CHARACTERISATION OF SMALL-SCALE STAND TYPES IN A MIXED HARDWOOD FOREST

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ABSTRACT

Gradients in soil moisture, texture, nutrient state and spacing patterns enable us to divide stands into separate substands, which have their own tree species composition and structures.
Nevertheless, such a separation is just the beginning of a set of conclusions and observations. It is based upon differences in flora and chemical characteristics. As a matter of fact, every separate substand has its own microclimate in which a well defined complex of environmental variables regulates regeneration, flora presence and leaf decomposition.
The results of such an intensive research should lead to the improvement of the stand tending.

1. Introduction and problems

The main purpose of this study is to examine how gradients in soil moisture, texture, nutrient state and spacing patterns produce variations within one well defined stand.
The study was effected in the state forest of Wijnendaele, which is located in the north-western part of Belgium, near the North Sea. The presence of small watershed areas, as well as the fact that the forest had been managed as a coppice with standards, were considered to be interesting starting points.
The research was carried out in one single parcel of the forest, one hectare of which was studied thoroughly. First of all, attention was paid to the spatial partition of small-scale stand types. This was based upon structural features, variation in tree species composition and in regeneration.
The stand types are largely considered by means of surveys and horizontal and vertical transects. In this way, the mixture-ratios and the stratification could be analysed. Attention was also paid to the driving forces of the regeneration and herbaceous stratum. In this respect due attention was paid to the chemical characteristics of the stand types, the decomposition of the organic matter and to the phytosociology. Indeed, this kind of research is by far the best method to control whether the spatial partition was well carried out.
The results of this intensive research should lead to the improvement of the stand tending. Indications are given as to treat each separate stand type as a single stand.

2. Site characteristics

The forest of Wijnendaele is the remaining part of a greater complex. Its area has been reduced drastically over the centuries, especially in Napoleon's time when the development of a road network induced the exploitation of the reputated oaks

in this complex.
The forest is located on the southern slight slope of the Plateau of Wijnendaele, which is part of a cuesta (clay-sand formation). Seven wells rise on this slope. These wells owe their existence to the presence of tertiary sediments from the Ieperian and, more important, the Paniselian layers.
The Paniselian outcrops at the northern part of the forest, where the slope is at its steepest. It appears as a clay-sandy complex which causes the formation of wells.
The Yperian is the main tertiary sediment in the southern part of the forest, even though it does not outcrop there. It is also composed of sand and clay layers and it is covered by wind-borne sand deposits (sandy-loam or loamy-sand) from the Holocene and the Plistocene. The presence of clay in the subsoil causes temporary high water levels. Most of the soils are not podzolised and are in fact hydromorfic regosols. They are only podzolised in the places which do not contain clay in the subsoil.
The hydric classes vary from E (watery) to C (moderately dry). The texture classes range from sandy loam to loamy sand but also sandy soils and clay soils are present.

3. Inventory

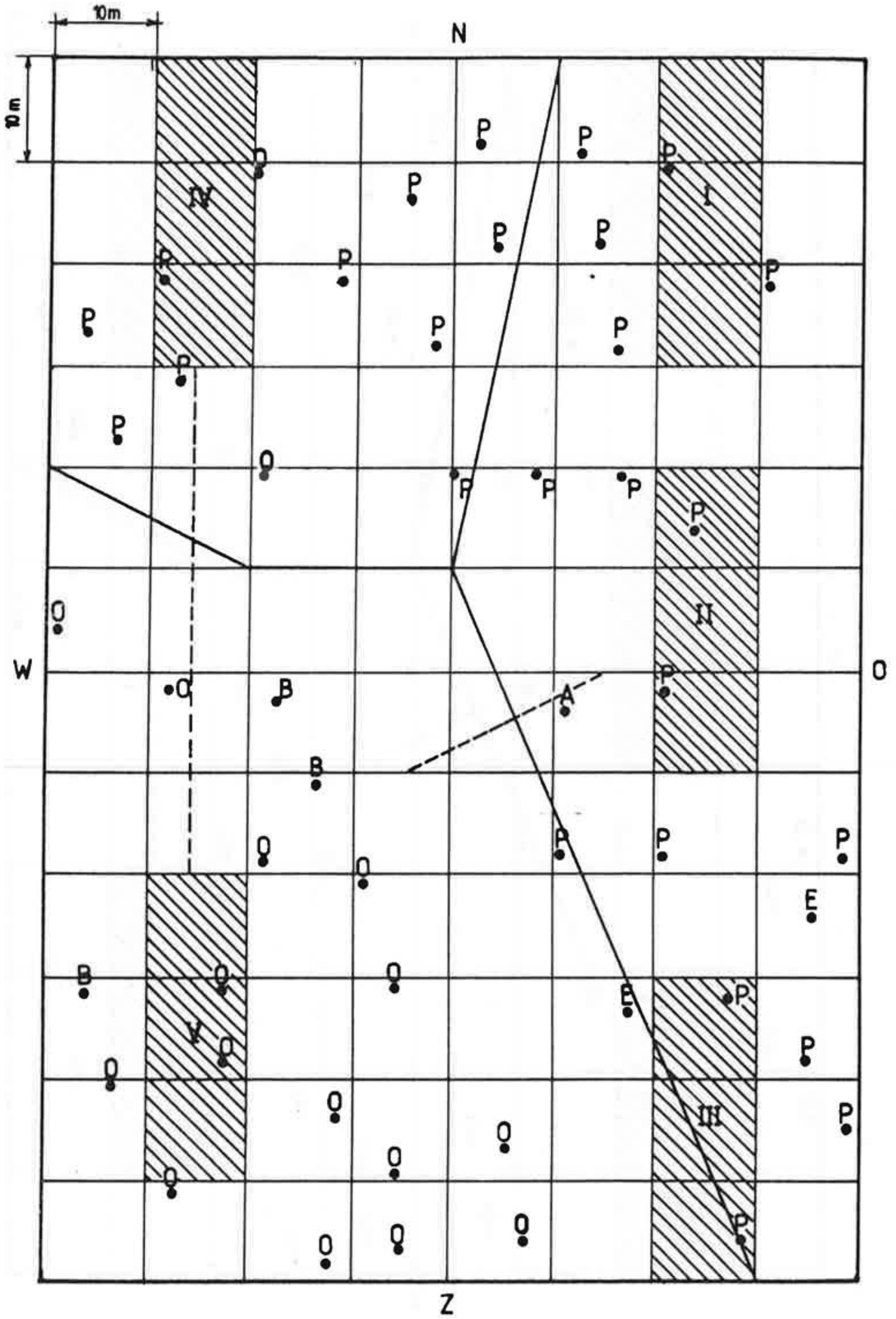
The research was carried out in one parcel of the forest. Just one hectare of this parcel was studied intensively (figure 1). As to the soil texture two clusters can be distinguished:

-76% sand, 16% loam, 8% clay= loamy sand;
-69% sand, 16% loam, 15% clay= sandy loam;

Figure 1 also shows the position of the brook and the water levels which were measured in December-January (1989-1990) and the texture classes. The altitude differences are also illustrated in fig. 1. It is clear that they match the differences in water levels.

As the major aim of the research is the identification of different stand types, it was necessary to create a ground plan of the involved reserve trees (fig. 1 overlay).

In this research, the area of one hectare was divided into one hundred units of one are. Then, an inventory of tree species and diameter was made in each unit of one are. It should be stressed here that a distinction was made between coppice stems and reserve stems. Furthermore, the fieldwork consisted of the observation of variations in stratification and regeneration.
The results obtained allowed us to gather neighbouring units (1 are) which showed similarities in tree species composition. Apart from the information received from the ground plan, the local structural differences were also taken in mind for the final creation of 5 stand types (Figure 1).
In this way, the general inventory leaded to the recognition of the following five stand types.



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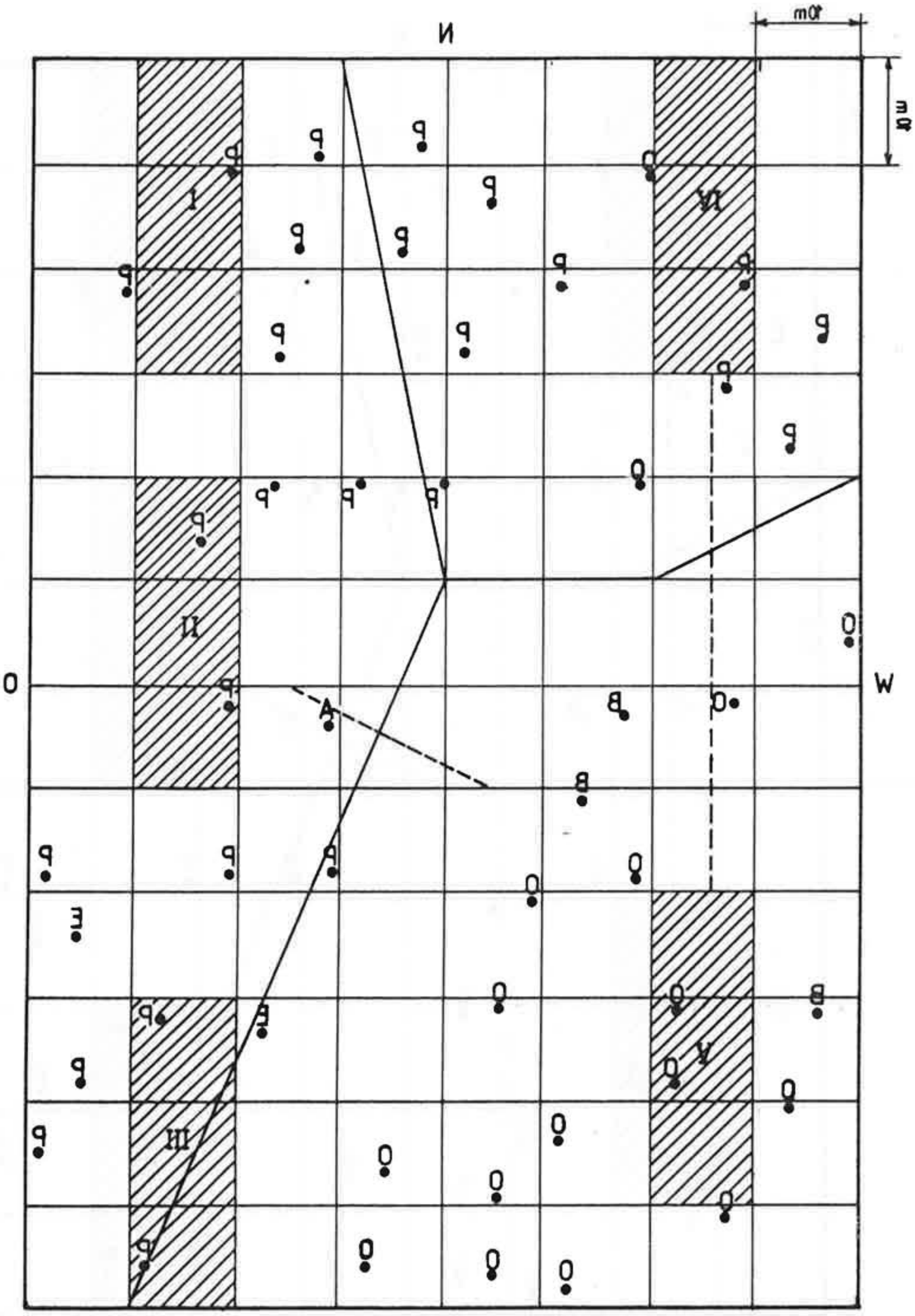
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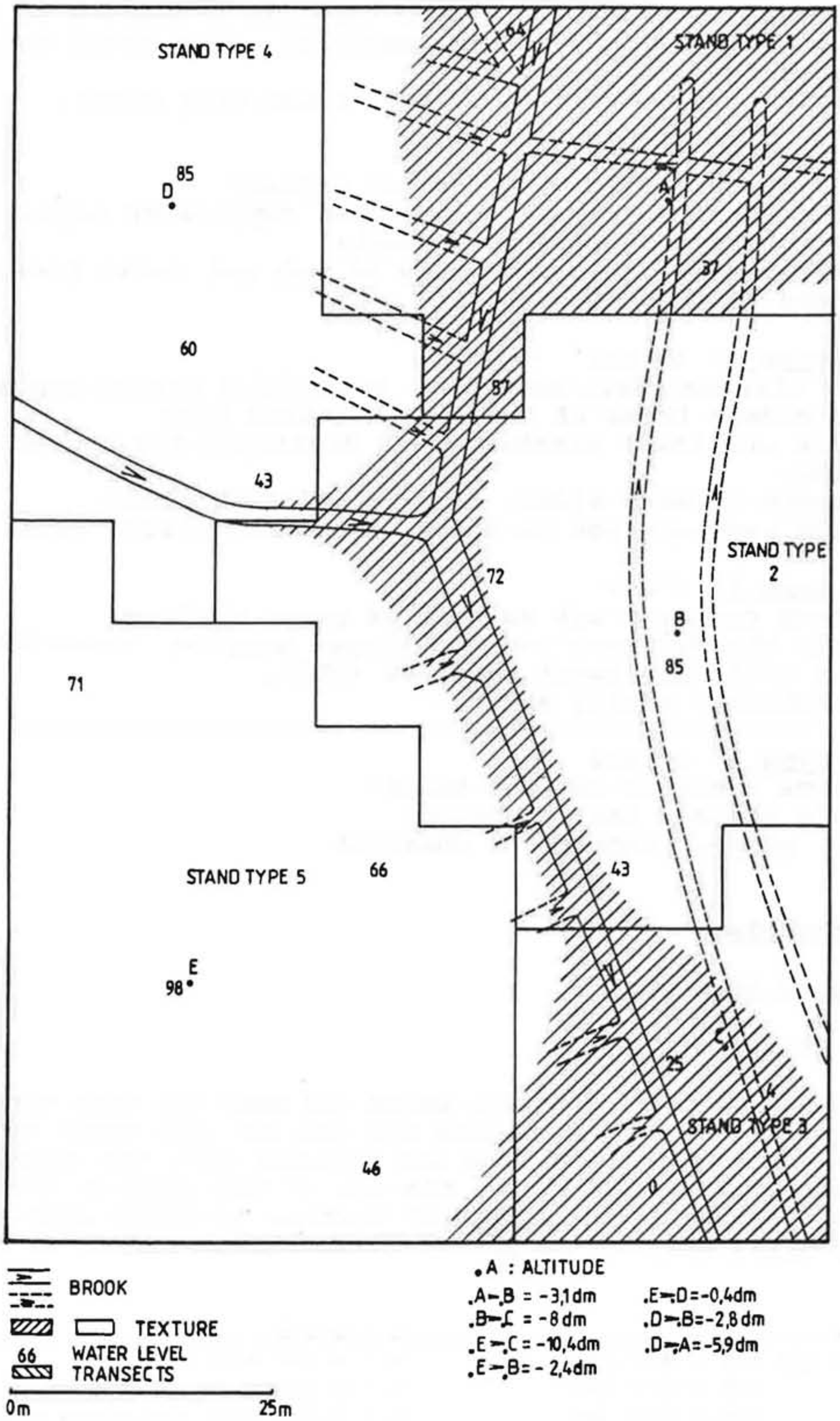


Figure 1: Situation of the brook and the stand types (including the position of the transects) and their texture classes, differences in water level and in altitude.
Overlay : Ground plan of the reserve trees including the position of the transects.
Legend : o:oak p:poplar b:beech
e:elm a:ash

stand type 1: 16 are
- slight diversity in tree species;
- upper storey: poplar;
  middle storey: poorly developed, only containing maple;
  under storey: well developed, especially suckers of the smooth-leaved elm (*Ulmus campestris*), also hazel and elderberry;
- absence of regeneration of ash, rowan,grey alder,...

stand type 2: 25 are
- upper storey: slight shelter of poplar;
  middle storey: very well developed coppice of maple;
  under storey: nearly not present;
- rich regeneration, especially of ash and rowan tree; less suckers of smooth-leaved elm

stand type 3: 10 are
- upper stratum: well developed, especially mature poplars, but also modern trees of the smooth-leaved elm;
- middle and lower stratum: less developed due to the decay of maples;
- presence of more alder, especially black alder;
- little regeneration in spite of the favourable light regime.

stand type 4: 17are
- reserve contains oak as well as young poplars;
- middle storey: very well developed coppice, contains maple (75%) and sweet chestnut (25%);
- understorey: nearly absent.

stand type 5: 28 are
- reserve contains oak and beech;
- middle storey: nearly absent;
- under storey: coppice of chestnut

4. Methodology

4.1.Stand Structure

4.1.1. Inventory.

Starting from the inventory, which was made for each single unit, an overall inventory was made for the various stand types.
The basal area of each tree was divided into the basal area of the reserve trees (BAr) and the one of the coppice trees (BAc).
The recognition of this kind of mixture is based upon the share of the basal area of the present tree species (LUST et al,1985).

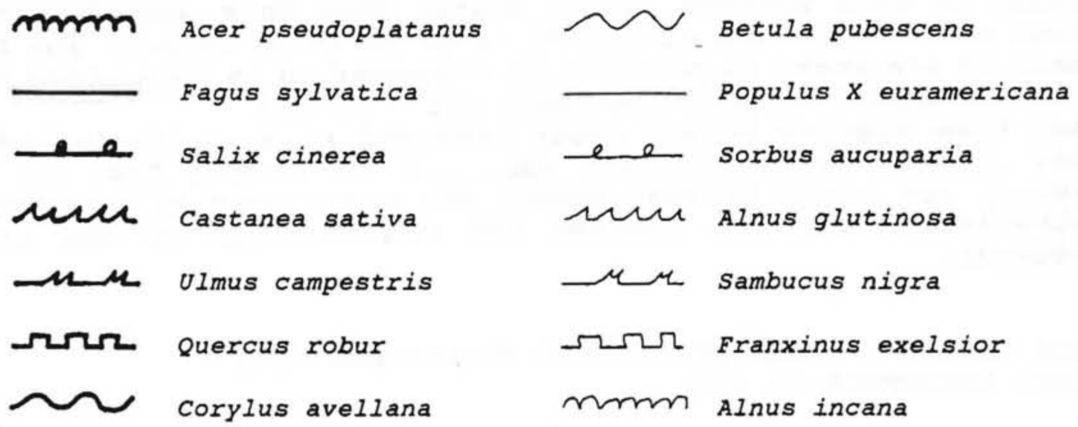
A > 90%	A - stand
A > 50% and 50% > B > 25%	A - stand with B
25% > B > 10%	A - stand mixed with B
10% > B > 5%	A - stand with admixture of B
5% > B > 2%	A - stand with slight admixture of B
50% > A > 25% and 50% > B > 25%	mixture A - B
25% > B > 10%	stand of A mixed with B
10% > B > 5%	stand of A with admixture of B
5% > B > 2%	stand of A with slight admixture of B

4.1.2. Transects

Fig.1 shows the position of the transects. They contain three neighbouring units of one are.
Only the trees, the crown projection of which was part of or touched the rectangle, were surveyed. Regeneration and suckers which did not reach a height of 4.80 metres, were noted in a separate table.
As to the horizontal projection, the coppice crowns are indicated in full lines whereas the contours of the crown projections of the reserve stems are presented in dotted lines. The crowns of the middle stratum are shaded.
The crown projections of each stratum were planimetried, so that the crown cover of each separate stratum could be measured in every unit. In this way it was possible to look for correlations between the different storeys.
Regarding the vertical projection, height measurements of the tree species were carried out with a Blume-Leiss (december,1989). Based upon the upper height ho (average height of the 100 tallest trees/hectare), three storeys could be distinguished:

upper storey: h >2/3 ho
middle storey: 1/3 ho < h < 2/3 ho
under storey: h < 1/3 ho
(with ho approximately 30.5 metres)

The outlines of the crowns of the different tree species were indicated with a different profile or with a different thickness, as shown below.



4.2. Organic Matter

In each stand type the organic layers were sampled according to the prescriptions of Klinka et al (1981). Therefore a distinction was made between the litter layer, fermented layer, the Ah1-horizon. The layers were sampled by removal of the organic matter, one by one, over a surface of 0.25 m^2/ha. They were weighed on the spot. From this matter, samples were taken for the chemical analysis. These samples were also weighed on the spot and dried at a temperature of about 80 degrees. Once the conversion factor was determined, the dry weight of the 0.25m^2-samples could be assessed.
All the layers were analysed chemically in order to know the significant differences between the stand types.
Measurements of litterfall (leaves) were carried out too. Yet only the leaves of the trees of which the leaf mass was important enough (> 5 g), were included in the analyses. The leaves were collected during four months (from September till December 1989)

and were harvested every two weeks in littertraps (Diameter = 37.5 cm).
In contrast to the stand types, the samples of each tree were mixed so that the standard deviation could not be calculated. An analysis of variance was performed within a particular layer in order to examine the significant differences between the five stand types. The Duncan-test was executed with a significance level of 0.05.

5. Stand structure

5.1. Surveys

In the survey a difference was made between the appearance in reserve (nr) or in the coppice (nh). The tree species are indicated with the abbreviations of their latin names (tables 1 to 5).

STAND TYPE 1: POPLAR STAND WITH MAPLE AND WITH ADMIXTURE OF SMOOTH LEAVED ELM

This stand type has the highest basal area (37.2 m^2/ha) and the highest stem number (8675 /ha). The reserve is completely made up of poplar (19.5 m^2/ha) whereas the maple (in most cases appearing as coppice) attains a basal area of 14.4 m^2/ha. The remaining basal area is split up (Smooth-leaved elm: 2.3m^2/ha; hazel and elderberry: 1 m^2/ha).
The high number of stems is explained by the strong spontaneous and induced suckering of the Smooth-leaved elm (nulm= 3820). In respect to this RACKHAM (1980) stated that this characteristic allows the elm species to invade large parts of forest. The high number of elm stems is practically compensated in this stand type by the decay of thicker specimens (12 - 16 cm).
Other tree species do not occur here and regeneration of other trees (alder, ash, mountain ash,...) is absent too. It is, however, not clear to what extent the appearance of suckers of Smooth-leaved elm has limited the regeneration of the other hardwoods.

STAND TYPE 2 : MAPLE STAND WITH POPLAR AND WITH SLIGHT ADMIXTURE OF ASH

Poplar and maple still dominate in this stand type (they contain 90 % of the basal area), but the degree of mixture is inverse. The maple takes up 17.2 m^2/ha (52 %) of the baseal area, whereas the share of the poplar is limited to 12 m^2/ha (36 %).
The only stand type where the ash plays a certain role, it occurs both in the coppice and in the reserve (total share: 1.6 m^2/ha 4.7 %). The regeneration of the ash is moderate but the seedlings are well consolidated and over one year old.
Grey alder and rowan are also well represented. There are less suckers of elm. This stand type shows an important regeneration, (especially ash, rowan, maple and sweet chestnut, even oak and beech).

STAND TYPE 3: POPLAR STAND MIXED WITH MAPLE AND SMOOTH-LEAVED ELM AND WITH SLIGHT ADMIXTURE OF GREY AND BLACK ALDER

In this stand type the reserve reaches the highest basal area of all the stand types. This is due to the presence of old

poplars and of modern elm trees.
Because of the decay of maple, the coppice is less developed. This phenomenon, however, is only limited to the sites of the stand with a high water level during the winter time.
The remaining part of the coppice is occupied by black (1.86 m^2/ha) and grey alder (1.45 m^2/ha). Black alder in particular is growing well on these hydromorfic soils.
Due to this mortality, more space became available for regeneration, particularly of black alder and grey willow; tree species which are ecologically more adapted to the moist soils of this stand type. After all, the regeneration of the black alder (160) and the grey willow (60) remains scanty since it has to compete with the rough herbaceous vegetation of the Cirsio-Alnetum: *Epilobium hirsutum*, *Lycopus europaeus*, *Solanum dulcamara*, *Cirsium palustre*...
Seedlings of other tree species are missing but there are a lot of suckers and stump sprouts from the Smooth-leaved elm (1000) and grey alder (600), which compensate for the scanty regeneration in this stand type.

STAND TYPE 4 : STAND OF MAPLE MIXED WITH POPLAR, COMMON OAK AND SWEET CHESTNUT AND WITH SLIGHT ADMIXTURE OF HAZEL

The coppice is well presented (20.5 m^2/ha) and consists mainly of maple with 75% (15.2 m^2/ha) and sweet chestnut (5.3 m^2/ha).

The reserve contains young poplars (50 %), oak (38 %) and also saplings of the (12 %) which were planted under shelter for conversion's sake. A lot of secondary tree species appear in this stand type (alder, mountain ash, willow,elm,...). In particular the share of the hazel is considerable (1 m^2/ha).
The regeneration is not as important as in stand type 2.

STAND TYPE 5 : OAK STAND MIXED WITH COMMON BEECH AND SWEET CHESTNUT AND WITH ADMIXTURE OF BIRCH

This stand type has a lush reserve (24 m^2/ha mainly composed of ancient oaks (18 m^2/ha but also beeches (4 m^2/ha which were planted under the oak canopy in order to replace the ancient oaks.Due to a recent cutting the coppice is the least represented (4.6 m^2/ha).
It contains especially sweet chestnut (3.4 m^2/ha) and, to a lesser extent, birch (1.2 m^2).
As far as regeneration is concerned, only saplings of birch occur. They are nearly always observed in small units of regeneration, appearing in the openings of the stand type.
The share of the sweet chestnut in this stand type will certainly decrease in the next decennia. The large stumps were excessively cut and are now completely exhausted. Moreover, in most cases the chestnusts suffered from a disease (*Endothia parasitica*).

Conclusion

The basal areas of the reserve and the coppice are complementary (table 6). The lesser importance of the upperstorey (reserve) is compensated by a better growth of the lower storeys (coppice).
In stand types 2 and 4 the coppice is well represented (20 m^2/ha), whereas in the other stand types the reserve dominates the coppice. The basal area of coppice and reserve are correlated negatively (r=-0.9).

Table 1: Survey of stand type 1.

spec\d	2	6	10	14	18	22	26 ·	46	50	54	66	70	74	nh of nr	ntot/spe	gr of gh	g tot/spe (m^2)	
ula ca nr	1587	144	6											1737	3830	0.954375	2.25625	
ula ca nh	1906	162	19	6										2093		1.301875		
cor av nr	56													56	737	0.01768	0.37298	
cor av nh	625	56												681		0.3553		
ace ps nr	100	25		19										144	3161	0.390625	14.42375	
ace ps nh	1494	762	337	237	169	12	6							3017		14.03315		
pop eur									6	6	19	6	19	56		19.54266		
sam ni nr	162	75	6											243	780	0.3122	0.57526	
sam ni nh	500	37												537		0.26306		
fra exc	19													19		0.005887		
que rob	6													6		0.002		
sor au nr	6	12												18	·74	0.0373		
sor au nh	56													56		0.00177		
n tot/dkl	6517	1273	368	263	169	12	6		6	6	19	6	19	N 8675			G 37.233806 m^2 Gh 15.953437 m^2 Gr 21.27715 m^2	42.846%

Table 2: Survey of stand type 2

spec\d	2	6	10	14	18	22	26	50	54	58	62	66	70	74	nh of nr	ntot/spe	gr of gh	g tot/spe (m^2)	
aln in nr	172	12	24	8											216	700	0.4	0.473	
aln in nh	464	8	8	4											484		0.073		
ace ps nr	64	46	28		1										141	2917	0.4776	17.1632	
ace ps nh	969	900	392	312	172	35	4								2776		16.6656		
pop eu								4		8		4	4	16	36		12.6988		
ula ca nr	564	36	4												604	932	0.3104	0.544	
ula ca nh	296	28		4											328		0.2336		
cor av nr	36														36	248	0.012	0.2588	
cor av nr	156	48	8												212		0.2476		
fra es nr	216										4				220	[illegible]	1.276	1.5685	
fra ex nh	12	4	20	8											44		0.2952		
sor au nr	172														176	220	0.116	0.12984	
sor au nh	44														44		0.01384		
sam ni nr	132	4													136	548	0.0528	0.192	
sam ni nh	408	4													412		0.1392		
rha fr nr	12														12	32	0.0036	0.01	
rha fr nh	20														20		0.008		
bet pu nr	64	8	15												88	92	0.1684	0.196	
bet pu nh			4												4		0.0312		
que rob	36														36		0.01135		
aln glu	16														16		0.0048		
fag syl	36														36		0.0076		
cas sa	4														4		0.00124		
ntot/dkl	3884	1100	504	336	173	36	4								N 6072			G 33.477 m^2 Gh 17.94424m^2 Gr 15.533m^2	55.00%

Table 3: Survey of stand type 3

spec\d	2	6	10	14	18	22	42	46	50	54	62	66	72	90	94	nr of nh	ntot/spe	gr of gh	g tot/spec (m^2)	
ace ps nr	260	40	20	10	10											340	1360	0.7603	4.8753	
ace ps nh	420	310	180	110												1020		4.115		
pop eu												10	10	10	10	50		22.09419		
aln glu m	160		10	10												180	400	0.283	1.86	
aln glu m	100	30	30	30	30											220		1.457		
ulm ca nr	630	60	20				10		10							730	1060	4.156	4.4859	
ulm ca nh	240	90														330		0.3299		
sal ci	60															60		0.019		
aln in nr	130	50	40	10												230	630	0.6503	1.4545	
aln in nh	310	30	40	20												400		0.8042		
cor av nr	30															30	210	0.00924	0.19144	
cor av nh	130	50														180		0.1822		
cas sa nh	40	20	30	20												110		0.613		
bet pu nr		10		10												20	140	0.182	0.7474	
bet pu nh	40	50	20		10											120		0.5654		
fag sy nr			30													30		0.02356		
que ro nr	10															10		0.00314		
sor au nr	20															20	40	0.00628	0.0125	
sor au nh	20															20		0.00628		
rha fr	10															10		0.00314		
sam ni nr	100	20														120	350	0.0879	0.1608	
sam nr nh	230															230		0.0729		
ntot/dkl	2940	760	420	220	50											N 4660		G 36.7565 m^2 Gh 8.19298 m^2 Gr 28.56352 m^2		22.29%

Table 4: Survey of stand type 4

spec\d	2	6	10	14	18	22	26	46	50	54	58	66	70	94	nr of nh	ntot/spe	gr of gh	g tot/spec (m^2)	
ace ps nr	121	36	7	7	7	7									185	3506	0.75847	15.19407	
ace ps nh	1750	714	429	286	114	21	7								3321		14.4356		
cas sa nr	42		7	14			7								70	443	3.668714	5.32725	
cas sa nh	93	50	79	86	29	29	7								373		1.658535		
pop eu								14	7	7		7			35		7.85621		
fag sy nr	14	21	7												42		0.177271		
que ro nr	21							7						7	35		6.150786		
fra ex	7														7		9.0026		
cor av nr	49														49	1056	0.001570	1.032235	
cor av nh	779	214	7	7											1007		1.016528		
ulm ca nr	229														229	479	0.071785	0.401642	
ulm ca nh	150	100													250		0.329857		
sam ni nr	64														64	271	0.09156	0.156632	
sam ni nh	207														207		0.06507		
bet pu nr	21	29	14												64	85	0.199714	0.22439	
bet pu nh	14	7													21		0.024678		
sor au nr	136														136	150	0.042635	0.047120	
sor au nh	14														14		0.004485		
aln gl nh		7	7												14		0.076295		
aln in nr	7														7		0.024528		
pru sp nr	29														29		0.008928		
ntot/dkl	3747	1178	557	400	150	57	21	21	7	7		7		7	N 6171		G 36.5863 m^2 Gh 20.5377 m^2 Gr 16.0522 m^2		56.121%

Table 5: Survey of stand type 5

specid	2	6	10	14	18	22	26	30	34	38	54	::	62	66	70	74	94	98	>1	nr of nh	ntot/spe	gr of gh	g tot/spec (m^2)
cas sa ah	432	593	189	4																1218		3.35365	
bet pu ar	375	229	18																	622	1051	0.9043	1.5147
bet pu ah	296	104	29																	429		0.610366	
fag syl			14	21	4	4	4				4			7						58		4.119974	
que ro ar	11					4			4	4	7	7	7	7	4	4	4		4	67		18.2338	18.28
que ro ah	13																			13		0.01458	
ace ps ar	6	11																		17	382	0.032538	0.047118
ace ps ah	261	61	39	4																365		0.455531	
pru sp ah	36																			36	.	0.03146	
rha fr ar	11																			11	29	0.093366	0.0089
rha fr ah	18																			18		0.00561	
aln gl ar		4	4																	8	12	0.038148	0.0931
aln gl ah			4																	4		0.05498	
sor au ar	96	14																		110		0.070685	
ntot/dkl	1555	1016	297	29	4	8	4		4	4	11	7	7	14	4	4	4		4	N 2976	G 28.01285 m^2 Gh 4.5833 m^2 Gr 23.42955 m^2		16.3612

Table 6: Distribution of the basal area over coppice and reserve (m^2/ha)

Stand type	1	2	3	4	5
Total	37.2	33.5	36.8	36.6	28.0
Coppice	15.9(42%)	18.0(55%)	8.2(22%)	20.5(56%)	4.6(16%)
Reserve	21.3	15.5	28.6	6.0	23.4

5.2. Transects

STAND TYPE 1

The vertical closure between upper (poplar) and middle stratum (maple) is incomplete (Fig. 4).
The middle storey contains 5.3 coppice specimens per are and reaches an average height of 14 meters. Its crown cover, however, measures only 26.5 %. The middle stratum is not closed, yet irregularly divided (table 7).

Table 7a. Crown cover (in %) in stand type 1.

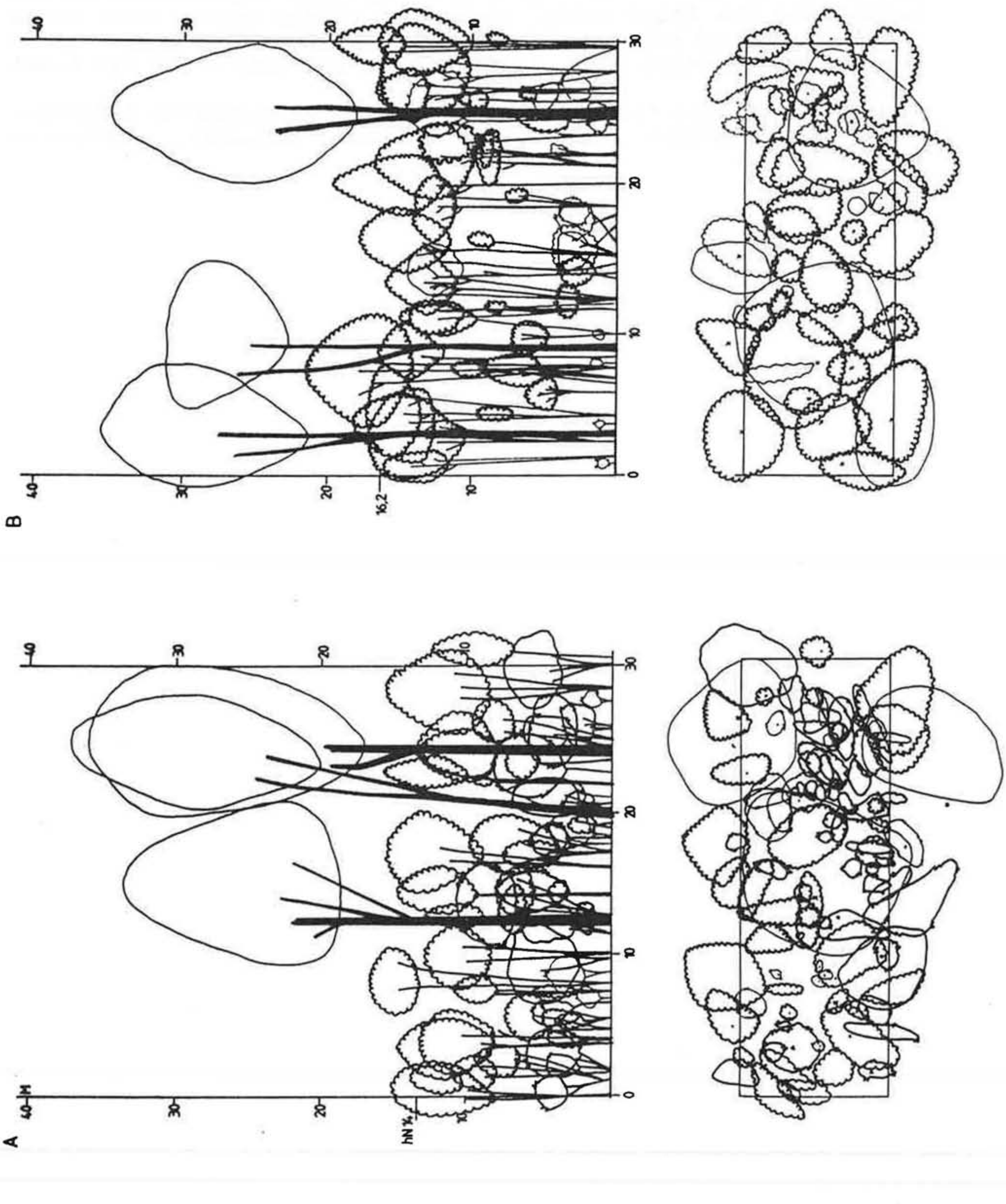
unit	1	2	3	average
Upper stratum	1.00	90.0	43.5	44.8
Middle stratum	43.5	16.0	20.0	26.5
Upper and Middle stratum	45.0	98.0	50.5	64.6
Lower stratum	49.5	54.0	57.3	53.5
Total cover	73.0	98.0	85.0	85.2

Table 7b : Regeneration (number per height class of 120 cm in stand type 1

Species	class	1	2	3	average
Smooth-leaved elm	1	10	8	7	8.33
	2	6	7	11	8.00
	3	4	9	7	6.66
	4	0	5	11	5.33
hazel	2	0	3	0	1.00
	3	0	3	0	1.00

The lesser importance of the middle storey is largely compensated by an intense outgrowth of the understorey, formed by coppice wood of hazel and maple (descending movement) and especially by suckers of Smooth-leaved elm.
The lower stratum and the elm suckers are best represented in the second and the third units, where the middle storey only forms a crown cover of respectively 16 and 20 %. The cover of the upper storey, on the other hand, is very dense in these units (90 % and 43.5 %).
The flora of this transect belongs to the Alno-Padion (*Stachys sylvatica Circaea lutetiana, Galium palustre, Arenaria trinerva,...*).

Fig. 2: Vertical and horizontal projection of the transects of stand types 1 (A) and 2 (B).



STAND TYPE 2

In this transect, the vertical closure is incomplete, which is quite normal for stands that are managed as coppice with standards (fig. 2).
This stand type is obviously two storeyed. There is a clear upper stratum and a middle one. The former is formed by poplar, the latter mainly by maple.
The middle stratum, however, is the most extended one. It also contains secondary tree species such as alder, birch and rowan. It is composed of 7 coppice specimens pro are and has an average height of 16.2 meters. The coppice is divided in a regular manner and forms a very dense crown cover (64%).

Table 8b : Regeneration (numbers per height class of 120 cm in stand type 2

Species	class	1	2	3	average
Ash	1	2	10	2	4.66
	2	0	6	0	2.00
	3	0	1	0	0.33
Smooth-leaved elm	1	2	0	0	0.66
	2	0	5	0	1.66
	3	0	2	0	0.66
Hazel	1	1	1	1	1.00
	2	1	0	1	0.66
Rowan	1	0	0	15	5.00
	2	0	1	0	0.66
	3	0	1	0	0.66
	4	0	1	0	0.66
Black alder	2	0	1	0	0.33
Birch	2	0	1	0	0.33
	3	0	1	0	0.33
Grey alder	1	0	1	0	0.33
	2	0	1	0	0.33
Oak	1	0	0	3	1.00
Maple	1	0	2	2	1.33
	2	0	2	0	0.66
Alder buckhorn	1	0	0	1	0.33

Table 8a: Crown cover (in %) in stand type 2.

unit	1	2	3	average
Upper stratum	60.3	38.0	57.3	51.8
Middle stratum	81.0	47.5	62.5	63.6
Upper and Middle stratum	93.5	61.8	82.3	79.2
Lower stratum	13.3	32.5	21.2	22.3
Total cover	95.8	84.0	89.5	90.0

There is a difference of more than two metres between the average heights of the middle storey of transects 1 and 2 (14 and 16.2). As the impact of competition is already neutralised by the internal rivalry between the different shoots of the stumps, it could be concluded that the maple attains a better growth on these fresher soils (higher yield class).
In comparison with the stand type 1 the crowns of the maple are considerably better developed. This too affirms the better growing conditions for the maple in the stand type 2.
In contrast with transect 1, there is practically no lower stratum and this might be the reason for the frequent presence

of seedlings. The regeneration is especially succesful in the second and the third units where the crown cover of the middle stratum is the least dense.
The ash seedlings are clearly better represented in the second unit, where the crown cover of middle and upper stratum is the least developed. Most of the seedlings were 5 years old and none of them were older than eleven years. This means that the regeneration of ash took place when the cover of the coppice was already completely formed. Lust, studying the behaviour of suppressed ashes in Virelles, found that ash seedlings were able to survive many years under a close canopy, while retaining the capac
ity to grow out afterward swhen the canopy was removed.
In these transects the flora of the *Alno-Padion* also dominates.

STAND TYPE 3

This transect was taken slanting across the brook. The stand is recovering from the recent decay of maples. The raising moisture gradient leads to the dominance of black and grey alder at the end of the transect (fig. 3).
The middle storey is composed of maple and alder and reaches an average height of 16.2 metres. This height is obviously pulled up by the fast growing alder trees. The average crown cover of the middle stratum accounts for only 26 %. An under storey is hardly present.

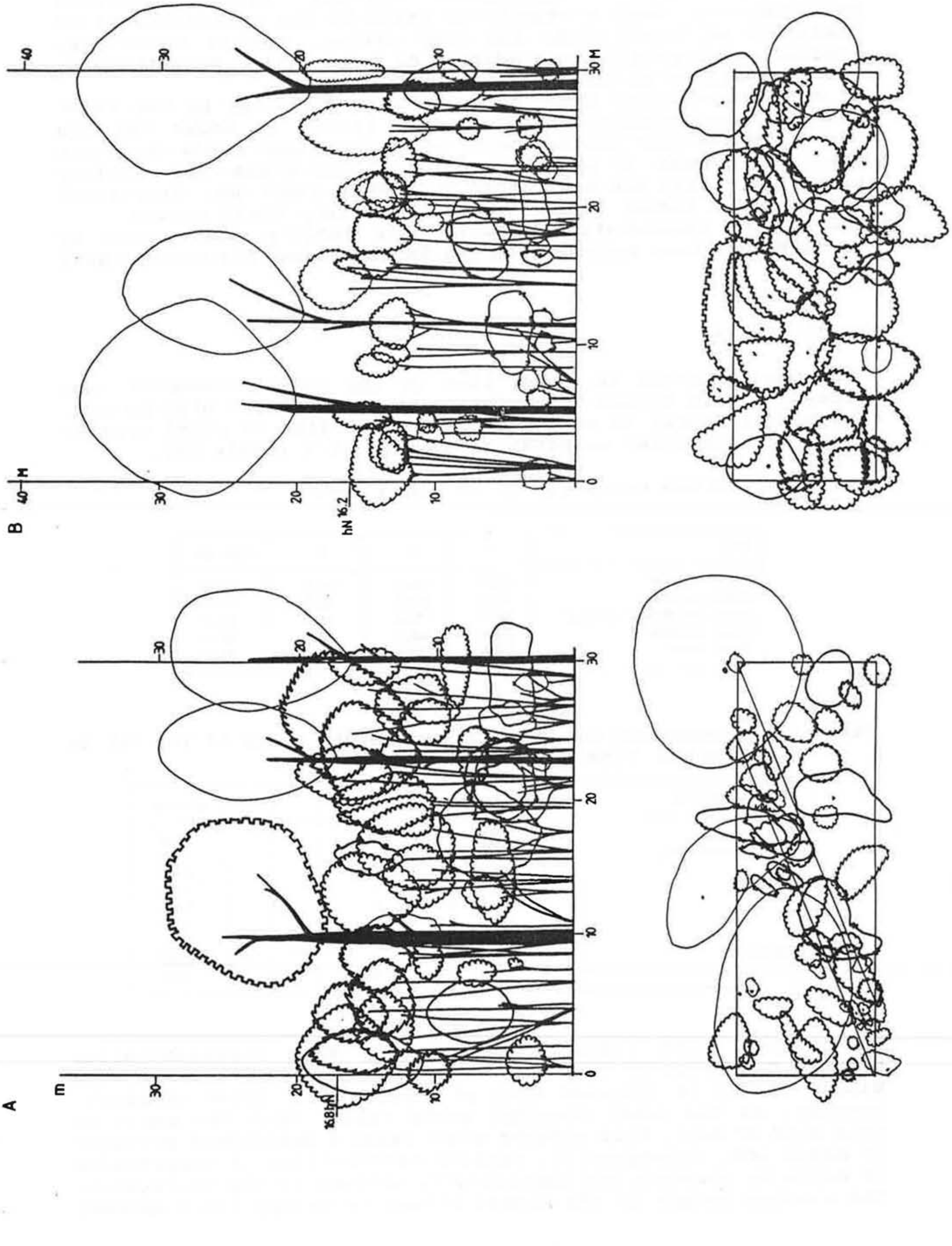
Table 9a: Crown cover (in %) in stand type 3.

unit	1	2	3	average
Upper stratum	76.5	31.5	25.0	44.3
Middle stratum	25.0	28.5	24.5	26.0
Lower stratum	25.0	43.3	28.8	32.3
Total cover	92.0	55.8	75.0	74.3

Table 9b : Regeneration (number per height class of 120 cm) in stand type 3

Species	class	1	2	3	average
Black alder	2	1	1	0	0.66
	3	1	1	0	0.66
	4	0	0	1	0.33
Birch	2	1	0	0	0.33
Elderberry	1	1	0	0	0.33
	3	2	0	0	0.66
	4	1	0	0	0.33
Grey alder	1	1	0	4	1.66
	2	8	3	0	1.00
	3	1	0	0	0.33
	4	0	2	2	1.33
Smooth-leaved elm	1	0	1	0	0.33
	2	3	3	0	2.00
	3	0	3	0	1.00
	4	0	2	0	0.66
Alder buckthorn	2	1	0	0	0.33

Fig. 3 : Vertical and horizontal projection of the transects of stand type 3 (A) and 4 (B).



The space, which came free after the decay was soon filled up by the light demanding flora of the Macrophorbio Alnetum (*Epilobium hirsutum*, *Epilobium montanum*) and the Alnion glutinosae (*Lycopus europaeus*, *Solanum dulcamara*, *Lythrum salicaria*, *Cirsium palustre*,...). Such a vegetation prevents the establishment of seedlings of black alder and grey willow, species which are, however, ecologically more adapted to moist sites. Nevertheless, their seedlings do not consolidate easily.
It can be concluded that this site is recolonized by the right species (autoregulation). The maple itself is known for its fertility and fast youth growth. Producing light seeds which are easily dispersed, it is able to colonize vast areas. The vitality problems usually are manifested only at an older age. Grey alder too showed a lesser vitality and formed very small crowns.
The scanty regeneration, however, is largely compensated by suckers and stump sprouts from the Smooth-leaved elm and the grey alder.

STAND TYPE 4

The upper stratum is, just like in the other transects, not closed. It is formed mainly by young poplars, but also by oak. The middle storey is well developed (just like in stand type 2) and its crown cover measures on average 65 % (Table 10).

Table 10a: Crown cover (in %) in stand type 4

unit	1	2	3	average
Upper stratum	18.0	36.8	57.8	37.5
Middle stratum	70.8	57.0	65.5	64.4
Upper and Middle stratum	88.0	79.0	78.0	81.7
Lower stratum	38.8	42.0	42.8	41.2
Total cover	91.8	98.0	99.0	96.2

Table 10b : regenaration (numbers per height class of 120 cm) in stand type 4

Species	class	1	2	3	average
Rowan	1	11	13	1	8.66
Smooth-leaved elm	2	0	0	1	0.33
	3	0	0	1	0.33
Maple	1	1	1	1	1.00
	2	0	1	11	0.66
	3	0	4	1	1.66
	4	0	1	1	0.33
Elderberry	2	0	0	1	0.33
	4	0	0	2	0.66

In contrast with transect 2, there is more differentiation between the trees of the middle stratum. In this stand type the middle storey is composed both of maple and of sweet chestnut. However, as the sweet chestnut grows faster than the maple on this kind of soil, this mixture might cause a descendent movement of maple and, consequently, tending difficulties. A suppression of maple by chestnut was particularly obvious in the third unit. The average height of the middle storey is raised (16.8 metres)

by the presence of chestnuts in the coppice.
The presence of a better developed under storey (40 %) might be the reason for the smaller number of seedlings (in comparison with 2).
The regeneration of maple is nearly exclusively found in the second unit, where the crown cover of middle storey is the least dense. Stump sprouts of rowan also appear here.
The mixture of sweet chestnut, oak and beech (in the middle storey) has generated a specific herbaceous flora, characterised by *Polygonatum multiflorum*, *Luzula pilosa*, *Maianthemum bifolium* (*Fago-quercetum*), *Galeobdolon luteum* (in the ditches), and partly by *Rubus spec.* (unit 1).

STAND TYPE 5

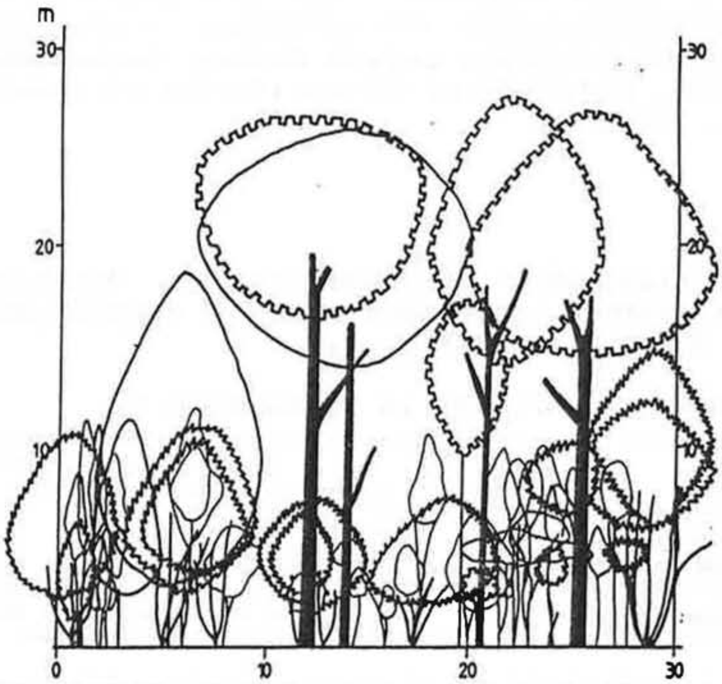
The transect illustrates that the reserve, containing oak and beech, is of a greater importance than the coppice which has been cut recently (Table 11 and Fig. 4).

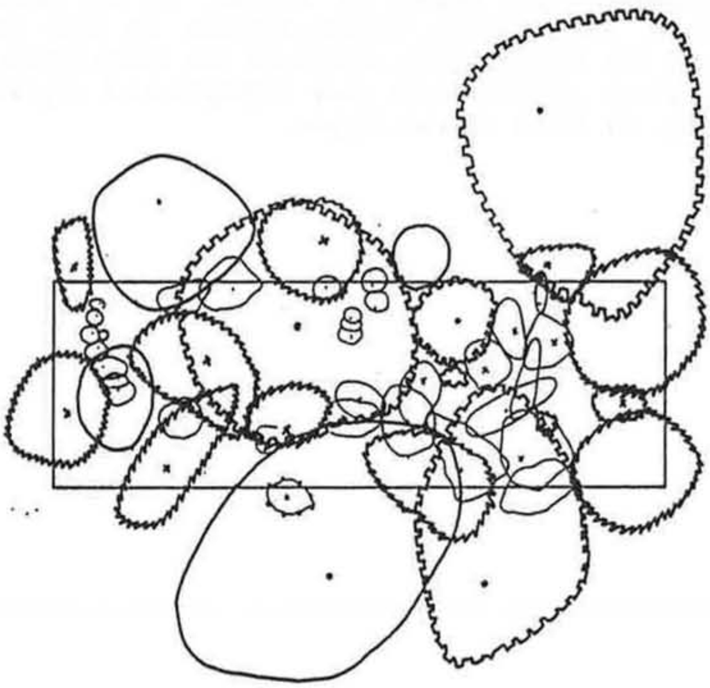
Table 11: Crown cover (in %) in stand type 5.

Unit	1	2	3	average
Upper stratum	22.5	81.0	25.3	43.0
Middle stratum	5.2	7.5	45.0	19.3
Upper and middle stratum	28.2	88.5	65.7	54.2
Lower stratum	73.0	39.8	38.8	50.0
Total cover	79.2	96.5	88.5	88.0

It is remarkable that there is no actual middle stratum. This might be the reason why the lower stratum, composed of chestnut coppice and regeneration units of birch, is so well developed. At the same time, some rowan trees appear in the lower stratum but regeneration of other tree species is completely absent.
Except for *Teucrium scorodonia* and *Dryopteris Filix-mas*, other flora is lacking in this stand type.

Fig. 4 : Vertical and horizontal projection of transect 5.





SYNTHESIS

The crown covers of the upper strata, ranging from 37.5 % to 52 %, do not vary too much, in spite of the great differences in basal area of the reserve trees (Table 12).

Table 12: Average crown cover of the three storeys in the five stand types (in %).

Stand type	1	2	3	4	5
Upper stratum	44.8	51.8	44.3	37.5	43.0
Middle stratum	26.5	63.6	26.0	64.4	19.3
Upper and middle stratums	64.5	79.2	51.0	81.7	54.2
Lower stratum	53.5	22.0	32.3	41.2	50.5
Total cover	85.2	90.0	74.2	96.2	88.0

The crown covers of the middle storeys are the greatest in the stand types 2 and 4 (64 %). As a matter of fact, the lower the basal area of the reserve, the higher the basal area of the coppice and the crown cover of the middle stratum. The high crown covers of the middle stratum of 2 and 4 could be attributed to the low basal area (15.5 and 16 m2) of the reserve in these stand types.

Excepting transect 1 (r1=-0.91), no strong negative correlation between the crown covers of the middle and upper stratums could be found (r3=0.9, r4=0.34, r5=-0.41). In transect 2 even a positive correlation is recorded. No correlation could be found in transect 3.
The crown covers of the under storeys of transects 2 and 5 are, however, negatively correlated with the total crown covers of middle and upper storeys (r2=-1 and r5=-0.92). With regard to transects 1 and 4, the under storey is correlated negatively with the middle storey (r1=-0.86, r4=-1), yet positively with the upper stratum (r1= 0.55 and r4=0.93). This means that the suppression of the under storey is caused more by the middle storey than by the upper storey.
The strong development of the middle storey in the stand types 2 and 4 would seem to impede the outgrowth of the understorey (respectively 22 and 44 %). On the contrary, the absence of a well developed middle stratum in 1 and 5 seems to create better growth conditions for the under storey. The latter is especially observed in the first stand type where the local absence of the middle stratum induced suckering of the smooth-leaved elm.
The same phenomenon is observed with the seedlings and suckers, which preferably occur in those units where the crown cover of the middle stratum is the least developed.
The basal area of the reserve seems to be the driving force for the regeneration and herbaceous flora. Low basal areas of the reserve, thus high basal areas of coppice, lead to the consolidation of ash, rowan and maple, whereas the opposite leads to more suckers of elm and herbaceous flora. This statement is born out by a canonical correspondence analysis (Fig. 7 and 8).

BAS	:	Basal area of the reserve
BET	:	Birch leaf mass
ACEC	:	Crown cover of maple
ALN	:	Crown cover of grey alder
QUEC	:	Crown cover of oak
ULMC	:	Crown cover of Smooth-leaved elm

Legend : MgL : Mg-content of the leaves
MgS : Mg-content of the Ah1 soil horizon
CNL : C/N-value of the leaves
CNS : C/N-value of the Ah1 soil horizon
F : Biomass of fermentation layer
HYD : Ground water level during winter

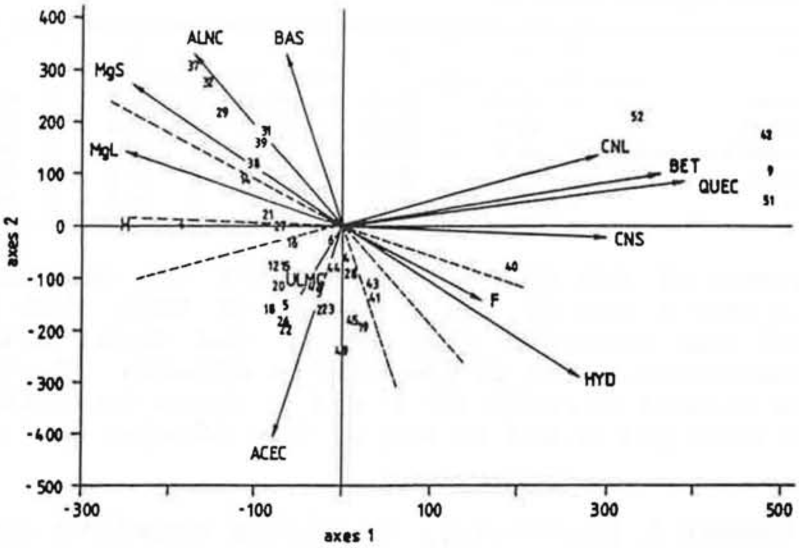


Fig. 5 : Ordination diagram (axes 1/2) based on a canonical correspondence analysis of the vegetation data with respect to 12 environmental variables (arrows).

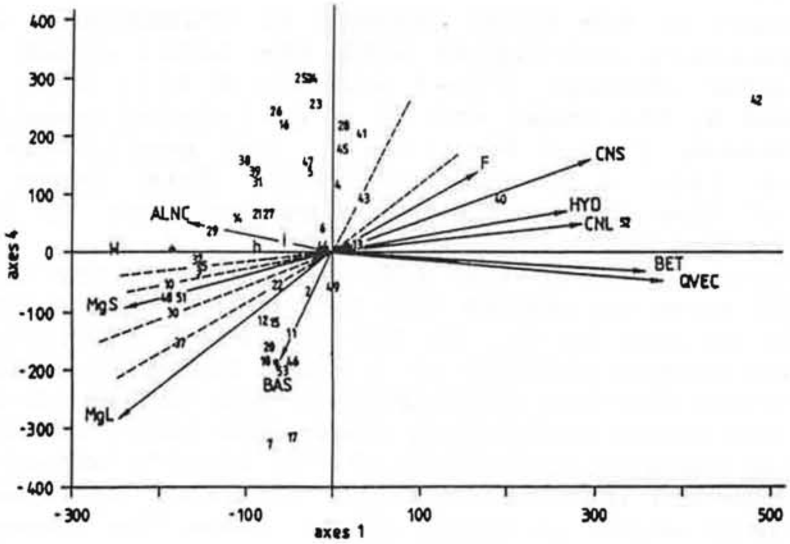


Fig. 6 : Ordination diagram based on a canonical correspondence analysis (axes 1/4).(legend fig. 5).

The seedlings of ash (45), maple (44) and rowan (43) are projected on the negative side of the arrow representing the basal area of the reserve (=low basal area of the reserve). They prefer to regenerate in stand types in which the coppice (the basal area of coppice is correlated negatively to the basal area of the reserve) is better developed and the rough herbaceous flora is suppressed.
Also shade-tolerant herbaceous flora such as *Polygonatum multiflorum* (19), *Hedera helix* (28) and *Maianthemum bifolium* (41) are looking for such stand types.
The light-demanding flora of the *Cirsio-Alnetum*

(A) depends on the crown cover of grey alder. This environmental variable is laying between the sides of two arrows representing a high Mg-content in the mineral soil and a high basal area of the reserve. This rough herbaceous flora is projected at the negative side of the water level-arrow and depends consequently on high water levels.

Regeneration of hazel (53), suckers of the smooth-leaved elm (46), *Deschampsia caespitosa* (20), *Stachys palustris* (13), *Ranunculus repens* (11), *Viola odorata* (18) and especially *Chrysosplenium oppositifolium* (7, L-value of Ellenberg = 6!) and *Glechoma hederacea* (17) are affected by high basal areas of reserve (Fig.8). As this also stands for lesser development of coppice, this could indicate that a lesser development of coppice leads to a favourable light regime for this light-demanding flora. This is in accordance with Rackham's observations in coppices with standards; cutting of the coppice leads to a greater abundance of flora (*Violaceae, Primulaceae*) florishing in spring tim

6. Organic matter

6.1.Leaf mass

In stand type 1 the poplar dominates (54%) and the ratio between the leaf mass of poplar and maple attains almost 2. In stand type 2 this ratio convers, corresponding to their basal areas (Table 13).

Table 13 : Share of the tree species in the leaf mass in each stand type (kg dry weight/ ha). (Standard deviation between brackets).

Stand type tree species	1	2	3	4	5
Poplar	1954(182)	930(198)	887(754)	615(318)	-
Maple	1151(230)	1836(222)	653(651)	1164(531)	27(44)
Elm	383(356	-	276(319)	33(26)	-
Hazel	51(77)	-	34(46)	48(82)	-
Oak	29(33)	89(136)	261(218)	1067(837)	2035(650)
Chestnut	63(109)	-	-	454(440)	530(424)
Ash	-	102(121)	-	-	-
Beech	-	89(136)	15(4)	105(67)	546(399)
Rowan	-	30(34)	-	-	-
Black alder	-	22(48)	171(191)	-	-
Grey alder	-	10(11)	26(28)	-	-
Birch	-	-	10(11)	-	345(304)

Only stand type 3 produced significantly less leaf mass than the other ones, which is explained by the decay of the maples.

6.2. Organic layers

The samples were taken mid-September, at a moment that fresh leaf layers were lacking.

Table 14 : Average amounts of the fermentation(F) and humus(H) layers in the different stand types (ton dry weight/ha); with standard deviation (within brackets) and multiple range test (95% confidence interval)

Stand type	1	3	2	4	5
F	0.6(1.34)	7.8(17)	11.3(9)	21.2(10)	39(14)

Stand type	3	1	4	2	5
H	30.5(68)	97(84)	123(86)	131(92)	206(66)

Stand type 5 attains mainly the largest amounts of fermented and humus matter. This stand type is composed of oak, beech and chestnut, the leaves of which do not decompose easily.
In stand types 1 and 3, appearing on the most moist sites of the parcel, the leaf decomposition is obviously the best. In stand type 3, neither a fermented, nor a humus horizon was observed (except in one sample).

6.3. Chemical analyses

The better decomposition in stand types 1 and 3 is partly due to the high degree of the mineral content of the leaves of the tree species appearing in these stand types (poplar, maple, elm, black alder) (Table 15).

Table 15: Mineral content of the leaves of the tree species with a considerable leaf mass.

tree species	Na(ppm)	K(ppm)	Ca(ppm)	Mg(ppm)	C%	N%
Oak	300	3100	5350	1175	50	1.17
Birch	450	4500	6700	1100	44	1.80
Chestnut	500	4200	2800	1023	48	1.45
Beech	850	7500	6150	802	52	1.30
Poplar	1000	7000	11750	2050	45	1.85
Elm	800	8500	22500	3350	44	1.77
Maple	550	5100	7500	950	46	2.33
Black alder	750	5000	15500	2550	47.5	2.50

The black alder (2.5%) and maple (2.33%) attain the highest nitrogen concentrations in their leaves. The high nitrogen content in the black alder leaves is due to a great extent to nitrogen fixation by Actinomycetes.
The leaves of chestnut, oak and beech have a high C/N ratio and are poor in basic cations too.
The elm accumulates the highest amounts of potassium, magnesiu and calcium, and is, in this respect, followed by the black alder and the poplar.
It is not clear if the relative low concentrations of Na, K, Mg and Ca in the maple leaves are connected with the lesser vitality of these tree species.

Next, attention was paid to possible significant differences in nutrient concentrations between the different stand types in the fermented(F), humus(H) and Ah1 horizon. It was interesting to compare the weighed average mineral content of the leaves with the concentrations available in the different layers (Table 16).

Table 16: Ca, Mg and K concentration in the organic layers of the different stand types and the weighed average mineral content of the leaves (ppm).

CALCIUM

STAND TYPE	5	4	2	1	3
Ah1	63(29)	186(105)	621(503)	1034(215)	1765(215)

H	5	4	1	2
	150(35)	460(452)	1380(1225)	1750(1597)

F	5	2	4
	2820(467)	2975(388)	3650(1246)

Leaves	5	4	2	3	1
	5330(472)	7076(786)	8734(170)	10996(1500)	11224(1550)

MAGNESIUM

STAND TYPE	5	4	2	1	3
Ah1	15(7)	42.5(12)	53(50)	112(30)	195(109)

H	5	2	4	1
	280(182)	434(134)	471(73)	718(160)

F	5	2	4
	494(65)	496(63)	577(53)

Leaves	5	4	2	3	1
	1096(57)	1250(70)	1303(30)	1790(300)	1880(250)

POTASSIUM STAND TYPE	5	4	2	3	1
Ah1	11(4)	48(15)	70(35)	74(45)	138(54)
H	5	4	2	1	
	220(57)	400(50)	530(135)	710(167)	
F	5	4	2		
	340(65)	630(115)	637(63)		
Leaves	5	4	2	3	1
	4120(400)	4840(600)	5700(70)	5960(760)	6510(470)

It seems that the differences in weighed average mineral content of the significant differences in the different layers and this especially so magnesium

Stand type 5 produces a forest floor which is significantly poor in basic cations, corresponding to its input. This stand type was the only one which contained significantly less nitrogen.
The fast decrease of cations through the layers is due to several variables. In contrast with nitrogen, cations like Ca, Mg and K are not involved in the formation of new substances in the humus layers and are nearly not immobilised in microbial biomass (Waring,1985). Cations can only be fixed at the exchange sites of the humus layer.
The concentrations in the fermentation horizon are much higher as the cations are still fixed in the remaining organic matter of
the leaves. The cations presented in the Ah1 horizon are leached by the acids released during the decomposition of the leaves.
It is obvious that particularly the stand types of the most moist sites of the parcel attain the highest nutrient state. This is partly due to the tree species composition. Poplar, elm and black alder accumulate large amounts of nutrients in their leaves. The high levels of Ca and nitrogen stimulate the microbial activity and, consequently, the decomposition. The biomass of the fermented layers are correlated significantly with the Mg content of the Ah1 horizon (r=-0.6) and with the water level during the winter period (r=0.55). The high water levels during the winter period improve the decomposition of leaves (hydro-mull). These moist sites show smaller amounts of organic matter.

7. General conclusions

A thorough analysis of a one hectare great parcel shows that the area could be split up into 5 small scale stand types. These stand types show differences in tree species composition as well as in structure, nutrient state, decomposition and phytosociology. These statements must be taken into consideration for the future management of the stand. Therefore it would be very interesting to continue the system of coppice with standards. Such a management is ecologically justified.
It would, however, be desirable to reform stand type 5 (oak stand, mixed with beech and chestnut and with slight admixture

of birch), as its tree species composition means no enrichment at all. Indeed, the stumps of sweet chestnut are nearly exhausted and it would be better to remove this exotic tree species completely and to manage this stand type as a high forest. Like beech, sweet chestnut forms a very dense cover which makes the growth of herbaceous flora impossible. Its poor nutrient content is under discussion too, as tree species which appear in the lower and middle stratum should have a beneficial effect on the humus quality. Therefore it might be important to introduce more interesting secondary tree species not only in this stand type, but even over the whole forest. With regard to the other stand types, an intense regulation of the mixture ratios is necessary. In stand type 2, for instance, an increase of the ash share could be considered as a real enrichment whereas the black alder share could be increased in stand type 3 in order to accelerate natural succession.

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