EVOLUTION OF BIODIVERSITY IN HOMOGENEOUS SCOTS PINE STANDS BY AN ECOLOGICALLY DIVERSIFIED MANAGEMENT

N. LUST and B. MUYS[1]
Laboratory of Forestry - University of Ghent

ABSTRACT

This study evaluates three important *parameters of biodiversity* in first generation Scots pine forests on sandy soils : *herbal layer, natural regeneration* and *stand structure*. The research was undertaken in the Belgian Campine Region, where the original oak-birch forest had been destroyed in the course of time and finally been replaced by monocultures of Scots pine. These pine forests are characterised by a low biodiversity. In maturing stands of this type, however, a spontaneous increase of biodiversity is noticed.

Herbal species diversity is very limited in all age classes. Spontaneous establishment of Scots pine seedlings is presently a widespread phenomenon in aging stands. Different regeneration patterns are found. Mainly due to the lengthening of the rotation in combination with the ingrowth of several hardwood species, the homogeneous Scots pine stands are gradually and spontaneously transformed into heterogeneous *mixed stands*, featuring a noticeable increase of biodiversity.

Nevertheless, selected human interventions may further increase biodiversity. The fundamental *management principles* are discussed : avoidance of big disturbances, lengthening of the rotation period, use of native tree species, utilization of natural regeneration, protection of small valuable biotopes and permanent monitoring.
Keywords : Scots pine; biodiversity; ecological management

1. INTRODUCTION

The UNCED conference of Rio de Janeiro 1992 mainly focused on two keywords : sustainability and biodiversity. The former was not a new concept for forestry, as many foresters have always strived for a sustainable yield. Although that objective, however, has not always been realized in practice. Moreover, the concept sustainability has to be considered more comprehensively. Not only a sustainable yield is important but also and especially a sustainable ecosystem is required.

Foresters, however, are less familiar with the concept biodiversity. Although it was already a keyword on the World Forestry Congress of Paris in 1991, and defined on the UNCED conference, this concept was hardly discussed on the IUFRO Centennial in Berlin 1992. Since then, it is tried to approach biodiversity in forestry but great and fundamental problems are remaining, such as assessment and value of biodiversity.

[1] Director K.I.N.T.-I.R.G.T., Brussels

Biologists are more familiar with this notion. It mainly corresponds with the protection of species or wildlife. It is evident that herewith all living plants and animal species are considered. Boyle (1991) emphasizes two major points in the definition. Firstly, biodiversity is a concept covering all levels of biological organization, including genes, species and ecosystems. Secondly it refers not only to numbers, but also to frequencies. This statement corresponds (more or less) to the definition agreed upon in the Rio Convention on Biological Diversity, viz. : " Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."
The concept of biodiversity is, however, not completely new to foresters. Indeed, there is a clear link between the familiar notion sustainability and the new term biodiversity. Sustainability is not possible without diversity. Besides it is well known that many foresters have paid special attention to the conservation of wildgame, to the protection of rare trees and plants and to bird protection, in particular to songbirds.
Biodiversity is mainly a concept of nature conservation. Indeed it is often considered as its major objective. According to Sandri et al. (1990) nature conservation especially aims at the conservation of all native organisms and of their associations in populations which are able to survive. In the Netherlands nature conservation particularly stresses the criteria diversity, naturalness and individuality. Diversity is aimed at in the appearance of species, associations and ecosystems. Completeness of associations and ecosystems is another objective (Anon.,1991).

Forests are important ecosystems for biodiversity. Bunnell (1990) reports that 76 % of Canadian terrestrial mammals and 60 % of Canada's breeding bird species are forest dwellers. Rohner (1988) states that 60 % tot 70 % of the species appearing in Switzerland are living in forests. Trees, however which form the basis of the forest ecosystem, have only a limited direct value in biodiversity. Indeed the species number is often very low. They can, however, have indirectly a very high value for biodiversity. After all the forest is also the biotope for herbs, animal species, insects, mosses and fungi. According to Peterken (1981), a total of 1856 living beings were found in a mixed hardwood in England (Monks Wood, Cambridgeshire, 157 ha) (fig.1). It is obvious that the number of tree species is only a fraction of the total number of plant species. The latter, on its turn, is only a small fraction of the total number of living organisms in the forest. Insects take up 63.1 %, flowering plants and ferns 9.6 %, fungi 8.7 %, spider species 7.5 %, etc.

It is evident that, next to the above mentioned living organisms, one has to take also into consideration the millions of individuals of the pedofauna as well as the still greater amount of pedoflora (bacteria, actinomycetes and fungi).
With respect to the number, insects are very important elements of the forest biodiversity. Research in England showed that a great number of insects and mites is living especially on oak, willows and birches (fig.2) (Kennedy et a., 1984). A great number of insects appear also on hawthorn, poplar, Scots pine, blackthorn, black alder, apple and hazel.
The number is much smaller with exotic tree species.

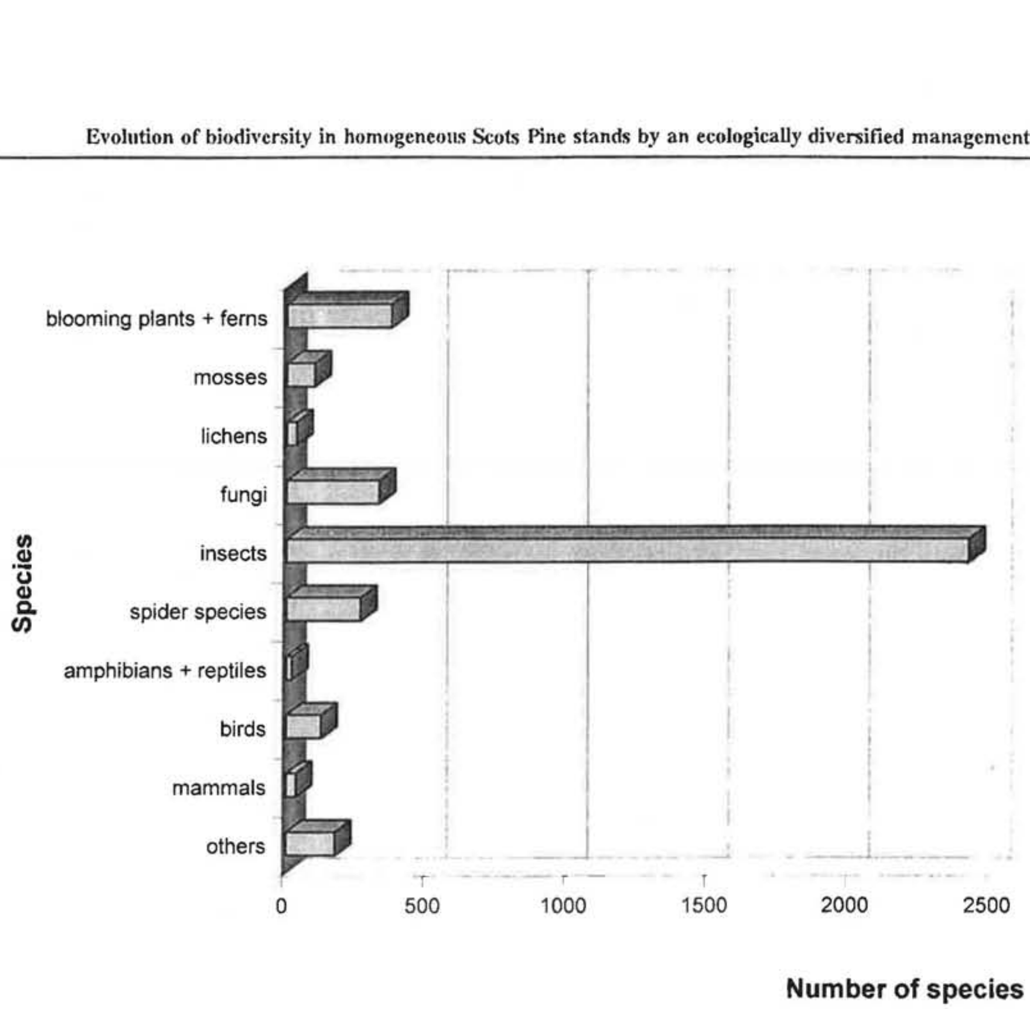

Figure 1 : Number of species of different groups of living beings in a mixed hardwood in England (according to Peterken, 1981)

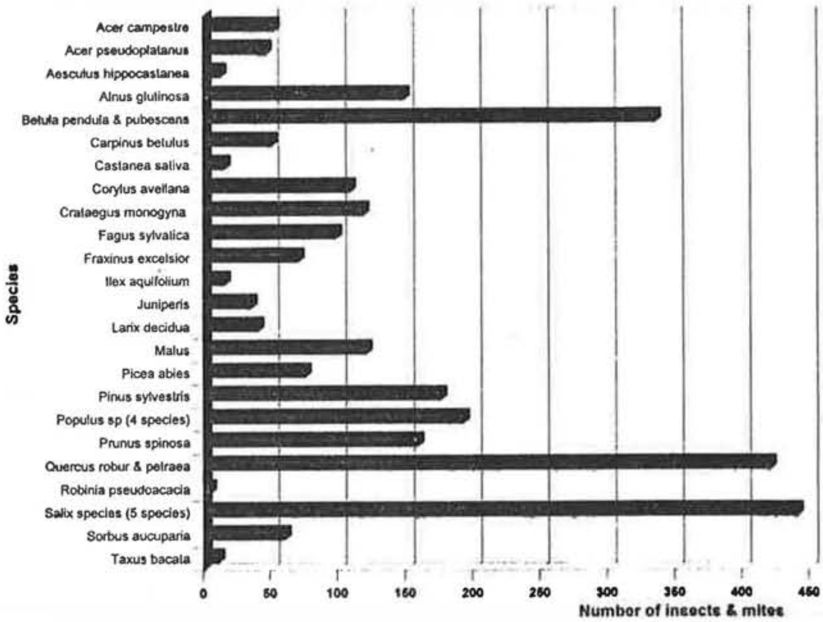

Figure 2 : Number of species of insects and mites, appearing on different tree species in England (according to Kennedy et al, 1984)

Conifers are also much less favourable, although the value of Scots pine is striking.

In former times, the Campine, a region situated in the N.E. of Belgium, was covered with an oak-birch forest of limited value. On the poor sandy soil appeared small dense formations based on pedunculate oak (Quercus robur L.), sessile oak (Quercus petraea LIEB.) and birch (Betula spp.). European aspen (Populus tremula L.) and beech (Fagus sylvatica L.) were scarcely dispersed, while rowan (Sorbus aucuparia L.) and alder buckthorn (Frangula alnus MILL.) were well represented shrubs. In the course of time, however, this forest has been almost completely destroyed and replaced by heathlands or drift sands. In the last centuries, especially since 1850, these sites have been (re)afforestated almost exclusively by means of Scots Pine. Before afforestation, the soil was completely ploughed, up to a depth of 30 cm, to break the iron-accumulation horizon. In this way monocultures on large areas were established.
Meanwhile many of these stands have reached the age of 60-70 years and are considered as mature. But due to several reasons, as well of economic as of silvicultural nature, these forests are nowadays highly discussed. The question arises as to their future. Anyway it is not longer acceptable to maintain homogeneous Pine stands. Also from the nature conservational point of view the question of biodiversity is clearly put.
Notwithstanding the poor quality and variation of the site, it can be accepted that the diversity of the primary forest was relatively high. Biodiversity, however, strongly decreased due to all kinds of cuttings and the appearence of large heath lands. It still diminished by the establishment of Scots pine monocultures, to reach a minimum in the closed middele-aged stands. Currently, however, all kind of processes occur in maturing stands, leading to a significant increase of biodiversity. Among others, this can be observed in the development of the flora, but mainly in the patterns of natural regeneration and stand structure. These three parameters are investigated in this study.

2. RESEARCH SITE AND METHODOLOGY

Numerous measurements were executed in different forests of the Campine. The research took place in stands of first or second generation, mostly established at the beginning of the 20th century with Scots pine. A mixed deciduous belt was planted on many places around the stands. After 1950, much stands were occupied by black cherry (Prunus serotina Ehrh.) either by artificial plantations or by spontaneous ingrowth.

The forest region is situated on an altitude of about 50 to 90 m above sea level. Although the climate can still be called atlantic, some continental aspects are already noticeable. Average temperature amounts up to 9.0° C and average annual precipitation is about 800 mm. Rainfall is relatively equally spread over the year, with an amount of 360 mm during the growing season.
Generally speaking the soils are poor, with a sand fraction accounting for some 90 % of the total grain size distribution. Nevertheless there are important differences in the loam and clay contents, but especially with respect to water economy. The groundwater table is out of reach of the tree roots in the high Campine, whereas it is high in the Low Campine (water table at 20-40 cm in winter-early spring).

The numerus sample plots were chosen in such a way, that variation could be established in soil, basal area, average diameter and height, presence of tree belts and of black cherry. Their situation, dimension and their number correspond to the specific circumstances and the preconceived purpose. The basal area of the stands ranges from 17 m^2/ha to 35 m^2, the stem number from 250 per ha to 540 per ha, the average height from 17 to 24 m, the diameter from 25 to 33 cm and the age from 45 to 75 year.

With respect to the specific objectives, the following measurements were carried out :

- Plant sociological surveys according to the Braun-Blanquet method. The plots, 2 to 4 in each stand, were of circular shape with a total area of 500 m^2.

  Surveys were executed in three typical stands of the Pijnven forest.
  - Stand 1 : a 45 year Scots pine monoculture on former heathland;
  - Stand 2 : a 75 year Scots pine monoculture on former heathland;
  - Stand 3 : a 69 year Scots pine monoculture on drift sands.

  Surveys of a one year old clearcut, after ploughing, were also carried out.

- Registration of all trees in the permanent plots, either circular or rectangular of shape and with a size ranging from 0,5 m^2 to 500 m^2. Tree species, height and diameter were recorded for every specimen. Age analysis was performed on only a fraction of the trees.

- A transect analysis was carried out according to the recommendations of Leibundgut (1959), Hallé et al.
  (1978), Koop (1989), and Oldeman (1990). Following date were recorded :

  - trees with a height < 1,5 m : position;
  - trees with a height > 1,5 m: position, diameter, height, branch free bole length, height at maximum crown width and crown dimensions.

3. RESULTS

The results were grouped in three classes : phytosociological surveys, natural regeneration data and stand structure.

3.1. Phytosociological inventory

Before the afforestations, two plant communities covered the Pijnven area (Rogister, 1959) :
- The Callunetum-Genistetum Tüxen (1937) on the podzolic soils;
- The Corynephoretum-canescentis agrostetosum caninae Tüxen (1937) on the drift sand areas.

Some relict species of the original oak-birch forest were sparsely present. Already in the fifties, it was difficult to distinguish both communities in the field, since the afforestation had led towards a more uniform species composition in the whole forest.
Current species presence is very limited (table 1).

Table 1 : Vegetation releves, with the Braun Blanquet method, of three Scots Pine stands

Stand	1		2				3		
Age	45		75				69		
Soil	spodosol		spodosol				inceptisol		
Plot	1	2	3	4	5	6	7	8	9
Species									
Upper storey									
Pinus sylvestris	3	3	2	2	2	2	3	2	2
Quercus rubra			1						
Understorey									
Betula pubescens						+			
Frangula alnus			+						
Prunus serotina	1	1	2	2	2	2	1	1	3
Quercus robur									+
Quercus rubra			3	2	3	3			
Herb layer									
Betula pubescens	+	+		+			+		
Frangula alnus	+	+						+	+
Pinus sylvestris	1	1	+	1	+	+	1	1	1
Prunus serotina	+	+	+	1	+	+	+	+	1
Quercus robur		+				+	+	+	+
Quercus rubra	+	+	+	+	+	1	+		
Sorbus aucuparia	+		+	+	+	+		+	
Calluna vulgaris		+							
Carex pilulifera				+					5
Deschampsia flexuosa	5	5	1	2	2	1	4	5	+
Dryopteris carthusiana	1	+	+	+		+	+	+	
Epilobium angustifolium	+	+		+	+		+	+	
Molinea caerulea				+					+
Vaccinium myrtillus		+	1	1		+			
Humulus lupulus				r					
Holcus mollis	r								

In all plots together, only nine herbaceous species were counted. Only one individual of Humulus lupulus and Holcus mollis was present, while only a few individuals of Calluna vulgaris and Carex pilulifera were found. Species such as Corynephoretum canescens, Festuca ovina, Agrostis Canina and Poa nemoralis were still common 30 years ago but have by now disappeared. New species have not established during this lapse of time. The dominating herb species is presently Deschampsia flexuosa, sometimes covering over 80 percent of the soil. Beside this grass species, only three herbal species (Vaccinium myrtillus L., Epilobium angustifolium L. and Dryopteris carthusiana (Vill) H.P. Fuchs) are present in more than 50 % of all plots. All stands can be described as acid, relatively dry soils with a weak nitrification level.

In the older stands, where an understorey of deciduous species has developed, the wavy hair dominance decreases due to a lower light intensity. In most cases the ground is left bare after the disappearance of Deschampsia, but Vaccinium myrtillus sometimes colonises the area. It is to be expected that this species will expand in the older forest parts.

Clearcutting and ploughing, in order to establish a new forest generation, returns the forest stand to an initial stage in which several species of the heathland community appear. (table 2).

Heather (Calluna vulgaris L.) is present in virtually all survey plots, species-richness of these stands is much higher than in nature stands. Several new species have likely survived in the seedbank. Typical is also the presence of a number of species indicating higher moisture levels (Juncus squarrosus, Molinea coerulea (L.) Moench). Their presence can probably be related to locally better water availability as a result of soil compaction, caused by the machinery used for exploitation and soil preparation of the stand. Scots pine seedlings are abundantly present. The pioneer aspect of the vegetation will only last for a couple of years, as most newly established species will disappear after canopy closure of the young trees.

Moss species are sparsely present in all stand (table 3). Ground coverage is very low and rarely exceeds 5 %. Moss species are located on particular micro-habitats, such as tree stumps, branches and mineral soil, brought to the surface by uprooted trees. In the 45 year old Scots pine stand 12 moss species were founded, covering a ground area of some 5 %. Their presence is much lower on drift sands.

Table 2 : Vegetation releve of a one year old ploughed clearcut stand

Releve	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Herbal layer (%)	8	5	5	5	10	5	5	<5	<2	20	5	2	5	5
Moss layer (%)	15	<5		20	2	1	25	<2	<2	20	15	15	5	
Upper storey														
Pinus sylvestris	1	1	2	1	2	2		1	1	+	1	1	2	2
Quercus rubra	1	+		+	+	+	1	+		2	+	+	+	
Quercus robur										r				
Prunus serotina	+		+	+	+		+	+	+	+	+		+	+
Betula pubescens														
Betula pendula					+						+		+	
Salix sp.								+						
Herbal layer														
Agrostis vinealis							1	1						
Calluna vulgaris	+	+	1	1	1	+	1	1	1	1	1	1	+	1
Rumex acetosella	1	+	+				1			+	r	+		+
Molinea coerulea		+			+	+	+			+	+			
Deschampsia flexuosa	2	1	1	2	1	1	1	1	+	1	r	1	2	1
Corynephorus canescens											+		+	+
Carex pilulifera	1	2	1	+	1	2	1	+	1	+	+	+	+	+
Juncus squarrosus		1	+		+	+		+			1			
Luzula multiflora							1		r	1				
Genista pilosa						+		+			+			
Ornithopus perpusillus		+												
Juncus effusus		+												
Spergula morisonii			+											1

Table 3 : Moss inventory of three Scots Pine stands

Stand	1	2	3
Age	45	75	69
Atrichum undulatum	+	+	
Brachythecium rutabulum			+
Campilopus sp.	+	+	+
Dicranella heteromalla	+	+	
Dicranum scoparium	+		
Eurhynchium praelongum	+	+	
Hypnum cupressiforme	+		
Lophocolea heterohylla	+	+	
Orthodontium lineare	+	+	+
Plagiothecium curvifolium	+	+	+
Pleurozium schreberii	+	+	
Pohlia nutans	+	+	+
Polytrichum formosum		+	
Pseudoscleropodium purum	+	+	

3.2. Natural regeneration

Although it was believed, until 30-40 years ago, that natural regeneration of Scots pine stands in the Campine was impossible, it is nowadays a widespread process, following diverse patterns.

The vigorous spontaneous ingrowth of several hardwood species is probably the most striking. A survey, made in 15 stands of Scots pine, established as monocultures 70 years ago on former heathland and surrounded with a deciduous belt, showed some interesting points (table 4):

- In all stands a fair occupation of deciduous trees has established. On average there are 7,000 saplings/ha.

- 80 % of the regeneration are black cherry. This species appears everywhere rather frequently, ranging from 3,500/ha to more than 11,000/ha. Its density is so high that it can form everywhere a complete cover.

- Nevertheless there is still a fair ingrowth of other species. A total of 10 tree species have regenerated. They can be divided into major tree species, such as red oak and pedunculate oak, and in secondary tree species, such as black cherry and rowan.

- Apart from black cherry, the red oak is found most frequently. It appears almost everywhere, with an average number of 761/ha.

- Pedunculate oak appears to a lesser degree, although it is found almost everywhere, with an average of 120 trees/ha.

- The regeneration of Scots pine itself is very limited. It is only found in stands where black cherry was regularly cut or pulled out.

Table 4 : Stem number of spontaneous ingrowth in 70 year old Scots pine (N/ha)

Stand	7	10(A)	10(B)	11	16	17	19	21	22	25	26	28(A)	28(B)	39	54	Average	%
Pinus sylvestris	/	/	/	323	/	347	/	18	/	/	/	107	/	/	/	56	0,8
Quercus rubra	766	425	844	1354	813	705	964	741	1098	367	359	1027	1547	406	/	761	10,8
Sorbus aucuparia	125	625	703	135	271	63	9	27	125	78	188	36	/	885	1359	309	4,4
Quercus robur	234	263	281	177	94	63	125	36	45	109	47	36	198	94	120	1,7	1,7
Frangula alnus	78	88	219	52	31	27	9	54	9	55	55	18	/	42	31	51	0,7
Betula pendula	/	113	/	113	141	21	31	/	63	36	9	/	8	/	141	46	0,7
Castanea sativa	125	13	16	10	/	45	/	9	9	63	63	/	/	/	31	22	0,3
Tilia cordata	109	/	/	/	/	/	/	/	/	/	/	/	/	/	/	14	0,2
Acer pseudoplatanus	47	/	/	/	/	/	/	/	18	8	/	/	/	/	16	6	0,1
Subtotal	1894	1525	2203	2072	1239	1251	1170	920	1313	680	719	1232	1563	1677	1641	1379	19,6

It is likely that black cherry plays a determinant role in the regeneration process. Nevertheless, there are still other important factors regulating the pattern of regeneration, a.o. the soil fertility and the stand density.

The regeneration process in Scots pine stands occurs according to various patterns. Also in middle-aged Scots pine stands on coarse sandy soil or on drift sands, one can find 8 regenerating tree species in the juvenile phase and distinguish six regeneration types (De Schepper,1988; table 5).

- Six tree species frequently come to regeneration, namely Scots pine, pedunculate oak, red oak, birch, black cherry and alder buckthorn.

- The following regeneration typology can be distinguished

  1. regeneration under cover of Scots pine:
     - Scots pine dominating type P.
     - Pedunculate oak dominating type Q
     - Black cherry dominating type Ps
     - Alder buckthorn dominating type Fa

2. regeneration under mixed cover of red oak and: pedunculate oak.
   - red oak dominating type Qr

3. regeneration on free field:
   - birch dominating type B

Table 5 : Species composition and density of regeneration N (stemnumber pro are) of the six regenerationtypes ranged pro species

R. type		Species								
		P.oak	R. oak	S. pine	Birch	Bl. ch.	Al. bu	Rowan tree	Holly	Total
Q	N	110,7	-	75	1	43,5	28,2	7,7	-	266
	%	41,6	-	28,2	0,4	16,4	10,6	2,9	-	100
Qr	N	-	4133,2	-	11	11	11	-	-	4166,2
	%	-	99,1	-	0,3	0,3	0,3	-	-	100
P	N	11,0	-	1414	13,8	5,5	44,3	2,8	2,8	1494
	%	0,7	-	94,6	0,9	0,4	3,0	0,2	0,2	100
B	N	17,2	1,2	95,2	562,5	1,2	3,8	-	-	681,2
	%	2,5	0,2	14,0	82,6	0,2	0,6	-	-	100
Ps	N	19,7	-	110,8	10,3	301,3	59	8,3	-	509,3
	%	3,9	-	21,7	2,0	59,2	11,6	1,6	-	100
Fa	N	40,3	-	56,3	18,3	-	1024	-	-	1138,8
	%	3,5	-	4,9	1,6	-	89,9	-	-	100

The types Q, B, Ps and Fa can be considered as mixed regeneration types, while the types Qr and P rather appear as homogeneous regenerations. Only two species, alder buckthorn and birch, were found in all six regeneration types. Scots pine is well represented in the several regeneration types, except in the type Qr.

Pedunculate oak occurs in five of the six types, while red oak is present in only two. Seedlings of red oak were found in a red oak stand, but never in Scots pine stands. Pedunculate oak, however, does not regenerate under its own cover but does under cover of Scots pine.

In the Belgian Campine natural regeneration also occurs on burnt areas of Scots Pine. As a result of 70 experimental plots, laid out 6 years after a big fire, an abundant regeneration was found (table 6).

- The total stem number reaches 18,554 per ha.

- In all, 11 species occur in the regeneration. In comparison with the above research forests, the presence of Salix aurita L., Quercus petraea LIEB., Fagus sylvatica L., Populus tremula, L. Castanea sativa MILL. and Sambucus nigra L. is new.

- Almost 95% of the stem number is taken up by two species, birch and Scots pine. The birch, which is present everywhere in the surroundings, takes up near 60%. The regeneration of Pine is more difficult.

- The nine other species represent hardly 5 % of the total, namely 1,039/ha. They can, however, play an important role in the future stand, both on the cultural and economic level. The near-absence of black cherry is remarkable.

Table 6 : Number of saplings 6 year after a fire in Scots pine stands

Species	Number/ha	%
Betula spp.	10919	58,6
Pinus sylvestris	6596	35,6
Salix aurita	443	2,4
Quercus rubra	228	1,2
Quercus petraeae	143	0,8
Fagus sylvatica	72	0,4
Prunus serotina	68	0,4
Populus tremula	52	0,3
Rhamnus frangula	20	0,1
Castanea sativa	10	0,1
Sambucus nigra	3	0,1

Regeneration of Scots pine itself is not always obvious. Nevertheless it can be found in many places and under different circumstances in the Pijnven forest.

- Regeneration of Scots pine under its canopy.

  A 69 year old stand, situated on continental sand dunes, displays an important regeneration, located in a dense mat of wavy hair-grass, dominated by Scots pine. Several deciduous species have also settled (Sorbus aucuparia L., Quercus robur L., Quercus rubra L., Prunus serotina EHRH. and Frangula alnus MILL.) but their development is severely influenced by browsing.

  Besides the seedlings, several already consolidated Scots pine regeneration groups can be detected. The following characteristics appear from the analysis of two groups :

- number per are	3,420	700
- average height (m)	0.45	1.10
- average diameter (cm)	0.62	1.63
- average age (y)	5.5	7.8

- Regeneration under canopy, after removal of the organic soil layer. In a 46 year old Scots pine stand, with a basal area of 29 m^2, the organic soil layer was locally removed during springtime. Only Scots pine has settled in the research plots. Regeneration averaged 1.45 million seedlings per hectare after one year. In that period one third of the initial seedling number had already disappeared, mainly during the first months after germination.

- Regeneration on a clearcutted area.

  A 65 year old Scots pine stand was clearcutted and, in order to achieve a natural regeneration of Scots pine, all black cherry shrubs were excavated and the whole stand was ploughed.

  After 1 year the regeneration resulted in a number of 270,000 seedlings per ha, being less than 20% of the above result after removal of the organic soil layer. Yet, average seedling height is twice as high (7.5 cm vs 3.5 cm)

3.3. Stand structure

As a result of spontaneous ingrowth and natural regeneration, the original homogeneous Scots pine stands are currently slowly but steadily transformed into heterogeneous mixed stands. This can be shown by the vertical projection of a 75 year old Scots pine stand, of which figure 4 is an example.

The highest stem number appears in the middle stratum, namely 760 trees/ha or 42 %. Nearly 70 % of the trees in this stratum are red oak, originating from the deciduous belt around the stands.

The upper stratum contains on average 32 % of the stem number. The pines take up, with 75 %, by far the greatest part. But even red oak, black cherry, native oak, locust tree and sweet chestnut have already penetrated into the upper stratum. In figure 4 red oak represents even already half of the stem number.

The lower stratum is the least represented.

An age analysis shows, that in these 75 year old stands the average age of the red and native oaks amounts respectively to 31.3 and 27.5 years.

The oldest trees of the red and native oak are 47 years, so that the pine stands were 27 years old, when the spontaneous ingrowth of the deciduous trees started.

Such kind of spontaneous regeneration, characterised by a long regeneration period, is very different with the regeneration strategy on fire areas. In the above discussed area the spontaneous resettlement after fire occurred very fast. Especially birch and Scots pine settled the second and the third year after the fire. The regeneration period was very short. There was no more regeneration after 4 years.

4. DISCUSSION

The impact of various forestry operations on forest ecosystems has been the subject of much debate. Especially the status of "old-growth" forest, the effect of harvesting and the habitat fragmentation have been strongly discussed.

Among others, the question arises to what extent forestry management has contributed to the disappearance of plants and animals. Nature conservationists generally state, and rightly, that forestry has influenced very negatively the biodiversity of forest ecosystems and that the treatment is even still increasing. According to the "red list" of 1986 the threat by forestry on vascular plants rose in Germany up to 255 species (Bundesforschungsanstalt, 1986). In 1988 it even contributes to the decline of 338 species, i.e. 47% of all threatened species. This way it is situated immediately after agriculture, as second most important cause, far before tourism and recreation (Korneck and Sukopp, 1988). Especially sensitive are wet regions. Drainage, conversion of hardwoods into conifers and clearcutting in combination with soil cultivation are considered as the major causes. Boyle (1991) on his site also stresses forest fragmentation and inappropriate exploitation techniques.

Anyway it is obvious that biodiversity is low in Scots pine monocultures, established on former heathlands in the Belgian Campine, and characterised by short rotations, relatively high stand density and uniform structure. It is, however, not sure that the biodiversity is lower than in the former degraded heathlands on the bare drift sands. Especially the more mature stands, characterised by a spontaneous ingrowth of several hardwoods, a complex structure, a variation in age, a relatively high herbaceous biomass (2.6 ton/ha) and a small amount of dead wood are tending to higher and valuable biodiversity. The former monocultures of Scots Pine have been spontaneously transformed into mixed forest, wherein native oak and birch, being important sources of biodiversity, often play an important role. Next to these species also other species like rowan, alder buckthorn, beech, locust tree, sweet chestnut and more scarcely also willow, lime, aspen, elderberry, maple and holly are represented. Unfortunately two exotic tree species threat the spontaneous ingrowth of native species, namely black cherry and American red oak.

The former is a real danger for the process of natural succession. Its expansion capacity and its density exclude almost completely the establishment of all other species and many forests tend already, at least without human intervention, to exist of monoculture stands of black cherry. Biodiversity in such stands, partly also due to the toxic components of the needles, is very low. They only provide a litter layer of good quality. Red American oak is likely to be compared with black cherry. It also dominates and finally excludes all light demanding and slowly growing species. Regeneration of other species is not possible under its dense cover. This counts also for the development of a herbaceous layer. It is a species, which leads on sandy soils to a very low degree of biodiversity. However, it is favoured by forest owners because of its fast growth even on poor and dry soils, its valuable wood and thus its high profitability.

Nowadays it is more or less accepted that black cherry should be eliminated as much as possible. The question is, however, how to manage it. The position of Red American oak is more under discussion. One might conclude that it must not be eliminated completely, that it can be very worthwhile on poor and dry soils, but that it may not exclude native valuable hardwoods both from the economic and the bio-diversity point of view.

Forest management can, also with monocultures on poor sandy soils, provide a lot of measures, which significantly increase the forest biodiversity, without endangering its economic value.

It is obvious to think of the creation of large scale forest reserves, without human interventions. Such forest types, however, may take up only a small part of the total forest area.

Limitation of forest fragmentation, on the one hand by avoiding further deforestation and on the other hand by connecting separated forest regions and by creating a network, is favourable for the conservation and the increase of plants and animals.

Peterken (1981) formulated, as an executive conservationist, seven principles to stress nature conservation aspects of woodland management :

1. Minimise rates of change within woods.
2. Encourage maturity by maintaining long rotations. If this is not possible, retain some scattered old trees after restocking.
3. Encourage native tree species and use non-native species only where necessary.
4. Encourage diversity of (a) structure, (b) tree and shrub species and (c) habitat in so far as this is compatible with other principles.
5. Encourage restocking by natural regeneration or coppice growth.
6. Take special measures where they are necessary to maintain populations of rare and local species.
7. Retain records of management.

All these fundamental principles can easily be followed in the daily practical management of Scots pine stands. Even more, they should be applied not only in public forests but also in private forests. Encouragement, by the forest service, should be given in two ways :

- by logistical support, meaning that forest owners must be convinced of the advantages of a more diversified forest. It includes that some forests must be treated as pilot forests.
- by financial support, e.g. for plantations of native species or for the maintenance of populations of rare and local species.

1. Minimal change

The principle of minimal change is also valid for the conversion of little diversified Scots pine forests into more complex forests in which conifers and hardwoods are mixed irregularly. In practice it means that the transformation period should be long enough and that indirect conversion methods must be used. Therefore clearcuts must be avoided and regeneration under cover must be applied.

2. Long rotation periods.

An urgent measure is the lengthening of the rotation period, so that forests can reach the mature phase of their live cycle, in which biodiversity is developing spontaneously. In former times the rotation of Scots Pine stand was only 40-50 years. Nowadays, by the loss of the pit-prop market, it has risen already to some 70 years, but observations and studies indicate that rotations of more than 100 year are easily feasible.

Natural development of forests goes through different phases. The bare phase is generally characterised by a wealthy herbal vegetation and a lot a seedlings of different species. In the juvenile phase life circumstances are still good for the development of a variety of plants and animals. Biodiversity is at its maximum in this young phases, but it decreases fast in the thicket phase and reaches a minimum in the pole phase, in which there are almost no mammals.

The crown density, however, decreases in the tree phase, by which the developmental possibilities of herbs and animals improve again (von Vuure, 1985).

3. Native tree species

Peterken (1981) emphasises that trees play three roles in relation to nature conservation. They are or may be :

- a component of semi-natural communities;
- an environment for wildlife;
- a substrate for wildlife.

The contribution of native species to these three roles of trees is by far much greater than that one of introduced species. Long established broadleaves, however, can reach already a noticeable value.

The choice of tree species is likely to be the most important measure in relation to biodiversity. Trees should be preferably native and one should strive for species diversity. Scots pine in the Belgian Campine cannot be considered as a native species, although it was present immediately after the ice ages. However, it is certainly a species which is appropriate to the site and which enables a high degree of diversity, especially in older stands with a long rotation. Therefore Scots pine must not disappear, but should be used in a more environmentally friendly way. It means hat the objectives must be adapted. Quality instead of wood mass should be the objective. Short rotations must be replaced by long rotations, homogeneous and uniform stands by mixed and uneven aged stands, artificial regeneration by natural regeneration under cover.

Among native species, especially oak and birch come into consideration. Both species, however, are probably able to eliminate Scots pine. Therefore an appropriate tending should be applied, ensuring the regeneration and development of Scots pine. It means that the stand density must be controlled and that the mixture pattern should pay due attention to the site quality. Indeed within the sandy soils of the Campine the differences in soil fertility are still great. Establishment of hardwood is recommended on the better soils, with a higher loam or clay content and belonging to the c or d drainage class. The possibilities of pedunculate and sessile oak are presently already more or less accepted, especially in public forests. Unfortunately there is a great lack of seed trees and planting results are often poor, certainly on open areas, unlike planting of oak under canopy of Scots pine, which normally succeeds quite well. Native oak, however, are strongly competed by red American oak, an exotic tree species with low biodiversity value. This species too must not be eliminated, but has to be controlled strictly. It should be mainly restricted to the poorer and dryer soils and to private forests. Not at all clear is the position of birch, still generally considered in that region as a weed tree. Therefore it is combated almost completely. It must be stressed, however, that birch is a tree species, which must be strongly favoured in future stands. Indeed as well from the silvicultural as from the biodiversity point of view it is a very valuable tree species. It improves degraded sites, it enables a mixture with other light demanding tree species, provided an appropriate tending takes place, it regenerates spontaneously and abundantly on open areas and production is fair. The following observations were noted after establishment of birch (Muys, 1991).

- more earthworms;
- faster litter decomposition;
- deeper action of thc organic matter with the soil;
- higher soil pH;
- more roots;
- increasing diversity of the herbaceous layer.

Unfortunately the timber market for birch is very bad. The production of more valuable logs must improve its profitability and justify its increased share in the tree species composition.

On the other hand there are still two exotic conifers, namely Corsican pine and douglas fir, which are very attractive from the economic point of view, but which are also heavily discussed from the ecological point of view. Both species have a very low biodiversity in their characteristic stands, featured by high canopy densities, relatively short rotations and clearcut systems. Moreover especially douglas fir tends to exclude other tree species. As these species have specific values in the whole spectrum of forestry, their presence can be accepted, albeit under strict control.

The conclusions with respect to the future species composition of the present Scots pine stands are obvious.

- The monoculture stands must be transformed into more or less complex mixed stands.
- The share of native tree species must be increased significantly. Oak and birch have to play a major role, but appropriate other species must be intermixed as much as possible. On the same time the use of native shrubs, mainly of rowan tree and alder buckthorn must be encouraged.
- Some compromise must be sought between mainly native broadleaf deciduous trees and evergreen conifers.

4. Diversity

Greater diversity of habitat enables more species to exist in a given area and assists more species to colonise (Peterken, 1981). Habitat diversity in Scots pine monocultures can be reached by diversity in stand structure both on the horizontal and vertical level and by a complex age class distribution in space and time. Also this kind of forestry has to strive for a small shifting mosaic structure. The realisation requires longer rotations, mixed stands based on tree species choice in accordance with the site quality and natural regeneration patterns.

Vertical stand diversity is built up by the spontaneous process of ingrowth of hardwoods and shrubs. Structures, which can be compared with those in selection forests, can and have arisen in less than 30 years. Such stands will obtain much higher stability, that tends to favour woodland fauna and flora.

Not only trees and shrubs are valuable. Attention must also be paid to the herbal vegetation. The latter can only develop in less dense, mature stands or in vertically well structured stands. In the Campine Scots pine forests herbal biomass production up to 3 ton has been recorded, almost completely realised by Deschampsia flexuosa. Analyses have shown, that even the herbal litter is richer in nutrients than the needle litter (Muys, 1991). It means that herbal litter is of better quality than needle litter and that it will contribute to the promotion of litter decomposition.

As a consequence a better development of pedoflora and pedofauna can be expected. However it should be clear, that the poor sites will never enable a rich and valuable flora, with the exception of some heather plants. Therefore there should always be open places, in which the historical development of heather is maintained.

As in every forest, forest edges are very valuable biotopes (Schoop, 1991).Well structured edges, gradually built up by native herbs, shrubs and trees, are highly appreciated, not only by nature conservation but also by farmers and from the landscape point of view. This principle should also be applied along the roads inside the forest.

5. Natural regeneration.

Peterken (1981) points out, that natural regeneration has several advantages over planting for nature conservation : it favours native species, it favours the species already on the site and minimises changes, it tends to generate mixed stands, the stand produced tends to have a more irregular structure, natural genetic variety can be better maintained and the natural distribution of tree species in relation to soil types is favoured.

Practice has shown that natural regeneration of former Scots pine monocultures is easily possible in different ways. It can be created on clearcut areas, after disturbances by fire or gales and also under a more or less dense canopy. It often leads to a not completely predictable tree species composition. Longer regeneration periods favour vertical diversity. If needed, human intervention, e.g. by removal of the litter layer or by soil injuring, can start or stimulate regeneration.

Natural regeneration, however, is a disadvantage when aggressive introduced species are present which are threatening to dominate the forest. It can also be discussed when the present origin is not fully adapted to the site. It is evident that black cherry is a threatening species, that must be destroyed completely. Also Rhododendron, which is spread locally, impoverishes the wildlife and ought to be controlled. The development of species like red American oak and douglas fir should also be monitored.

With respect to the regeneration system, it must be referred to the applied silvicultural system, and more specifically to the clearcutting. Some contradictory data like to appear. On one hand clearcutting obviously causes enormous changes to the forest ecosystem, with dramatic consequences to many organisms. For this reason, it has been the target of environmental groups. On the other hand, however, the effects of clearcutting are highly variable. Indeed the system generates a new juvenile phase, promoting the development of a rich herbal layer and favourable life conditions for all kind of mammals and songbirds. On large afforestated areas, featured by mosaic structures, clearcuttings are not absolutely negative for biodiversity. Moreover the scale and pattern of clearcuts are also vitally important in determining the response of different species to disturbance.

The final conclusion, however, is obvious : biodiversity is not the ultimate objective of forest management and clearcuts must be avoided as much as possible on the sensitive Scots pine stands. If not, loss of nutrients will lead to still greater soil degradation and the impossibility to enrich the stands with hardwoods.

6. Specific measures

Specific measures for the protection of small habitats, valuable for the conservation of rare and local species, can be taken without significant impact on the economic results. Biotope and species protection should not be underestimated and considered as a secondary objective. Fens, ponds,swamps, dishes, glades, roads and rides are important habitats, which increase the range of biodiversity. Most are artificial in origin and survive only by active management. Ott (1990) stresses the value of protection measures in favour of birds, bats and ants hills.

The rate of dead wood should be increased. The standing as well as the lying necromass is important. Crown wood and bark should be left and decomposed on the spot. Old big tree bodies should be left standing or lying in the forest. Dead wood is not only valuable for the biological aspects of the forest, but also for the nutrient cycle (Jedicke, 1991; Schoop, 1991).

Infrastructure operations should be reduced to a minimum. Drainage should be avoided on floristic valuable sites, as well as construction of new roads and road paving. Under no circumstances, forest exploitation should thoroughly disturb the ecosystem. With (re)afforestations the use of technical implements should be reduced to a minimum. Use of herbicides and fertilisers and application of soil preparation are not allowed in areas valuable for nature conservation.

7. Records

Records of management measures are useful to understand the impact of the actions on the environment. One approach is to maintain control ecosystems which are absolutely or relatively free from human influence. The second approach demands either to set up trials whose results can be assessed in the future, or to study the consequences of actions which were taken in past (Peterken, 1981).

As a general conclusion, it can be stated that biodiversity can easily be increased in economically valuable Scots pine stands and that must be strived for systems which combine profitability, stability and diversity. In practice a lot of measures can be recommended :

- conversion into mixed stands, with use of native tree species and shrubs;
- use of natural regeneration;
- use of long rotations;
- small-scale group treatment, leading to a mosaic structure; restricting of clearcuttings, striving for regeneration under canopy;
- creating a normal age structure and vertically well structured stands;
- retaining existing diversity by conservation of small biotopes and rare species;
- limiting of soil preparations, stopping of litter robbery, no-burning of timber residues, debarking on the spot, avoiding of fragmentation, study of site characteristics and limiting of wildgame.

Although biodiversity of Scots pine stands can be increased significantly, the wildlife potential of its normal site will always be limited.

5. SUMMARY

Sustainability and biodiversity were recently strongly stressed. Although foresters are familiar with the concept of sustainability, they are much mess so with the biodiversity concept. Besides, the latter is still subject to some fundamental questions.

Forest ecosystems are very important for biodiversity. Trees have only a limited direct value but a very high indirect one.

In former times the Belgian Campine was covered with an oak-birch forest of limited value. Later on this forest was for the greater part replaced by heathlands, which were on their turn afforestated the last centuries with monocultures of Scots pine, featured by a low diversity. Currently, however, all kinds of processes significantly increase biodiversity.

Research was carried out with respect to plant phytosociology, natural regeneration and stand structure.

Current herbal species presence is very limited. Some species, common 30 years ago, have disappeared, whereas new species have not settled during this period. Natural regeneration of Scots pine stands is nowadays a widespread process, following diverse patterns. The most striking is the vigorous spontaneous ingrowth of several hardwood species. Several tree species are involved and different regeneration types can be distinguished, either on former heathlands, or on drift sands, after clearcut or after fire. The natural regeneration of Scots pine itself is not always obvious, but is appearing under its own cover, after removal of the organic soil layer or on clearcutted areas.

Currently the homogeneous Scots pine stands are slowly but steadily spontaneously transformed into heterogeneous mixed stands. Several hardwoods have already reached the upper stratum.

Monocultures of Scots pine stands are obviously characterised by a low biodiversity and are strongly criticised. More natural stands, however, show several processes of spontaneously increasing biodiversity. Nevertheless a specific forest management must be applied in order to favour biodiversity. Next to some general measures, such as the creation of forest reserves and the limitation of forest fragmentation, a lot of fundamental principles, originating from the nature conservation circle, can be implemented.

1. Minimal change. The transformation period should be long enough and indirect conversion methods must be applied.

2. Rotation period. It can be lengthened from the former 40-50 years to more than 100 years.

3. Native tree species. Conversion of Scots pine stands must be based on the use of native hardwood species. Especially native oaks and birch are strongly recommended. Scots pine itself, although not native, must be maintained, but a compromise must be sought between native broadleaves and Scots pine. Black cherry must be eliminated completely, unlike red American oak, Corsican pine and Douglas fir, which must be controlled.

4. Diversity. It will be the spontaneous result of a lot of measures. An irregular mixed forest, based on a variety of tree species, shrubs and herbal vegetation, will display a valuable biodiversity.

5. Natural regeneration. With respect to nature conservation the system has several advantages over planting. Practice has proven that natural regeneration can appear, with or without human intervention. Clearcutting systems, although able to increase, at least temporary, biodiversity, must be avoided as they impoverish the overall forest ecosystem.

6. Specific measures. They are needed for the protection of any habitats, valuable for the conservation of rare and local species. The rate of dead wood should be increased, while infrastructure operation and use of technical implements must be reduced to a minimum.

7. Records.They are needed to understand the impact of forest management on the environment.

In practice, several measures can be recommended to increase significantly biodiversity, ranging from the introduction of native species, the lengthening of the rotation period, the application of natural regeneration systems to almost pure technical items such as limitation of soil preparation and wildgame or a thorough study of the site.

6. BIBLIOGRAPHY

Anonymous, 1991. Natuurbehoud en bosbouw gaan goed samen. Boomblad 3(6) : 14-15.

Boyle, T.B., 1991. Biodiversity of Canadian forests : current status and future challenges. The forestry chronicle, 68, 4, 444-452.

Bundesforschungsanstalt für Naturschutz und Landschaftsökologie, 1986. Die rote Liste. Gefährdete Pflanzen in der Bundesrepublik Deutschland, Forsch. - Rep. Ernährung, Landwirtschaft, Forsten, Heft 1, 29-31.

Bunnell, F.L., 1990. Biodiversity : What, where, why and how. In : A Chambers (ed.). Wildlife forestry symposium, Prince George, B.C. For Res.

De Schepper, C, 1988. Typology of the natural regeneration in a middle-aged Scots Pine Forest. Silva Gandavensis. 53, 29-60.

Dev. Agreement Rep. 160, B.C. Ministry of Forests, Forestry Canada, Victoria B.C., 29-45.

Hallé, F, Oldeman, R.A.A. and Tomlinson,P.B. 1978. Tropi- cal trees and forests. An architectural analysis. Springer Verlag Berlin, Heidelberg, New York, 414 p.

Jedicke, E., 1991. Biotopverbund im Forest. Allgemeine Forstzeitschrift, 46, 703-705.

Kennedy C.E.J. & Southwood T.R.E., 1984. The number of species of insects associated with British trees : a re-analysis. J. Animal Ecology, 53, 455-478.

Koop, H., 1989. Forest dynamics. Silvi-Star : a comprehensive monitoring system. Springer-Verlag Berlin, Heidelberg, 229 p.

Hornbeck, D und K. Sukopp, 1988. Die Liste der in der Bundesrepublik Deutschland ausgestorbenen, verschollenen und gefährdeten Arten Farn- und Blütenpflanzen und ihre Auswertung für die Arten- und Biotopschutz. Schriftenreihe für Vegetationskunde, H. 19, Bonn-Bad Godesberg.

Leibundgut, H., 1959. Über Zweck und Methodik der Struktur- und Zuwachasanalyse von Urwäldern. Schweiz. Z. f. Forstwesen, 110, 3, 111-124.

Lust N., 1987. An analysis of a spontaneous ingrowth of deciduous trees in 70 year old stands of Scots pine. Silva Gandavensis, 52, 1-28.

Lust, N., 1988. Analysis of a natural regeneration of Scots Pine Forest in the High Campine after a fire, 53, 3-28.

Lust, N., 1991. Arme gronden, rijke bossen : besluiten en bedenkingen. Groene Band 83-84, 64-77.

Lust, N., 1992. Forestry policy on multiple use forestry in Europe. Silva Gandavensis, 57, 46-77.

Lust, N., 1993. Waldwirtschaft und Naturschutz auf Weltveranstaltungen und in der Praxis. Silva Gandavensis, 58, 115-140.

Lust, N., D. Maddelein and S. Meyen, 1989. Rehabilitation of forest ecosystem on former heathlands by a first generation of Scots pine, 54, 3-12.

Maddelein, D., 1991. Mogelijkheden en beperkingen voor de bosbouw op arme zandgronden. Groene Band, 83-84, 1-10.

Maddelein, D & N. Lust, 1992. Silvicultural characteristics of a Scots pine stand on drift sands. Silva Gandavensis, 57, 16-27.

Maddelein, D. & N. Lust, 1992. Soil and forest floor characteristics of Scots pine stands on driftsands. Silva Gandavensis, 57, 10-15.

Maddelein, D, N. Lust, S. Meyen & B. Muys : Dynamics in maturing Scots pine monocultures in North-East Belgium, 55, 69-80.

Maddelein, D., Meyen S. and N. Lust, 1991. Driving forces and limiting factors in long-term dynamics of forest ecosystems on sandy soils. Final report, Laboratory of Forestry. State University of Ghent, 223 p.

Maddelein, D., Neirinck J., & Sioen G., 1993. Growth and management of mixed Pinus silvestris, Quercus robur stands in Flanders, Belgium, Silva Gandavensis, 58, 91-100.

Muys, B, 1991. Strooisel en humus : onbekend is onbemind. Groene Band, 83-84, 11-35.

Muys B. & D. Maddelein, 1993. De Amerikaanse vogelkers : van troefkaart tot bospest, 91, 1-22.

Oldeman R.A.A., 1990. Forests : elements of silvicology. Springer Verlag Berlin, Heidelberg, 624 p.

Ott, W., 1990. Leistungen für den Naturschutz. Allgemeine Forstzeitschrift, 45, 6-7, 141-146.

Peterken, G.F., 1981. Woodland conservation and management. Chapmann & Hall, London 328 p.

Rogister, J.E., 1959. Ecologische en bosbouwkundige kartering van het domeinbos Pijnven. Proefstation Groenendaal, 63 p.

Sandri et al., 1990. Spannungsfeld Waldbau. Natur- und Landschaftsschutz. Schweizerische Zeitschrift für Forstwesen, 141-23-54.

Schoop G, 1991. Multifunktionale Forstwirtschaft. Allgemeine Forstzeitschrift, 46, 20-22.

Van Vuure, T, 1985. Zoogdieren, bossen en wederzijdse invloeden. Pudox, Wageningen, 135 p.