DYNAMICS IN MATURING SCOTS PINE MONOCULTURES IN NORTH-EAST BELGIUM[1]

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SUMMARY

The State Forest Pijnven, created early this century by afforestation with Scots pine *(Pinus sylvestris L.)* of heathland areas is now characterised in most stands by an important ingrowth of deciduous tree species. Ingrowth is dominated by red oak *(Quercus rubra L.)* and black cherry *(Prunus serotina Ehrh.)*, both being species originating from North-America. Deciduous ingrowth in the pine stands profoundly influences herbal composition of the stand. *Deschampsia flexuosa (L.) Trin.*, abundant in all older pine stands, disappears when deciduous trees settle and species diversity, already low in the pine stands, further diminishes. Important oak and cherry regeneration is depending on the presence of seed trees in the vicinity; when lacking, a new pine generation manages to settle. A good red oak regeneration can be useful as a basis for stand conversion towards a mixed, uneven-aged deciduous forest type, but in many cases this possibility is hampered by massive invasion of black cherry, preventing all other species to regenerate.

RESUME

La forêt domaniale Pijnven située au Nord-Est de la Belgique, a été créé au début du XXième siècle par l'afforestation d'un grand terrain de bruyère. Cette afforestation s'est presque entièrement réalisée avec le pin sylvestre *(Pinus sylvestris L.)*. Aujourd'hui, ces forêts se charactérisent souvent par une importante régénération naturelle d'essences feuillus à l'intérieur des peuplements de pins. Deux espèces de provenance nordaméricaine dominent cette régénération, à savoir le chêne rouge *(Quercus rubra L.)* et le cerisier tardif *(Prunus serotina Ehrh.)*. L'introduction d'arbres feuillus modifie très fort la composition du strate herbacé. Par conséquent la canche flexueuse *(Deschampsia flexuosa (l.) Trin.)* , abondamment présente dans les peuplements de pins, disparaît presque entièrement et la végétation, déjà très pauvre en espèces, appauvrit encore plus. La présence d'arbres-mères aux alentours des peuplements est une condition sine qua non pour l'obtien d'une bonne régénération d'arbres feuillus dans les peuplements. En cas d'absence de ces arbres, une nouvelle génération de pins sylvestre à la fin réussit à se déveloper sous le vieux peuplement. Une bonne régénération de chêne rouge peut se réveler utile comme base d'une conversion de peuplements purs vers un type de forêt

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d'arbres feuillus mixte et inéquienne. Mais souvent, cette évolution est empêchée par l'invasion massive du cerisier tardif, mettant ainsi obstacle à la régénération de toute autre espèce.

INTRODUCTION

The North-Eastern part of Belgium, known as the Campine region, is characterised by its poor, sandy soils. Various human activities have resulted into the disappearance of the former vegetation type (oak-birch forest) and have led to the presence of vast heathland areas. In an attempt to rehabilitate this area, large parts were reafforestated starting from the mid of last century.The reafforestation was executed almost exclusively with Scots pine *(Pinus sylvestris L.)*. Today, secundary succession trends are fully noticeable in numerous maturing Scots pine monocultures *(VAN MIEGROET, 1985; LUST, 1987; DE SCHEPPER, 1988)*. Several deciduous tree species have settled under the pine canopy and can prove to be useful as a basis for a second generation forest.

SITE DESCRIPTION

This research was executed in the state forest Pijnven situated near Hechtel-Eksel (fig. 1).

The state forest Pijnven covers about 800 hectares and was established early this century on former heathlands. Part of the forest is situated on continental sand dunes.

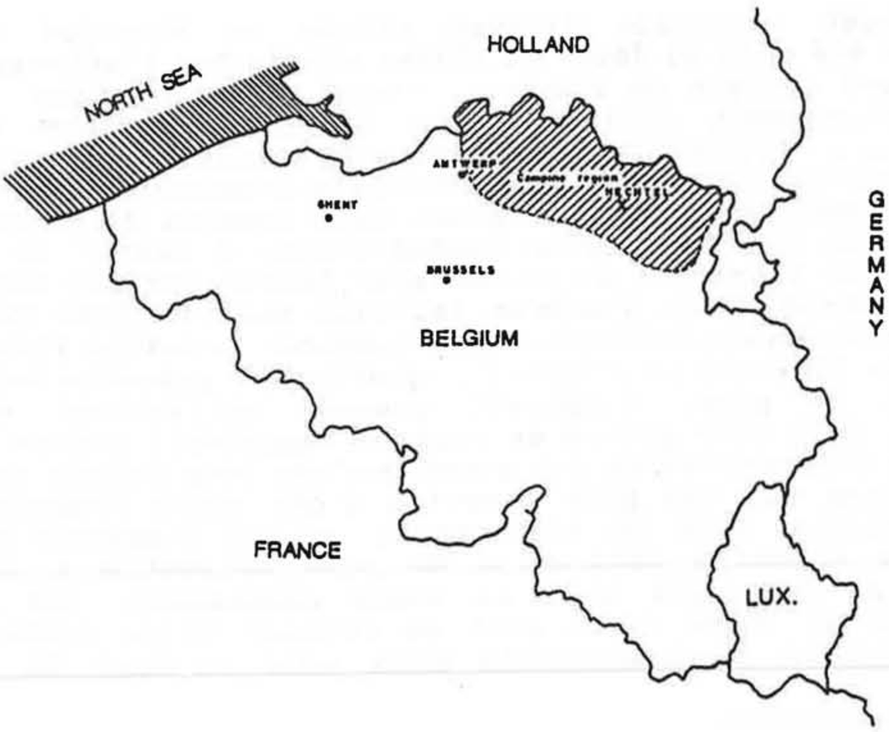

Figure 1 : Location of the research area.

Forest soil is very poor, with sand fraction (particles ≥ 50 μm) accounting for about 90 % of the total grain size distribution. Before afforestation, the soil was completely ploughed (up to a depth of 30 cm) to break the iron-accumulation horizon. Later lupines were grown for three consecutive years in order to fix nitrogen in the soil. Finally an additional fertilization with phosphorus and lime was supplied. The afforestation was executed by employing a geometrical pattern dividing the forest in rectangular stands with a surface of 4 to 5 hectares. The stands are separated by broad roads surrounded by a deciduous tree species shelterbelt. The shelterbelts originally consisted of various tree species, but are nowadays dominated by red oak *(Quercus rubra L.)*.

Later, especially beyond 1930, most reafforestations were executed with Corsican pine *(Pinus nigra Arnold subsp. laricio)*, that shows greater yield than Scots pine and by now occupies over 50 % of the total forest area. Scots pine only amounts to 35 % of the total forest area, but the bulk of those stands are over 60 years old and ready for conversion.

MATERIALS AND METHODS

In order to study secundary succession trends in Scots pine monocultures, a number of stands, representing different succession phases, were selected. A short overview of these stands is presented in table 1.

For the inventory of tree species, a number of plots was established in each stand. For all trees higher than two metres, diameter at breast height (dbh) and total tree height were recorded. Plant sociological releves were performed using the Braun-Blanquet method.

The organic soil layer was described by the thickness of litter (L), fermentation (F) and humus (H) horizons. The biomass of the holorganic layer was measured by harvesting six 0,25 m² plots.

Mineral soil was analysed on combined samples collected in every stand (sampling depth 10-15 centimetres), and the following chemical analysis were performed : carbon content (Walkley & Black); nitrogen (modified Kjeldahl); Ca, K and Na (flame photometry); Mn, Mg, Fe, Al (atomic absorption spectrometry); SO_4 and Cl (ion chromatography) and P (colorimetry).

The inventory was conducted during spring and summer 1988. Soil samples were collected in December 1988.

Statistical data processing was carried out with the programm BIOMECO, developped by the biometric group of the Centre d'Ecologie Végétale et Evolutive (CNRS) at Montpellier, France.

Table 1 : Main characteristics of the research stands.*

Stand number	Stand age	Domin. sp.	Main characteristics
1	45	Scots pine	monoculture, established after clearcutting of poor growing 30 year old pine stand ; on former heathland
2	56	Red oak	monoculture established through sowing under 25-year old pine stand; 1959: removal pines ; located on blown-over podzol profile
3	69	Scots pine	monoculture, located on land-dunes
4	75	Scots pine	monoculture, on former heathland
5	69	Scots pine	monoculture, on former heathland
6	69	Scots pine	monoculture, on former heathland

* All stands are first or second generation forests and were afforestated early this century.

RESULTS AND DISCUSSION

Plant sociological inventory

Before reafforestations, two plant communities covered the Pijnven area *(Rogister, 1953)* :

- The *Callunetum-Genistetum* TÜXEN (1937) on the podzolic soils ;
- The *Corynephoretum-canescentis agrostetosum caninae* TÜXEN (1937) in the drift sand area.

Sparsely, some relict species of the original oak-birch forest were present.
Already in the early 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. Species like *Corynephoretum canescens, Festuca ovina, Agrostis canina* and *Poa nemoralis* were still common 30 years ago, but have by now disappeared from all research stands (table 2).

Current species presence is very limited. In all plots together, only seven herbaceous species were present. Dominating herb species in all stands is *Deschampsia flexuosa*, sometimes covering over 80 per cent of the soil. Spontaneous regeneration of tree species is dominated by black cherry and red oak, except for stand 3 where Scots pine is most widely spread. Only in this stand, natural evolution is tending towards a second generation forest dominated by Scots pine, while elsewhere deciduous species will prevail. Regeneration of autochthonous tree species (birch, oak, rowan, ...) occurs only on a limited scale, due to the low seed tree presence in the surroundings and the very high browsing damage on the seedlings present. In fact, selective browsing by roedeer effects all deciduous trees with the exception of black cherry.

Table 2 : Species presence in the research stands (method Braun-Blanquet).

Stand		1		4				2			3		
Plot		1	2	3	4	5	6	7	8	9	10	11	12
Species	Symbol												
Betula pubescens Ehrh. (juv.)	BET	+	+	-	+	-	-	-	-	-	+	-	-
Calluna vulgaris (L.) Hull	CAL	-	+	-	-	-	-	-	-	-	-	-	-
Carex pilulifera L.	CAR	-	-	-	+	-	-	-	-	-	-	-	-
Deschampsia flexuosa (L.) Trin	DES	5	5	1	2	2	1	+	+	+	4	5	5
Dryopteris carthusiana (Vill.) H.P. Fuchs	DRY	1	+	+	+	-	+	-	-	-	+	+	+
Epilobium angustifolium L.	EPI	+	+	-	+	+	-	-	-	-	+	+	-
Frangula alnus Mill. (juv.)	FRA	+	+	-	-	-	-	-	-	-	-	+	+
Molinia caerulea (L.) Moench.	MOL	-	-	-	+	-	-	-	-	-	-	-	-
Pinus sylvestris L. (juv.)	PIN	1	1	+	1	+	+	+	-	-	1	1	1
Prunus serotina Ehrh. (juv.)	PRU	+	+	+	1	+	+	+	+	+	+	+	1
Quercus robur L. (juv.)	QRO	-	+	-	-	-	+	-	-	-	+	+	+
Quercus rubra L. (juv.)	QRU	+	+	+	+	+	1	+	+	+	+	-	-
Sorbus aucuparia L. (juv.)	SOR	+	-	+	+	+	+	-	-	-	-	+	-
Vaccinium myrtillus L.	VAC	-	+	1	1	-	+	-	+	-	-	-	+

S t a n d   i n v e n t o r y

The results of the stand inventory are given in table 3. In this table all tree species with a diameter of less than 8 centimetres at breast height are excluded.

Stand 1 is showing extremely good yield for Scots pine on this soil type, whereas stand 2 is of very poor quality. Average tree volume in stand two is about equal to that of the naturally established red oaks in stand 4. This extremely low standing crop is probably caused by the doubtful origin of the oak seeds. Stands 3 to 6 are mature Scots pine stands. Typical for all except for stand 3 is the presence of an important naturally established deciduous tree layer. This understorey is composed by only two species : red oak *(Quercus rubra L.)* and black cherry *(Prunus serotina Ehrh.)*, both being North-American species. In fact, the trees mentioned in table 3 (dbh > 8 cm) only form a small fraction of the total consolidated natural regeneration (table 4).

A distinct difference can be noticed between the total amount of ingrowth present in every stand. Stand 4 is dominated by red oak, while black cherry largely dominates stands 5 and 6. In all cases, black cherry is dominating the lowest diameter and height classes, often showing a shrubby habitus. Since it is doubtful that black cherry can produce valuable timber on these soils, most attention in forest management is paid to red oak. When comparing the global red oak regeneration, only stand four can be called satisfactory. Here, an important fraction of the trees are present in upper diameter classes, and some trees have even reached the pine canopy. Moreover, a considerable oak fraction is present in the understorey of this stand (table 4). In the other stands, red oak regeneration is limited because massive regeneration of black cherry inhibits new oak settlements.

Table 3 : General features of the research stands.

Stand	Tree Species	Stem number (with dbh≥8cm)	mean dbh (cm)	mean height (m)	Basal area (m2/ha)	Standing volume (m3/ha)
1	Scots pine	1100	18.1	15.2	29.1	210
2	Red oak	695	12.7	13.1	12.7	67
3	Scots pine	413	27.5	19.4	24.8	213
4	Scots pine	220	29.1	20.6	15.0	135
	Red oak	335	11.8	12.0	5.1	22
	Black cherry	70	9.7	9.3	1.1	2
	Total	625	17.6	14.7	20.2	159
5	Scots pine	338	25.7	17.8	17.9	145
	Red oak	88	8.9	8.6	0.5	2
	Black cherry	113	9.2	6.6	0.8	2
	Total	539	19.5	14.0	19.2	149
6	Scots pine	334	27.3	19.5	19.8	173
	Red oak	127	9.2	9.5	0.9	3
	Black cherry	27	8.0	7.0	0.1	0
	Total	488	21.9	16.5	20.8	176

Tree age analysis using a Pressler-corer in stand four showed that the red oaks varied in age between 16 and 43 years, black cherry between 16 and 27 years. Forest management records mention that in this particular stand, black cherry was planted in 1954. Obviously, those trees failed to survive and were replaced by naturally established trees. Age analysis proves that red oak regeneration started when the pine stand was only 32 years old and that the regeneration period took very long.

Soil analysis

Organic layer

Analysis of variance could not detect any significant differences between the thickness and biomass of the holorganic layer of stands 1, 2, 3 and 4. Nevertheless, stand 1 contains about 30 tonnes less dry organic matter per hectare than the other stands (table 5). In general, organic matter accumulates at a rate of 1,5 tonnes per hectare per year. Current annual litter input is highest in both stands 1 and 2. In stand two, decreasing litter production by the maturing pine trees, is fully compensated by the important deciduous litter contribution of the ingrowth *(Maddelein & Meyen, 1989)*.

Table 5 : Soil characteristics of the research stands.

Fractions	Subject	Stand 1	Stand 2	Stand 3	Stand 4
Mineral Horizon (10-15 cm)	pH H2O	4.03	4.21	4.27	4.14
	pH KCl	3.09	3.31	3.49	3.46
	C (%)	1.23	1.06	0.81	0.64
	N (ppm)	151	181	180	187
	Na	5	6	6	7
	K	2	2	4	4
	Ca	4	4	4	6
	Mg	3	3	3	4
	Al	182	209	216	142
	Fe	209	173	250	212
	Mn	0.3	0.2	0.2	0.3
	P	10.6	3.5	4.2	7.7
	SO4	98	89	109	95
	CEC (meq/100g)	4.22	4.40	3.63	2.85
	Base Cation Saturation (%)	2.04	1.47	1.05	0.77
Organic Horizon	Thickness L-Layer (cm)	0.2	0.8	0.9	0.4
	F-layer	5.3	4.8	2.2	5.0
	H-layer	1.2	2.1	4.5	1.9
	Total biomass (tonnes.ha-1)	76.2	105.3	103.9	107.7
	Annual litter input (kg.ha-1)	5049	4849	4100	4560

Significant differences between stands are detected for thickness of litter ($\alpha = 0,01$), fermentation ($\alpha = 0,001$) and humus layer ($\alpha = 0,001$). Stands with deciduous species present (2 and 3) possess a thicker litter layer than pine stands. The red oak stand differs from the other stands through the development of an important humus horizon and a thin fermentation horizon. In pine stands, a thick fermentation horizon usually develops under the influence of *Deschampsia flexuosa (Mettivier Meyer et al., 1986)*.

Mineral soil

Of all analysis performed on the mineral soil fraction, only few indicated significant differences between the stands.
Total carbon content differed very significantly between the stands. This is explained by a higher humus content in the upper soil layers of stands 1 and 2, originating from the spodic horizon being disturbed by ploughing before afforestation (± 1905). Cation exchange capacity and base cation saturation are very low, stressing the extremely poor soil conditions.

O r d i n a t i o n   a n d   c l a s s i f i c a t i o n

In the 4 investigated stands, a total of twelve plant sociological releves was completed (table 2). Following the Braun-Blanquet scale, species presence in every plot was appreciated according to seven classes, going from (example for *Calluna vulgaris*) CAL1 : absent, to CAL7 : soil coverage 75-100 %.

Table 6 : Coverage classes of woody vegetation in upper and understorey.

Plot		1	2	3	4	5	6	7	8	9	10	11	12
Upper storey	Code												
Q. rubra	BAM	1	1	1	1	1	1	6	6	6	1	1	1
P. sylv.	BPI	5	5	4	4	4	4	1	1	1	5	5	5
Under storey	Code												
Q. rubra	NAM	1	1	5	5	5	5	2	2	2	1	1	1
P. sylv.	NPI	1	1	1	1	1	1	1	1	1	1	1	1
P. serot.	NSE	3	3	4	4	4	4	1	1	1	2	3	5

Then, it was tried to explain species composition by a number of ecological variables. The apparently most important variable was the tree species composition in upper- and understorey. This variable is responsable for light penetration towards the soil vegetation, and possibly also for the nutrient status of the forest soil. As for the herbaceous vegetation, the tree species coverage was estimated by classes going from 1 (0 %) to 7 (75-100% coverage). This resulted in a matrix presented in table 6.

The tree coverage matrix was crossed with the original species presence matrix and the resulting matrix was subjected to an factorial correspondance analysis, with the plots as supplementary variables (figure 2).

This procedure was followed by the classification of Ward, based on the euclidic distance between points and resulting in the encircled groups of the figure. The first factorial axe explained 57 % of total variability. The negative edge of the axe was mostly formed by the absence of pines in the upperstorey, the dominance of red oak and the absence of black cherry in the understorey. Herbal vegetation is very sparsely present, pine and *Dryopteris carthusiana* being absent. Stand 2 is located in this area (vegetation type III). The positive end of the first axe is characterised by a relatively dense pine upperstorey, accompagnied by a more or less important presence of black cherry in the substorey. Red oak is absent. The herbaceous vegetation is

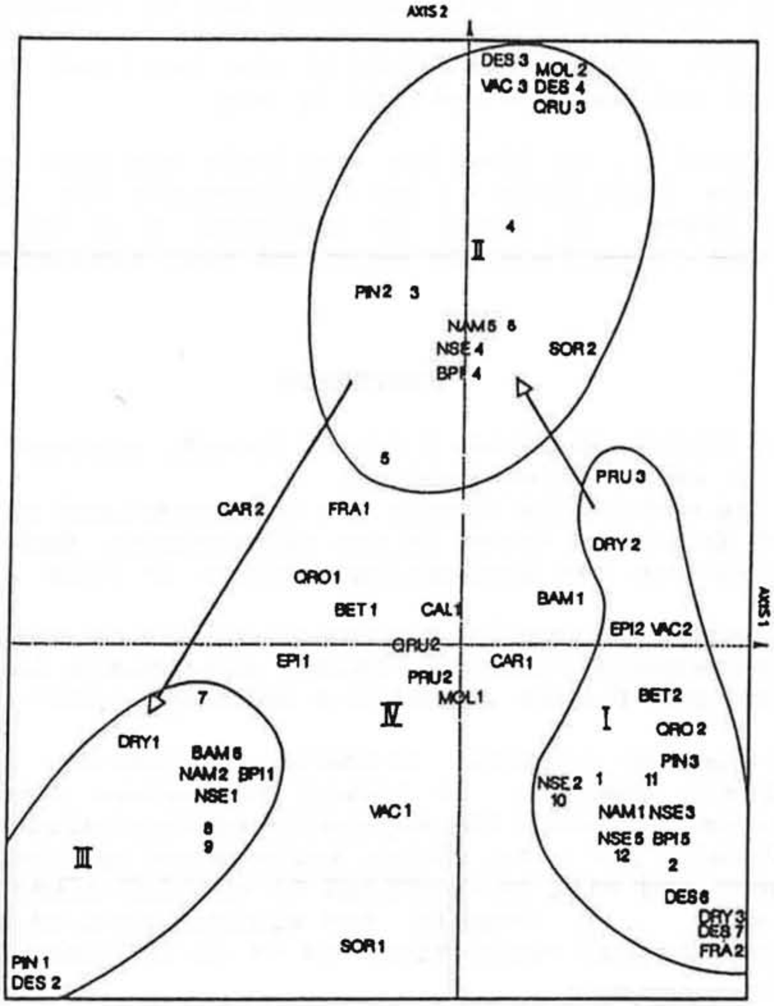

Figure 2 : Factorial Correspondance Analysis of the crossed matrix of herbal vegetation and tree cover. Plane of the first and second factorial axes with indication of the plots as supplementary variables (1 to 12), main vegetation types (I to IV) and the successional chronosequence (arrows).

abundant and dominated by *Deschampsia flexuosa*. Dispersed seedlings of Frangula, Pinus and Quercus robur are evenly present (vegetation type I). The second axe explains 33 % of the variation. This axis is mainly formed by a, somewhat less dense, pine canopy and a dense substorey consisting of oak and cherry. The herbal vegetation is characterised by the presence of Vaccinium, Molinea and Sorbus and the restricted presence of Deschampsia and pine seedlings (vegetation type II).

Vegetation group IV consists in the absence of the species Molinea, Vaccinium, Sorbus, Epilobium, Betula, Calluna, Carex, Frangula and Quercus robur. This group is not typical for any stand ; these species can be absent in any forest type.

A successional chronosequence starting from group I and passing through group II to end up in group III can be distinguished and is probably the general scheme for a first generation of pine planted on heathland in this region. However, the final stage with absolute dominance of red oak, here artificially established in stand 2, will probably not be reached. It is more likely that future forest generation will be dominated by both oak and cherry, with cherry taking the overhand in the younger stands where oak has not settled by now.

Additionally, an identical analysis was performed in order to assess the importance of soil parameters for explaining the vegetation types. As could be expected from the analysis of variance, the classification detected high similarities between the stands.

SYNTHESIS

In the young, man-made Pijnven forest, succession is widely dominated by exotic tree species.
Globally, the older pine stands are characterised by an important presence of deciduous trees in the understorey. Red oak and black cherry are by far the dominating species in this layer.

When deciduous species manage to settle in homogeneous pine stands, *Deschampsia flexuosa* rapidly disappears to survive only in remaining sun flecks *(Packham & Harding, 1985)*.

After canopy closure, bilberry *(Vaccinium myrtillis)*, a shade tolerant species, is likely to become dominant in the herbal stratum, although the expansion of Vaccinium-groups occurs at a relatively low rate. Other herbaceous species will settle very sparsely and will be confined to special sites (sun flecks, disturbed soil, ...). Overall, the biggest part of the soil will probably lack herbal vegetation, as it is the case for stands 2, 4, 5 and 6.

Seed origin of both ingrowing tree species are to be found in the deciduous fire-belts from where seeds are dispersed in the stands by birds and rodents. Where these fire-belts are lacking (stand 3), settlement of deciduous species is very limited and finally a new pine generation settles.

Both cherry and oak germinate and grow up under the pine canopy without any difficulty although they are normally considered as rather shade intolerant *(Runkle, 1985 ; Auclair & Cottam, 1971)*. However, *Crow (1988)* and *Stroempl (1987)* already mentioned the good growth conditions for red oak under pine canopies.

Black cherry was introduced on a limited scale in the Pijnven area in the early fifties. Today about 3000 hectares are colonised by this species. Similar massive invasions are mentioned by *Borrmann (1988)*, *Eysackers & Oldenkamp (1976)*, *Smith (1975)* and *Lust (1987)* for pine forests, and by *Auclair & Cottam (1971)* for North-American oak stands. This process causes enormous problems for forest management, since forest regeneration is in many cases impossible without clearcutting the pine stand and subsequently elimination of black cherry. The great vigour of this species (enormous sprouting capacity) has made this objective very hard and costly to attain. Overall, mechanical root excavation has proved to be the best method and is now most practised in Belgium. This method causes an intensive soil cultivation and creates good conditions for Scots pine natural regeneration. If this regeneration is unsuccesful or unsatisfactory, artificial regeneration (Scots pine, Corsican pine, Douglas fir, ...) can be used.

For all stands with red oak dominating the understorey, forest management is aiming at an indirect conversion towards a red oak dominated, uneven-aged, mixed forest. The remaining pines pose little threat to the understorey development, and will slowly be removed in the coming decades as they will slowly loose vigour.

Parts of the stands which are unsuccesfully regenerated can be planted up with different species, according to the gap size and orientation. In this way, reintroduction of autochthonous tree species (pedunculate and sessile oak, beech) in the forest area can be actualised *(Ebeling & Hanstein, 1988)*. Introduction of those species can already be started in rather well stocked pine stands. This technique can avoid the further expansion of black cherry as is illustrated in stand four.

Combination of all possibilities should result in a future forest generation consisting of a more diverse, species rich, uneven-aged forest providing a versatile number of goods and services for the human society.

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