# SILVICULTURAL CHARACTERISTICS OF A SCOTS PINE STAND ON DRIFT SANDS

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## 1. INTRODUCTION

In Flanders, important drift sands areas were afforestated with Scots pine during the last century. Drought stress and nutrient availability are two major limiting factors of tree growth on these sites. Nevertheless, the afforestation succeeded extremely well.

In a previous article (Maddelein & Lust, 1992) the authors discussed soil and forest floor characteristics of this stand.
This contribution considers the silvicultural characteristics of the stand, the distribution of natural regeneration and the successional patterns.

## 2. MATERIALS AND METHODS

The inventory of trees and deciduous regeneration was executed by means of two circular plots, with an area of 500 m². For every tree and shrub, taller than two metres in height, the following characteristics were determined : tree species diameter at breast height (1.3 metres), three height and branch-free bole fraction.
The presence of herbaceous vegetation was also mapped.

At the same time a transect analysis was carried out in both plots, according to the recommendations of Leibundgut (1959), Koop (1989), Oldeman (1990) and Hallé *et al.* (1978).
The latter mentions that the length of the transect should be at least equal to the stand height, and the transect width about 1/3 to 2/3 of the height. In this investigation, transect size was 25.26 m (equals plot diameter) x 5 metres. This area seemed large enough for describing this homogeneous first generation forest. Of the trees with a crown overlapping the transect area, following data were recorded:

- trees with a height > 1.5 m
    - position ;
    - diameter ;
    - height ;
    - branch free bole length ;

- height at maximum crown width ;
- crown dimensions.

- trees with a height < 1.5 m :
  - position only.

Since broadleaved seedlings (excluding Black Cherry) were only sparsely represented, their presence was located over the whole plot area.

These data allowed to make up horizontal and vertical projections of the stand.

Furthermore, the stand is characterised by local presence of small Scots pine regeneration units. Two of these groups were analysed in detail.

## 3. RESULTS AND DISCUSSION

### 3.1. The old tree population

The characteristics of the 70 years old stand are presented in tables 1, 2 and 3.

Table 1. Stand characteristics.

| Species | Stem number | dbh (cm) | Height (m) | Upper height (m) | Basal area ($m^2$/ha) | Standing Volume ($m^3$/ha) |
|---|---|---|---|---|---|---|
| Scots pine | 407 | 27.6 | 19.4 | 22.1 | 24.7 | 213 |
| Pedunculate oak | 6 | | | | | |

Table 2. Diameter distribution of the pines.

| Dbh classes (cm) | 20-24 | 24-28 | 28-32 | 32-36 |
|---|---|---|---|---|
| Tree number ($ha^{-1}$) | 67 | 120 | 127 | 53 |

Table 3. Height distribution of the pines.

| Height classes (m) | 14-16 | 16-18 | 18-20 | 20-22 | 22-24 |
|---|---|---|---|---|---|
| Tree number ($ha^{-1}$) | 7 | 40 | 213 | 120 | 27 |

It is a clearly homogeneous even-aged stand, with a relatively low stem number. The average diameter corresponds with a mean annual circumference growth of 1.24 cm. Already 340 trees/ha reached the threshold value of 70 cm in circumference for small sawnwood. In the next future some trees will cross the value of 120 cm in circumference. It is to be expected that, at the age of 100 years, circumference will vary around 125 cm, the size of good sawnwood.

According to the IUFRO classification all trees belong to the upper storey. There is, however, considerable difference in social position, crown development and vitality, which can be detected in the horizontal and vertical projections (see further).The stand has a normal basal area and standing volume (Dufrane, 1983).

Between 1960 and 1990 about 90 $m^3$ metres of pinewood was extracted in the course of consecutive thinnings. Current annual increment can still be considered good with 4.9 $m^3.ha^{-1}.yr^{-1}$. Stand growth is still relatively good for this site and age, and a new generation is settling spontaneously under the pine canopy (see further). Conditions are ideal for the creation of a high forest with reserves (Matthews, 1989). This way, the best trees can be reserved for a number of decades, while a second generation of Scots pine slowly develops underneath. The possibility of such a stand conversion is also mentioned by Köstler (1950) and Röhrig (1982). Erteld (1986) proposes the use of a regeneration period of at least 25-30 years for this silvicultural system.

Taking into account the stand age and average stand height, it can be derived that the stand displays the yield class II.9 according to Wiedemann (1957). Anyway, the current stem number is considerably lower than the value mentioned in that yield class. This illustrates the high thinning intensity in Flemish pine forests. In comparison with the English tables of Bradley *et al.* (1966), based on top height of the stand, the site belongs to the yield class 100-120. For Scots pine and yield class 120 the age with maximum mean annual volume increment is situated between 70 and 75 years, while for yield class 80 between 77 and 82 years. It is clear that, also in this view, a rotation period of less than 70 years is not to be recommended.

The profile drawings of the stand (plot 1 is represented in figure 1) show the uniform verticale structure of the stand. There is a complete lack of middle storey while the substorey just started to develop on some scattered spots. At the same time they reveal big differences in crown development. The crown characteristics allow to presume that an important number of trees can still be kept for some decades.

Table 4 represents a number of parameters for the individual pine trees. Crown width varies around 24 % of tree height, while Erteld (1986) mentions normal values to fluctuate between 10 and 30 %. The ratio h/d is low and indicates the high stability of the trees against storms. This was proved during the winterstorms of 1990. On the 25th of January, wind speeds of over 160 kilometres per hour were registered, and one month later, on the 28th of February, wind speeds of around 150 km per hour were again recorded. The state forest Pijnven was severely damaged by both storms. Nevertheless this particular stand on drift sand was

virtually unaffected by the storms. Only one tree was broken off in plot 1.
Crown length is about 38 %. According to Wiedemann (1948) this value is quite normal.
The crown closure of the pine canopy varies around 50 per cent.
The closure is relatively irregular. Black cherry is present under the cover as well as in open places.

Table 4. Some characteristics values of the old pine trees.
(D = crown diameter ; d = stem diameter ; h = tree height ; $h_{cr}$ = height of crown basis, n = number of measured trees)

| | D (m) | h/d | D/h | $h_{cr}$/h | n |
|---|---|---|---|---|---|
| average | 4.59 | 69.62 | 0.24 | 0.62 | 26 |
| stand. deviation | 0.88 | 8.27 | 0.04 | 0.11 | |

## 3.2. Natural regeneration

### 3.2.1. General regeneration survey

The soil is covered by a dense *Deschampsia flexuosa* mat. In this herbal layer, however, a considerable amount of seedlings has spontaneously settled (table 5). Scots pine is by far dominating the natural regeneration in number (average 14,400 individuals per hectare).

Table 5. Numbers of seedlings (height > 10 cm and < 150 cm) recorded per are.

| | Plot 1 | Plot 2 |
|---|---|---|
| Scots pine | 225 | 67 |
| Black cherry | 3 | 17 |
| Total | 228 | 84 |

Also Black cherry is represented in both plots. This species develops a very shrubby habitus with crowns that cover an important soil area. It grows much faster than pine seedlings (table 6), dominates and eliminates them very quickly. It already produces seeds after a few years.

### 3.2.2. Broadleaved regeneration

Regeneration analyses on the transect area gave an incorrect view on broadleaved regeneration. Therefore, broadleaved seedlings were located over the two complete plot areas.

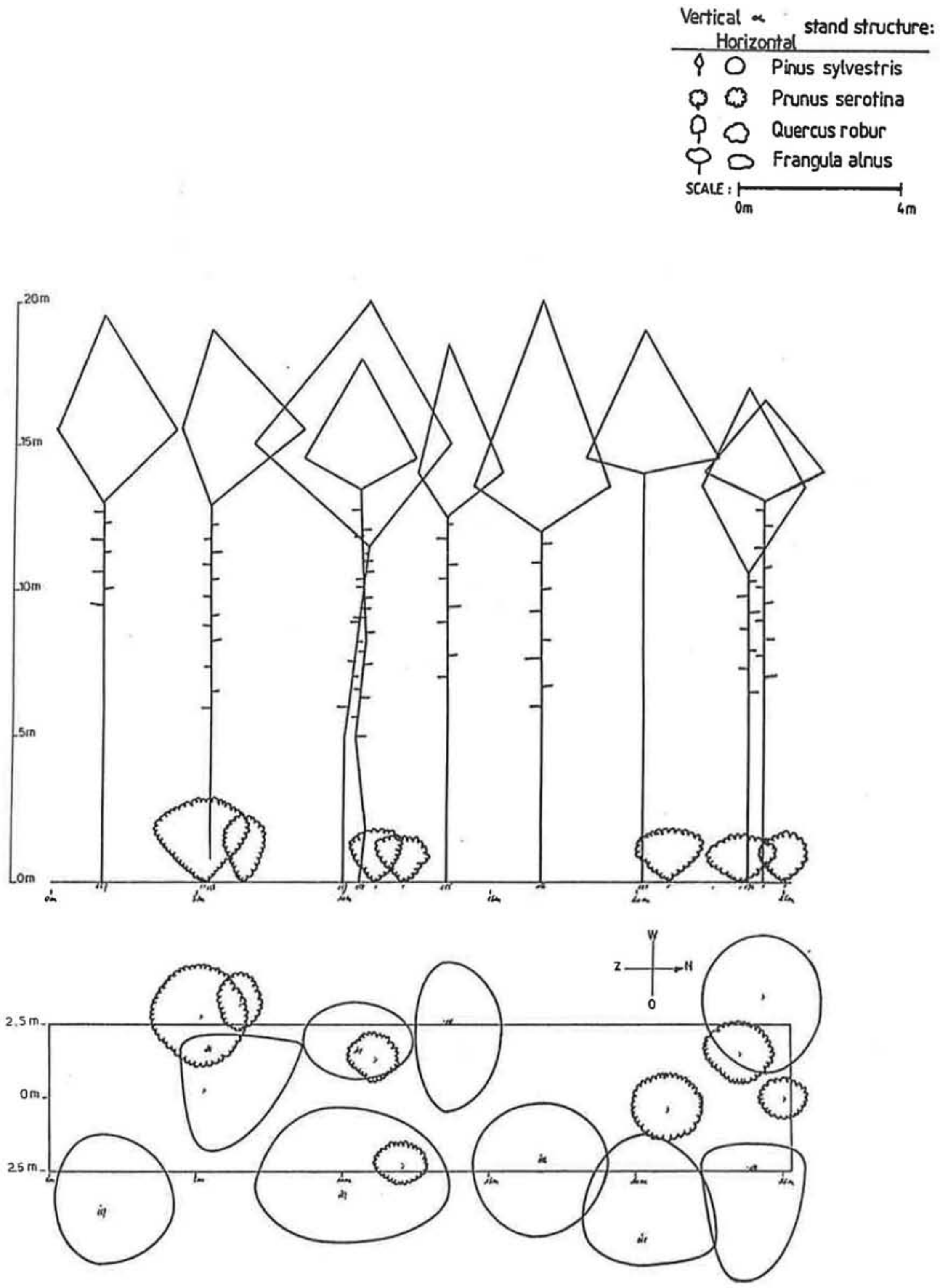


Figure 1. Transect analysis of plot 1 of the stand.

Table 6. Average height of the natural regeneration.

| | Plot 1 | Plot 2 |
|---|---|---|
| Scots pine | 20 | 18 |
| Black cherry | 70 | 80 |

Broadleaved regeneration amounts up to 1400 individuals per ha in plot 1 and 800 in plot 2 (table 7). This is only a fraction of the scots pine seedling presence in the plots (resp. 22,500 and 6,700 per ha ; see 3.2.1.). Besides, almost 75 per cent of all broadleaved regeneration consists of black cherry. This means that on average only 700 individuals per ha of "wanted" species are present. The low number is explained by the absence of seed trees.

Table 7. Natural broadleaved regeneration in the two plots (plot surface 500 m$^2$).

| Plot | 1 | | | 2 | | | all | | |
|---|---|---|---|---|---|---|---|---|---|
| Tree species | number | % | browsed % | number | % | browsed % | height (m) | s.e.m. | max |
| Quercus robur | 10 | 14 | 60 | 4 | 10 | 50 | 0.25 | 0.03 | 0.52 |
| Quercus rubra | 1 | 1 | 100 | 0 | 0 | - | 0.32 | - | - |
| Sorbus aucuparia | 2 | 3 | 50 | 1 | 2.5 | 100 | 0.47 | 0.11 | 0.73 |
| Rhamnus frangula | 6 | 8 | 33 | 5 | 12.5 | 40 | 0.80 | 0.09 | 1.50 |
| Prunus serotina | 51 | 72 | 0 | 30 | 75 | 0 | 1.55 | 0.11 | 3.70 |
| Betula pendula | 1 | 1 | 0 | 0 | 0 | - | 0.30 | - | - |

Red oak, abundant in other stands, is virtually absent here. On the contrary indigenous oaks are relatively well present in the stand (± 140 ex. per hectare). Unfortunately browsing damage, by rabbits and roedeer, is very high on these trees (> 50 %). It severely inhibits the chances of consolidation in the stand and is therefore to be considered as a major limiting factor for the development of these species.

Other species of the oak-birch forest type are also present too, but browsing also causes problems for their survival. The complete absence of browsing damage on black cherry is noted.

Black cherry must be considered as a second major inhibiting factor for the oak survival, but also for the pine seedling survival. Average height of the black cherry seedlings already doubles that of alder buckthorn and is the sixfould of the oaks. Moreover young black cherry trees develop very wide crowns that prevent all other species to regenerate. Regeneration of black cherry will continue at an increased speed, since several of the larger individuals in the stand already carry fruits. In the period September-October 1990, a cherry seed production of 11.7 g.m$^{-2}$ was recorded in litter traps. This means an average seed input of 120 per square metre. The important cherry regeneration in the vicinity of bigger individuals is striking. As a result of this fast cherry expansion, the possibilities for natural regeneration of Scots pine and other tree species are much enhanced, since seedling settlement or survival under cherry trees is virtually zero.

Anyway, it can be concluded that in the homogeneous stands of Scots pine on drift sands the possibilities are present to establish a future forest generation dominated by Scots pine, with a considerable admixture of indigenous broadleaved trees (oak, birch, rowan and alder buckthorn). Conditions for this succesful conversion will be the removal of black cherry and the protection of broadleaved regeneration against browsing.

### 3.2.3. Special survey of Scots pine regeneration units

In the investigated stand a number of well developed Scots pine regeneration groups are present. Although they all fall outside the general plot areas, two of these groups (with a surface of 10 and 12 $m^2$) with consolidated seedlings have been examined more thoroughly.

The first group counted 3420 seedlings per are with an average height of 0.45 m, an average diameter at the base of 0.62 cm, and an average age of 5 to 6 years. The second group counts only 700 seedlings per are, but the plants are taller, bigger and older : average height of 1.10 m, average diameter is 1.63 cm and average age about 8 years.

Height growth of the pine seedlings is strongly limited by the upper canopy. Average annual shoot length is 8 centimetres in group 1 and 15 cm in group 2. These values are only a fraction of initial pine growth on clearcut areas. This reduced shoot growth may not be too disadvantageous, since research showed that it can be compensated by a better wood structure (smaller annual rings and branches) and that this reduction in initial height growth can be fully recovered after 30 to 40 years (Jüneman, 1986).

Corresponding to the lower shoot length, the diameter growth in group 1 is also much more reduced than in group 2. Average annual diameter growth equals 0.11 cm in group 1 and 0.21 cm in group 2. So in both groups there was a similar reduction of height and diameter growth.
In the first group, most seedlings have settled in a short lapse of time (80 % of all seedlings within three years), while regeneration was more spread in time in the second group, with two peaks (fig. 2). Regression analysis indicated a much better relationship between tree age and tree height in the older group than in the younger one.
Regression : $y = a + bx$, with $y$ = tree age and $x$ = tree height
Group 1 : $a = 3.22$ ; $b = 5.05$ and $r^2 = 0.47$ ($p < 0.001$)
Group 2 : $a = 4.43$ ; $b = 2.95$ and $r^2 = 0.76$ ($p < 0.001$).

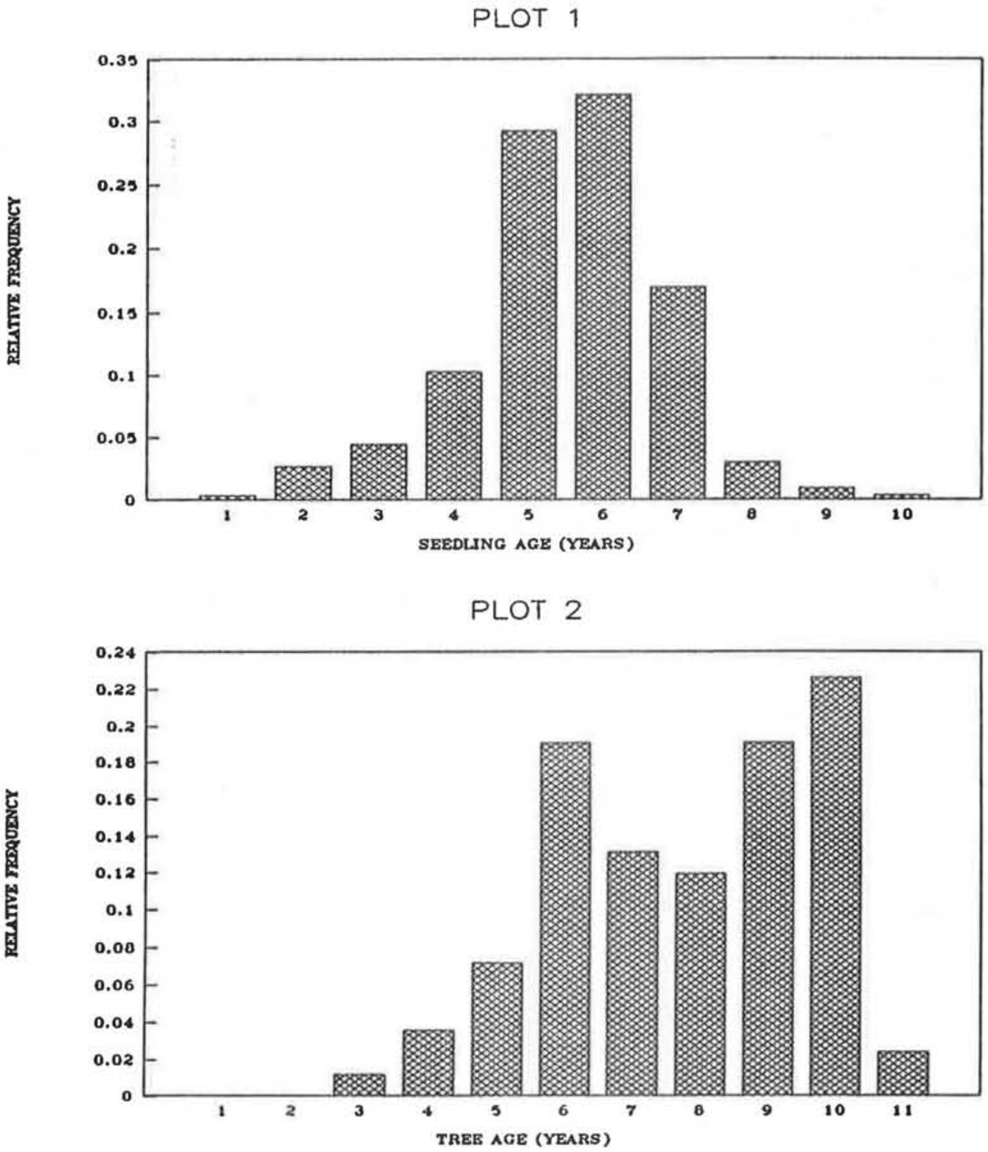


Figure 2. Relative frequency distribution of the age of the pine seedlings.

The much higher seedling density in group 1 resulted in higher competition between the seedlings. In this particular group, an important seedling fraction is already overgrown by others and their current growth is very limited. This explains the lower correlation between age and height.

In general, the oldest pine seedlings show the highest height growth. The early settlers thus preserve their advantageous position and are likely to remain dominant in the stand. Similar situations were described by Van Miegroet (1985) and De Schepper (1987).

Seedling density is more than satisfying. Rottmann (1987) mentions a minimum stem number of 2 per square metre in well developing consolidated natural pine regenerations. Erteld (1986) from his side considers values of 15 to 20 seedlings per square metre for 3 to 4 year old natural regenerations as very satisfactory. Furthermore, too high regeneration densities under canopy may not be desirable, for they create further suppression and also lead to more early and costly interventions in the regeneration.

Both groups have settled in a normal humus profile and probably also in a well developed Deschampsia vegetation. Wagenknecht *et al.* (1956) mention that a Deschampsia cover can dry out the upper soil layers in summer and that pine regeneration therefore is very much limited. Also Fanta (1982), Tweel (1984) and Frochot *et al.* (1990) mention the very difficult natural regeneration of pines and other tree species in Deschampsia vegetation. The main causes for this impossible natural pine regeneration seem to be very high root competition of Deschampsia in the organic soil layers, and the physical damage and increased risk of infection caused by the high Deschampsia litter production. All investigations in this stand, however, prove that Scots pine regeneration on a normal humus layer and in a Deschampsia mat is possible, but proceeds slowly. Regeneration period will be very long before a new generation will have successfully settled over the whole area. More than likely some open spaces in the stand will continue to remain.

## 3.3. Forest succession

Natural regeneration of deciduous species under pine canopy and a clear evolution towards broadleaved forests are well known features in Belgian and Dutch pine plantations on sandy soils (Van Miegroet, 1985 ; Lust, 1987 ; De Schepper, 1988 ; Fanta, 1982). Fanta (1982) cited that within three generations an original Pine forest would develop into a mixed Oak-Birch forest on the poorest Querco-Betuletum sites.

In the Pijnven forest, an evolution towards broadleaved species in also noticeable, but, in opposition to the results of the authors mentioned above, this regeneration is largely dominated by exotic species like red oak and black cherry (Maddelein *et al.*, 1990).

Black cherry was introduced at the beginning of this century, but on a rather limited scale. Locally, the spontaneous ingrowth of cherry was already noted very early (Neunheuser, 1922). The real proliferation of black cherry only started in the

last three decades (from 1960 on). In the fifties, important underplantings with black cherry were still carried out in the pine forests. In the last decades, black cherry massively invaded most pure pine stands, although cherry expansion was restricted in stands where an important red oak substorey had settled by then.
In the last decades, important red oak regeneration in pine stands has not been noticed. Further oak regeneration is clearly suppressed by black cherry.
In this research stand where broadleaved seed-trees lack in the vicinity (no fire-belts), spontaneous regeneration of Scots pine has occurred recently, admixed with some broadleaved species. Browsing strongly reduced the broadleaved ingrowth possibilities, with the exception of black cherry which is now invading these areas rather quickly. Youth growth of cherry is very fast and the slowly growing pine regeneration will face great difficulties in surviving.
It is not unlikely that black cherry will dominate the understory of the entire forest area. Although black cherry's height growth and longevity are limited, its annual seed production is so abundant that it is very likely that the species will replace itself in future generations. In addition, it will probably succeed red oak in future generations.
An identical evolution is described by Lust (1987) for the Ravels-forest in Flanders, a forest with a similar history as the Pijnven. Here too, black cherry is dominating natural regeneration since 1960, while previously red oak and, to a lesser extent, pedunculate oak, managed to settle under pine canopy.
Hofmann, et al. (1990) state that the rapid black cherry expansion of the last decades in pine forests, is also the result of the higher nitrogen-inputs with atmospheric deposition. The effects of this factor on the forest dynamics is a feature that certainly needs further consideration.

## 4. SUMMARY AND CONCLUSIONS

The study of a seventy years old stand of Scots pine on drift sands proves that Scots pine growth on these sites was and is still relatively good : average diameter 27.6 cm, average height 19.4 m, standing volume 213 $m^3$ and an annual increment of 4.9 $m^3.ha^{-1}.yr^{-1}$. All Scots pines belong to the upper storey. Yet considerable differences in crown development and vitality are observed. The current growth rate and the spontaneous settlement of pine seedlings under canopy show the ideal conditions for the creation of a high forest with reserves. Anyway a rotation period of more than 70 years is recommendable.
On several places a consolidated regeneration of Scots pine seedlings under canopy occur. Groups with a stem number of 700 to 3,500 seedlings per are, ranging in age from 3 to 11 years and in height from 10 to 170 cm, are present. This Scots pine regeneration has developed in a normal mor humus layer and in a dense Deschampsia mat.
Broadleaved regeneration is not so abundant, and consists for 75 % of black cherry. Absence of seed trees, browsing damage and the exclusive character of black cherry

are the limiting factors for the installation and survival of valuable indigenous species, such as pedunculate oak.
Provided that black cherry is removed and that the regeneration is protected against wild damage, it is possible to create a mixed forest dominated by Scots pine but with a considerable admixture of indigenous broadleaved trees. However, if black cherry will not be sufficiently controlled, it can be expected that in a first phase black cherry will dominate the understorey, that it will prevent the regeneration of all other species and that, very soon, it will form an almost single-species dominated stage in forest succession.

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