difference in thickness of the litter layer.
It proves once again that the results are bound very locally and that they can not be generalized. Results can not always be predicted.

3.3.4. The treatment

In stand 3 the regeneration, especially of the birch, was abundant. Therefore, by way of experiment, the stem number was reduced in a mechanical way. So three different situations arised :

a. the mowed strip ;
b. the strip adjacent to the mowed zone
c. the non-treated zone.

The sample plots 49 and 50 are situated on 70 m from the old stand, the plots 47 and 48 on 135 m.

As the old stumps are still present, it has been mowed on a variable height of 20 to 40 cm. The results of this were not good. The plants did not die, they were just growing on.

The effect of the treatment on the composition of the tree species and on the height growth was examined. A possible afterregeneration in the zone a was taken into consideration, and also a better growth in the zone b, due to an increased light supply and a diminished competition.

It seems, however, that the treatment has got very little result (Tab. 9).

Table 9. Results of the several treatments in stand 2

	sample a	plots b	49&50 c	sample a	plots b	47&48 c
Stem number of pines	180	170	255	100	160	170
Stem number of birches	375	350	495	430	575	535
Total stem number	565	525	760	535	760	720
Average heigth $\bar{h}$	50	110	98	56	112	107
$\bar{h}$ Scots pine	49	84	34	39	41	78
$\bar{h}$ birch	52	125	119	57	134	116
$\bar{h}$ of the ten highest trees	103	213	213	103	223	215

As to stem number, no significant differences can be found, neither for pine or for birch. No afterregeneration has taken place. Of course the moving led to height differences.

The treatment has got, also from the silvicultural point of viewn hardly any affect. There was no reduction of the stem number, as was aimed at. In the future the intense competition between and within the species will have to be regulated further in a selective way.

3.3.5. The fire regime

The fire regime affects for a great part the regeneration result. It causes changes in the chemical and fysical soil characteristics and even in the thickness of the litter layer. The fire regime affects also other factors, such as exposition and slope. Taking all these elements into account, the final result can be very complex.

Austin & Baisinger showed, that the mineral content after a fire was increased strongly : K 2 times, P 2 times, Mg 4 times and Ca 8 times.
The pH was increased from 4.5 to 6.7. The original content of most of the minerals was repaired two years after the fire. The Ca-content, however, is still 3 times higher and pH amounts still to 5-7.
Ahlgren & Ahlgren stress, however, that the higher concentrations of nutrients are not always favourable for the plant, because the relations between the nutrient elements are not well-balanced and their dispersion over the area varies strongly.

Moreover, there is a real danger for important losses of nutrients by leaching. Therefore the fire area must be resettled as soon as possible. By the way, one can point out the influence of forest fires on the surroundings. Hetsch (1980) found, that rain, arising from smoke out of a forest fire, contains 20 to 70 times more nutrients than normal rain.

A forest fire has also an important influence on the waterholding capacity of a soil. When the soil temperatures are mounting up to 200° à 300°C the soil is becoming hydrophobe. So the waterholding capacity diminishes to a large extent, which can be of great significance for dry sandy soils.

When a fiarly thick litter layer is present, a temperature of 200°C is rapidly reached. With a temperature of 300°C the upper 5 cm of the soil contains a normal waterholding capacity, yet a hydrophobe layer appears between a depth of 5 to 10 cm (Hetsch, 1980). On soils with such a profile the regeneration is likely to die off after one to two years. These hydrophobe layers have not yet disappeared on the Lüneburger heath after 5 years.

Local differences concerning relief, thickness of the humus layer, fire regime, hydrophobe layers, etc. lead thus to a strongly varying regeneration result.

More or less the same results were found by Austin & Baisinger after forest fires in Oregon and Washington. The soil structure deteriorates due to loss of organic matter. In this way the waterholding capacity of the soil decreases and erosion increases. After two years the situation is not yet ameliorated.

When a thick organic layer is burnt insufficiently, a good regeneration will not come about. When, on the oter hand, the litter layer is burnt partly and the rests aremixed with ashes, ofthen a good regeneration appears. In this case, however, a sudden mortality can occur after 1 to 2 years (Ahlgren & Ahlgren).

Jahn (1980), West, Shugart, Botkin ed. (1981) concluded that birch generally appears often on less burnt places, while the conifers are dominating on naked soils. Conifers are also more tolerant of the unfavourable situation of hydrophobe soil layers.

Besides the fire regime has still an indirect influence on the regeneration result. The high temperature destroys all weed seeds too, by which the seedlings have less competition. The forming of such ashes, on the contrary, stimulates a strong grass growty, affecting obviously the regeneration in a negative way.
In short, the regeneration results after a forest fire are very precarious and for the greater part unpredictable.

3.4. The social differentiation

After only six years considerable height differences can be found between the samplings (Tab. 10). These differences are partly due to age differences and partly to genetic and site differences.

Table 10. Repartition of the stem numbers in height classes.

height classes	birch		Scots pine		other species		all species	
	abs.	%	abs.	%	abs	%	abs	%
0-25	240	7,2	118	5,8	141	44,2	499	8,8
25-50	233	7,0	227	11,2	57	17,9	517	9,1
50-75	205	6,1	210	10,4	44	13,8	459	8,1
75-100	224	6,7	315	15,6	24	7,5	563	9,9
100-150	636	19,0	599	29,6	18	5,6	1,253	22,0
150-200	755	22,5	398	19,7	17	5,3	1,170	20,5
200-250	512	15,3	136	6,7	7	2,2	655	11,5
250-300	374	11,2	22	1,1	7	2,2	403	7,1
300-350	111	3,3			2	0,6	113	2,0
350-400	45	1,3			2	0,6	47	0,8
400-450	14	0,4					14	0,2
450-500	3	0,1					3	0,1
	3352		2025		311		5,696	

The 1000 highest birches per ha belong to the height class 250 cm and over. Hardly any Scots pine belong to this class.
By its number and growth birch is offering a considerable competition to Scots Pine. The greatest part of the pines will die in the next years.

The situation is still much more dramatic for the other intermixed species : they are not abundant, maintain their height and have only a small competition capacity.

A suitable silvicultural treatment will be necessary in order to maintain the mixture of birch and Scots pine and to enable Scots pine to finally take up a dominant position.

With a hundred high and low pines the annual shoot length was measured (Fig. 3). The lowest pines are, an average, 1 year younger than the highest. Their growth arrears becomes greater from year to year. The growth was the same in the first year, yet there was already a difference in the second year. After 5 years the height differences were already increased to more than 40 %.

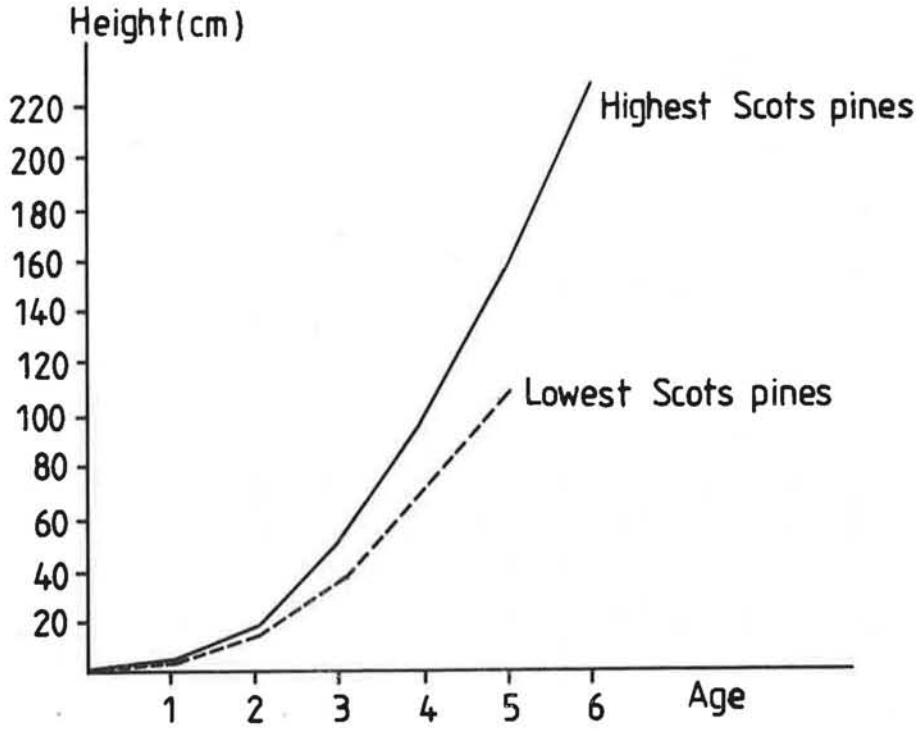

Fig. 3. The growth course of the lowest and highest Scots pines.

Analogous observations were made with birch. The smallest birches are the youngest, while in contrast, the highest are the oldest. (Fig. 4). Nearly all trees with a height of more than 3 m are 5 or 6 year old. The length of the latest annual shoot of the highest trees is 57.8 cm, the one of the lowest 37.5 cm.

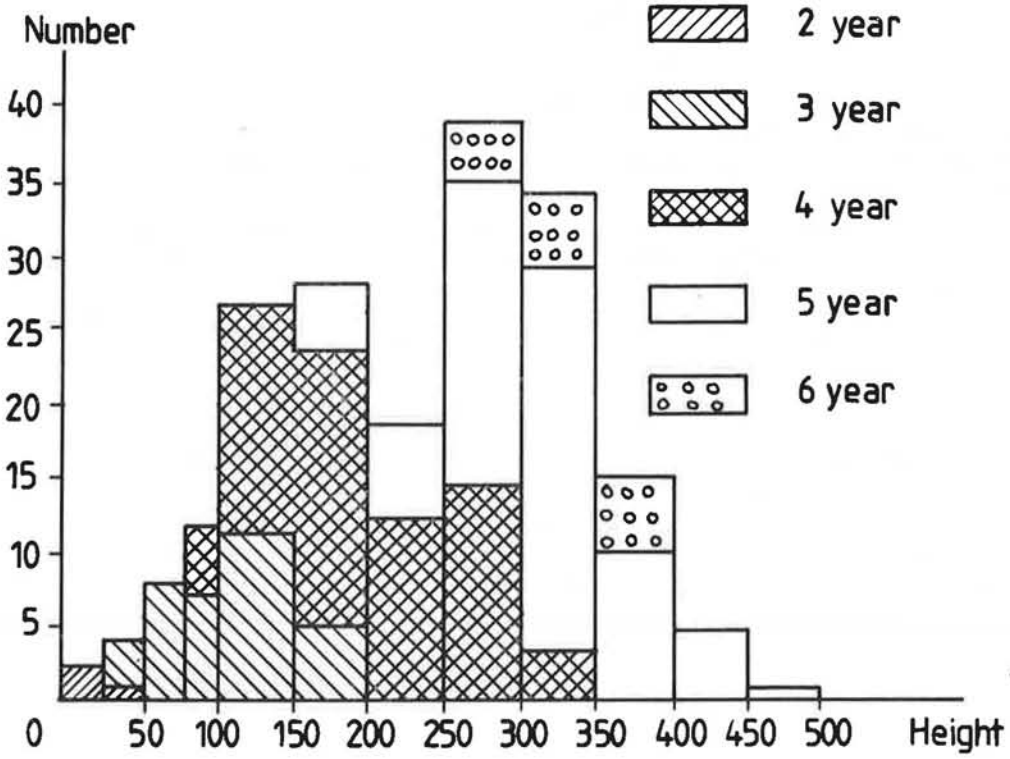

Fig. 4. Repartition of the birches over height and age classes.

The results of the growth differences stress clearly the following points :

1. With all tree species, different social classes are formed very fast.
2. The age is a very important factor for reaching the highest social class. This class is reserved to a limited age class. Only the oldest trees are reserved for this.
3. Later on, an even aged stand will be formed.
4. The silvicultural treatment will be of decisive importance for the future stand structure. A very early treatment is necessary to regulate the mixture relations.

4. SUMMARY AND CONCLUSIONS

The study of a spontaneous resettlement after a great fire in a pine forest allows us to formulate some interesting conclusions.

1. The spontaneous resettlement occurs very fast. A lot of seedlings, especially of birch and Scots pine settles the second and the third years after the fire. These two species take up 95 % of the stem number. The rest is taken up by 9 other species.

2. The total stem number equals on average 18.554/ha. The regeneration is good or even very good on 70 % of the area. The regeneration period is very short. There is no more regeneration after 4 years.

3. The results of the regeneration are very precarious. They are determined by a large number of factors.
   Very important are the fire regime and, combined with this, the thickness of the litter layer. The decomposition of the litter is for the greater part necessary.
   The fire regime determines the thickness of the litter layer, and also the chemical and fysical soil features. It even influences the effect of exposition and slope.
   High soil temperatures are not favourable in all cases. They can cause the dying off of seedlings after 1 or 2 years.

4. The situation of the parent stand plays an important role too. Seed supply is necessary for the Scots pine. Birch on the contrary, prefers the favourable effect of the micro-climate. The overall influence of the parent stand is, however, limited in distance.

5. The results of the Scots pine are not affected by the exposition. Birch, on the contrary is much more abundant on the northern expositions. The humous layer can be washed away by the slope, favouring in this way the regeneration of the Scots pine.

6. The regeneration is growing up very heterogeneous. Important height differences and social strata appear very soon. Only the oldest plants can reach the upper stratum.

7. Birch and Scots pine behave in a different way. The Scots pine prefers more open and dry places. The more the humous layer is decomposited, the better. Birch, on the contrary, needs more humidity. It is grateful for a protection of the parent stand.
   It prefers the more fresh N-slopes. The seedlings can dry out on sites that are too dry.

This study allows us also to draw certain conclusions for the practice of the transformation and the regeneration of homogeneous pine stands :

- The natural regeneration of pine, birch and a number of other species is possible.

- The result of the regeneration can be ameliorated by taking into account all kind of parameters : thickness of the litter layer, situation of the parent stand, slope, exposition, etc.

- The result is very precarious and often unpredictable.

- A silvicultural treatment is necessary after the regeneration : the competition between the species has to be regulated.

- In most cases, a fairly varied pine forest can be obtained, starting from a homogeneous pine forest.

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