STRUCTURE AND DYNAMICS OF A 215-YEARS OLD BROADLEAVED FOREST STAND RECENTLY INSTALLED AS A TOTAL FOREST RESERVE

K. VAN DEN BERGE*, P. ROSKAMS*, A. VERLINDEN**, P. QUATAERT*, B. MUYS*, D. MADDELEIN*, J. ZWAENEPOEL***

* Laboratory of Forestry, State University Ghent
Geraardsbergse steenweg 267, B-9090 MELLE-GONTRODE

** Institute of Nature Conservation, Ministry of the Flemish Community, Administration of Land Use and Land Planning, Kiewitdreef 3, B-3500 HASSELT

*** Forestry Department of Groenendaal, Ministry of the Flemish Community, Administration of Land Use and Land Planning, Reebokweg 25, B-3090 OVERIJSE

ABSTRACT

Since 1983, a 215-years old broadleaved stand in the state owned Zoniën Forest (Belgium, Flanders) has been withdrawn from all silvicultural treatments.
Thanks to the completely reviewed forest law in Flanders of 1990, the stand is now officially installed as a total forest reserve.
The present contribution gives an overview of the principal site characteristics, and then focuses on the woody component of the ecosystem. Stand structure analysis starts from the situation of 1986, *i.e.* dating from before the spring tempests of 1990.
Subsequently, the impact of those gale forces is evaluated as a driving factor in forest dynamics. In this particular stand, it was found that an abrupt change-over took place from the regeneration phase to a real decaying phase, resulting in a mosaic pattern with remnants of the old stand, consolidated regeneration, canopy gaps and windfall areas of different size.

1. INTRODUCTION

In Flanders, 1990 will be a remarkable year in the silvicultural sphere. On the 13th of June, a total new decree on forests and forestry became law.

One of the important changes concerns the aim to establish a network of forest reserves. Doing so, Flanders will get rid of a pitiful time-lag with regard to many other countries. Indeed, up to now no forest reserves are officially established.

The new law stipulates that the primary function of forest reserves is of scientific nature. Many authors stress on this function (*e.g.* LEIBUNDGUT, 1990), as well on the function of nature conservancy (ZUKRIGL, 1990).

The scientific function is indeed very important, because there is an urgent need to have the disposal of own reference-ecosystems, on the basis of which both silviculture and nature conservancy can learn a lot. For this, it is not always sufficing to refer to i.c. forests from other regions as the site (location) plays a very important role in the natural dynamics of an ecosystem.

Although the first forest reserves in Flanders could not officially be installed before the new decree became law, the intention to do so existed since several years. So, it was possible that a total forest reserve became *de facto* installed in the state own Zoniën Forest, shortly after the tempests of 1982-'83 which created an ideal starting situation in one of the stands.

In accordance with the important scientific purpose of forest reserves, an extensive investigation was started at this particular forest stand from 1985 on. The aim was to map and to describe in detail the starting situation. Subsequently, the gales of spring 1990 caused a remarkable step in the natural dynamics of the stand, what led to an update of the first investigation.

The results of all these investigations are brought together in VAN DEN BERGE *et al.* (1990). The present contribution focuses on one aspect : the structure and dynamics of the woody component of the ecosystem.

2. SITE DESCRIPTION

A global description of the study area has already been given by MUYS *et al.* (1988) in a contribution dealing with some aspects on natural regeneration in the same forest stand.

However, in the context of the present contribution that is meant to be the start of a series of contributions on the dynamics of the forest stand, it seems necessary to give a more detailed overview of the site characteristics.

2.1. Zoniën Forest

Zoniën forest is located south - south-east of Brussels, between 50°49' and 50°43' latitude north, and 4°23' and 4°32' longitude east (fig. 1). The total surface of the forest amounts up to 4380 ha, of which the major part is located in the Flemish region. As 90 % of the total surface is occupied by broadleaved tree species (mainly beech), it's one of the largest broadleaved forests in Flanders.

Altitude above sea-level varies from 120 m in the south to 60 m in the north.
Meteorological data emanate from the observatory of Ukkel,

only a few kilometers away from the forest. Annual temperature averages 9.4 °C, yearly precipitation totals 838.1 mm on an average, and the prevailing wind-direction is south-west. Precipitation is equally spread over the year. The frost-proof period counts 194 days on an average, the vegetation-period, *i.e.* the period with a temperature above 10 °C, amounts up to 172 days.

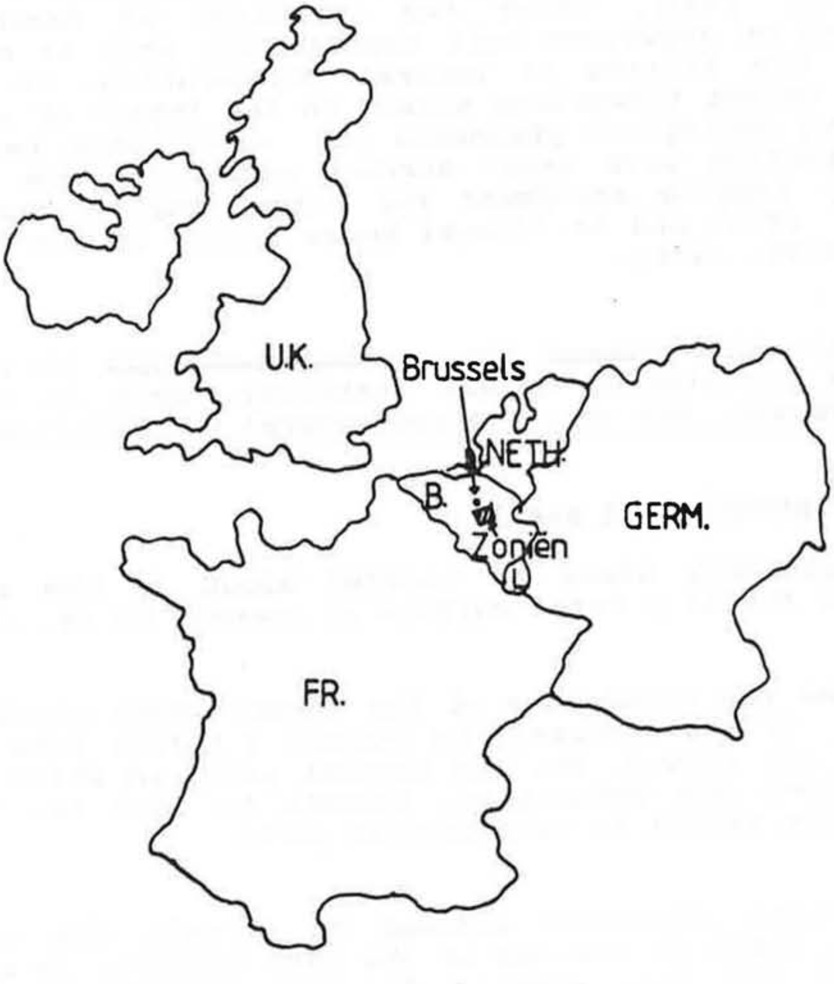

Fig. 1. Location of the research area.

The basic geological substrate consists almost completely of tertiary aged sediments (Brusseliaan sand), which is covered by a several metres thick loamy layer of quaternary age (*i.e.* niveo-eolic loess origin). As Zoniën Forest has never been deforested, the original geomorphological pattern of the substrate is conserved for the greater part until now. So, a network of little and middle-sized valleys dating from the last glacial period is still present. As groundwater is found rather deeply today, *i.e.* out of the range of the vegetation, most of those valleys are dry and so called fossil.

An other - important - aspect linked with the original geomorphological soil structure, is the present-day occurence of a very compacted loamy subsoil horizon, which is, according to LANGOHR and co-workers (LANGOHR & CUYCKENS, 1985 ; LANGOHR & VERMEIRE, 1982) a result of paleoperiglacial phenomena.

Although the Zoniën Forest has never been deforested, human impact has always been very important. The present-day of the forest originates for the greater part from the rather drastic interventions in the 18th century, when the major surface of the forest was planted up with beech monoculture.

According to some authors (*e.g.* MANIL, 1951 ; DUDAL, 1953 ; GALOUX, 1953), those two centuries of beech monocultures caused an important soil degradation, what is said to explain *e.g.* the failing of natural regeneration. In this context, more recent viewpoints stress on the impact of soil compaction due to geological phenomena (*cf. supra*) what ha to be seen in combination with upper surface compaction due to the use of heavy logging equipment for forest exploitation (*cf.* FROEHLICH, 1976) and to illegal horse riding in the stands (*cf.* VAN MIEGROET, 1974).

Anyway, the present forest management has to face some problems threatening forest stability, such as unusually high winddamage, and very limited natural regeneration.

2.2. <u>Investigated stand</u>

The research stand is located about in the middle of the Zoniën Forest ; total surface of amounts to ca. 18 ha.

Because the boundaries of the forest stand consist of forest-roads, it was necessary to install a buffer zone of about 50 m broad all around. So, the central part, in which no management practices are undertaken, amounts to 10.5 ha. The following analysis refers to this central part.

Historical documents allowed to situate the origin of the forest stand at the end of the 18th century. In all probability, it has been planted for the greater part, perhaps in addition to some eventual natural regeneration. Tree-ring analysis on an uprooted beech from the buffer zone (January 1990) affirmed the age of the stand, as 210 annual rings have been counted at the stem basis of the tree. As a consequence, tree-age of the old trees is about 215 years.

About 70 per cent of the surface consists of a severely lessivated loamy soil (gray-brown podzolic). Another 15 per cent exist of superficially disturbed soils (historical siderurgic activities), while 5 other soil types are only locally represented, especially at or near the fossil valleys.

Plant association belongs to the *Milio-Fagetum* NOIRFALISE & ROISIN, 1981 (synonyms : *Periclymeno-Fagetum* SCAMONI, 1960 ; and *Convallario-Fagetum* NOIRFALISE & SOUGNEZ, 1963), and more particularly to the subhumid subassociation *athyrietosum* or *caricetosum* with frequent presence of *Carex remota* JUSL. *ex* L., *Athyrium filix-femina* (L.) ROTH, *Dryopteris dilatata* (HOFFM.) A. GRAY, *Dryopteris carthusiana* (VILL.) H.P. FUCHS, *Luzula sylvatica* (HUDS.) GAUDIN, *Circaea lutetiana* L. a.o. Zones with extreme superficial soil compaction, mainly as a result of logging operations in the past, are found scattered over the stand. They are characterised by the presence of quasi-permanent surface water and a deviating vegetation, with local dominance of *Carex remota* JUSL. *ex* L., *Juncus effusus* L. and *Polygonum hydropiper* L. (ZWAENEPOEL, 1989).

The stock of game is very small. Of big game species only the roedeer (*Capreolus capreolus*) is represented. Although there has been no hunting since 1973, the density is low due to several disturbances in the Zoniën Forest (a.o. recreation, traffic, ...). Estimates mention 4.15 animals/100 ha on an average (1989). Rabbits (*Oryctolagus curriculus*) are found only in small numbers. bank voles (*Clethrionomys glareolus) are very common*. Hare (*Lepus capensis*) and red squirrel (*Sciurus vulgaris*) are rather rare.
At the contrary, the Korean chipmunk (*Eutamias sibericus*), an exotic rodent occuring in Zoniën Forest since about 1975, is very numerous. Although its ecology *c.q.* feeding habits have not been studied in this new habitat, it's probably one of the animals that influence forest dynamics the most at the moment in the study area (eating and hiding beechnuts, browsing seedlings).

3. METHODOLOGY

Stand structure analysis is based on the following data-sets :

1. The full inventory of the old stand. In the winter of 1985-1986, all big trees (dbh ≥ 0.3 m) have been numbered individually and mapped using a tacheometer type Zeiss RTa4 (fig. 2). Of all these trees, species was recorded, dbh and height were measured.
   In the autumn of 1989, *i.e.* four growing-seasons after the first measurement, dbh and height were remeasured on a sample taken at random.

2. The data of a strip-transect.
   In the autumn of 1989 a strip-transect of 400 m lenght and 10 m width was pegged out in south-north direction. Of all trees the following data were collected :
   - co-ordinates at the stembasis in an x-y-axessystem
   - circumference at 1.3 m of the old trees (d ≥ 0.3 m)
   - tree-height
   - height of branch-free bole
   - crown-radii of the old trees in the four principal wind directions.

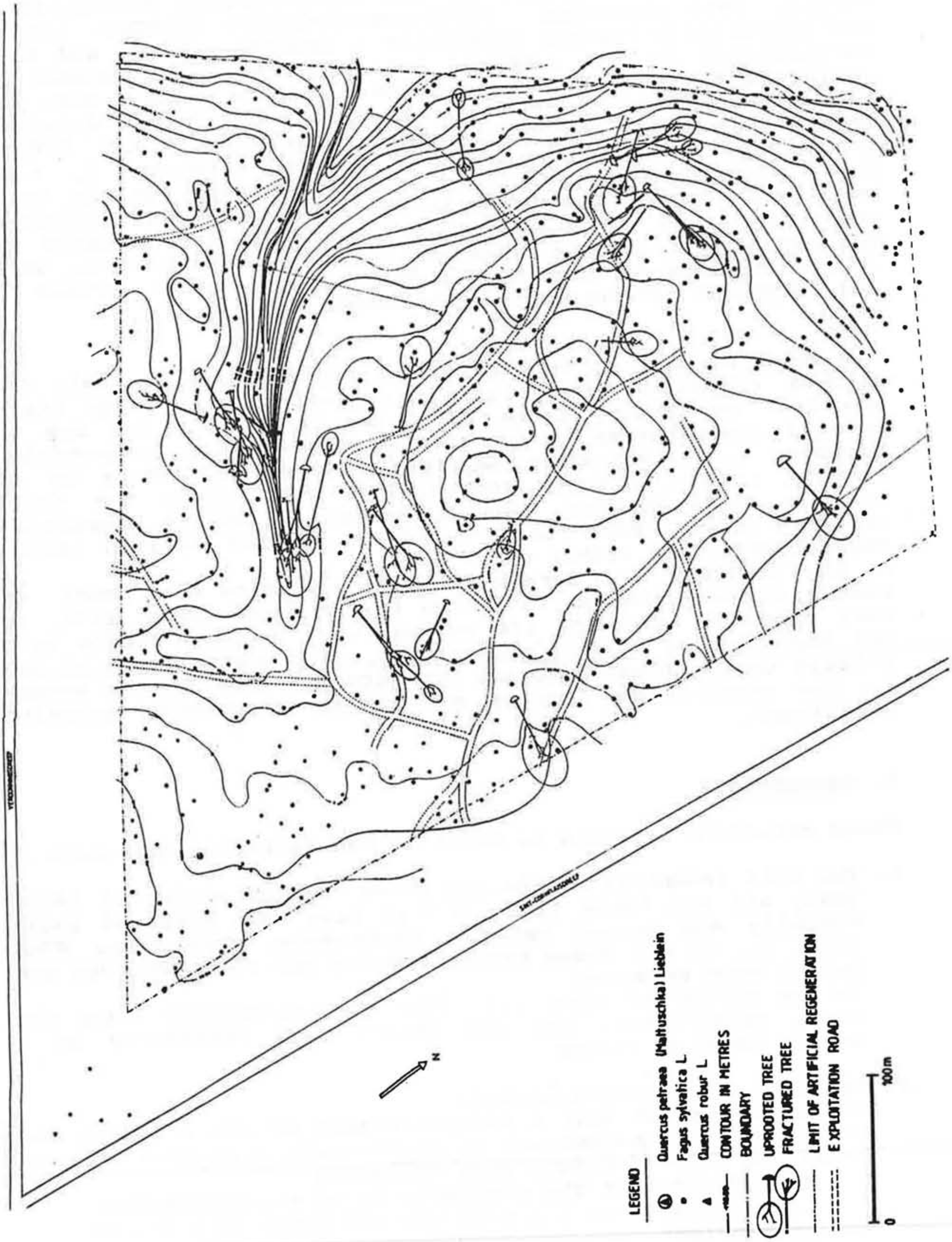

Fig. 2. Ground-plan of the investigated stand, 1989.

3. The data of 20 felled young beeches from the bufferzone.
   In the autumn of 1989 a line-transect was pegged out in the bufferzone of the forest reserve. Every ten metres the tree (with dbh < 0.3 m) nearest to the line-transect was cut down. Total height and circumference at the stembasis were measured, and a stem-disk from the tree basis was taken for tree ring analysis in laboratory.
   The line-transect was pegged out in the bufferzone of the forest reserve, since no destructive methods can be permitted in the central part because of the nature of "total" forest reserve.

4. The analysis of an old uprooted beech (spring 1990) from the bufferzone (*cf. supra*).
   Two stem-disks were collected for analysis in laboratory : one taken at the stembasis, and another at 25 m height. Total tree height was also recorded.

5. The data of the tree-necromass, *i.e.* the necromass from dead big trees or tree-limbs (diameters ≥ 0.3 m).
   Following data were collected :
   - the year of coming into being necromass
   - tree species and inventory-number
   - the way of origin of coming into being necromass (uproo-ting, stem-fracture, fork-fracture, died off standing, ...)
   - the orientation of the lying necromass-components
   - the diameter and lenght of the necromass-components.

4. RESULTS AND DISCUSSION

4.1. General description of the stand

4.1.1. Structure

The Zoniën Forest is well known for its so called "cathedral" stands, consisting of majestic beeches all of the same age and characterized by the lack of a substorey or even an understorey or shrublayer. However, the particular stand investigated has lost this look for the greater part. Indeed, the vertical structure of this forest stand is characterized by an upperstorey of old - mostly very big - beeches and some oaks, and an actual understorey of young beeches that occur scattered in the stand, individually or in small or greater groups. A substorey is all but absent.

Also in the horizontal plane there is a remarkable structural diversity.
Canopy closure is very irregular ; several small or greater gaps occur, mainly caused by the falling off of some old trees during the tempests of the last decennium. Beside the absolute dimensions of the old trees in general, the numerous dead big trees form one of the most striking aspects of the forest stand.
At the start of the investigations in 1985, two windfall areas of about a quarter up to half a hectare were already created.
During the heavy spring tempests of 1990, they were extended, while new ones were created (fig. 3).

There are also two well bordered groups of artificial beech regeneration. One, located in about the middle of the forest stand, has a surface of 0.55 ha and dates from 1963.
The other group is situated in the north-east of the stand and runs out into the bufferzone. It dates partly from 1945, partly from 1956. The surface inside the bufferzone amounts to 0.35 ha.
Altogether, artificial regeneration occupies 8.6 per cent of the total forest reserve area.

4.1.2. Tree species

In the investigated forest stand, 10 tree species are represented : *Fagus sylvatica* L., *Quercus robur* L., *Quercus petraea* (MATTUSCHKA) LIEBLEIN, *Acer pseudoplatanus* L., *Fraxinus excelsior* L., *Carpinus betulus* L., *Sorbus aucuparia* L., *Betula pubescens* EHRH., *Salix caprea* L. and *Salix sp.* (*Salix aurita* L. ?). The last mentioned species could not be determinated for certain as it existed of very young seedlings).
All *Salix*- and *Betula*-specimens have joint very recently the gamma of tree species as they occur exclusively on root clods and in their very near surroundings (see also MUYS *et al.*, 1988). As a consequence, almost all seedlings of these 2 species still belong to the herb layer. Apart from some very young seedlings at or near the root clods, *Sorbus aucuparia* L. is only represented by two specimens belonging to the understorey (dbh 0.16 m and 0.12 m).

Other species occurring only in the understorey of the forest stand are *Carpinus betulus* L. (3 specimens, dbh 0.13 m, 0.06 m and 0.07 m), *Fraxinus excelsior* L. (2 specimens, dbh 0.22 m and 0.32 m), and *Acer pseudoplatanus* L. (3 specimens, dbh 0.2-4 m, 0.24 m and 0.22 m).

4.1.3. Age, vitality and yield class

Upperstorey

As was already mentioned above, the age of the old trees could be determined by counting the annual rings of an old beech, uprooted in January 1990. The sampled tree, 42.5 m heigh and with a circumference of 2.60 m at breast height (*i.e.* a specimen with average dimensions - *cf. infra*), was about 215 years old.

At a height of 25 m, 148 annual rings could be counted. Thus, the tree must have been close to 70 years old when he was that high. Situated on site index curves for beech according to SCHOBER (1972), it appears that the stand must be of heighest site index (fig. 4).

Situated in the diagram for non-calcareous loams of BROWN (1953), who inserted also the Quality Classes I to V from MOLLER's Danish yield tables, the high site index of the stand is affirmed (fig. 5).

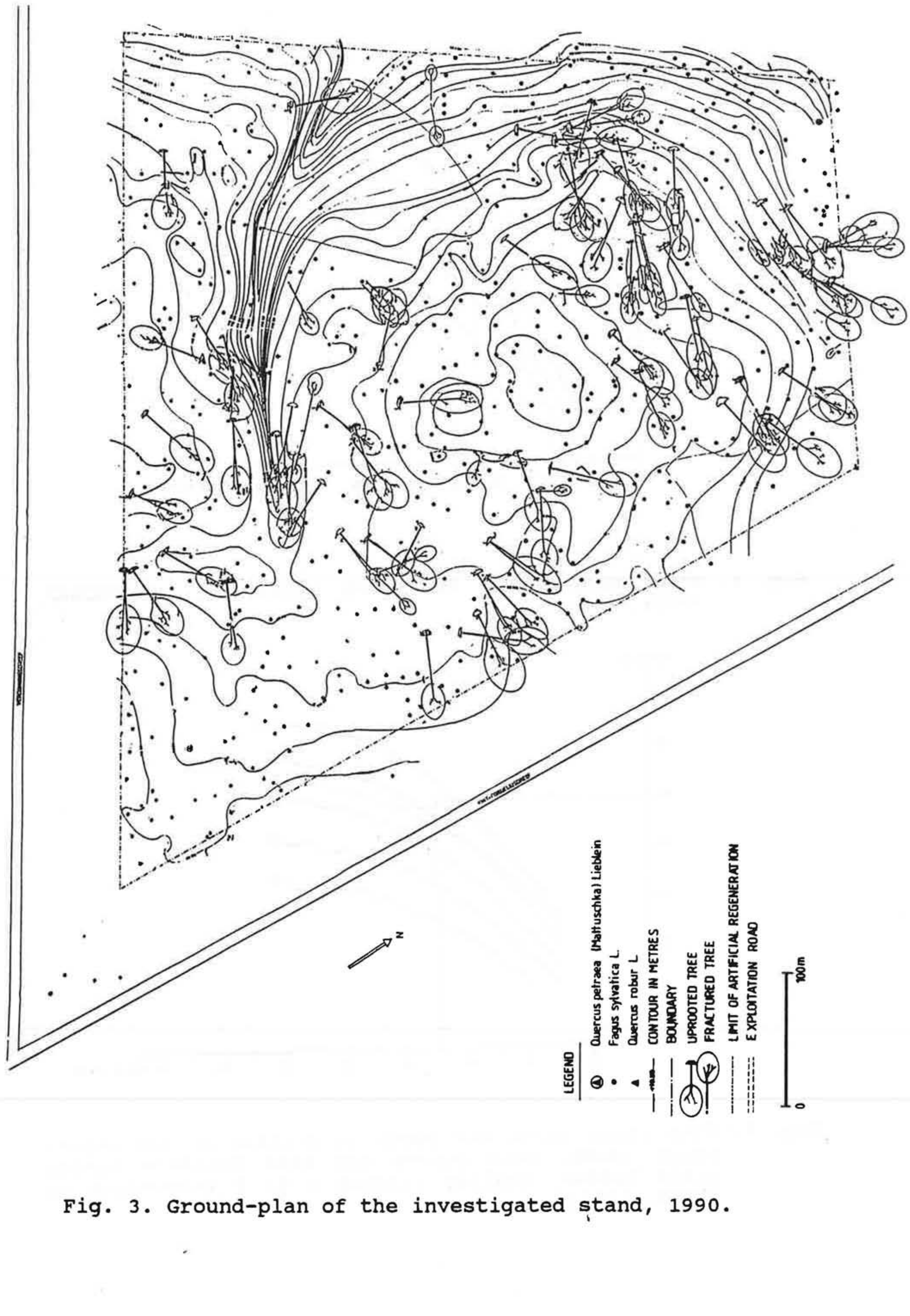

Fig. 3. Ground-plan of the investigated stand, 1990.

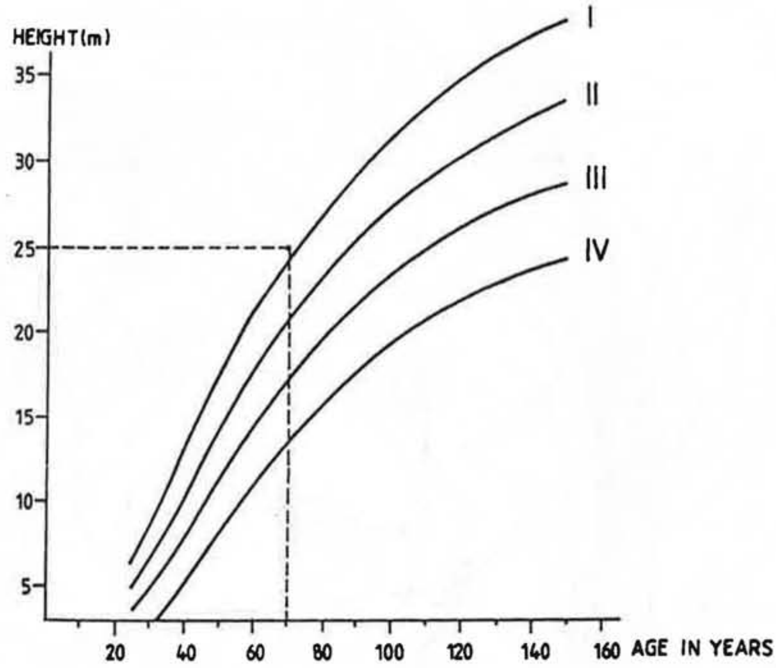

Fig. 4. Site index curves for beech (according to SCHOBER, 1972).

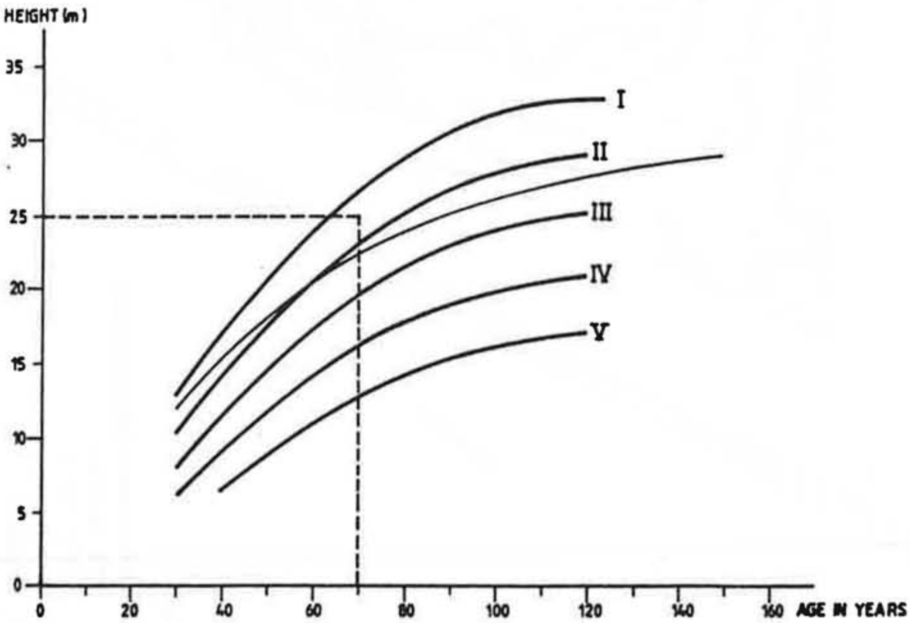

Fig. 5. Site index curve for beech in Britain on non-calcareous loams. Bold curves are from MOLLER's Danish yield tables, Quality Classes I to V (according to BROWN, 1953).

In general, vitality of the old trees is still good, although their height-growth has stopped since a long time. However, it has to be taken into account that some trees being parasitized by fungi such as *Fomes fomentarius* (L. *ex* FR.) KICKX and *Meripilus giganteus* (PERS. *ex* FR.) KARST. have disappeared yet from the canopy after windfall or windbreak during tempests.
Some beeches clearly show the consequences of local extreme soil compaction. This is expressed by a rather severe defoliation. It's very likely that they will die back soon.
The international European phenomenon of spectacular dieback of oaks can also be observed in the Zoniën Forest ; up to now, three oaks (*Quercus robur* L.) died back completely (on a total of 33 oaks) in the investigated forest stand, while some others show marked symptoms of weakening. Anyway, oaks account for all but a small part of the trees in the forest reserve.

Understorey

The results of the measurements on the 20 felled young beeches from the bufferzone are shown in table 1.

Table 1. Age, diameter and height of the felled beeches from the bufferzone (age = number of annual rings + 2)

Serial number	Age (year)	Diameter (cm)	Height (m)
1	34	13.4	12.30
2	26	4	6.80
3	30	8.2	7.43
4	30	4.2	3.10
5	29	6.3	5.20
6	28	9.3	8.65
7	18	2.2	2.30
8	18	4.5	3.70
9	12	1.9	2.72
10	40	11.7	9.09
11	39	10.2	8.80
12	29	3.3	8.40
13	23	3.9	5.10
14	29	3.0	2.95
15	26	7.2	5.55
16	47	12.7	7.23
17	40	7.3	8.97
18	34	9.4	10.28
19	20	3.3	4.90
20	43	8.3	6.65
mean	29.8	6.7	6.5
std.	8.9	3.5	2.7

In this context, it must be remarked that the mean diameter and height of the young beeches of the strip-transect (*cf. infra*), *i.e.* in the central part of the reserve, do not differ significantly (p = 0.01) from the mean diameter and height of the beeches from the bufferzone. Both samples are thus comparable, what means that the results of the analyses of felled beeches can be assigned to the strip-transect, and, with some reserve, to the whole forest stand.

As table 1 shows, the minimum age is 12 years, the maximum age 47 years, the mean age about 30 years with a variation coefficient of about 30 per cent.

Analysis of regression could not find a clear relation between age and height or between age and diameter. So, considerable differences in diameter and height can be noticed for specimens of the same age.
This can be due to local differences in stand quality, but particularly to a different canopy cover and social position as has been shown by KURTH (1946) and MAYER-WEGELIN & MÖHRING / SCHULZ-BRÜGGEMAN (1952).

The irregular pattern of the regeneration is found in the bufferzone as well as in the central part of the forest stand. This is well demonstrated by the ground plan of the strip-transect (*cf. infra*).

As one can clearly distinguish two beech populations, a differentiation between "the old tree layer" and "the regeneration" will be made in the further discussion.

For the old forest stand, the situation of 1986 will be focused on first as most of silvicultural inventory data were collected in this year.

4.2. <u>The old tree layer</u>

4.2.1. Stem number

In the upperstorey, only *Fagus sylvatica* L., *Quercus robur* L. and *Quercus petraea* (MATTUSCHKA) LIEBLEIN occur. In the further discussion however, no distinction will be made between both oak species as their absolute numbers are insignificant.

The number of stems per hectare averages 53 (beech and oak together), what is low. However, taking into consideration the age of the forest stand, the remarkable dimensions of the trees, the increment fellings from the past and the reduction of the stand density during tempests (a.o. the tempests of November 1983 and 1984), the stem number looks quite normal.

On the basis of their contribution to the number of stems (table 2) tree mixture can be characterized as follows :

- contribution beech : 94.3 %
- contribution oak : 5.7 %

Table 2. Tree species composition according to stem number (1986 ; dbh ≥ 0.3 m)

Tree species	N	N/ha	%
Beech	524	50	94.3
Oak	33*	3	5.7
Total	557	53	100.0

* *Quercus robur* L. : 31, *Quercus petraea* (MATTUSCHKA) LIEBLEIN : 2

As a consequence, beech is by far the dominant tree species according to stem number, but also (see *infra*) according to basal area and to standing volume. Besides, oaks are being found grouped for the greater part in a corner of the stand, while the small number of them does not allow a justified use of statistics. So, in the further discussion most attention will be paid to beech.

4.2.2. Stem distribution

Stem distribution for beech is given in figure 6, for oak in figure 7. Diameter classes amount 5 cm.

Both the beeches and the oaks are characterized by a high value of the mean diameter, to wit 82 cm and 71 cm respectively. The most impressive trees have a diameter of 135 cm and 94 cm respectively (table 3).

Table 3. Diameter - old tree layer : mean, standard deviation, minimum and maximum.

Tree species	Mean	std (cm)	min	max
Beech	82	16	33	135
Oak	71	12.5	45	94

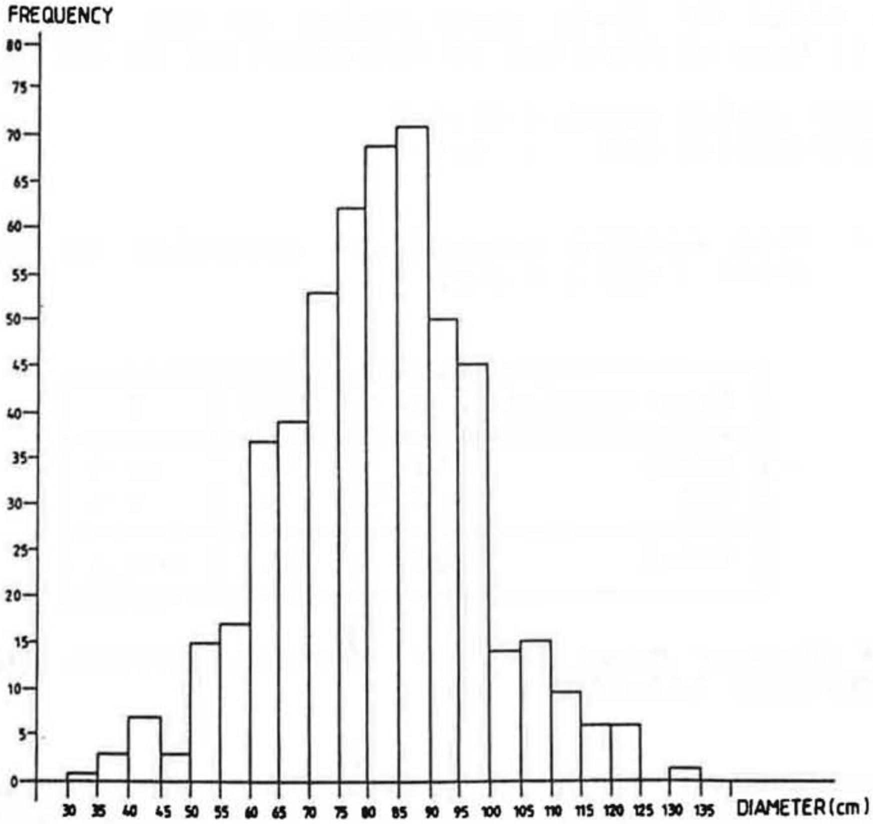

Fig. 6. Stem distribution for beech (1986, dbh ≥ 0.3 m).

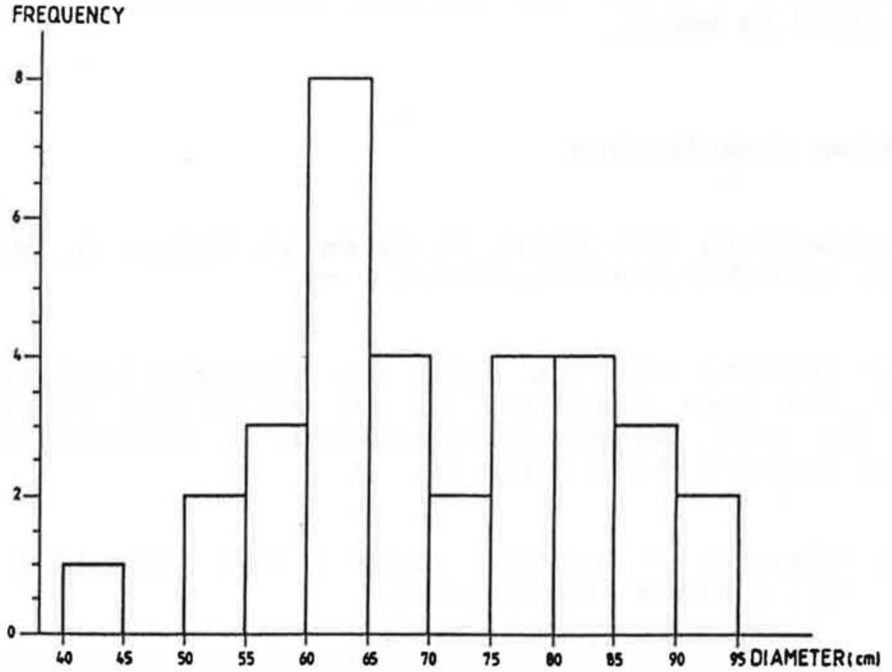

Fig. 7. Stem distribution for oak (1986, dbh ≥ 0.3 m).

A X^2-test on normality learns that stem distribution for beech is normally distributed (level of sign. : 0.11). As a consequence, the distribution is also symmetric (skewness = -0.04, i.e. ± = 0). This seems very acceptable taking into account the homogeneity in age and tree species of the beech stand.

However, as old forest stands in which some trees are reaching the limit of physiological growth possibilities are characterized by a right asymmetry (skewness < 0) of the stem distribution, it must be concluded that the beeches of the investigated stand do not have reached their growth limits by far after 215 years. So, diameter growth may continue for a long time yet. Increment measurements seem to affirm this (see *infra*).

4.2.3. Height class distribution

Height class distribution for beech is given in figure 8, for oak in figure 9. Height classes have an interval of 2 m.

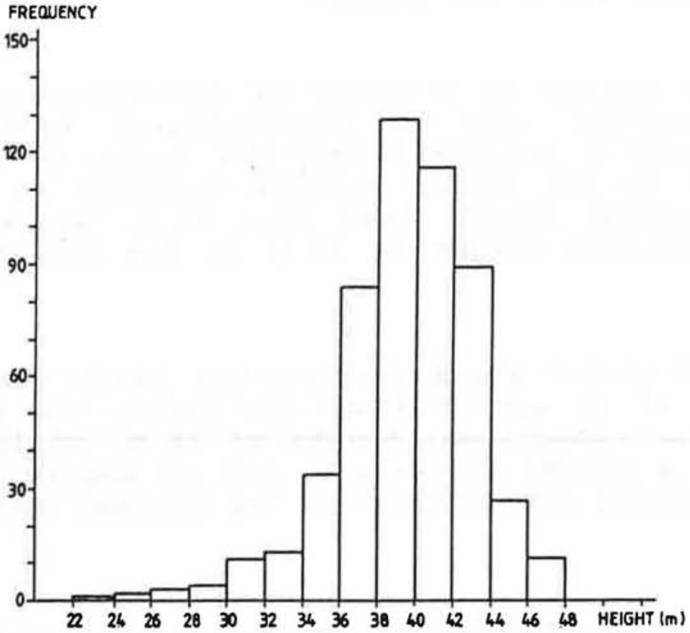

Fig. 8. Height class distribution for beech (1986, dbh $\geq$ 0.3 m).

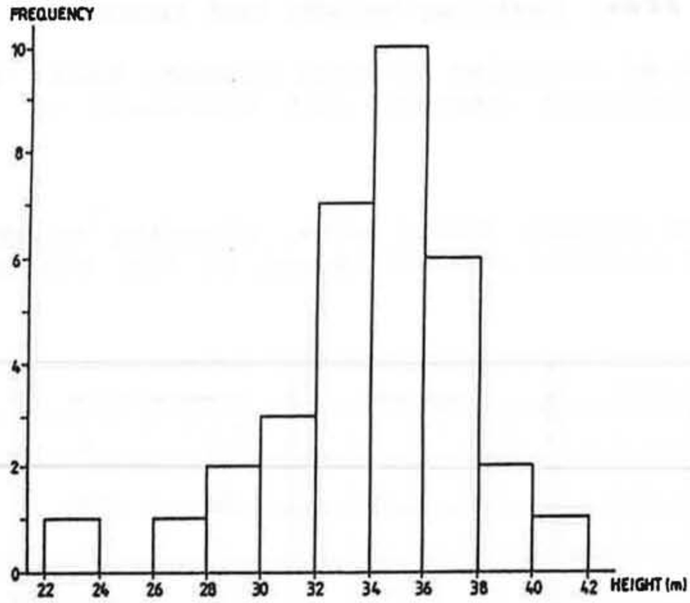

Fig. 9. Height class distribution for oak (1986, dbh $\geq$ 0.3 m).

A X^2-test learns that height classes for beech are not normally distributed (level of sign. 1 x 10^{-6}) ; the classes 38-40 m and 40-42 m are by far the most represented and hold almost half of the total tree number.

The distribution is clearly right asymmetrical (skewness = -0.86). A similar distribution is characteristic for homogeneous even-aged stands. It is, on the one hand, caused by the competition for light for which each individual, even the one with a small diameter, tries to reach a social position as high as possible, and, on the other hand, by the fact that most of the old trees have reached the physiological limit of height growth a long time yet. In this context, BECKER (1981) states that real height growth of beech stops at an age of about 120 - 150 years.

Maximal tree height in a stand is depending on site quality and tree species, not on silvicultural treatment. BECKER (1981) mentions a maximum height for beech of 40 m. PINTARIĆ (1978) found in the forest reserve Peručica in Bosnia (Yugoslavia) a maximal height less than 40 m, while MAYER (1971) recorded a maximum height of 45 m in the Buchen-Urwald Dobra (Austria).

In the investigated stand the average height amounts to 40 m (std. 3.6 m) at an age of about 215 years. The maximum height amounts to the exceptional height of 48 m, while 25 specimens are reaching a height of 44-46 m, and 10 specimens are 46-48 m high. They belong undoubtedly to the highest beeches in Europe.

For the oaks, the mean height is 34.5 m (std. 3.6 m) ; minimum height is 23 m, maximum height 41 m.

4.2.4. Basal area, Standing volume and Increment

Table 3 gives an overview of stem number, basal area, standing volume (merchantable timber) and increment of the old tree layer.

Table 3. Stem number, basal area, standing volume (merchantable timber) and increment of the old tree layer per ha

Tree species	Stem number		Basal area		Standing volume		Increment	
	ha^{-1}	%	$m^2.ha^{-1}$	%	$m^3.ha^{-1}$	%	$m^3.ha^{-1}.yr^{-1}$	%
Beech	50	94.3	27.3	95.5	688	96.6	6.1	95.3
Oak	3	5.7	1.3	4.5	24	3.4	0.3	4.7
Total	53	100.0	28.6	100.0	712	100.0	6.4	100.0

Basal area

The old tree layer has a basal area of 28.6 m^2, of which the oaks account for 1.3 m^2 or 4.5 per cent. The mean basal area per tree is 54.8 dm^2 (std. 21.12) for beech and 41.1 dm^2 (std. 14.45) for oak.

Figure 10 shows the distribution of the basal area classes for beech, figure 11 for oak.

It appeared to be quite impossible to compare these values with data from literature handling on similar stands.
However, basal area can be considered to be relatively high, certainly when taking in to account the different gaps in the stand. ROSKAMS & VAN DEN BERGE (1988) calculated a basal area of 37.4 m^2 for a ca. 150 years old beech stand at Buggenhout (30 km from the site) at a stand density of 100 trees per hectare (96 per cent beech, 4 per cent oak). SCHOBER (1972) mentions for beech of first quality and at high thinning degree a basal area of 26.8 m^2 at an age of 150 years and a stand density of 76 trees per hectare. However, in yield tables basal area remains relatively constant from an age of about 120 years on as the thinnings take away not more than the basal area increment. In the investigated stand, this seems to have been the case too.

Standing volume

Standing volume was computed with the table constructed by BOUCHON (1981), for only in this tariff values are given for trees of very big dimensions. Volume of the oaks was computed with the tables of GRUNDNER & SCHWAPPACH (1952).

Table 4 gives an overview of the compilation of the standing volume.

The standing volume of 768 m^3 per hectare (712 m^3 or 92.7 % merchantable timber, 56 m^3 or 7.3 % branchwood) is considerable, certainly when taking into account the irregular stand density. Moreover, the real standing volume will be higher yet as trees with a diameter at breast height less than 0.3 m are not included.
MAYER (1971) mentions a merchantable timber volume of 700 m^3 per hectare for the beech forest reserve Dobra in Austria. FRÖHLICH (1951) states that the primeval beech forest does not have a high standing volume on the average : *i.e.* 250 m^3 - 500 m^3 merchantable timber per hectare, rarely 600 - 700 m^3 per hectare. He concludes that the standing volume of a virgin beech forest usually is considerable lower than a silviculturally treated forest of moderate quality in Central-Europe.

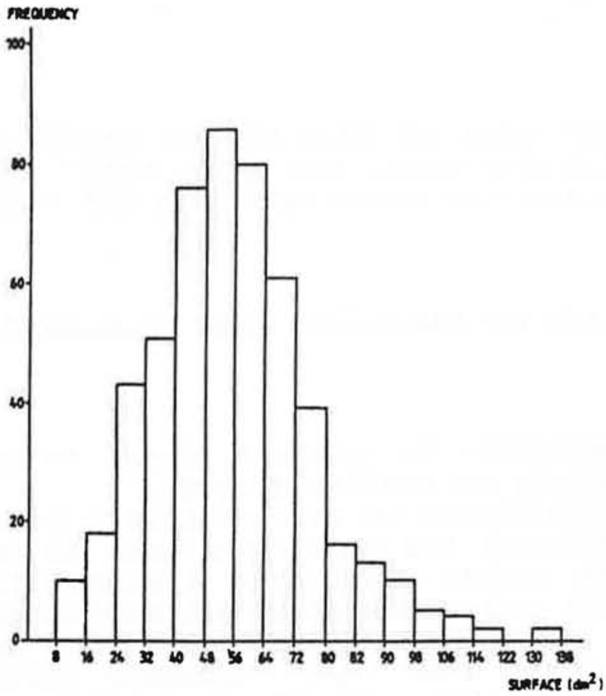

Fig. 10. Distribution of basal area classes for beech (1986, dbh ≥ 0.3 m).

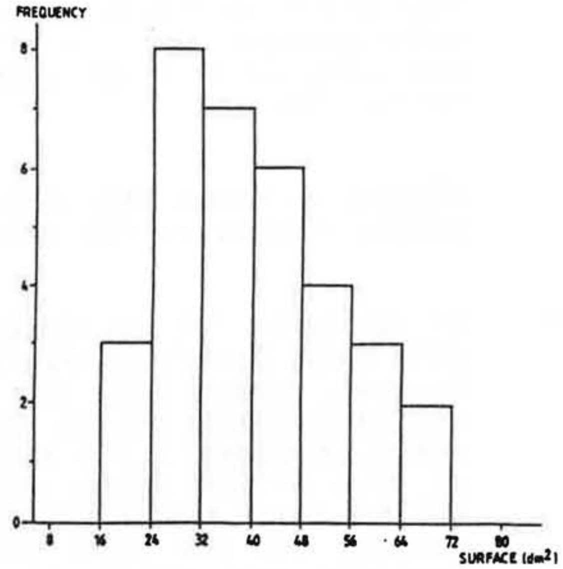

Fig. 11. Distribution of basal area classes for oak (1986, dbh ≥ 0.3 m).

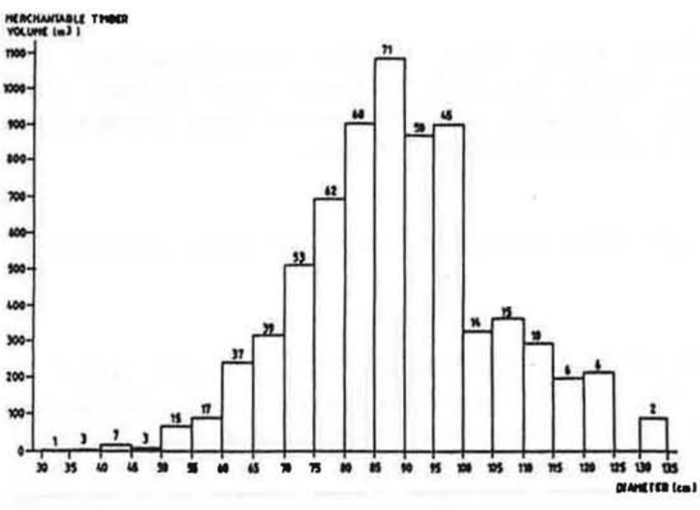

Fig. 12. Distribution of volume classes for beech (1986, dbh ≥ 0.3 m).

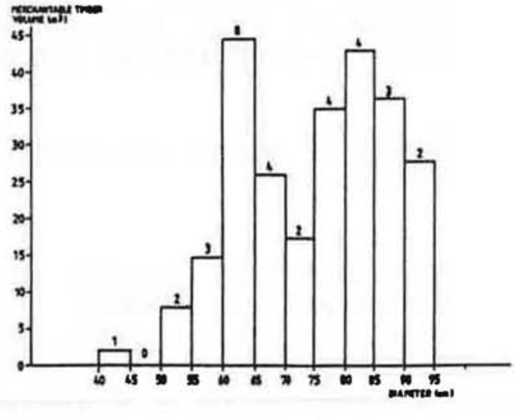

Fig. 13. Distribution of volume classes for oak (1986, dbh ≥ 0.3 m).

Table 4. Compilation of the standing volume (1986 ; dbh ≥ 0.3 m)

Tree species		Merchantable timber		Branchwood		Total volume	
		m^3	%	m^3	%	m^3	%
Beech	total forest reserve	7226	92.6	580	7.4	7806	100
	per hectare	688		55		743	
	%	96.6		97.8		96.7	
Oak	total forest reserve	253	95.1	13	4.9	266	100
	per hectare	24		1		25	
	%	3.4		2.2		3.3	
Total	total forest reserve	7479	92.7	593	7.3	8072	
	per hectare	712		56		768	100
	%	100		100		100	

The distribution of volume classes for beech is shown in figure 12, for oak in figure 13.
For both distributions it appears that the greatest part of the volume is concentrated in trees with high diameter. For beech, about 70 % of the merchantable timber comes from trees with dbh > 0.8 m (mean dbh : 0.82 m) ; for oak, 64 % of the merchantable timber comes from trees with dbh > 0.7 m (mean dbh : 0.71 m).
According to LEIBUNDGUT (1982), a similar concentration of the standing volume in massive trees is also found in untreated forests being in the optimal or ageing phase.

Increment

In 1989, *i.e.* after four growing seasons, diameter and height were measured again on a sample of 181 old trees, of which 162 beeches.
Height growth appeared to be nihil, as could be expected taking into account the age of the trees (*cf. supra* : BECKER, 1981). On the other hand, diameter increased significantly ($p = 0.001$).

The circumference of beech increased over this four years period with 4.6 cm on an average, the increase for oaks was 4.3 cm on an average. On an annual basis this means an average diameter increment of 0.37 cm for beech and 0.34 cm for oak. So, the current annual increment for beech is 6.1 m^3 per hectare, for oak 0.3 m^3 per hectare. Current annual increment per tree is 0.12 m^3 for beech, 0.10 m^3 for oak. This means that the present share of oak in the current annual increment is greater than in basal area or standing volume.

SCHOBER (1972) notices a current annual increment of 10 m^3 per hectare for 150 years old beeches of the first quality class. Extrapolation to a stand age of 215 year results in a current annual increment of about 6.5 m^3 per hectare, what is indeed very similar to the present value for the forest reserve.

Data about the mean annual increment cannot be given, as the volumes of the former thinnings are not available. The mean annual increment of the present stand, *i.e.* exclusive the thinnings, amounts 3.2 m^3 per hectare. In this context, SCHOBER (1972) mentions 3.8 m^3 at an age of 150 years for the first quality class of beech.

Analysis of the stem disk from the uprooted beech in the bufferzone learns that annual ring thickness remains quite constant yet at an age of 215 years, affirming the general good vitality of the stand mentioned above.
Supposing that calamities, like the spring tempests of 1990 stay away, the trees in the forest reserve will still realize a considerable increment in the future.
Indeed, BROWN (1953) refers to several beech stands with about 250 years old trees ; yet, beeches older than 300 years are exceptional. However, MAYER (1952) found in the Rothwald of Austria 4 beeches of 400 - 450 years old. Annual ring thickness, although rather small, remained quite constant up till the age of about 400 years !

4.3. <u>The consolidated regeneration</u>

4.3.1. Stem number

The consolidated regeneration or understorey (dbh < 0.3 m) consists almost exclusively of beech. Only one or a very few specimens of other species occur (*cf. supra*) ; of oak there is no consolidated regeneration at all.

Stem number is estimated by extrapolation of the regeneration in the strip-transect (N = 204). There is only beech involved. With 510 young beeches per hectare, the stem number of the regeneration is also low. In comparison, KURTH (1946) found a natural regeneration density of 9400 specimens per hectare 26 years after a windfall in a 125 years old beech stand in Switzerland.

However, as regeneration in the forest reserve is not at all homogeneously spread, stem number is locally much higher or lower.
This irregular pattern appears also from the strip-transect as can be seen in figure 14 and 15.

Regeneration groups of high density are found here and there, mostly under the canopy of old trees. Only 37 of the 204 young trees do not stand under an old tree canopy. As total canopy cover degree amounts to 62 per cent for the whole transect, there are 2.4 young trees per are not under canopy and 8.2 under canopy. Especially in the greater gaps there is no consolidated regeneration. This has in all probability to do with the competition from the herbaceous vegetation, but undoubtedly also with the local absence of seed-trees.

4.3.2. Stem distribution

The mean diameter at stembasis in the strip-transect amounts to 5.5 cm (table 5). Stem distribution is given in figure 16. Diameter classes amount to 2 cm.

Table 5. Diameter - regeneration : mean, standard deviation, minimum, maximum, and quartiles (diameter at stembasis)

Tree species	mean (cm)	std (cm)	min.	max.	lower quartile (cm)	upper quartile (cm)
Beech	5.5	3.2	1.0	18.5	3.2	7.0

A X^2-test on normality learns that the distribution is not normal (level of sign. 2.4×10^{-9}), but yet with one single maximum, more or less similar to a normal distribution.

The diameter class from 2 to 4 cm is highly represented ; the number decreases then with increasing diameter. The left end of the distribution is abruptly shorted as diameter of young stands is of course bound by zero.

Figure 17 gives the cumulative stem distribution graphic. The mean diameter corresponds with 57 per cent of the stem number ; *i.e.* 116 trees of the 204 measured specimens have a diameter less than 5.5 cm. In young stands, the mean diameter usually corresponds with about 60 per cent of the stem number. The figure shows also the similarity with a normal distribution, as about 68 per cent of the trees have a diameter between 2.3 cm and 8.7 cm.

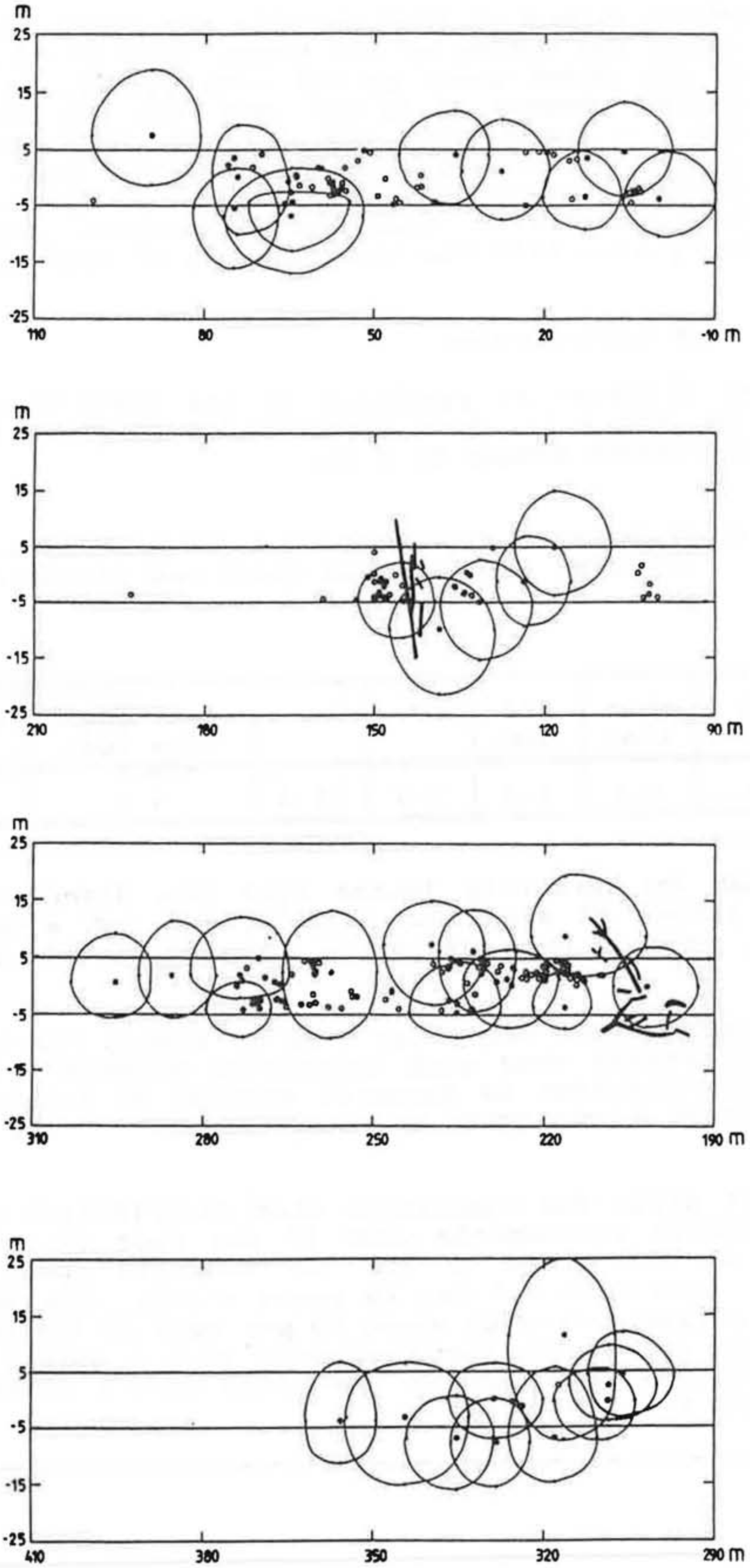

Fig. 14. Situation of the trees of the strip-transect in the horizontal plane, with crown projection for the big trees (dbh $\geq$ 0.3 m). Old tree : ● ; young tree : 0.

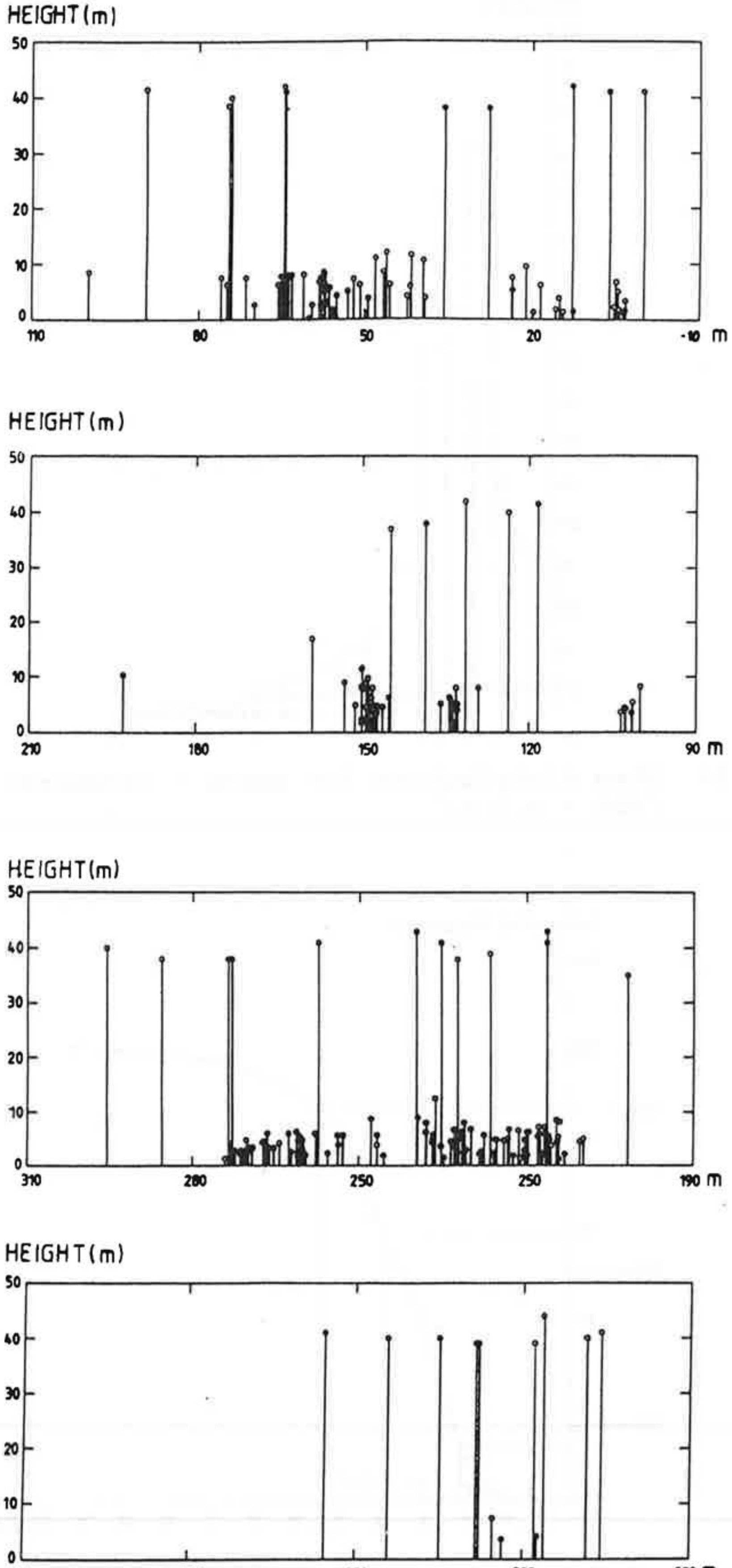

Fig. 15. Situation of the trees of the strip-transect in the vertical plane.

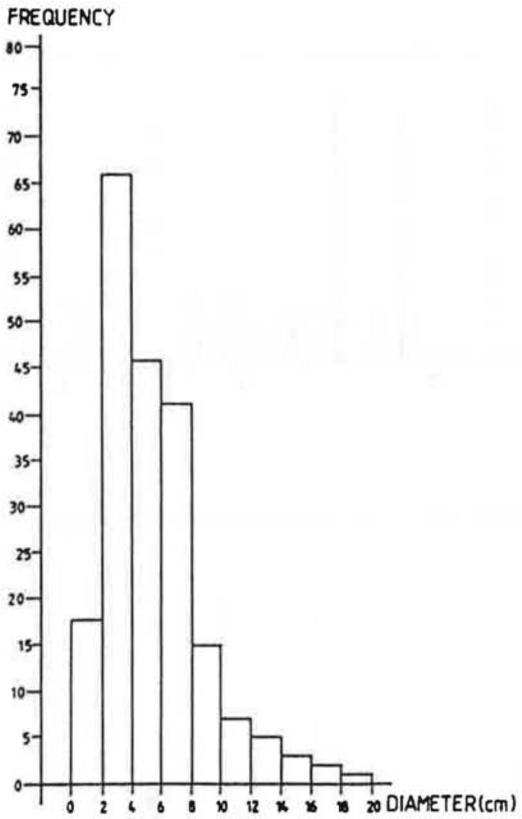

Fig. 16. Stem distribution for beech - regeneration (dbh < 0.3 m).

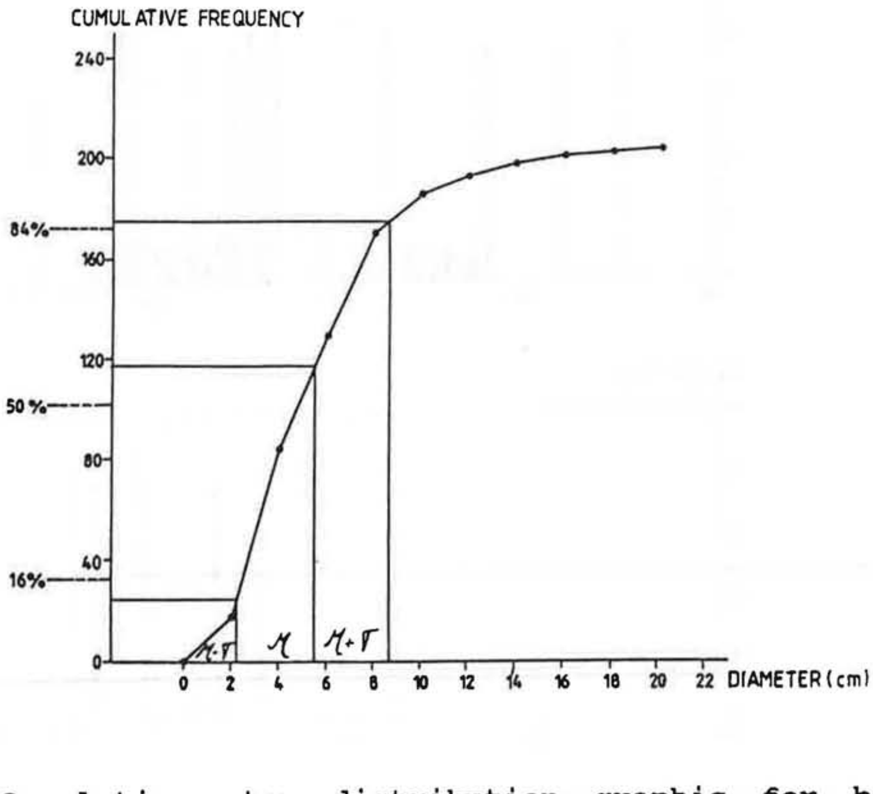

Fig. 17. Cumulative stem distribution graphic for beech - regeneration (dbh < 0.3 m).

4.3.3. Height class distribution

The mean height of the young beeches of the strip-transect amounts to 5.0 m (std. 2.7 m). Minimum height is 0.2 m, maximum height 17 m.
The distribution of the height classes is given in figure 18 ; height classes have an interval of 2 m.

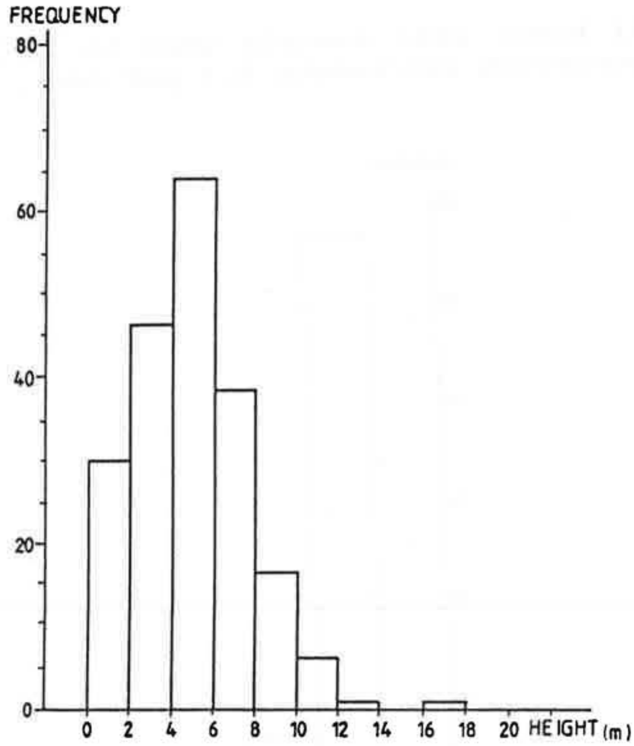

Fig. 18. Height class distribution for beech - regeneration (dbh < 0.3 m).

The distribution shows a left asymmetry, what is quite evident since regeneration height classes start from zero.

The substantial height differences suggest age differences, what has been affirmed yet above, although there could not be found a clear relationship between age and height. The degree of canopy cover and social tree position is undoubtedly playing an important role in the observed phenomenon. In this context, it can be stated globally that the regeneration with an average height of 5.0 m and an average age of 30 years, has grown quite well taking into account the presence of the old tree canopy (*cf.* canopy density : 62 per cent).

4.3.4. Basal area

The basal area of the regeneration was estimated by extrapolation of the basal area in the transect. It amounts to 1.6 m^2 per ha. The distribution of basal area classes is given in figure 19.
Almost 84 per cent of all trees measured has a basal area less than 0.5 dm^2 ; only some more than 6 per cent has a basal area higher than 1 dm^2.

The total basal area amounts thus to 30.2 m^2 per ha, of which the regeneration represents 5.3 per cent.

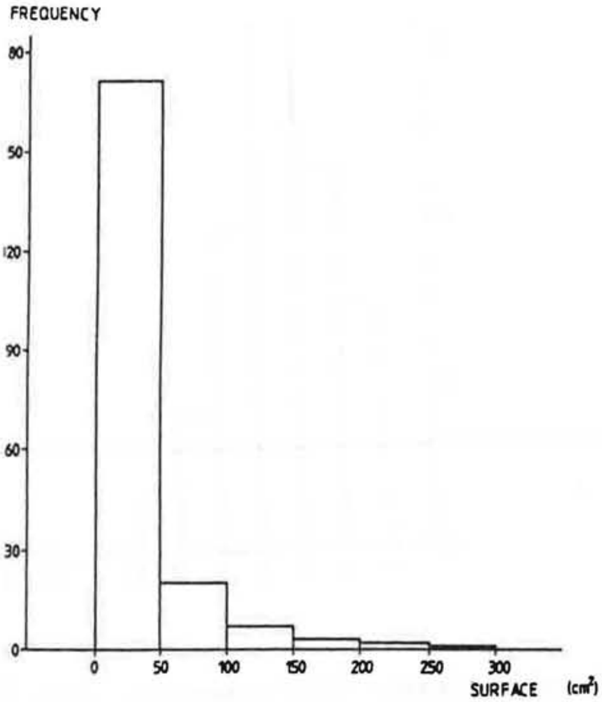

Fig. 19. Basal area for beech - regeneration (dbh < 0.3 m).

4.4. <u>Tree necromass dating from before 1990</u>

The oldest necromass-components date from 1983 (*cf.* fig. 2), with the exception of some root-stumps, saw-wedges and stem-fragments originating from the last exploitation (second half of the seventies) and earlier.

Since the autumn tempests of 1983 and 1984, two windfall areas were created, while scattered in the stand also some individual trees have been uprooted or fractured.

In all, before the spring tempests of 1990, already 22 dead trees were present in the stand as a consequence of tempests. All of them are beeches, of which 16 were uprooted and 6 fractured. They represent, together with some large tree-

fragments (fork-fracture ...) and the exploitation rests, a total beech necromass of about 320 m^3, divided into 92.6 per cent merchantable timber and 7.4 per cent branchwood.
In 1987-1988, two oaks died off standing, resulting in 9.7 m^3 dead oak-wood, of which 5.7 per cent branch wood.
There are no standing dead beeches, only standing stem fragments originating from fractured trees.
Table 6 gives an overview of the proportions of stem numbers and volumes of this necromass. Before 1990, 4.2 per cent of the total stem number had deceased, representing 3.9 per cent of total biomass.

Table 6. Proportions of stem number and volumes of the necromass dating from before 1990

Tree species		Stem number (totally deceased trees)				Volume (total necromass)			
		abs	ha^{-1}	% of living trees	% of old trees	m^3	$ha^{-1}(m^3)$	% of living trees	% of old trees
Beech		22	2.1	4.2	4.0	319.7	30.4	4.1	3.9
	%	91.7				97.1			
Oak		2	0.2	6.5	6.1	9.7	0.9	3.8	3.6
	%	8.3				2.9			
Total		24	2.3	4.3	4.1	329.4	31.3	4.1	3.9
	%	100				100			

It was striking that several trees with stem-fracture or limb- and fork-fracture clearly showed attacks from lignin decomposing fungi such as *Fomes fomentarius* (L. *ex* FR.) KICKX and *Meripilus giganteus* (PERS. *ex* FR.) KARST. For some uprooted trees, root rot was undoubtedly a determinating factor in decreased windfall resistance, as some of the root clods were very small.
For other trees, there is no evident cause for the uprooting. A precise explanation for the genesis of the two windfall areas can equally not be given. In all probability, it's a matter of combination of several factors, such as the presence of an existing canopy gap caused by an exploitation some time before, a local disturbation of the upper soil surface (compaction) caused by the logging equipment, and the presence of some trees attacked by fungi or with a low fork.

Both windfall areas expanded a little in the period 1984-1989. Although the total number of uprooted trees was still low, the impression was strengthened that a once existing gap decreases windfall resistance of the bordering trees.

4.5. The spring tempests of 1990

4.5.1. Proportions

The extremely heavy tempests of spring 1990 have augmented tree necromass considerabely. In all, 56 old trees (only beech) were added to the necromass by uprooting (52) en fracturing (4), what is more than 10 per cent of the total stem number before the tempests (table 7).

Table 7. Proportions of stem number and volume of the necromass dating from the spring tempests of 1990

Tree species	Stem number (totally deceased trees)				Volume (total necromass)			
	abs	ha^{-1}	% of living trees	% of all trees	m^3	$ha^{-1}(m^3)$	% of living trees	% of all trees
Beech	56	5.3	12.0	10.7	919.3	87.5	13.3	11.7
Total			11.2	10.1			12.8	11.4

The volume of wood that became necromass is not only resulting from those 56 (integral) trees, but also from fractured tree-limbs and lots of branchwood. In all, a volume of 919 m^3 deceased beech wood could be computed on the basis of the data collected in the field. The determination of the volume of the scattered branchwood *in situ* yet was impossible. One can assume however, that the total volume of necromass resulting from the tempests amounts at least to 925 m^3, *i.e.* 88 m^3 per hectare and 11.5 per cent of the total biomass of the old trees before those tempests (table 7). 92.4 per cent of it (about 855 m^3) is merchantable timber, 7.6 per cent branchwood.

4.5.2. Windfall causes

Elementary parameters

The great number of fallen trees allows a statistical approach of some factors possibly playing a role in windfall resistance. Applying the X^2-test the distributions of both the fallen trees and the whole old tree stand from before the tempests were compared for diameter, height, basal area, and degree of slimness (h/d).
Figures 20, 21, 22 and 23 give the distinct distribution pairs, for none of which a significant difference could be found (level of sign. resp. : 0.63, 0.61, 0.11, and 0.62). So, the reason why some trees have been uprooted while others stayed upright must be looked for elsewhere.

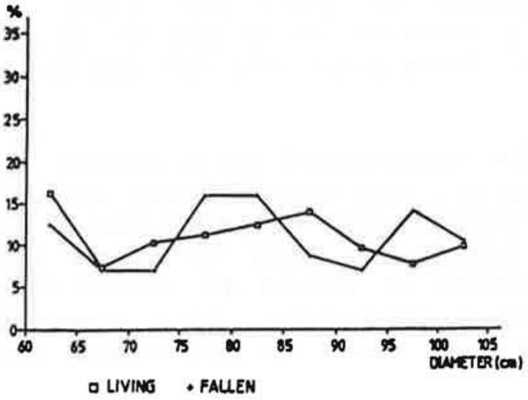

Fig. 20. Distribution of the beeches fallen in spring 1990 over diameter classes with respect to the distribution of 1986.

Fig. 21. Distribition of the beeches fallen in spring 1990 over height classes with respect to the distribution of 1986.

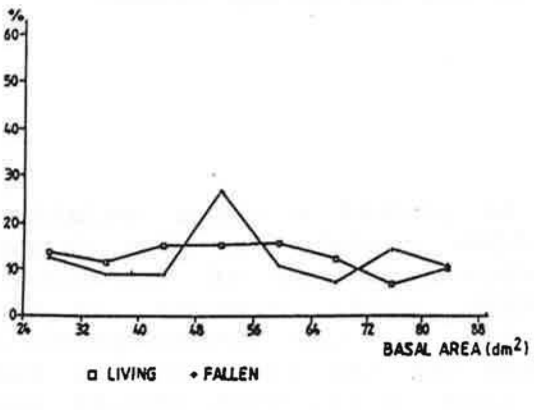

Fig. 22. Distribution of the beeches fallen in spring 1990 over basal area classes with respect to the distribution of 1986.

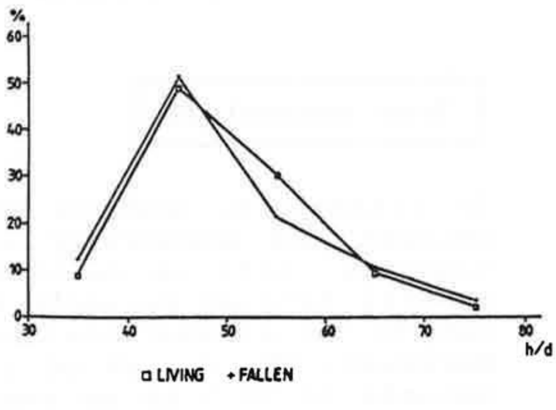

Fig. 23. Distribution of the beeches fallen in spring 1990 over h/d classes with respect to the distribution of 1986.

Vitality

In this context, it was striking that none of the fallen trees of 1990 was (visibly) attacked by fungi - in contrast with the trees fallen during the tempests of 1983 and 1984. On the contrary, some beeches clearly showing symptoms of decreasing vitality for several years yet, have survived the gales.

Root rot, on the one hand to be considered as a normal senility symptom up to a certain degree, but undoubtedly also considerably influenced by soil compaction as mentioned before, played in all probability an important role in storm stability. Indeed, on several root clods it could be noted that the vertical roots had deceased for a long time. As a consequence, the anchoring of the trees in soil must be decreased considerably.

Exposition

The irregular canopy closure, as mentioned and illustrated above (*cf.* fig. 14 and 15), is also a stormstability decreasing factor. However, only one of the two existing windfall areas was clearly extended (fig. 2 *versus* fig. 3). A new windfall area was formed on the northern slope, where several trees were overturned by the uprooting of a neighbouring tree. The other uprooted or fractured trees are more scattered over the stand, but often still occur in little or middle-sized groups. Again, the impression is strengthened that a gap decreases windfall resistance of the bordering trees.

Tree morphology

In literature, nowhere could be proved a clear relationship between the morphology and storm resistance. The degree of slimness (h/d) as mentioned above, is one of the most frequently handled parameters (FABER, 1975). However, it appears not to be a determinating factor for the investigated case. Moreover, the degree of slimness for the total forest reserve amounts to 50.3 on an average (std. 8.8), what should lead to the conclusion that the trees are very stable. The great number of uprooted trees does not seem to affirm this. In fact, several parameters should be taken into account. Table 8 gives the mean values for some tree parameters of the old beeches in the strip-transect.

Table 8. Tree parameters of the old beeches in the strip-transect - height, diameter, crown diameter and crown length in m

	Height (m)	Dia-meter (d)	Crown diameter (D)	Crown length (l)	Crown propor-tion (l/h)	Crown deve-lopment (D/h)	Crown dia-meter quo-tient (D/d)	Degree of clumsi-ness (D/l)	Degree of slim-ness (h/d)
Avg	39.99	0.84	16.05	22.93	0.57	0.40	0.19	0.73	48.34
Std	1.85	0.11	2.49	5.15	0.12	0.06	0.02	0.21	5.56

Although the branch-free bole is (absolutely) long, crown proportion is quite high, what means that the centre of gravity of the tree is lowered. This should result in a better tree stability. The high degree of clumsiness on the contrary decreases tree stability.

Whatsoever, it's likely that above all the absolute dimensions of the tree crowns have increased windfall sensibility. The mean crown diameter amounts to more than 16 m, the mean crown length almost 23 m, what is resulting in a very big wind-screen.
In combination with other factors mentioned above, such as root rot and an irregular canopy closure, this must lead to a decreasing storm stability.

Apart from all that, it must be stressed on that the exceptionally heavy tempests of spring 1990 have caused *everywhere*, *i.e.* in different stand types, lots of wind damage. Also in the Zoniën Forest there is scattered much storm damage, in several beech stands characterized by different tree parameter values. So, the question can be asked if, under a similar gale force, wind damage does not occur undependently of stand characteristics up to a rather high degree and is more a result of an accidental process caused by local turbulence effects.

4.6. <u>The actual situation (June 1990)</u>

4.6.1. Description

Table 9 gives an overview of the proportions of stem numbers and volumes of the total necromass in the forest reserve. The share of standing dead wood is given in table 10.

Table 9. Proportions of stem numbers and volumes of the necromass (June 1990)

Tree species		Stem number (totally deceased trees)				Volume (total necromass)			
		abs	ha^{-1}	% of living trees	% of all trees	m^3	$ha^{-1}(m^3)$	% of living trees	% of all trees
Beech		78	7.4	16.7	14.3	1245	117.9	18.0	15.3
	%	96.3				98.8			
Oak		3	0.3	10	9.1	14.9	11.1	5.9	5.6
	%	3.7				1.2			
Total		81	7.7	16.3	14.0	1259.9	119.3	17.6	15
	%	100				100			

Table 10. Standing dead wood - per cents of the necromass (merchantable timber)

Tree species		< 1990		1990		Total	
		m^3	%	m^3	%	m^3	%
Beech		15.1	5.1	42.3	4.9	57.4	5
	%	62.1		90		80.5	
Oak		9.2	100	4.7	100	13.9	100
	%	37.9		10		19.5	
Total		24.3	7.9	47	5.5	71.3	6.1
	%	100		100		100	

Oak

In 1990 1 oak died off standing. The number of dead oaks became thus 3, what is 10 per cent of the living oaks and 9.1 per cent of all oaks.

The total volume of dead oak wood amounts to 14.9 m^3, of which 93.4 per cent is merchantable timber and 6.6 per cent branchwood. This volume represents 5.9 per cent of the biomass of living oaks, and 5.6 per cent of all oak biomass. All dead oak wood is standing. Diameter (dbh) varies from 0.52 m to 0.63 m, height from 28 m to 37 m.

Beech

For beech, the total necromass is quite considerable.
The number of dead old beeches is 78, what is 16.7 per cent of the living number and 14.3 per cent of all old beeches.

Between the mid-seventies and 1990, a total volume of 1245 m^3 dead beech wood was formed, divided into 92.5 per cent of merchantable timber, and 7.5 per cent of branchwood. This volume represents 18 per cent of the biomass of the living old beeches, and 15.3 per cent of all old beech biomass. Of all dead beech wood 4.6 per cent (57.3 m^3) is standing. It concerns 11 stem fragments, with a height varying from 0.5 m to 22.5 m (avg. 10.7 m, std. 7.1 m), and a diameter from 0.62 m up to 1.15 m (avg. 0.81 m, std. 0.14 m).

Total

Considering the whole forest reserve, 81 old trees (beech and oak together) have died off, representing 16.2 per cent of the number of living trees and 14 per cent of all trees.

The necromass totals a volume of 1260 m^3, what is about 120 m^3 per hectare, of which about 111 m^3 per hectare merchantable timber. This volume represents 17.6 per cent of the biomass of the living trees, and 15 per cent of the total tree biomass.
The total volume of standing dead wood amounts to 71.3 m^3, what is 6.8 m^3 per hectare and 6.1 per cent of the necromass (merchantable timber).

28.6 25.6

In respect of the situation of 1986, the stand density decreased from 53 to 48, the basal area from ~~30.2~~ m^2 to ~~25.2~~ m^2, and the standing volume (merchantable timber) from 711.5 m^3 to 628.8 m^3 per hectare, or a decrease of respectively 9.4 per cent, ~~9.9~~ per cent and 11.6 per cent.
10.5

(enkel oud bestand t.o.v. oud + jong samen)

4.6.2. Interpretation

KOOP (1983) gives an overview of estimates of dead wood volume per cents with respect to total biomass (living and dead) for the most spontaneous forests in Europe. The quantities are varying from 50 to 100 m^3 per hectare, with exceptional values like 20 and 160 m^3.
It is noticed that some of these values are too high to be in conformity with so called natural situations as they have reference to the decaying phase of trees that have been planted all in the same time on a certain area, or have germinated simultaneously under anthropogeneous influences.

In figure 24, the situation in the Zoniën Forest reserve is situated with respect to those estimates, both before and after the spring gales of 1990.
Before 1990 the share of dead wood seems rather small, but since 1990 the mean necromass volume per hectare is not only absolutely but also proportionally big or very big, certainly when compared with the three other *Milio-Fageta* (numbers 3, 4 and 5).

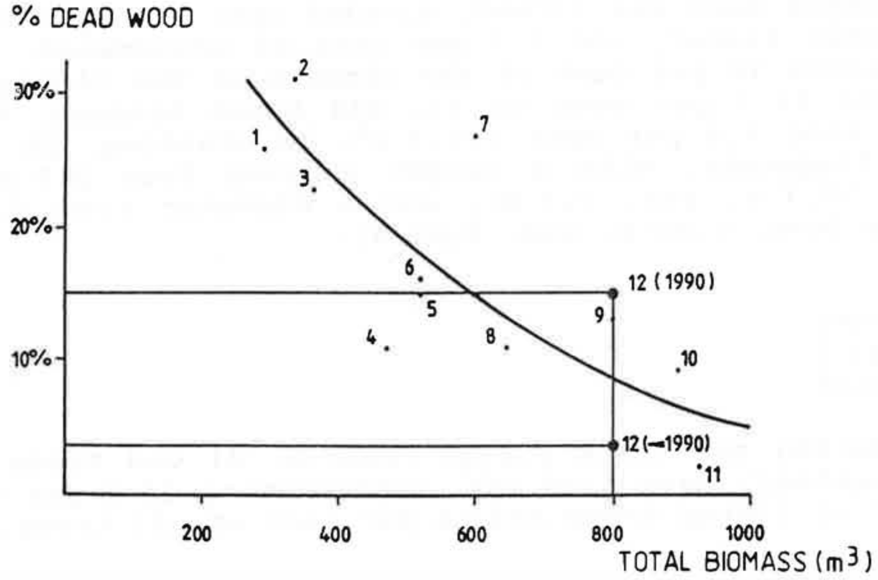

Fig. 24. Estimates of dead wood per cents of the total biomass per hectare (living and dead) : situating the Zoniën Forest, *Milio-Fagetum* (12) both before and after the spring tempests of 1990, in respect of transects at Fontainebleau, *Fago-Quercetum* (1), Hasbruch, *Carici-remotae-Fraxinetum* (2), Hasbruch, *Milio-Fagetum* (3), Neuenburg, *Milio-Fagetum* (4), Hasbruch, *Milio-Fagetum* (5), Bialowieza, *Tilio-Carpinetum* (6), Neuenburg, *Stellario-Carpinetum* (7), Fontainebleau, *Fago-Quercetum* (8), Neuenburg, *Fago-Quercetum* (9), Fontainebleau, *Melico-Fagetum* (10), Hasbruch, *Carici-remotae-Fraxinetum* (11) (after KOOP, 1983).

This high value of the actual situation is not only to be explained by the fact that also the forest reserve of Zoniën was simultaneously planted some time ago (or was created anyhow in a limited period of time by anthropogeneous interventions), but especially by the exceptional heavy tempests of spring 1990. These have increased the necromass suddenly and considerably.

In this context, LEIBUNDGUT (1982) noticed the following relationship between, on the one hand, the ratio of increment in respect of decrement (coming into being dead wood), and on the other hand the phase of forest development :

- optimal phase : increment > decrement
- ageing phase : increment = decrement
- decaying phase : increment < decrement

Above, a mean annual increment of 6.4 m^3 per hectare was found for the period from 1986 to 1989. The mean annual decrement for the period from 1983 to 1989 amounts to 4.1 m^3 per hectare ; for the period from 1983 to June 1990 (*i.e.* the spring tempests of 1990 included) the annual decrement volume increases up to 14.8 m^3 per hectare.

On the basis of the given relationship between the increment - decrement ratio and the forest development phase, it could be stated at first sight that the forest reserve, although the considerable age of the beeches, was still in the optimal phase until 1990.

For the investigated forest reserve, it must be thoroughly taken into account that silvicultural interventions and exploitations regularly took place until the seventies.
As a consequence, a certain quantity of potential or real necromass has been removed out of the stand. Moreover, this proportionally high increment is to be considered as a time-lag following earlier thinnings and increment-fellings. Both facts have a co-operating effect in respect with the expressed relationship.
In general, it can be stated that silvicultural treatments have prolonged the optimal phase, what is indeed in agreement with the principle that the forest treatment must strive for an increased forest stability (VAN MIEGROET, 1984).
Under such circumstances a gradual change-over to the so called regeneration phase with scattered natural regeneration groups can be expected, rather than a real decaying phase (LEIBUNDGUT, 1959).

A similar development is indeed, up to a certain degree, noticed in the investigated stand (*cf.* figures 14 and 15). Age analysis (*cf.* above) learns that the regeneration-flux started about half a century ago, after a long period without regeneration (more than one and a half century). An analogous phenomenon was also found at Fontainebleau by KOOP & HILGEN (1987). For the investigated stand in Zoniën however, it can not be excluded for certain that natural regeneration groups locally have been planted out in a wider pattern.

With the spring tempests of 1990, the real decaying phase has been ushered, resulting in a spatially alternating pattern of consolidated regeneration groups, remnants of the old canopy (still on quite a great surface), and several uprooted or fractured trees.

In 1988, MUYS *et al.* (1988) found the very beginning of a possible new regeneration flux at or near root clods. This regeneration appeared to be favoured mostly by the soil-tillage effect allied to the uprooting, in combination with the increased insolation.

It can be expected that lots of seedlings will benefit from the new situation inasmuch as soil-tillage effect and insolation are increased on a large scale since the spring tempests of 1990.

In this way, a temporary and local dominance of pioneer trees such as *Salix, Betula* and *Sorbus* is possible. However, as it was found that also and *especially beech* is favoured by those new circumstances (MUYS *et al.*, 1988), beech is likely to take again its dominant position within a measurable time.

Another possibility is a quick extension and the coming into being dominant of the locally extant farn population (especially *Pteridium aquilinum* (L.) KUHN) over quite a surface, resulting in a treeless succession phase for a long time.
Also in this alternative scenario, it is likely that only beech will reoccupy the area ultimately, as it is the only tree species being able to regenerate under a *Pteridium*-canopy (KOOP & HILGEN, 1987 ; KOOP, 1990).

5. CONCLUSIONS

In this contribution the structure of the forest reserve of Zoniën was analysed by means of silvicultural parameters, supplemented with some specific investigations. This analysis allows to characterize the forest stand in respect with forest dynamic phases and to diagnose some of the factors playing a role in these dynamics.

In the forest stand, two storeys can clearly be distinguished, to wit an upperstorey - mostly consisting of beech and, to a lesser extent, of oak - and a quite discontinuous understorey, consisting almost exclusively of beech. A substorey is all but absent.

The trees of the upperstorey find themselves in the ageing phase since a long time yet and many of them have reached spectacular dimensions. So, the basal area and standing volume are quite high (resp. 30 m^2 and 712 m^3 per hectare), despite the presence of several little to middle-sized canopy gaps and the low stem number (53 per hectare - situation of 1986). Globally it can be stated that the forest stand has been growing very well.

Tree vitality is in general very good ; some specimens attacked by fungi have been uprooted or fractured during gales in the eighties.
Taking into account the symmetry of the stem distribution, the fysical limit of diameter growth is not reached yet by far - contrary to height growth. A repeated diameter measurement after four growth seasons affirms this, and allows to compute a current annual increment of 6.4 m^3 per hectare for the period of 1986 to 1989 (tables of BOUCHON (1981) for beech, tables of GRUNDNER & SCHWAPPACH (1952) for oak).

The heavy tempests of spring 1990 have changed stand characteristics considerably. Stem number is reduced to 48, basal area to 27 m^2 and standing volume to 629 m^3 per hectare - *i.e.* a descent of respectively 9.4, 9.9 and 11.6 per cent. In accordance to this, the total necromass has increased considerably, and amounts to about 120 m^3 per hectare, of which 111 m^3 merchantable timber (diameter $\geq$ 0.07 m).

On the subject of windfall resistance, nor diameter, height, basal area or degree of slimness (h/d) of the uprooted trees appeared to have played a role. In this context, the determinating cause must be seen in the combination of several factors, such as the irregular canopy closure, root rot (for the greater part caused by the unfavourable soil structure), and the extreme gale force.

Taking into account that the stand has been submitted to a classic silvicultural treatment up to about ten years ago - resulting in an artificial "prolongation" of the optimal phase according to some aspects such as the increment - decrement ratio - it appeared that the forest stand was finding itself in the regeneration phase for the last half a century.
As a result, natural regeneration occurs scattered over the stand in little or middle-sized groups. Although they have possibly been planted out in a wider pattern, they show a typical discontinuous dispersion. However, stem density (determined by extrapolation) is low and amounts not more than 510 specimens per hectare.

Since the spring tempests of 1990 the real decaying phase is entered, resulting in a mosaic pattern with resmnants of the old stand, consolidated regeneration, canopy gaps and windfall areas of different size. A similar abrupt change-over is typically the result of an event of stochastic nature like *i.c.* a heavy gale.
Creating canopy gaps with exposition of mineral soil (root clods and immediate surroundings), a situation is created with possibilities for pioneer vegetations.

An investigation on older root clods (*cf.* MUYS *et al.*, 1988) is affirming this trend to a certain degree, but learns above all that beech also profits immediately of these situations. The presence of beech in the same regeneration group as the pioneer tree species will possibly result in an early die back of the latest, a phenomenon that was *e.g.* observed by LEMEE (1985) at Fontainebleau.
Although it is quite speculative at this very moment, it can be expected that in the future stand beech will soon win again a dominant position, and that a real pioneer tree stadium will only be able to develop very locally and temporary.

The alternative way is a local extention of the *Pteridium*-population, resulting in a treeless succession phase for a long time but ultimately bowling down to beech dominancy too.

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