AN ANALYSIS OF A SPONTANEOUS INGROWTH OF DECIDUOUS TREES IN 70 YEAR OLD STANDS OF SCOTS PINE

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Abstract

In 70 years old homogeneous Scots Pine stands, bordered by a hardwood belt, an analysis was made about the spontaneous ingrowth of natural seedlings. The analysis involved especially the following points : species and stem number, influence of the hardwood belts, diameter and height distribution, age, growth and structure. From the age of 30 years, a spontaneous regeneration of hardwoods established in Scots Pine stands. There are on average 7,000 plants per ha, 80 % of which are black cherry and another fair number are red oak and pedunculate oak. The regeneration has an average age of 25 to 30 years, it is uneven aged, contains several diameter and height classes and has already partially penetrated the upper stratum.
The spontaneous ingrowth allows to convert in a simple way the homogeneous coniferous stands into mixed hardwood stands.

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1. INTRODUCTION

The campine, a region with a sandy and very poor soil, was in earlier times covered with an oak-birch forest of limited value. In the course of the centuries, however, it has been almost completely destroyed. On many places it has been replaced by heather. From 1850 onward, most of these heather-fields have been afforestated almost exclusively by means of Scots pine. In this way monocultures on big areas were established.

Meanwhile many of these stands have come to maturity. The question now arises as to the future of these forest. It is, for many reasons, not longer acceptable to maintain homogeneous Pine stands. The replacement by plantations of Corsican pine allows a strong increase of the increment, but at the same time it entails a number of risks and it is very disputable from the ecological point of view.
It proves to be more and more necessary to plant more deciduous trees and to strive for mixed deciduous-conifer stands. Here, a lot of variants are possible. Natural regeneration might also be an acceptable alternative.
The main purpose is the establishment of worthful stands, which can continuously and rationally deliver the products and services the society is asking for. The humic layer and the soil condition of the forests should be improved. Contrary to the findings of Heinsdorf & Kraus (1974) and Preuhsler & Rehfuess (1982) little improvement is expected from fertilization, liming, dealing compost and soil preparation.

Under certain circumstances, natural regeneration is a possibility to keep in mind. Also Seitz (1980) comes to this conclusion. At the same time the latter points out the loss of humus and nitrogen by artificial reafforestation and also the increase of the soil fertility by abandoning the clear cut system. In order to achieve natural regeneration a sound planning is necessary and the site, the initial stand and the hereditary predisposition are to be taken into consideration. At the same time suitable forestry measures should be taken. The regulation of the crown cover, the fight against inconvenient vegetation and appropriate soil preparation are of the utmost importance (Seitz, 1980 ; Leibundgut, 1981 ; 1984; Eckhart, 1984).

The practice of natural regeneration of Scots pine is, however, not simple. Gürth rightly stresses the complexity of this phenomenon and the lack of qualitative and quantitative data, i.e. of scientific knowledge.
Rottmann (1981) points out the great importance of the soil preparation, especially the reduction of the litter layer, of the present soil vegetation, and of the opening of the canopy.
The intermixture of deciduous trees in Scots Pine stands is very disputable. Several intermixed species are said to be dangerous or harmful. According to Henckel however, their maintenance is to be considered on a basis of biological,aesthetic or silvicultural qualities.

Sinner (1978) argues very strongly for a reorientation of the culture of homogeneous Scots Pine stands. It is insufficient to take measures such as the establishment of fire belts or group and individual mixture of deciduous trees.

Soil preparation and fertilization have only a short-lived positive influence. He recommends a " biological stand conversion ". The homogeneous Pine stands should be converted spontaneously, from the phase of young timber on, by natural ingrowth of deciduous trees and, on the better sites, by natural regeneration of the Pine itself. A long regeneration period, coupled with a slow removal of the crown leads to mixed unevenaged stands with a well-balanced structure.

Junach (1978) agrees on the purpose and the general principles of the biological conversion, as formulated by Sinner. In practice however, he comes to somewhat other results. Sinner obtained ingrowth of deciduous trees on the more poor soils and natural regeneration of Scots Pine on the more rich soils, whereas Junach found precisely the opposite.

Hochtanner (1978), on the other hand is very sceptical about the biological conversion of homogeneous pine stands. The sites, on which this method can be used, are rather restricted. Perhaps it can be more applied in forests with an important social and a minor economic function.

Petri (1978) is not a great supporter of conversion of pine stands either. He considers it significant to a limited extent. The share of Scots Pine sould be limited to 70 - 75 %. According to Petri, conversion is not necessary to improve the site, to limit the fire danger, to avoid biotic damages, to improve the economic situation, to excercise the recreative function or to prevent a fall of the ground water.

In the Belgian Campine the spontaneous formation of " biological conversion " of homogeneous pine stands is easily observable. From 30 year onward there is a natural ingrowth of deciduous trees, which disperse from the fire belts out. This conversion is favoured by early strong thinnings and an open canopy. The general positive consequences of early strong thinnings in Scots Pine stands are also recognized by Franz (1983) and Huss (1983). At the same time the latter stresses the necessity of openings in the canopy for the growth of the intermixed tree species.

In this respect also the results of Trillmich and Uebel (1982) are interesting. In a 65 year old stand of Scots Pine, with a degree of density = 0.7 an underplanting with American red oak was carried out. At the same time the stand was fertilised. After 18 year the pine stand, with a growing stock of 300 m^3 and a stand density = 0.9 was cut. Meanwhile the American oak had grown quite well, especially on the fertilised places. Its growth could be equated with one of a 10 y old stand on the free field. The positive effect of the underplanting with American oak and of the fertilization was most clearly demonstrated by the improvement of the humic layer.

2. OBJECT AND METHODOLOGY

The research took place in the State Forest of Ravels. This forest, with an area of 816 ha and situated in the Campine, was established in the beginning of the 20th century. In former times it was a part of a great heather field. It was planted for the greater part with Scots Pine.

At the time the main purpose was to produce pit props with a short rotation varying from 40 to 50 years. Since then,however, situation has changed, so that most of the stands are still standing. Nearly half or the stands belong nowadays to the age class 70-80. They show more or less phenomena of senelity.

During the plantation the forest was divided into parcels of 10 to 12 ha. The main roads were bordered with a 6 m wide deciduous belt, the lateral roads with a 4 m wide belt.
The following trees were planted : black alder (Alnus glutinosa Gaertn.), speckled alder (Alnus incana Mönch), birch (Betula pendula Roth.), white willow. (Salix alba) goat willow (Salix caprea L.) red oak (Quercus borealis MIchx), pedunculate oak (Quercus robur L.), sessile oak (Quercus petraea Lieblein), black cherry (Prunus serotina E.H.R.H.),locust tree (Robinia pseudoacacia L.), sweet chestnut (Castanea sativa Mill.), beech (Fagus sylvatica L.), ash (Fraxinus excelsior L.) and maple (Acer pseudoplatanus L.).
Starting from these deciduous trees, a spontaneous natural regeneration has established in the course of the years. The present inventory of the potential older seed trees shows the following average values of stem number per ha and average diameter

	N/ha	$\bar{d}$
- red oak	117	37.5
- indigenous oak	75	28.3
- beech	54	36.8
- sweet chestnut	27	30.5
- other deciduous trees	15	31.8
- larch	32	36.0
	320	

The red oak is found in practically every belt. The indigenous oaks and the beech appear quite frequently, while the other species are less dispersed. In some stands old seed trees are not found, unlike a number of young trees which already produce seed. This is for instance the case with black cherry. This species appears frequently in each belt, either as seedling or as stump sprout. It is not clear whether it is planted or not.
The surveys occured in 15 stands of about 70 year old (table 1). The sample plots were chosen in such a way, that a difference could be established in soil, basal area, average diameter and height, presence, exposition and species composition of the tree belts and presence of black cherry.

The soils of the state forest Ravels are typical heather podsol (Rogister, 1973). The plots 7,11,16,17 and 22 are found on moderately dry sandy soils, the numbers 10,19,21 and 28 on rather wet sandy soils, the numbers 39 and 54 on wet soils with a loamy texture and the numbers 25 and 26 are found on moderately wet to wet soils with a light sandloam texture.
The basal area of the stands ranges from 16.8 m^3/ha to 35.5 m^2/ha, the stem number from 250/ha to 540/ha, the average height from 17.5 m to 24 m and the average diameter from 25.3 to 33.6 cm.

Table 1. Characteristics of the experimental stands

nr.	age	soil	number of sample plots	measured area (m^2)	stem number (N/ha)	basal area (m^2/ha)	$\bar{d}$ (cm)	$\bar{h}$(m)
7	77	Zcg - Zdg	4	640	250	22.8	33.1	19.8
10(A)	76	Zdg - Zeg	5	800	500	26.9	25.8	19.5
10(B)	76	Zdg - Zeg	4	640	410	26.0	28.0	19.0
11	76	Zeg _ Zdg	6	960	260	16.8	28.2	20.5
16	75	Zdg	6	960	530	27.9	25.3	19.0
17	75	Zdg	7	1120	320	21.1	28.5	23.0
19	73	Zdg _ Zeg	7	1120	480	27.2	26.3	17.5
21	73	Zdg - Zeg	7	1120	540	28.2	25.4	22.0
22	75	Zcg - Zdg	7	1220	380	35.5	33.6	24.8
25	72	Sdg _1Seg _sPdg	8	1280	340	27.6	31.7	22.5
26	72	Lsdg-Peg-SPdg	8	1120	430	35.5	32.0	21.0
28(A)	71	Zdg - Zeg	7	1120	390	25.5	28.4	19.5
28(B)	71	Zdg - Zeg	4	640	320	21.9	29.3	19.5
39	69	1Seg	6	960	320	22.8	29.7	22.5
54	62	LSdg - LSeg	4	640	430	24.5	26.6	20.5

Per stand 4 to 8 sample plots, with an surface of 160 m² were measured. In all, 100 plots were laid out and the following measurement were carried out :

- species and stem number of all spontaneous ingrowth.
- diameter and height : the diameter was determined at 1.30 m height or, for small samplings, 10 cm above ground level ; for the three main species, red oak, indigenous oak and black cherry, in each diameter class the height of a certain number of trees was measured.
- the age and the growth of the three main species ; a certain number in each diameterclass was examined.
- the stand structure : 8 transects with a width of 8 m and a length of 40 m were determined. The vertical projections are presented in 2 zones of 4 m width.

3. CHARACTERISTICS OF THE NATURAL INGROWTH

3.1. Species and stem numbers

In all stands a fair occupation of deciduous trees has settled. On average there are 7,000 samplings/ha (table 2). It is remarkable, however, that 80 % of the regeneration are black cherry.
This species appears everywhere rather frequently. Its number ranges from 3,500 to more than 11,000 ha. It is found in two forms either, as a tall tree or as a stump sprout, coming about after cutting. Its density is so high, that it can form everywhere a complete cover.
Nevertheless there is still a fair ingrowth of other species. In all 10 tree species have regenerated. They can be divided into main tree species, such as red oak and common oak, and in secondary tree species, such as black cherry and rowan tree (Sorbus aucuparia L.).

With the exception of black cherry, the red oak is found most frequently. It appears everywhere, except in stand 54. Its number attains on average 761/ha and ranges from 360 to 1,550/ha. The pedunculate oaks appears to a lesser degree. although it is also found nearly everywhere, with an average of 120 trees/ha.

The combined number of red oak and common oak, possibly still increased by other main species, is in principle in many cases high enough as to serve as a starting point for an indirect conversion of Scots pine stand into mixed stands on a hardwood basis. There are, however, some important technical difficulties.

Table 2. Stem number of spontaneous ingrowth in 70 year old stands of Pinus sylvestris (N/ha)

Stand	P.S. seedling	Querc. rubra	Sorb. auc.	Querc. robur.	Rhamn. frang.	Bet. verr.	Cast. sat.	Tilia cord.	Acer pseud.	subtotal	Prunus serotina	Total	% Pr. serotina
7		766	125	234	78		125	109	47	1894	2703	4187	64.6
10(A)		425	625	263	88	113	13			1525	5850	7375	79.3
10(B)		844	703	281	219	141	16			2203	9094	11297	80.5
11	323	1354	135	177	52	21	10			2072	7615	9687	78.6
16		813	271	94	31	31				1239	4927	5166	79.9
17	347	705	63	63	27		45			1251	6661	7912	84.2
19		964	9	125	9	63				1170	5991	7161	83.7
21	18	741	27	36	54	36	9			920	2661	3582	74.3
22		1098	125	45	9	9	9		18	1313	4554	5867	77.6
25		367	78	109	55		63		8	680	5563	6243	89.1
26		359	188	47	55	8	63			719	2859	3578	79.9
28 (A)	107	1027	36	36	18					1232	4866	6098	79.8
28 (B)		1547								1563	6078	7641	79.5
39		406	885	198	42		31			1677	8062	739	82.8
54			1359	94	31	141			16	1641	7375	9016	81.8
Average	56	761	309	120	51	46	22	14	6	1379	5657	7036	80.4
%	0.8	10.8	4.4	1.7	0.7	0.7	0.3	0.2	0.1	19.6	80.4	100	

- The dominance of the black cherry. The repression of this species demands much labour.
- The relation red oak-pedunculate oak and other intermixed species. By its fast growth and explosive crown development the red oak suppresses the common oak. An individual mixture of both species is not to be recommended.
- There are always some small openings, dispersed over the stands, which must be filled up. Fast growing and more tolerant trees are therefore to be considered., e.g. maple, wild cherry, (Prunus avium) lime and beech.
- The intermixture with conifers. The recent natural regeneration just attains a small number of Scots pine seedlings. It is very doubtful whether these seedlings will stay alive. Their maintenance requires an intense and continuous liberation.
- The exploitation of the old stand. Measures should be taken to protect the regeneration.

Although the recent regeneration is very worthful, it is certainly not to be appraised as an ideal situation.It should, however, be borne in mind, that this regeneration has come about without an active escort and help of the forester.

It must be possible to get a better result by taking positive measures, before as well as after the regeneration.
It is striking, that the regeneration of the Scots pine itself is very limited. It is just found in 4 plots, even scarce. In these parcels the black cherry was regularly cut or pulled out, for exploitation sake.
The last cut was executed some months before the measurements. In such stands a restricted number of seedlings was present, with the exception however of parcel 7.

The black cherry apparently pays a determinative role in the regeneration process. The observations in the deciduous trees, however, do not directly bear out this statement. Indeed, in most cases an important number of black cherry is recorded with the greatest ingrowth of other species (parcel 10 B, 11, 39,54) and on the contrary the least ingrowth is found where only a small number of black cherry appears (parc. 21 and 26). So there are, beside the black cherry, still other important factors regulating the pattern of regeneration, among others, the soil fertility and the stand density.

It is clear, however, that regeneration is determined by a complex of factors, the secrets of which are still for the greater part unknown. On the poor sandy soils of the parcels 7,11,16,17 and 22 the regeneration is very variable. On the richer soils of the parcels 25 and 26 the regeneration is scanty to moderate. So the correlation between the soil and density of regeneration is very bad. Somewhat better is the relation between stand density and regeneration density. In the five clearest stands the regeneration ranges from 4,187/ha to 9,739/ha.
The two stands with the greatest basal area have a stemnumber of regeneration ranging from 3,578 to 5,867/ha. The two stands with the greatest basal area have a regeneration stem number ranging from 3,578 to 5,867/ha.

The four parcels with the greatest and the smallest regeneration are to be characterized as follows :

Nr.	Soil	Basal area (m²)	ingrowth (N/ha)
10(B)	Zdg-Zeg	26.0	11,297
39	Seg	22.8	9,739
11	Zeg-Zdg	16.8	9,687
54	LSdg-lSeg	24.5	9,016
...			...
22	Zeg-Zdg	35.5	5,867
7	Zeg-Zdg	22.8	4,187
21	Adg-Zeg	28.2	3,582
26	lSdg-Peg-sPdg	35.5	3,578

With some prudence, the following general statements can be formulated :

- natural regeneration of several deciduous trees is possible under the cover of conifers ;
- the regeneration comes about under different starting positions ;
- the soil richness can differ ; the drainage class seems to be more important ; a wealthy regeneration wasnot found on c-soils.
- also the basal area may vary strongly; it is not necessary to open up the stand very strongly in order to bring about regeneration ; even in rather dense stands a fair regeneration is able to develop.

3.2. The influence of the deciduous tree belt

For exposition's sake the regeneration was determined in 15 sample plots, on one side at a distance of 0-20 m and on the other side at a distance of 50-70 cm from the deciduous tree belt (table 3).

For the whole regeneration, a significant difference in density can be noted depending on the distance to the tree belt. The regeneration in the zone 0-20m is 29 % higher than in the zone 50-70 m.
Yet the differences are statistically not significant for most of the individual tree species : red oak, indigenous oak, sweet chestnut, birch and rowan tree.
On the contrary they are very significant for black cherry and locust tree. For the former species the difference attains 35 %; while for the latter, which however appears much less, the relation reaches about 4/1.
Any influence of the exposition cannot be indicated, unless for the birch.For this species the influence of the west wind (SW or NW) is clear.
These observations can be explained for the greater part by the different way of seed dispersion by the tree species. Most of the seed of the present deciduous trees is dispersed by animals. The heavy seeds of the oak are mainly dispersed by the jay and the wood pigeon.

Table 3. Stem number of the regeneration in relation to the distance and the exposition of the hardwood belt (N/ha).

distance to hardwood belt	exposition	number of measurements	Qru	Qro	C.s	R.f.	Sa	Be	Ac	Ti	P.sex.	Tot.
0 - 20	-	34	834	117	32	92	199	40	9	10	5921	7254
50 - 70	-	34	742	109	18	24	285	41	2	5	4399	5625
0 - 20	ZW	10	782	106	19	88	219	81	0	38	7681	9014
50 - 70	ZW	10	750	100	13	25	375	50	0	0	4506	5819
0 - 20	NW	9	841	174	35	77	375	49	21	0	5861	7433
50 - 70	NW	9	632	167	21	42	459	97	0	19	4611	6048
0 - 20	NO	6	697	63	54	72	98	0	0	0	3643	4627
50 - 70	NO	6	598	98	9	27	90	18	9	0	3959	4808
0 - 20	ZO	9	1014	125	21	132	104	28	14	0	6313	7751
50 - 70	ZO	9	986	70	28	0	216	0	0	0	4521	5821

The light pulpy fruits of black cherry and rowan tree are eaten by several smaller bird-species and deposited in the forest by the excrements.
Only the birch has an eolic seed dispersion, by which the exposition has an important role.
So the deciduous tree belts should not lie too close to each other, in order to serve as a starting point for a spontaneous regeneration. But they have to be wide enough in order to produce seeds. Due attention should also be paid to the fauna, as an important element in the seed dispersion.

3.3. Diameter- and height distribution of the regeneration

The average diameter of the main species, red oak, attains 10 cm, and the one of the common oak reaches 5.2 cm. The overall average diameter, however, is only 2.9 cm (table 4). This is due to the average diameter of the dominating black cherry, namely 1.4 cm. Also the lime and the sweet chestnut have already sizable dimensions.

Generally speaking, all diameter classes up to 28 cm are represented. The greatest part, however, is found in the lowest class from 0 up to 2 cm, viz. 71 %. Over 8 cm, only 10 % of the stem number appears, i.e. 720 stems per ha. This is, nevertheless, an important number which might allow to form the basis of the future stand.

Table 4. Distribution of stem number and average diameter (cm) of the spontaneous ingrowth.

Diameter class (cm)	Q.ru.		Q.ro.		others							
	abs	%	abs	%	abs	%	abs	%	abs	%	abs	%
0 - 2	43.7	5.8	25.0	23.4	242.4	58.5	311.1	24.3	4406.9	81.7	4718.0	70.8
2 - 4	64.6	8.5	12.5	12.1	48.7	11.8	125.8	9.8	416.0	7.7	541.8	8.1
4 - 8	181.9	23.9	46.5	43.9	74.4	18.0	302.8	23.6	393.8	7.3	696.6	10.4
8 - 12	229.9	30.2	17.4	15.9	31.3	7.6	278.6	21.7	127.0	2.4	405.6	6.2
12 - 16	170.8	22.5	3.5	2.8	9.1	2.2	183.4	14.3	39.6	0.7	223.0	3.3
16 - 20	53.5	7.0	1.4	1.9	4.2	1.0	59.1	4.6	9.0	0.12	68.1	0.9
20 - 24	13.2	1.7	-	-	1.4	0.3	14.6	1.1	1.4	0.03	16.0	0.2
24 - 28	3.5	0.4	-	-	2.8	0.7	6.3	0.5	0.7	0.01	7.0	0.1
Average	10		5.2		3.5		7.3		1.4		2.9	

The diameter distribution, however, differs from one species to another. For the red oak it looks like a normal curve. The greatest number appears in the class 8-12. The higher or the lower the classes, the smaller is the stem number. The limited number in the lower class is to be considered unfavourable. There are yet already 470 trees/ha with a diameter greater than 8 cm.
For the indigenous oak the situation is somewhat else. There is a clear maximum in the class 4-8 cm, so 1 class lower than for the red oak. There is, however, a second maximum in the lowest class, which was not the case for the red oak. Heavier indigenous oaks, with a diameter of more than 8 cm, are still rather scarce.

With the black cherry on the other hand the greatest part by far is found in the lowest diameter class. For more than 80 % the diameter is still lower than 2 cm. Only 3 % is greater than 8 cm, which nevertheless still corresponds with 178 trees/ha. This is mainly due to the regular cutting of the growing up black cherry. This is done in order to facilitate the normal exploitation and also to prevent its overgrowth. The question arises, however, if it would not be better to let grow up the first ingrowing plants of black cherry. In this way they can grown up into the middle stratum and afterwards, they may be taken up in the reserve and involved in the conversion. Anyway, not cutting avoids the sprouting up of numerous shoots, which form a dense soil cover.

Also the sweet chestnut, which is, however, more scarce reaches already important dimensions. This is mainly the case on parcels which contain a certain amount of loam. The maples, on the contrary, just grow moderately.
It is obvious that the results differ to some entent from stand to stand.
So the stem number of the trees with a diameter above 8 cm ranges from 430/ha to 998/ha. The four stands with the highest and the lowest number of heavy trees are to be characterised as follows.

nr.	stem number/ha with d < 8 cm	soil type	basal area	ingrowth N/ha	bl.cherry N/ha
39	998	Lseg	22.8	9739	8062
19	948	Zdg - Zeg	27.2	7161	5991
28(B)	908	Zdg - Zeg	21.9	7641	6078
25	845	Sdg - LSeg - Spdg	27.6	6243	5563
...					
54	518	lSdg - lSeg	24.5	9016	7375
10(A)	517	Zdg - Zeg	26.9	7375	5850
17	511	Zdg	21.1	7912	6661
26	430	lSdg - Peg - sPdg	35.5	3578	2859

From these figures it is to conclude that there is no clear relation between the number of heavy trees in the ingrowth on one side and the soil type, the basal area or the stem number of the red oak on the other side.
It is apparent, that a high or a low stem number of heavy trees can appear under different circumstances.
In spite of the cover height growth is rather fair. For a same diameter class the red oak is mostly somewhat higher than the common oak or the black cherry. In the class 16-20 cm the height attains about 15 m. The height growth of black cherry is comparable with the one of the red oak and of the indigenous oaks (table 5)

Table 5. The average height (m) and degree of slenderness (DS) per diameter class.

Diameter class (cm)	red oak		indigenous oak		black cherry	
	H	SG	H	SG	H	SG
0 - 2	0.1	-	0.1		0.3	-
2 - 4	5.2	173	4.6	153	5.6	187
4 - 8	9.7	162	8.4	140	6.2	103
8 - 12	12.9	129	11.1	111	11.0	110
12 - 16	14.9	106	12.9	92	12.6	90
16 - 20	15.4	86	16	89	14.9	83
20 - 24	16.8	76	-	-	16.5	75
24 - 28	20.9	80	-	-	19.0	73

In the beginning the ingrowth is very slender. The degree of slenderness, however, decreases strongly with increasing diameter, so that this value fall under 100 for a diameter from 12 to 16 cm. On that moment the risk that stems would bend by an eventual liberation is not so high anymore.

The observations confirm, that deciduous trees are able to grow in spontaneously in Scots Pine stands that get older, and that it is not necessary to liberate strongly the stand cover, even on a very poor site. The indirect conversion of Scots Pine into mixed forests can proceed spontaneously and is quite well feasible with the help of the forester.

3.4. Age and growth

The average age of the red and nature oaks amounts respectively to 31.3 and 27.5 years. There has been, however, a rather long regeneration (Table 6 & table 7).

Table 6. The average age (y) and the age limits per diameter class

Diameter class (cm)	red oak		indigenous		black cherry	
	aver.age	limits	aver.age	limits	aver.age	limits
2 - 4	23.6	13/29	29.2	25/37	22.3	15/18
4 - 8	30.4	25/39	35.9	28/42	26.7	22/32
8 - 12	35.2	28/43	37.6	30/44	35.1	32/38
12 - 16	35.2	32/46	37.7	31/47	39.1	29/42
16 - 20	38.7	31/47	34.0	26/46	40.7	34/45
20 - 24	34.4	38/47	-	-	45.2	35/51

Table 7. Distribution of stem number per age class.

red oak		indigenous oak		black cherry	
age	stem number	age	stem number	age	stem number
< 18	5.8	< 17	23.4	< 16.5	81.7
18 - 22	8.5	17 - 22	12.1	16.5 - 20	7.7
22 - 30	23.9	22 - 31	43.9	20 - 27	7.3
30 - 37	30.2	31 - 40	15.9	27 - 32	2.4
37 - 44	22.5	> 40	4.7	32 - 41	0.7
> 44	9.1			> 41	0.2

The oldest trees are 51 year for the black cherry and 47 year for the red and native oak. The pine stands were 27 year old, when the spontaneous regeneration of the deciduous trees started.

There are two main reasons which explain that the regeneration first started about the age of 30 : the young pine stands are too dense and the trees of the deciduous border are still too young to produce seed.

The age differences of the actual occupation are properly speaking not so great :

- For the red oak the average age ranges from 23.6 year in the class 2-4 to 38.7 year in the class 16-20. More than 75 % of the plants are between 22 and 44 year. Only 5 % are younger than 18 year.

- For the indigenous oak the variation is of the same order ; the average age varies from 29.2 year in the class 2-4 cm to 37.7 year in the class 12-16 cm. Most of the plants have an age ranging from 22 to 31 year. For 70 % it is varying between 17 and 40 years. A fair number, 23 %, is younger than 17 year.

- For the black cherry the age increases rather regularly with increasing diameter class, namely from 22.3 years in the class 2-4, up to 45.2 years in the class 20-24 cm. More than 80 % of the plants are, however, younger than 17 year. This is mostly the consequence of the regularly cutting of the black cherry.

With the exception of the lowest diameter class, there is hardly, if any, difference in age between the larger trees of red oak and common oak. A 30 year old tree can reach a diameter either of 8 cm or of 25 cm. The most red oaks are older than 30 year. Most of the indigenous oaks, on the contrary, are younger than 30 year. The spontaneous ingrowth was the highest, when the Pine stands were between 30 and 50 years old.

The ingrowth decreased strongly from the age of 50. On that moment the black cherry had an explosive expansion. This is probably the main reason, why afterwards the spontaneous ingrowth of the deciduous trees was so scanty. There are no data about the number of seedlings and the reduction of the stem number in the past.There is, however, nowadays still a great number of seedlings, notwithstanding the bad circumstances for ingrowth. Seedlings of different species were observed. In all, 2,211 seedlings/ha were counted, this is 31 % of the total stem number of the regeneration. From these, however, more than 85 % were seedlings of black cherry. In the second place a fair number of seedlings of rowan trees were counted, namely 199/ha. Also 53 seedlings of Scots Pine appeared.For the rest a restricted number of seedlings of red oak, native oak, birch, locust tree and sweet chestnut were found.

However the question is, wether these seedlings will survive and wether they will be able to grow. Normally it may be expected, that the greater part is expected to die off. Seedlings of black cherry are found in all stands. Also rowan tree appears nearly everywhere. The other species were found in about half of the stands.

After calculating the correlation between age, height and diameter significant correlation coefficients are determined.

For all stands together the following equations were computed :

1. Relation L-d.

   - black cherry : $y = 7.49 + 0.59\ x$; $r = 0.87$; t +++
   - red oak : $y = -8.21 + 0.55\ x$; $r = 0.68$; t +++
   - native oak : $y = -5.88 + 0.45\ x$; $r = 0.58$; t +++

2. Relation L-H :

   - black cherry : $y = -3.81 + 0.44\ x$; $r = 0.89$; t +++
   - red oak : $y = -3.65 + 0.43\ x$; $r = 0.71$; t +++
   - native oak : $y = -1.94 + 0.33\ x$; $r = 0.63$; t +++

Both diameter and height growth of the native oak are on average somewhat slower than with the other species. The course of the height and diameter growth of blackcherry is nearly the same as the one of red oak.

The results, however, are not parallel in all stands. In most cases the differences in height and diameter between red oak and native oak become ever-increasing. This is normal, taking into account the larger tolerance capacity of red oak. In parcel 11, however, which has a low basal area (16.8 m^2) the differences between both species become ever smaller and it is even to be expected, that the indigenous oak will overgrow shortly the red oak.

- relation L - d :
  - red oak : y = -8.47 + 0.61 x ; r = 0.64 ; t +++
  - indigenous oak : y = - 13.88 + 0.63 x ; r= 0.78 ; t ++
- relation L - H :
  - red oak : y = -1.32 + 0.40 x ; r = 0.71 ; t +++
  - indigenous oak : y = -3.08 + 0.50 x ; r = 0.76 ; t ++

The high negative values of the a-factor in the equations indicate the slow youth growth. This is especially the case for the indigenous oak.

3.5. Stand structure

The Scots Pine stands were, originally, typical, homogeneous, even aged and uniform pine stands.They were predestined to be cutted as pit-props at the age of 40-50.

As a consequence of all kinds of circumstances the stands are nowadays much older. They have become a complex structure due to the spontaneous ingrowth of the deciduous trees.

The height of the dominant trees amounts mainly to 23.7 m. It ranges however from 21.0 m to 26.4 m. The difference in dominant height is important. The comparison between dominant height and soil type is as follows :

nr.	dominant height	soil type	nr	dominant height	soil type
54	21.0	lSdg-lSeg	28	25.8	Zdg-Zeg
11	21.9	Zeg-Zdg	26	26.1	lSdg-Peg-Spdg
7	22.5	Zeg-Zdg	22	26.4	Zeg-Zdg
17	22.5	Zdg			

The differences in dominant height cannot be explained either by the soil type or by the age. The origin is likely to play an important role.

The average distribution of the species over the three strata is as follows

	lower stratum	middle stratum	upper stratum
height (m)	0-7.9	8.0-15.8	15.9 - 23.7
% share	25.8	42.3	31.9

The highest stem number occurs in the middle stratum, namely 760 trees/ha pro 42.3 %. Nearly 70 % of the trees in this stratum are red oak.

The rest is formed by native oak, sweet chestnut, locust tree, maple birch, rowan tree, black cherry and some remaining Scots pine trees.

The upper stratum contains on average 32 % of the stem number, or 575 trees/ha. The share ranges from 21 % to 44 %. The pines take up, with 75 %, by far of the greatest part. But even red oak, black cherry, native oak, locust tree and sweet chestnut have penetrated already into the upper stratum. In plot 7 (1) the red oak occupies even already the half of the stem number.

The lower stratum is the least represented. Its share is restricted to 1/4 of the stem number. All kinds of species are found in it. According to the circumstances one definite species dominates. In most cases, there is an excess of black cherry ; but also red oak, birch, rowan tree and even lime can be represented fairly.

In the lower stratum the one year old seedlings were not taken into account. Yet they can occur rather frequently. On average 26/are were counted, especially seedlings of black cherry. The number of seedlings, however, varies very strongly from parcel to parcel. Apparently it is not determined by the density of the canopy. In some stands also seedlings of Scots Pine appear. Most of them are found in stand 27, which is rather clear and where more than 6000 small black cherries occur. There are 12 Scots pine seedlings per are. Their appearance is probably due to the recent cutting of the lower stratum of black cherry, which allows more light on the forest soil. However, the question is, how long the seedlings will survive. Nowhere in the forest a consolidated regeneration occurs. The main reasons for this is the unsuitability of the litter layer and the increasing density of the black cherry.
The vertical and horizontal structure of the stands is generally characterised by diversity. Eventually three types of stand structure can be distinguished (Fig. 1 tot 6).

1. Practically completely vertical and horizontal closing (Fig. 1 and 2). Such a situation is not directly a typical one for a homogeneous, even-aged Pine forest. Nevertheless this is the general pattern in this forest. The share of the hardwoods is already very large. Its crown cover is superior to the one of the Scots pine. The hardwoods penetrate already into the upper stratum.
   A lot of seedlings of several species appear. They are divided regularly over the whole area.

2. The closing is incomplete due to the limited stem number in the upper stratum (fig. 3 and 4). The upper stratum is not closed, although it is divided regularly.It is formed completely by Scots pine. The hardwoods appear only in the lower and middle stratum. They form here already a dense cover. Its canopy is even larger than the one of the upper stratum. The wry stand of many trees is remarkable.
   The very small number of seedlings is also remarkable.

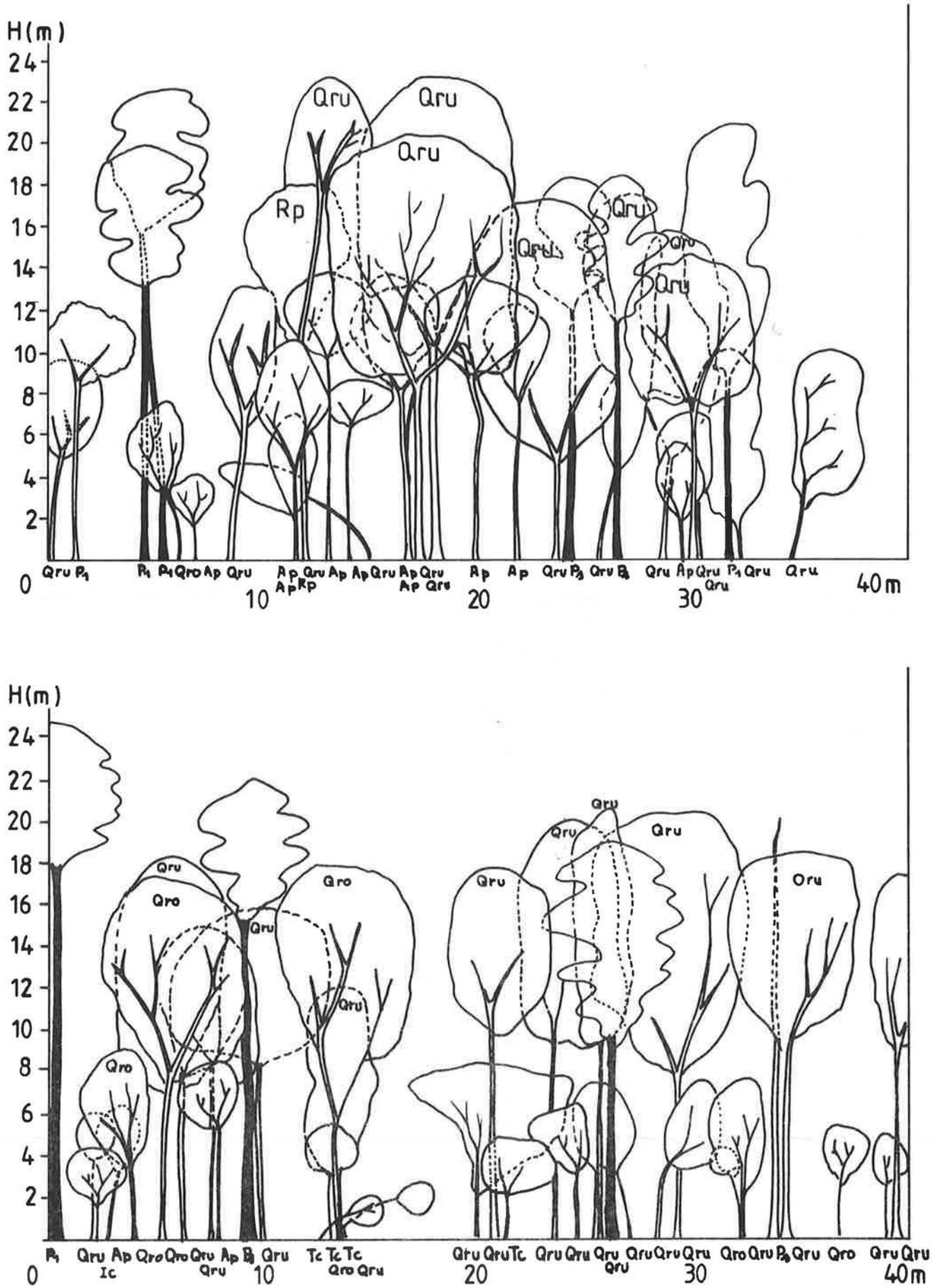
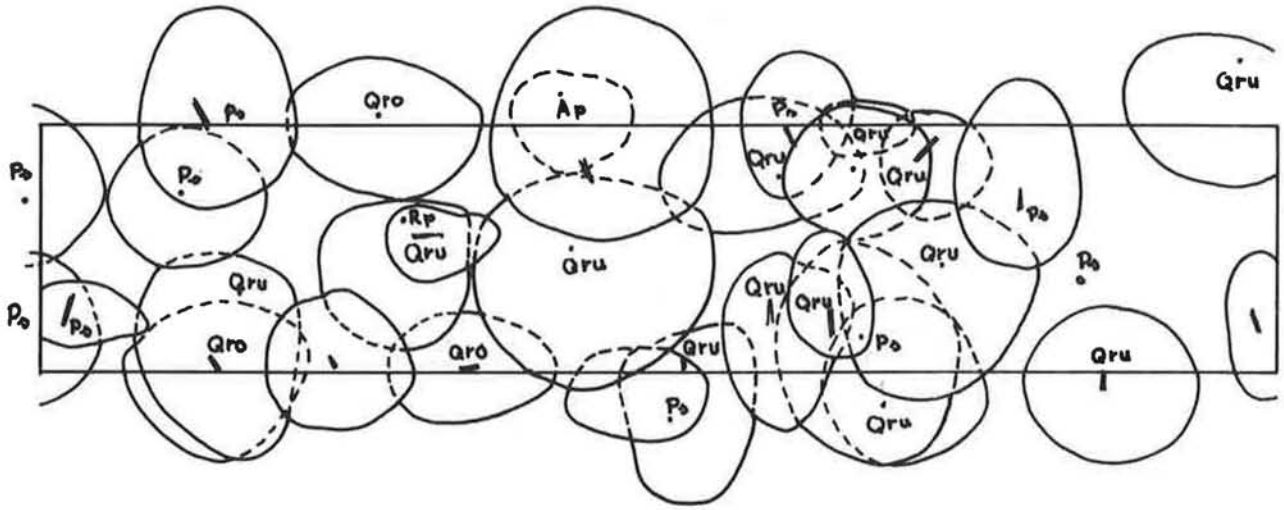
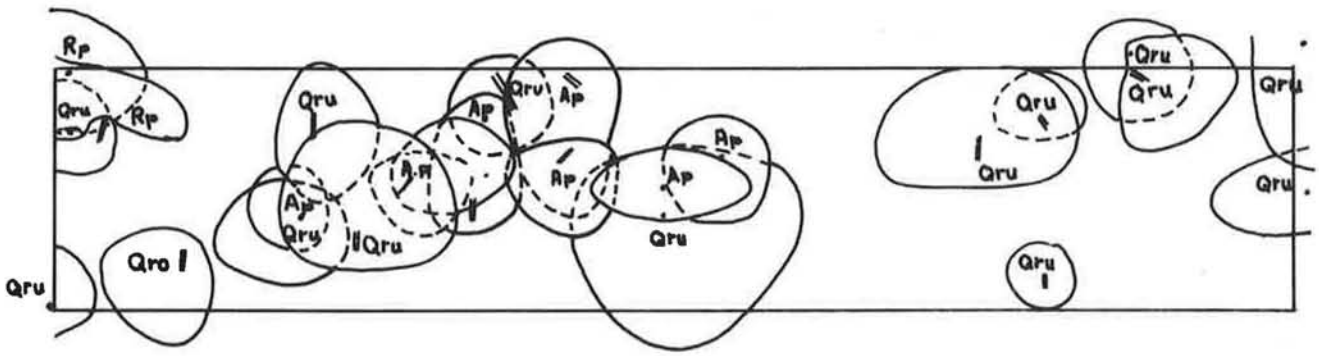


Fig. 1 : Vertical projection of the transect in parcel 7(1), 77 years, 250 trees/ha.

Horizontal projection of the upper stratum.



Horizontal projection of the middle and lower stratum.



Seedlings and stump sprout

✱ seedling of PS	ᵛ seedling of Pr.s.	♂ stump sprout of Pr.s.
• seedling of Q.ro.	▲ seedling of S.a.	♂ stump sprout of Q.ru.
✖ seedling of R.p.		o stump

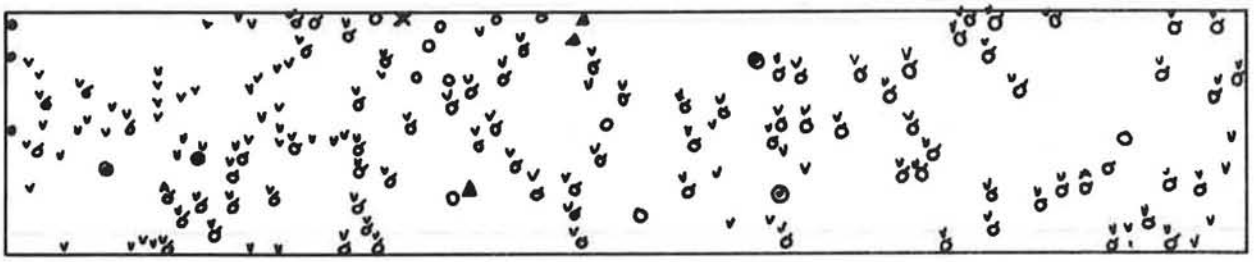
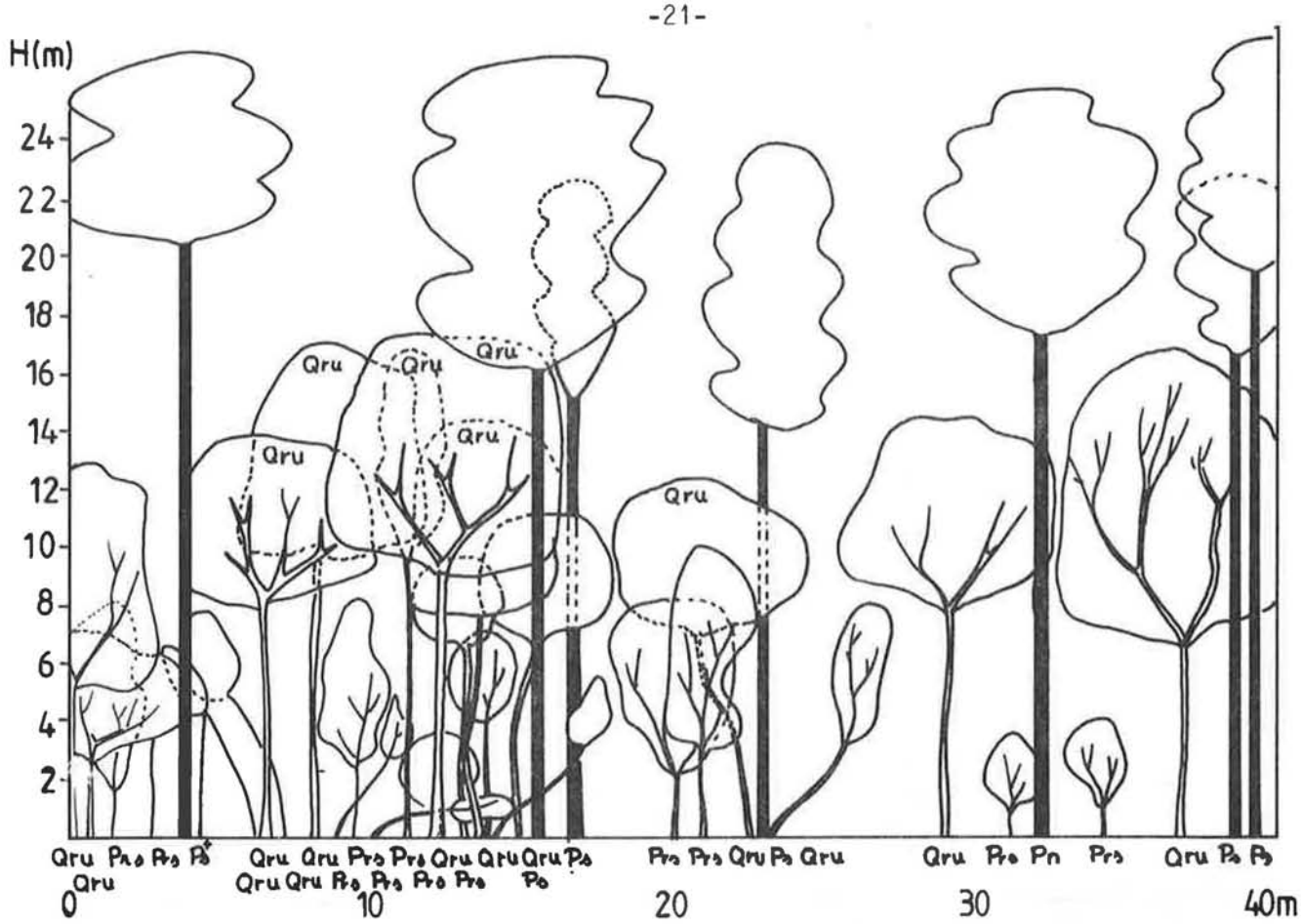


Fig. 2 : Horizontal projection of the transect in parcel 7(1).



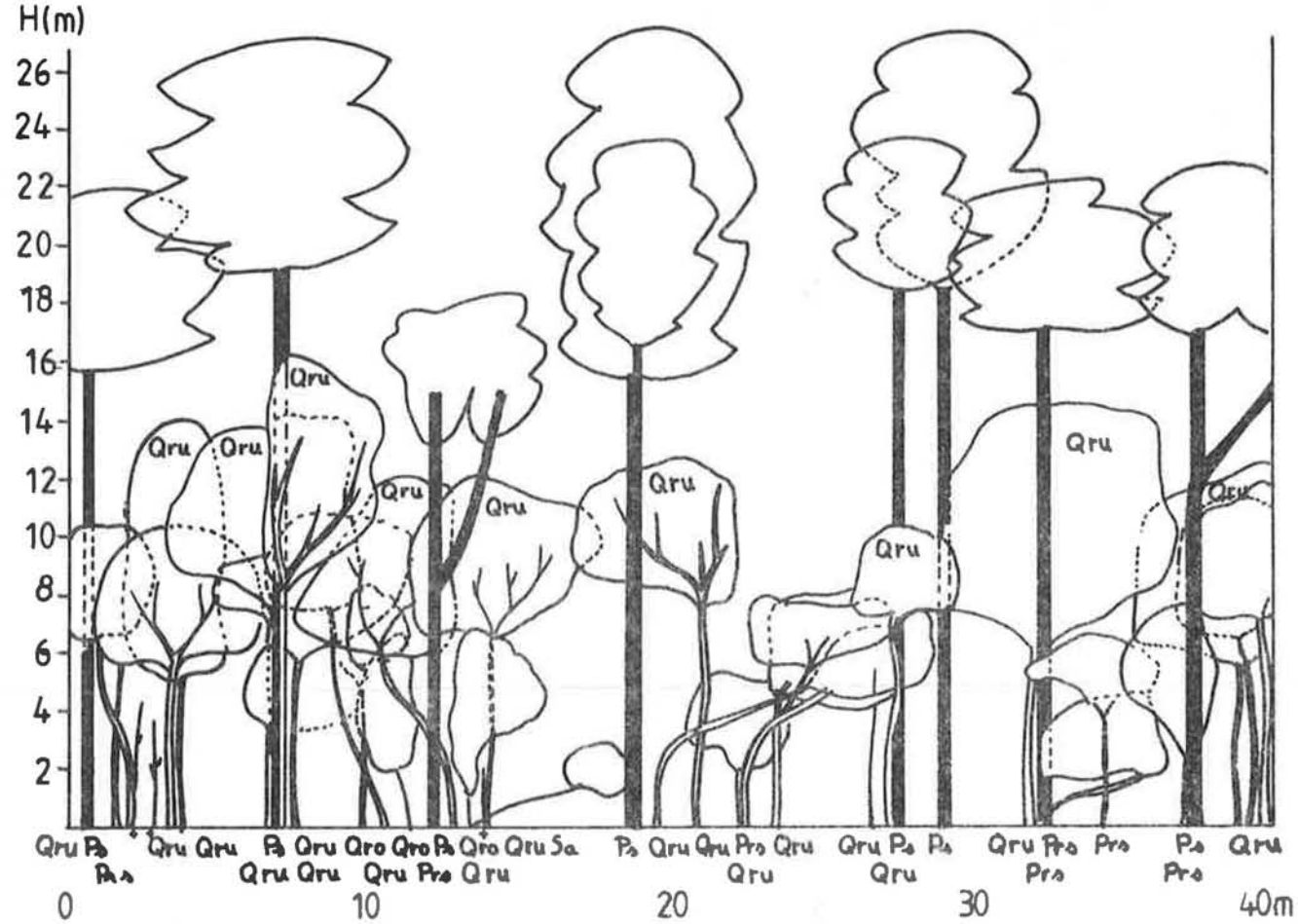
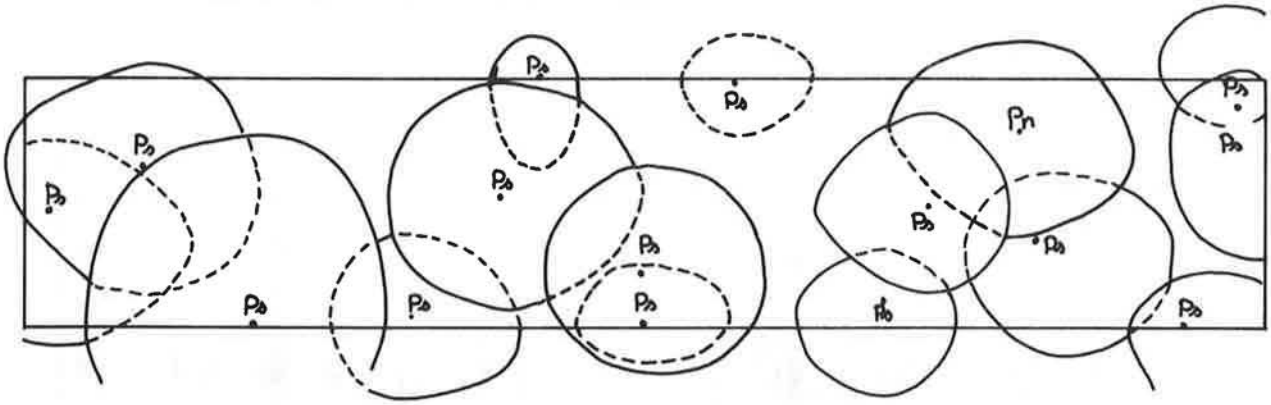
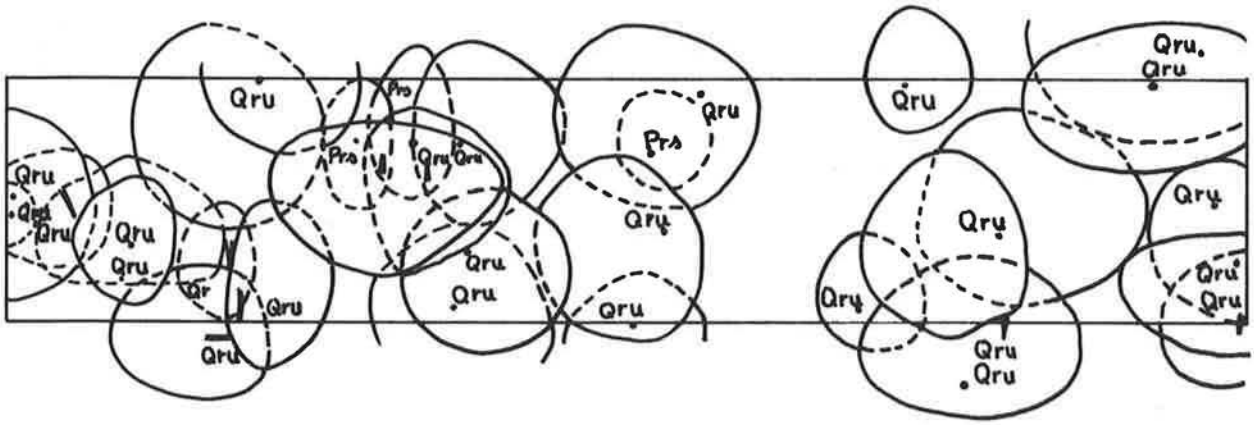


Fig. 3 : Vertical projection of the transect in parcel 22, 75 years, 380 trees/ha.

Horizontal projection of the upper stratum.



Horizontal projection of the middle and lower stratum.



Seedlings and stump sprout

▲ seedlings of S.a.
ᘐ stump sprout of Pr.s.
v seedlings of Pr.s.
o stump

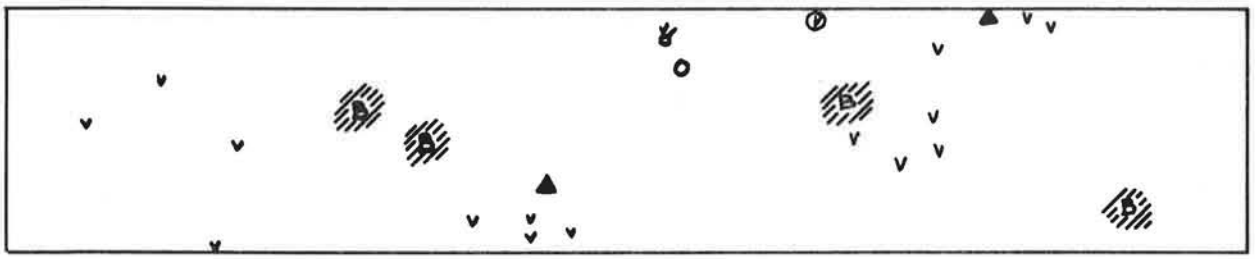
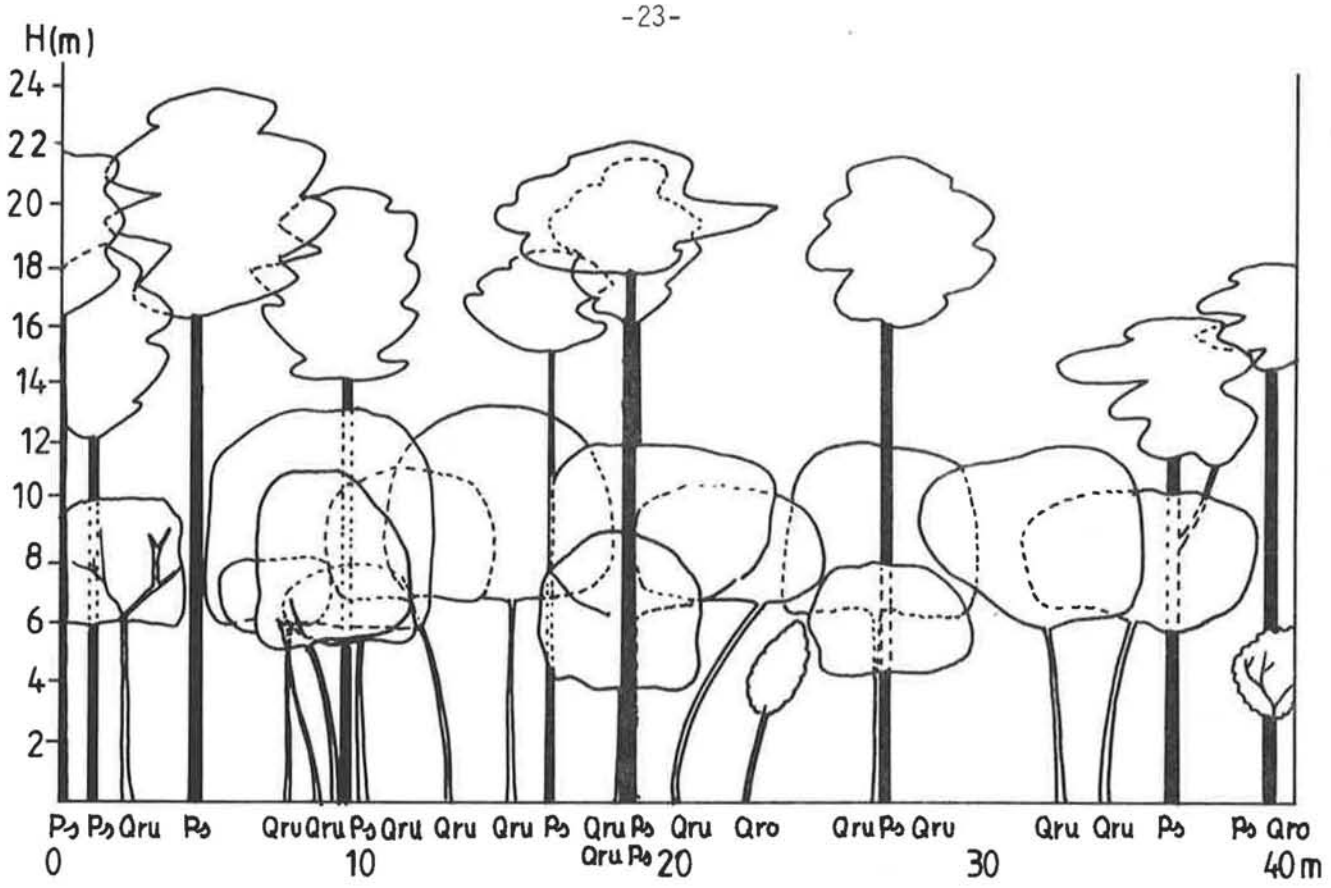


Fig. 4 : Horizontal projection of the transect in parcel 22.



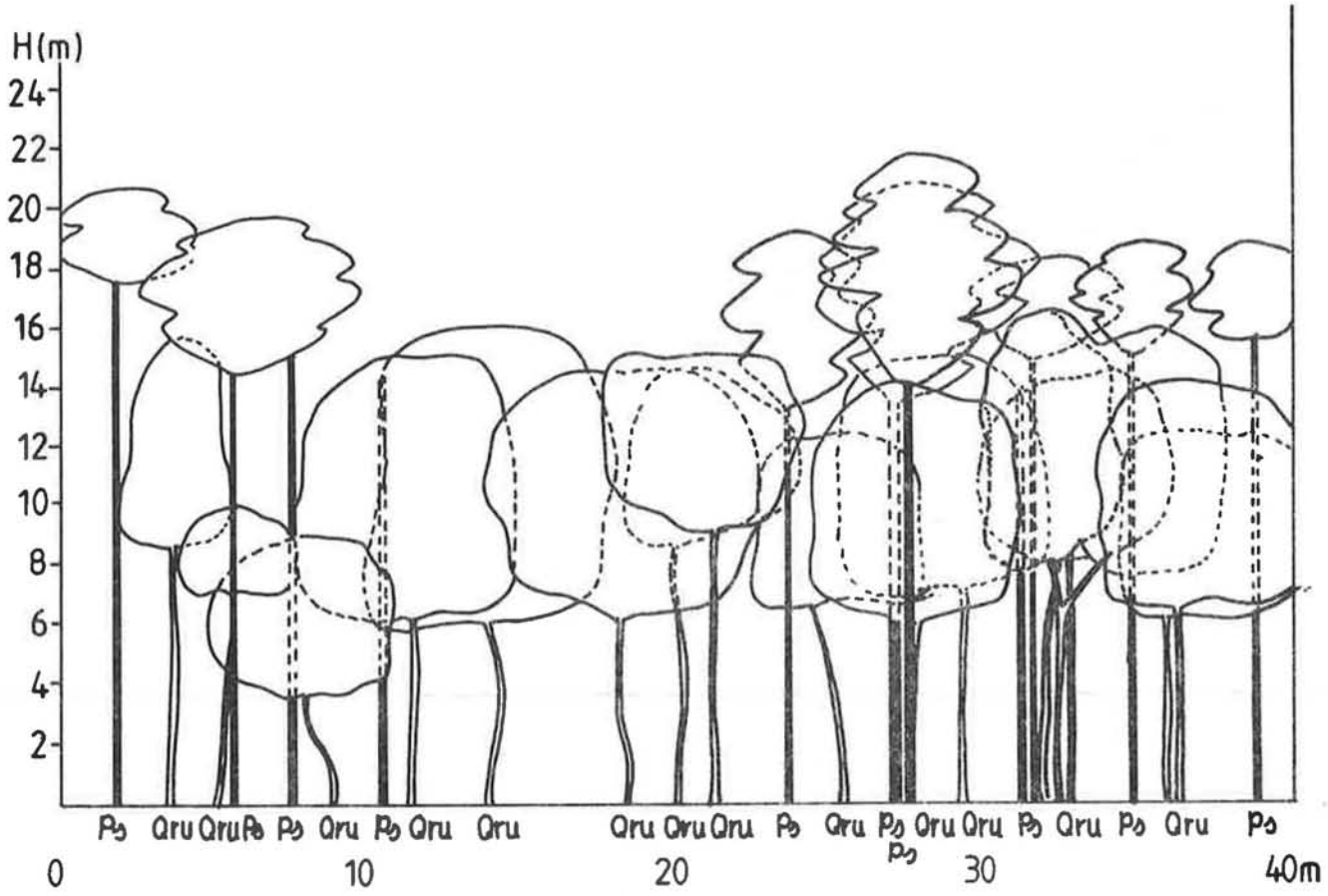
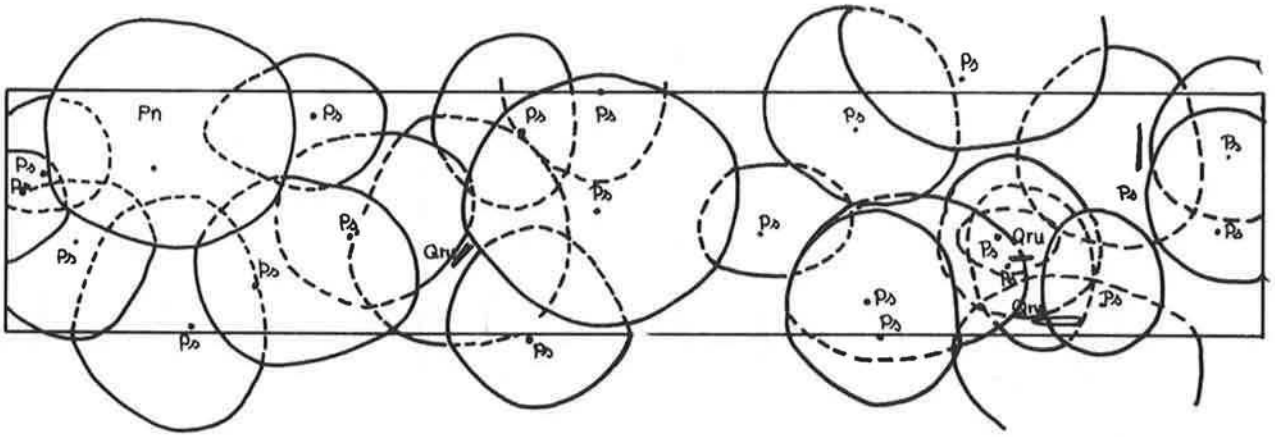
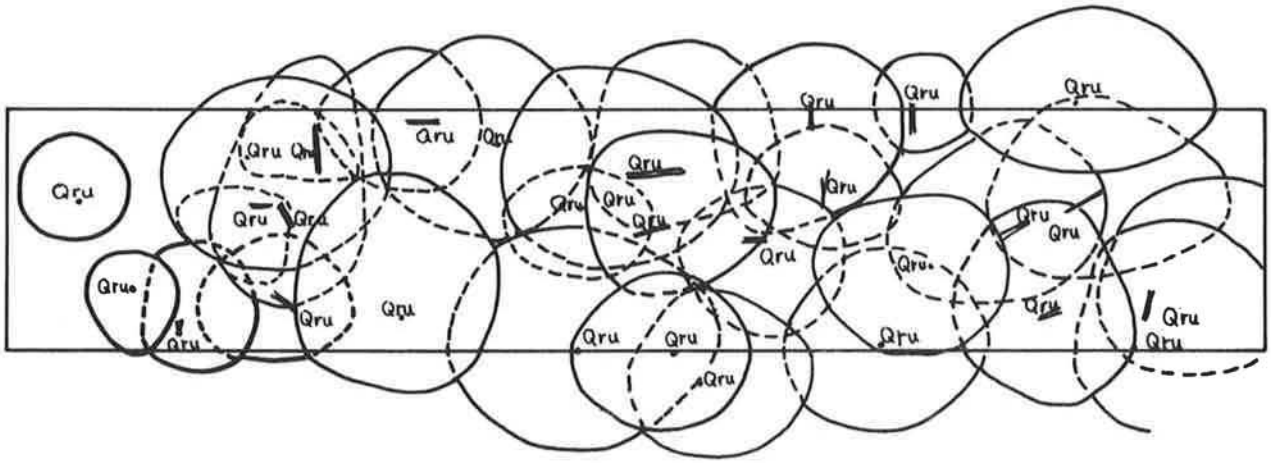


Fig. 5 : Vertical projection of the transect in parcel 17, 75 years, 320 trees/ha.

Horizontal projection of the upper stratum.



Horizontal projection of the middle and lower stratum.



Seedlings and stump sprout.

- ✱ seedling of PS
- ■ seedling of Q.ru.
- ● seedling of Q.ro.
- ♦ seedling of C.s.
- ♦ seedling of Fs.
- ▲ seedling of S + a
- v seedling of Pr.s.
- ♂ stump sprout of Pr.s.
- ♂ stump sprout of Q.ru.
- o stump

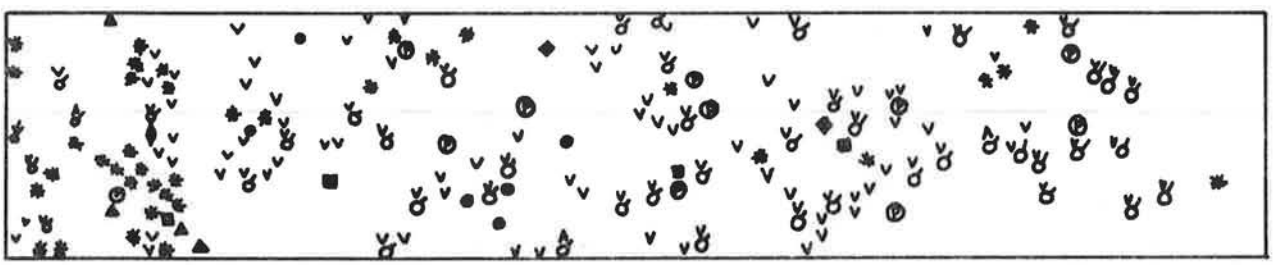


Fig. 6 : Horizontal projection of the transect in parcel 17.

3. The appearance of two more or less uniform strata (Fig. 5 and 6). There is a clear upper and middle stratum. The former is formed by Scots Pine, the latter by hardwoods. Both strata are nearly equivalent by cover. Together they form a complete closed canopy. The lower stratum is missing due to the recent cutting of the black cherry. This might, on the contrary, just be the reason for the frequent presence of seedlings, also of Scots pine.

4. CONCLUSIONS

The analysis of the spontaneous ingrowth of deciduous trees show the possibility of a spontaneous indirect conversion of homogenous even aged Pine stands to mixed hardwood stands or to mixed stands on a basis of hardwoods and softwoods. The conditions for this purpose are the presence of a limited number of seed trees of hardwoods and a certain opening of the aging Scots Pine stand. Better results, as well qualitative as quantitative, can be achieved by taking tending measures in the regeneration.

The natural regeneration of the deciduous trees occurs in a complex way. Several starting points can lead to the same results. The course of the regeneration is difficult to predict. The deciduous tree belts should not be too numerous and too wide in order to bring about a sufficient regeneration.
The regeneration of the deciduous trees established mainly when the Scots Pine stands were about 30 to 50 years old. In all 10 species appear. The regeneration seems to have a certain preference for humid soils. It can grow for years under a cover of stands with a basal area ranging from 20 to 30 m^2.
From a morphological point of view the trees are of good quality. There is little danger for snow or wind damage.

The spontaneous ingrowth of deciduous trees results in the fact, that the originally homogeneous Pine stands have nowadays a complex structure, with a practically complete horizontal and vertical closing. At the moment the middle stratum is represented the most, with 42 % of the stem number. The upper stratum still exists for 75 % of Scots Pine, but on average already 25 % is taken up by hardwoods.

A particular problem is formed by black cherry. It is largely represented in all stands. It is not clear to what degree it has restricted the regeneration of the other hardwoods. It might not be necessary to cut this species regularly. It might be the best to let it grow normally. Meanwhile other species might have the opportunity to establish. Later on black cherry can be cutted or it can be taken up in the upper stratum.

The intimate mixture undoubtedly causes tending difficulties. Especially the relation between the slow growing pedunculate oak and the fast growing red oak gives problems. It will be necessary to spend enough attention to the regulation of the mixture.

Also the absence of the Scots Pine itself should be considered as unfavourable. It is, however, possible to bring this species artificially in. This can occur by preference on places where the natural regeneration is insufficient or of bad quality. The share of the conifers may rather vary in accordance with the circumstances.

BIBLIOGRAPHY

ABETZ, P. (1972) : Zur waldbaulichen Behandlung der Kiefer in der nordbadischen Rheinebene, A.F.Z., 27, 591 - 594.

BØRSET, O. (1976) ; Problemen der Naturverjüngung in den nordischen Wäldern. Schweiz. Z. Forstw.,Zürich, 127, 3, 165 - 181.

DENK, J. (1974) : Kiefernpflege-selektiv- oder schematisch ? AFZ, 29, 110-111.

ECKHART, G. (1984) : Gedanken zur Planung von Naturverjüngungen. Allg. Forstztg. Wien, 95.2, 31-33

FRANZ, F. (1983) : Zur Behandlung und Wuchsleistung der Kiefer. Forstwiss. Cbl. Hamburg, 102, 1, 18-36.

GÜRTH, P. (1981) : Entscheidungshilfen zur Optimierung der Naturverjüngung. Allg. Forst. u. Jagdztg. Frankfurt. 152, 1, 1-8.

HEINSDORF, D. & KRAUSS, H.H. : Ergebnisse eines Meliorationsversuche zu Kiefer und Roteiche auf einem humusarmen Sandboden im Tieflandsgebied der DDR.

HENKEL, W. (1975) : Zur Problematik der Beseitigung " gefährender " oder " schädigender " Mischbaumarten, besonders in Fichten- und Kiefernbeständen. Soz. Forstwirtsch., Berlin, 25,5, 152-153.

HOCHTANNER, G. (1978) : Zur biologischen Bestandesumwandlung von Kiefern-Reinbeständen. Allg. Forstz., München, 33, 23, 676-677.

HUSS, J. (1972) : Steht die Kiefernwirtschaft vor einem Umbruch ? Forstarch. 41, 65-70.

HUSS, J. (1983) : Durchforstungen in Kiefernjungbeständen. Forstw. Cbl. 102, 1 1-17.

JOHNSON, C.L. (1986) : Factors affecting the establishment and distribution of Corsican pine natural regeneration at Holkham National Nature Reserve. Quart. J. Forest. London, 70, 2, 95-102.

JUNACK, H. VON (1978) : Stellungnahme zu Karl Sinner " Zur Neuorientierung der Kiefern-Reinbestandswirtschaft ". Allg. Forstz., München, 33, 6, 133-134.

KREMSER, W. (1963) : Versuch einer Würdigung von Stand und Aussichten des Strebens nach dem " höchstmöglichen Ertrag " am Beispiel von 12 Kiefern - Forstämtern in Regierungsbezirk Lüneburg. Forst- U. Holzwirt 18, 392-398.

LEIBUNDGUT, H. (1976) : Zum Problem der natürlichen Waldverjüngung in gemäszigten Zonen. Schweiz. Z. Forstw. Zürich, 127,2, 106-115.

LEIBUNDGUT, H. (1981) : Die natürliche Waldverjüngung. Bern, Haupt, 107 p.

LEIBUNDGUT, H. (1984) : Näturliche Verjüngung - Spielerei oder wirtschaftliche Notwendigkeit ? Allg. Forstztg. Wien, 95, 2 - 29 - 31.

LOIDL, W. (1984) : Alternativer Kunst- und Naturverjüngungsbetrieb in einem fichtenreichen Gebirgsrevier. Allg. Forstztg. Wien, 95,2 36-38.

PETRI, G. VON (1978) : Möglichkeiten und Grenzen einer Umwandlung von Kiefernbeständen in der nordbadische Rheinebene. Allg. Forstz., München, 33, 6, 127-128.

PREUHSLER, T. & REHFUESS, K.E. (1982) : Ueber die Melioration degradierter Kiefernstandorte (Pinus sylv. L.) in der Oberpfalz. Forstwiss-Cbl. Hamburg, 101, 6, 388-407.

ROTTMANN, M. (1981) : Möglichkeiten der natürlichen Verjüngung der Kiefer in Bayern. Allg. Forstz. München, 36, 9/10, 222-223.

SEITZ, R.A. (1980) : Untersuchungen zur natürlichen Verjüngung der Kiefer (Pinus sylvestris L.) in Bayern (Mittelfranken, Oberfranken und Oberpfalz). München, Univ., Forstw. Fak., Diss. 234 pp.

SINNER, K. VON (1978) : Zur Neuorientierung der Kiefern - Rheinbestandswirtschaft. Allg. Forstz., München, 33,6, 19-21.

TRILLMUCH, H.D. & UEBEL, E. (1982) : Ergebnisse eines Roteichenvoranbaues unter einem 64 jährigen Kiefernbestand bei gleichzeitiger mineralischer Düngung. Beitr. f.d. Forstwirtschaft, Berlin, 1, 34-39.

VAN MIEGROET, L. (1983) : The early stages of spontaneous forest regeneration on poor soils and continental sand dunes in northern Belgium. Silva Gandavensis, 49, 47-74.

VOEGELI, H. (1963) : Beitrag zur Frage der Föhrenverjüngung und - erziehung S.Z.F., 104, 11/12, 561-594.

VOEGELI, H. (1961) : Die Schattenerziehung der Föhre. S.Z.F., 112, 5/6, 350-363.