SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

SPSD II

FEASIBILITY OF FOREST CONVERSION: ECOLOGICAL, SOCIAL AND ECONOMIC ASPECTS (FEFOCON)

K. VERHEYEN, N. LUST, M. CARNOL, L. HENS, J.J. BOUMA

MIXED ACTIONS

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(SPSD II)

Part 4:
Mixed actions

FINAL REPORT

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MA/04

Ecological teams
Frédéric Degrave, Sandrine Malchair (ULg),
An De Schrijver, Guy Geudens, Leen Gielis, Jeroen Staelens (UGent)
Promoters: Monique Carnol (ULg), Noël Lust, Kris Verheyen (UGent)

Social team (VUB)
Karolien Van De Steene, Ann Van Herzele, Lies Vandaele
Promoter: Luc Hens

Economic team (UGent)
Albert Schram, Tom Verbeke
Promoter: Jan Jaap Bouma

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Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person:
Mr Marc Van Heuckelom
Secretariat: +32 (0)2 238 37 61

FOREWORD

This work is the final report of the FEFOCON research project, which ran between December 2003 and February 2006, under the auspices of the Belgian Science Policy under the terms of the Second Multiannual Scientific Support Plan for a Sustainable Development Policy (SPSD II) – Mixed actions. Forest conversion of secondary conifer plantations is generally agreed upon by forest policy makers in Europe as an important component of sustainable forest management and the concept has broad support among experts in forestry and nature conservancy. Nevertheless, the effects of a tree species change on forest ecosystem functioning (nutrient cycling and biodiversity) should be considered with care before taking meaningful management decisions at large scale. Forests in Belgium provide multiple services to society, the value of each of which might be affected by forest conversion. Finally, the implementation of forest conversion in Belgium requires quite an effort from countless private forest owners.

We organized three fruitful meetings with our Users' Committee. We would like to thank the members:

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- Wim Demaeyer (Bosgroepen)
- Noah Janssen (Vereniging voor Bos in Vlaanderen)
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Authors' references

BOUMA Jan Jaap	CEEM, UGent
CARNOL Monique	Laboratory of Plant and Microbial Ecology, ULg
DEGRAVE Frédéric	Laboratory of Plant and Microbial Ecology, ULg
DE SCHRIJVER An	Laboratory of Forestry, UGent
GEUDENS Guy	Laboratory of Forestry, UGent
GIELIS Leen	Laboratory of Forestry, UGent
SCHRAM Albert	CEEM, UGent
STAELENS Jeroen	Laboratory of Forestry, UGent
VAN HERZELE Ann	Human Ecology Department, VUB
VAN DE STEENE Karolien	Human Ecology Department, VUB
VERBEKE Tom	CEEM, UGent
VERHEYEN Kris	Laboratory of Forestry, UGent

The FEFOCON research partners

Laboratorium voor Bosbouw (Laboratory of Forestry)
Faculteit Bio-ingenieurswetenschappen, Universiteit Gent (UGent)
Geraardsbergsesteenweg 267 9090 Gontrode
Tel. ++32 (0)9/264 90 27
www.fbw.ugent.be/LabBosbouw

Laboratoire d'Ecologie Végétale et Microbienne (Laboratory of Plant and Microbial Ecology)
Institut de Biologie végétale, Université de Liège (ULg)
Bât. B22, Boulevard du Rectorat 27 Sart Tilman 4000 Liège
Tel. ++32 (0)4/366 38 45
www.depscenv.ulg.ac.be/unites/liege_unit/ecovege.htm

Vakgroep Menselijke Ecology (Human Ecology Department)
Faculteit Geneeskunde en Farmacie, Vrije Universiteit Brussel (VUB)
Laarbeeklaan 103 1090 Brussel
Tel. ++32 (0)2/477 42 81
www.vub.ac.be/MEKO

Centrum Milieueconomie en Milieumanagement (CEEM),
Faculteit Economie en Bedrijfskunde, Universiteit Gent (UGent)
Hoveniersberg 24 9000 Gent
Tel. ++32 (0)9/264 34 78
www.feb.ugent.be/ceem

CONTENTS

1 GENERAL INTRODUCTION

Geudens Guy, Degrave Frédéric, Verheyen Kris & Carnol Monique

1.1 Definition

Forests of Scots pine and Norway spruce are distributed far beyond their assumed natural range in Europe. Currently Norway spruce has a share of 21% in the total European forest area (thirty countries), Scots pine one of 31% (Spiecker *et al* 2004). Also in Belgium large surfaces of homogenous conifer plantations are on sites naturally dominated by broadleaved species. In Flanders, this concerns about 33,500 ha of Scots pine (*Pinus sylvestris*) and 11,500 ha of Corsican pine (*Pinus nigra var. laricio*) stands on sandy soils (Afdeling Bos & Groen 2001a). In Wallonia, pure Norway spruce (*Picea abies*) stands occupy 172,400 ha (Le Comte *et al* 1999).

Forest conversion is the sylvicultural process of changing the tree species composition from one dominated by conifers to one dominated by native broadleaves.

The changes in forest tree species composition have an impact on the functioning of the forest ecosystem: wood production as well as biogeochemical cycling, biodiversity and resistance against disturbances. Almost all goods and services provided by forests are directly or indirectly affected, including the income of forest owners, the perception by forest users as well as significant environmental services (Spiecker *et al* 2004).

1.2 Feasibility of forest conversion: ecological, social and economic

Forest conversion could be a very strong policy tool with high potentials: (i) as an effect-oriented measure in stopping forest (soil) degradation driven by exogenous emissions, (ii) conservation and protection of biodiversity and (iii) as a technical intervention to raise the economic outcome of forest management. The FEFOCON research project addressed these points and results are given in Chapter 2 and Chapter 3 Ecological feasibility and Chapter 6 Economic feasibility. But, as will become clear from the following sections of this Chapter 1 General Introduction, most of the forests in Belgium and also the secondary conifer plantations are privately owned. At present, little information is available on the readiness to convert by private forest owners, nor on the optimal strategies for the government to encourage it. Both sociological and economical aspects of forest (conversion) management for small private forest owners in Flanders were investigated in the FEFOCON research project and results are given in Chapter 4 Sociological feasibility and Chapter 1 Economic feasibility. Forest policy recommendations concerning conversion result from this research are given in Chapter 6.

The following sections of this introductive chapter address the current situation of secondary conifer forests in Belgium, the ownership situation, the history, the sylvicultural context of management goals and scenarios of conversion and a brief overview of the forest policy aspects relevant to conversion in Flanders.

1.3 Forest situation in Belgium

Pine forest statistics in Flanders (Afdeling Bos & Groen 2001a)

Of the total Flemish forest area of 146,000 ha, homogeneous stands[1] of Scots pine cover 22.7% or 33,140 ha and 11,680 ha or 8% consists of homogeneous Corsican pine stands. The ecoregion of the Kempen, covering the Northeast of Flanders, contains 90% of these stands with 35% of its area being Scots pine stands and around 10% Corsican pine (Figure 1-1). The distribution of pine plantation in Flanders is obviously linked to poor sandy soils.

[1] A forest stand is homogeneous when one tree species occupies more than 80 % of the basal area (Bos & Groen 2001a).

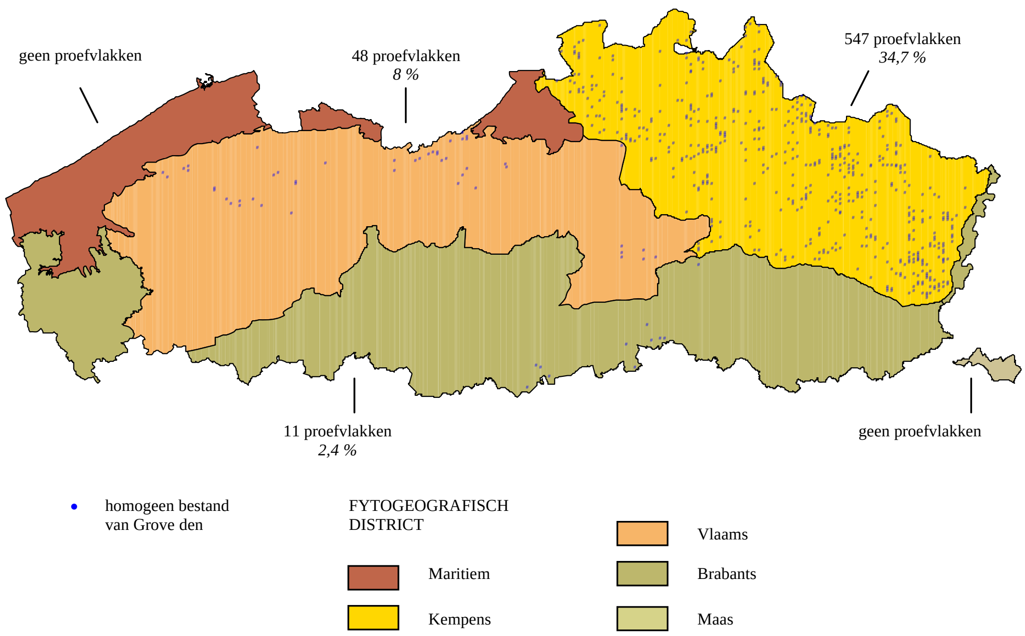


Figure 1-1: Distribution of grid points covered with homogeneous Scots pine stands. The Kempen ecoregion covers the northeast of Flanders (yellow).

The age distribution of Scots pine stands reveals their history: less than 5% of the homogeneous Scots pine stands is under 20 year old, 55 % is between 20 and 40 years old, 35% is older than 40 years and less than 5 % is multiple aged. 75 % of Corsican pine stands is under 40 years old. Public owners have on average a bit fewer older Corsican pine stands (15% as compared to 30% of the stands is over 40 years old). This may be due to continued planting of heathlands by municipalities and to strict clear cutting and replanting management schemes in public forests that continued to be practiced through the late 1970's, some time after the profitability of this practice fainted (see Section 1.5.1).

Of the homogeneous Scots pine stands, 2/3rd has an understorey and natural seedlings. The most common species in the understoreys and among the seedlings are rowan (*Sorbus aucuparia*), black cherry (*Prunus serotina*), birch (*Betula pendula* and *B. pubescens*), (alder) buckthorn (*Frangula alnus*), pedunculate oak (*Quercus robur*), red oak (*Quercus rubra*) and seedlings of both pine species themselves.

The main stand parameters of Scots and Corsican pine stands are shown for private and public forests in Table 1-1. From the higher stem number in private forests for a comparable age distribution (in general older forest stands tend to have less trees), the lower intensity (or the absence) of thinning measures is revealed. This also explains the higher amount of standing dead wood in private forests, because when no trees are removed in dense forest stands, suppressed trees die naturally.

Table 1-1: General stand parameters of homogeneous Scots pine and Corsican pine stands in Flanders.

		Scots pine		Corsican pine	
		Private	Public	Private	Public
Stem number	/ha	759	583	1272	1120
Basal area	m²/ha	29	24	41	34
Stem volume	m³/ha	231	197	329	258
Standing stock	1000m³	4402	2801	1748	1813
Standing dead wood	m³/ha	4.1	2.3	7.2	2.3

Norway spruce forest statistics in Wallonia (Le Comte et al 1999)

During the 1980's, the area covered by Norway spruce reached a maximum of nearly 200,000 ha, *i.e.* 37 % of forested area (545,000 ha) in Wallonia. Afterwards, concerns about the environmental impact of conifer monocultures have slowed down the extension of Norway spruce plantations. A potential degradation of soil fertility and a change in the hydrological balance were mentioned as negative consequences of conifer forestry. Other negative aspects of Norway spruce stands are their sensitivity to storm and pest outbreaks. Moreover, dense conifer monocultures are sometimes perceived as 'ecological deserts', inconsistent with a multifunctional forest management. These potential negative impats of Norway spruce plantations, the dieback symptoms observed since the 1980's and the storm events of 1990 in Belgium are responsible for the present reduction of Norway spruce stands in Wallonia. The decrease of young Norway spruce stands (less than 20 yrs old) is even more pronounced.

In 1999, homogeneous stands of Norway spruce ("pessières") occupied 172,400 ha (36% of the total forest area) in the Walloon Region. Within this area, 1600 ha of stand openings and 11,700 ha of clear cuts are included. Of the homogeneous Norway spruce stands 58% is owned by private owners. 90% of these stands are in the Ardenne ecoregion, where they occupy 52% of the forests (see Table 1-2). The standing volume increased by 11% as compared to 1984. The distribution of Norway spruce in Wallonia is obviously linked to altitude (Table 1-3).

Table 1-2: Distribution of homogeneous Norway spruce stands in the ecoregions of Wallonia

Ecoregion	Area			Standing volume
	(ha)	(%)	(% within ecoregion)	(m^3 x 1.000)
Sandy loam region	0	0.0	0.0	0
Löss region	700	0.4	2.5	128
Condroz	4,600	2.7	7.4	1,333
Famenne	5,400	3.1	10.2	955
Ardenne	155,400	90.1	52.0	42,470
Jurassic region	6,300	3.7	20.9	1,372
Total Wallonia	172,400	100	36.1	46,258

Table 1-3: Distribution of homogeneous Norway spruce stands in Wallonia over altitude layers

Altitude (m)	(%)
under 200	2.3
200-299	8.8
300-399	25.3
400-499	36.8
over 500	26.7

Only 8% of the homogeneous Norway spruce stands are over 70 years old. One third of the stands are younger than 30 years. The age distribution of stands shows two waves of plantation in private forests: the first after World War II and especially in the 1960's, and the second in the 1990's on wind throw sites (Figure 1-2). The age distribution of homogeneous Norway spruce stands in public forests is more even, although stands over 70 years are rare, with the exception of some thousand hectares of spruce stands over 100 years.

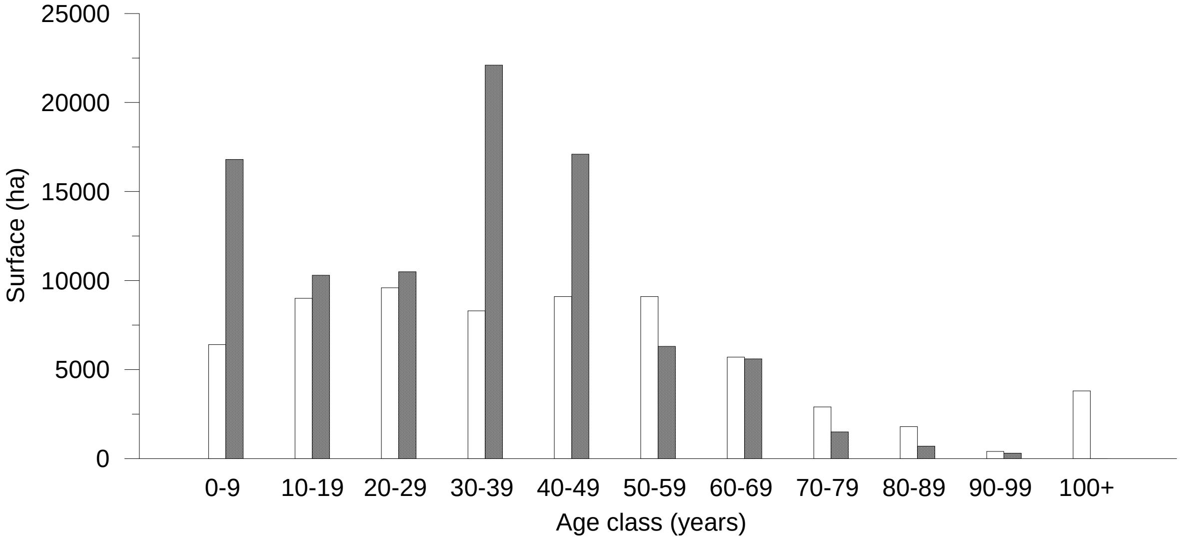


Figure 1-2: Age distribution of homogeneous Norway spruce stands in Wallonia for private (grey) and public (white bars) owners.

Stand management differs between private and public spruce forests. Especially after age 40, the stem number is clearly higher in private forests and the mean diameter is lower (Figure 1-3). Stand rotation (age of clear cut) is on average 56 years in private forests and 72 years in public forests. Clear cuts are on average larger in private than in public forests: 4.2 ha as compared to 3 ha.

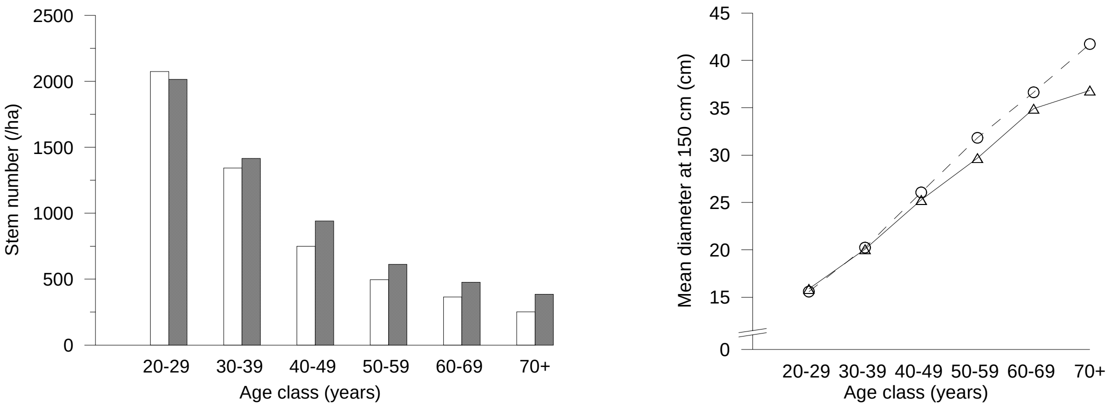


Figure 1-3: Evolution of stem number per ha and mean diameter (at 150 cm) in private (grey bars, triangles) and public (white bars, circles) homogeneous Norway spruce stands

43% of the homogeneous Norway spruce stands over 50 years have natural regeneration (under the canopy of the mature stand). This natural regeneration covers over 2/3[rd] of the stand in 30% of these stands and under 1/3[rd] of the stand in 50% of these stands.
Planting is only performed in clear cuts of Norway spruce (16,000 ha). 59% of this surface was replanted with Norway spruce, 19% with broadleaved species and 15% with mixed conifers (larch, Douglas). In private forests replanting with Norway spruce is slightly more common than in public forests.

Douglas (*Pseudotsuga menziesii*), larch (*Larix sp.*) and pine are the other main coniferous species in Wallonia. They constitute about 7.2% of all stands. Since 1984 mixed conifer stands show an increase with an actual area of 20,000 ha. This progression mainly reflects the success of Norway spruce stands in mixture with Douglas fir (Colson *et al* 2002b).

1.4 Forest owner situation in Belgium

Approximately 70% of the Flemish forest area is privately owned (100,000 ha). The number of private Flemish forest owners is roughly estimated at around 100,000, the mean property area being 1 ha. Of the homogeneous Scots pine stands 57% is owned by private persons, 20% by municipalities, 17% by the Flemish or federal government and 5% by other public owners. The ownership of the homogeneous Corsican pine stands is 43% privately owned, 30% municipal forest, 20% regional or federal forest and 7% other public forest.

Of the Walloon forest 290,000 ha (53%) is privately owned. Based on a national statistical survey of 1970, the number of private owners is estimated at 100,000. This is comparable to Flanders but the mean property would be about 2.5 ha.

1.5 History of secondary conifer plantations in Belgium

The primary European temperate forests have undergone many changes since the development of human activities. Dynamic, structure and composition of forest ecosystems are concerned with these modifications. In Belgium, the forested area has increased since 1850, in parallel to the decrease of open landscapes resulting from traditional agricultural practices (Noirfalise & Vanesse 1975). Robust and easily growing tree species were used to restore forest cover on these poor soils under rigorous climatic conditions (Weissen 1995). The main characteristic of this plantation campaign was to use coniferous species planted on large area. Initially, these conifers were imported from other regions of Europe (Norway spruce, Scots pine, Corsican pine) and from North America afterwards (Sitka spruce *Picea sitchensis*, Douglas) (Augusto *et al* 2002). The forest area in Belgium increased from 485,000 ha in 1846 to 625,000 in 1959. While in 1846 only 35,000 ha was coniferous forest, in 1959 conifers covered 262,852 ha (Van Miegroet 1970).

1.5.1 Scots and Corsican pine plantations in Flanders

Sandy soils cover the Vlaamse Zandstreek and the Kempen in Flanders and the Netherlands. Between 1250 and 1850 the prevailing farming system on sandy soils was more or less intensive plaggen management (Bastiaens & Verbruggen 1996, Spek *et al* 2004). The vegetation and organic topsoil were periodically removed from large areas of heathlands and degraded woodlands. This biomass was mixed with animal manure and applied to fields. Additionally large sheep herds were grazing the heathlands. This resulted in strong podsolisation and loss of soil fertility on the heathlands. The according landscape image can be seen in the ordnance survey maps of count de Ferraris from around 1775. From the 17th century on, small Scots pine stands were planted on both heathlands and marginal fields. In the second half of the 19th century, industrial development paralleled agricultural crises. Plaggen management declined and Scots pine plantation on heathland as well as on marginal fields was a profitable alternative. Pitwood was in high demand by the coal mining industry. Vast areas were reclaimed. From 1850 on, the forest area increased steadily to a maximum around 1900. This is conforming to the description of forest history in the Netherlands (van Tol *et al* 1998) and the study of historical maps of Flanders by De Keersmaeker *et al* (2001). These authors stress that only 9,000 out of 80,000 ha of the forests on poor sandy soils have been permanently forested between 1775 and 2000.

The main management system in the pine plantations was clear cut and reforestation with Scots pine or (from the 1930's) Corsican pine in a typical rotation period of about 40-50 years. At the time of clear cut, litter was removed and even stumps were thorn out. Soil was mostly ploughed before reforestation. From the 1970's the mining industry declined and timber prices stagnated. Many (private and public) owners lost sylvicultural interest in the pine stands. In public pine forests thinning operations proceeded, but clear cuts and expensive stand renewal were generally avoided. Only 3% of Scots pine stands was younger than 21 years in 1999 (Afdeling Bos & Groen 2001a). Stand age increased and many stands grew out of the pole and young tree stages into the tree stage. In the ageing pine stands forest succession proceeds and structural diversity increases (Kint 2000).

1.5.2 Norway spruce plantations in Wallonia

Similar to the evolution described above, many of the Norway spruce stands in the Ardenne in Wallonia were planted after 1850 through afforestation of mires, bogs, heathland and poor grasslands ("fagnes, bruyères, landes"). As in flanders, at first Scots pine was planted, but Norway spruce, showing high potential on poor soils and good wood qualities, rapidly extended all over the Ardenne even at lower altitudes. In the 20th century many ancient coppice with standards broadleaved forests and marginal grasslands and fields were transformed to Norway spruce plantations (Noirfalise 1985).

1.6 Conversion needs

A great majority of forest managers agrees that a sylvicultural system based on even aged, 50-70-year-rotation pine monocultures is no longer appropriate in Flanders. Some exceptional views confirm this general rule (Dufrane 2005a & b) (but see Section 5.4). Article 18 of the Flemish Forest Law (Bosdecreet 1990) states: "The care of the conservation, development or restoration of the ecological function of the forests consists among other things of:

1. encouraging autochthonous tree and shrub species;
2. stimulating spontaneous processes;
3. promoting a varied forest structure by striving for an uneven age distribution, for dissimilarity and for sufficient amounts of dead trees and dead wood."

In Flanders, all homogeneous Scots and Corsican pine stands are prone to conversion (Afdeling Bos & Groen 2001b; Criteria Sustainable Forest Management). The alternative forest type to aim for is however still quite vaguely defined as "a mixed forest dominated by native broadleaved species, vertically structured in several stories, horizontally structured in small- and medium-scale patches, with a broad spectrum of ages" (Afdeling Bos & Groen 2001b: public forests) and "a stand with 90% of mixed indigenous tree species" (Criteria Sustainable Forest Management: all forests within VEN). Nevertheless, Scots pine stands over 70 years of age that have an understorey of indigenous broadleaved tree species can be granted with a subsidy for ecological function (see section 1.6). Scots pine is considered to be a native species in itself, but homogeneous Scots pine stands are undesirable.

Contrasting to the policy principle in Flanders, where all stands of non-native conifers are candidates for conversion to broadleaved forest, in Wallonia there is a shared judgment. On sites where a sustained timber production can be expected, even pure coniferous stands are considered to be on their rightful place, if the manager respects some ecological considerations (e.g. distance to streams or wet sites) (Claessens 2001 for Norway spruce, Pauwels & Rondeux 2000 for larch, Colson *et al* 2002a for a mixture Norway spruce - Douglas). Even in protected areas like forests in the Natura 2000 Network, conversion into native broadleaved stands is not an absolute dogma (Mohimont 2004). For the Ardenne region, the suitability of sites currently under pure Norway spruce stands was investigated using GIS (Geographical Information System) (Claessens *et al* 2001). Infomation was combined to determine the suitability of sites for certain forest types and according tree species (Claessens *et al* 2002). From the regional forest inventories of 1980 and 1999 (partial) (Lecomte *et al* 1999) plots were under pure Norway spruce stands were identified. Based on criteria of climate and soil and criteria of patrimonial value (biodiversity, landscape, history), distinction was made between (1) sites unsuitable for spruce and (2) sites rather unsuitable for spruce.

Of the pure Norway spruce stands in the Ardenne region, 27% was incompatible with the site, 21% was rather incompatible. Table 1-4 and Table 1-5 give a description of the sites with incompatible Norway spruce forest.

Table 1-4: Description of the unsuitable sites for Norway spruce in the Ardenne region

Sites unsuitable for Norway spruce	Area (ha)	%
xerocline sites at low altitude (<350 m)	8,090	16
alluvial sites	9,024	18
pseudogley soils on clay substrate ("Argile blanches")	17,922	36
other: ground water influenced sites, podsols, peat soils, stony calcareous soils, superficial soils, altitude<150 m, ...	15,060	30
total Ardenne	50,096	100

The 17,000 ha of pure Norway spruce forest outside the Ardenne region (10% see Table 1-4) can all be considered to be incompatible with the site (<150 m altitude).

Table 1-5: Description of the rather unsuitable sites for Norway spruce in the Ardenne region

Sites rather unsuitable for Norway spruce	Area (ha)	%
sites at low altitude (150-350 m)	24,150	62
hydromorphous sites	6,050	16
superficial soils	4,100	10
xerocline sites	2,700	7
Jurassic region	1,050	3
other	750	2
total Ardenne	38,800	100

In the German state of Baden-Württemberg, where forest conversion has already been adopted in management for 20 years, it has been observed that the effect of storms on the share of broadleaves was very positive. Storm events like those of 1990 seem to hasten the adoption of conversion management (Baumgarten *et al* 2005). However, Claessens *et al* (2001) observed that young plantations of Norway spruce (after 1980) are still being planted on unsuitable sites, e.g. at open areas where Norway spruce was blown down in 1990 (see Figure 1-2). However, that the share of spruce is decreasing at lower altitudes of the Ardenne region, and that in general the Norway spruce forest area decreased since 1980 (Lecomte *et al* 1999).

In Belgium the conversion of pure pine and (rather) unsuitable Norway spruce stands comprises 144,000 ha. In Baden-Württemberg for example, one of the most forested federal states in Germany, 112,600 ha of (mixed) Norway spruce forests need conversion management (Baumgarten *et al* 2005).

1.7 Forest conversion management: goals and scenarios

There are two steps in the management decision process: (i) definition of goals and priorities, (2) choice of the management scenarios to evolve the current situation towards the goal.

1.7.1 Definition of goals and priorities

The conversion needs of pine and Norway spruce plantations in Belgium were clarified in the Section 1.6. The types of conifer stands over which forest policy agrees on conversion have been defined and quantified. The goals are however not defined in terms of (i) shares of specific indigenous tree species in the future stands (e.g. beech versus oak in Wallonia, birch versus oak in Flanders), (ii) desired age class distribution, (iii) the future timber quality and quantity in view, (iv) a priority map with a conversion urgency score for each conifer forest/stand, or (v) milestones (e.g. % of conifer plantations to be converted by a certain year).

Which conifer stands should be converted within what time period following environmental sustainability, biodiversity and socio-economic criteria? To be sustainable and effective the goals should be quantitatively defined giving priority rules and minimal, optimal and maximal figures within a specified time and spatial frame (space: regional, forest complex and stand level, time: short term= one planning execution period of 20 years, mid term: 2 planning periods = 40 years, long term: 4 planning periods = 80 years). Priority should be given to sites with a high risk for conifer stands and a high suitability to broadleaf tree species (Kazda & Englisch 2005). Good examples are Norway spruce stands on hydromorphous, peaty soils in the Ardennes (Section 1.6). They are highly unstable and these sites are very suitable to black alder or downy birch (Claessens *et al* 2001). Another example are pine stands on loamy sandy soils that are not yet completely acidified (pH > 4) and where good potentials for plant diversity exist, e.g. at or near ancient forest sites (Section 3.1.2).

What is the forest type (stand structure, tree species composition at different scales) we aim at? Mostly reference is made to (ancient) broadleaved stands that indeed display many of the positive ecological and sylvicultural characteristics (biodiversity: e.g. highly specialised forest organisms, biogeochemistry: less acidified forest soil, quality timber: large dimensions of noble species) associated with the aims of conversion (Kint 2005). However, such stands are quite rare on the typical sites of undesired coniferous stands (see Section 1.5) and moreover their stand structure and tree species composition results from a management history (e.g. coppice with standards) completely irrelevant to the starting situation of a homogeneous conifer stand. A possible workaround is modelling the expected evolutions based on ecological characteristics of the tree species at hand (Kint *et al* 2004) and validating them with the few conversion examples that evolved accidentally or as an experiment a long time ago (e.g. the Mortzfeldt group cuttings: Bilke 2004, or the forest reserve Mattenburg: Kint 2003). Nevertheless care should be taken when extrapolating these very specific examples to the large areas of secondary pine and Norway spruce forests in Belgium.

1.7.2 Choice of management scenarios: from the current situation towards the goal

To be sustainable and effective at low cost a scenario should be a motivated, well planned management regime that conducts the natural processes (based on forest succession and disturbance regimes). At set time intervals the stand and forest characteristics should be assessed and evaluated to be able to adjust the conversion management.

Forest conversion scenarios in pine forests in Flanders

For the sandy soils in Flanders, the long-term goal is a mixed stand dominated by native broadleaved species (90% or with a share of old Scots pines in the overstorey), vertically structured in several stories, horizontally structured in small- and medium-scale patches, with a broad spectrum of ages. The natural forest types on these soils are birch-oak forests and on the long term (undisturbed succession) poor and typical oak-beech forests. At the forest complex level, 80% of public forests should be composed of such stands in the long term. Of private forests in ecologically sensitive areas, 20% should be composed of such stands within the next 20 years (see Section 1.6).

In general, two conversion scenarios for homogeneous pine stands seem plausible: **continuous stand cover (thinning)** and **group cutting**. Of course, in practice a combination of both is possible, where the remaining forest stand in between the groups is being thinned. These reasonable scenarios can be contrasted to two extreme scenarios: **no intervention** and complete **clear cut**. Sylvicultural considerations (practical and ecological) about these four conversion management scenarios are given in the Appendix Forest Conversion Scenarios.

In Germany, a justified timing between onset of the broadleaved regeneration (natural or seeding/planting) and final cut of the main part of the current conifer stand is 20-60 years, unless in the case of clear cut. Concerning the expected speed of conversion (= percentage converted of the original area of secondary conifer plantations after a certain time period), Figure 1-4 gives a general scheme of reasoning.

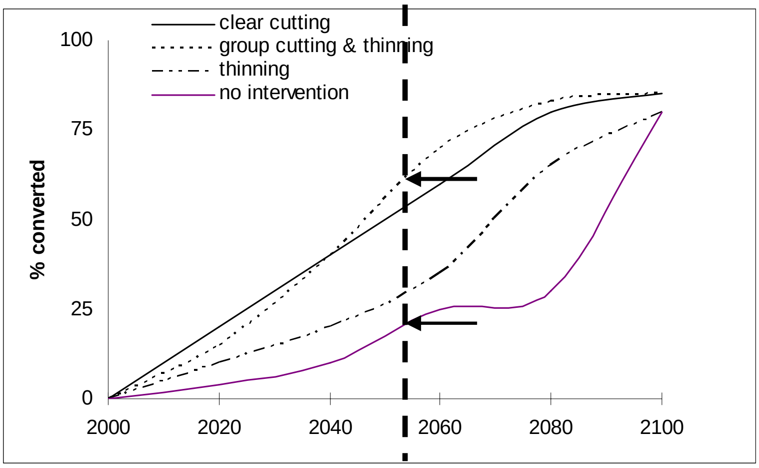


Figure 1-4: Expected conversion rate under four different conversion management scenarios over the 21st century

- All scenarios consider about 20% of the pine stands that will be managed (and regenerated) as conifer stands and will not be converted into broadleaved forest, e.g. outside ecologically sensitive areas at sites with a poor potential for broadleaved tree species, or in areas where pine forests are considered as relevant to the traditional landscape image.
- Any sensible clear cut scenario will strive for a balanced age distribution of the future stands and cut a more or less constant area each year. Because a rotation period of 120-140 years is actually considered reasonable for Scots pine stands from a sylvicultural point of view (but see Section 5.4 on TORP) and the average pine stand age is actually between 40 and 60 years (see Section 1.3), the clear cut program would have converted 80 % within about 80 years.
- A scenario based on continuous thinning within the aging pine stands will keep the pine canopy for a long period and % converted will be realised as an increased share of broadleaves within all the pine stands. After about 50 to 60 years, the broadleaved understorey will grow through the pine canopy and start outcompeting the remaining pines. From that stage the percentage converted will increase at a faster rate.
- When adding group cuts in an otherwise normally thinned pine forest, the percentage converted will initially increase strongly while in the long term the conversion speed will decrease. This is because the group cuttings are spread over time to create a balanced age distribution in the future forest and the remainder of the pine stand in between the groups is taken away with a certain delay after the creation of the groups.
- No intervention leaves the pine stands to natural thinning processes (pines dying of competition with other pines). Even in such stands broadleaved species colonise the understorey and will eventually grow into the canopy. The onset of broadleaves reaching the canopy is delayed, but these pine stands are probably more prone to large scale natural disturbances (storm events, insect attacks). This can induce "jumps" in the percentage converted.

The main difference between the different scenarios is (i) the percentage converted in the mid-term (2050) (Figure 1-4) and (ii) the species composition of the broadleaved generation. Given a starting point of closed Scots or Corsican pine plantations on poor sandy soils in western Europe, the conventional wisdom is that the balance between *Betula*, *Quercus* and *Fagus* in succession will depend on how fast the canopy opens and what seed sources are available, and furthermore that stand development may be short-circuited or deflected by unpredictable disturbances (Kint *et al* 2004). Fast and large scale removal of the pine canopy promotes birch (and pine), while long conversion periods promote beech. Oak takes an intermediary position.

Bilke (2004) investigated pedunculate oak groups that were installed following the ideas of forest manager Mortzfeldt in the late 19th century in North-eastern Germany, among others in pure pine forests. The intended complete pine stand renewal through extension of the oak groups and gradual removal of the remaining pine stands, had however not taken place. He noticed a strong contradiction. On the one hand there was a general contempt of the quality of the oak trees in the rather small groups and of the manageability of the stand mosaic. On the other hand the forestry guidelines in this region encourage conversion into a small-scale mixed forest (as is the case in Flanders) and what's more, many foresters recognise the oak groups as a stabilising factor in the surrounding pure pine forests. Research has been done on the ecological impacts of introducing broadleaves in pure conifer stands (see Chapter 2 and Chapter 3), but much fewer research has been performed and few experience is available concerning the sylvicultural consequences of different conversion management scenarios (future timber quality, feasibility of practical stand management) (e.g. Peters & Bilke 2004). Such information is especially lacking in pine forests on sandy soils, e.g. in Flanders, the Netherlands and Northern Germany (Bilke 2004).

Forest conversion scenarios in Norway spruce forests in Wallonia

Depending on the expected stability of the Norway spruce stand, Baar (2005) proposes two major scenarios for conversion of Norway spruce stands.

1. Advance planting of beech in small cells of 25-50 plants under canopy gaps in the Norway spruce stand, with a maximum of 30-40 cells per ha. Each of the cells will produce one crop tree in the final stand. Normal thinnings and harvest in the Norway spruce stand continue.
2. Small clear cuts or bandwise cuttings. After 5-15 years of spontaneous development in these clear cuts regeneration of Norway spruce, birch, rowan, black alder and other species is expected. Within this young mixed stand beech or oak is planted in small cells, while good elements in the spontaneous stand can be promoted to become future crop trees.

In France, the conversion scenarios for homogeneous Norway spruce stands also include (i) clear cut and replanting or natural regeneration, (ii) advance planting and promotion of broadleaved species admixture in Norway spruce stand and gradual removal of the spruces (Di Placido 2002, Di Placido *et al* 2002).

Baar (2005) and Neruda (2000) draw much attention to any spontaneous regeneration, of secondary broadleaved species and of Norway spruce, which develops during the conversion process.

1.8 Current forest policy towards private owners in Flanders

Because of the expected complexity of the forest owner situation, we restricted the sociological and economic research to Flanders. Meanwhile, attention was paid to research in the Walloon situation (Feremans 2004, Colson *et al* 2002b). In this section, the important policy currently available for Flemish forest owners is addressed. The lack of systematic data on the ownership of private forests in Flanders (and Wallonia) makes the targeting of forest policy a tricky affair. In pine forests on sandy soils, a large part of the private forest owners doesn't perform any effective forest management. Natural processes induce a spontaneous development towards a more mixed forest with an increasing share of broadleaves, be it with a considerable share of the exotic species black cherry and red oak. In this respect, forest conversion is the effort to speed up and direct this transformation process towards well-structured native broadleaved forests.

In Flanders, a myriad of government institutions exist that execute, and formulate forest policy. There are also different organs which advice the government on forest policy. In addition, there are several influential non-governmental organisations, which criticise government policy or carry out their own specific programs. Inevitably in such a context, coherence and continuity in forest policy can be improved. For example, the need for forest conversion was stressed in the Beheervisie voor Openbare Bossen and in the Criteria Sustainable Forest Management. But a recent advice by the Hoge Bosraad does not even mention the subject (Bossenverklaring, Van Langenhove & Spaas 2003).

Afdeling Bos & Groen (Forest & Green Areas Division) of the Ministry of the Flemish Community (www.bosengroen.be) administers all public forests, but it is also responsible for stimulating suitable management of private forests. Official foresters have to combine inspectorate of private forests with the practical management of public forests. The Cel Bosbeleid (Forest Policy Cell within Afdeling Bos & Groen) coordinates, prepares and supports the forest policy initiatives in Flanders. The MiNa Raad (Environment and Nature Council) provides advice to the Flemish government and since 1999 also to the parliament (www.minaraad.be). It has been given wide powers, and it pronounces itself on diverging themes like, sustainable development, urban planning, energy, infrastructure, use of natural resources, etc. The Vlaamse Hoge Bosraad (High Forest Council) exists since 1991. It can provide unsolicited advice. It consists of 29 members, of which at least half are (larger) forest owners. The others are stakeholders' representatives. This council provides policy advice on long-term execution plans, propositions for new laws. The Vlaamse Hoge Raad voor Natuurbehoud (High Nature Conservation Council) is composed of independent experts, who provide advice on forest policy questions only when requested.

The current Flemish forest policy is mainly based on three pillars: forest area conservation, forest area enlargement, multifunctional forest management. Forest conversion in private forests falls under the latter. Instruments for private forest owners are legislative, informative and financial (Vedung 1998). An important recent instrument towards private owners is the forest group ("bosgroep"). It's a voluntary cooperation between different forest owners in a working area from 4,000 to 15,000 ha forest. The management freedom of the owner is a central issue. Forest groups take a neutral position between government, owners and forest users. It receives a yearly fixed subsidy, for the salary of one coordinator and a secretary and an additional subsidy per ha under management. Furthermore, a project based subsidy can be paid out for specific improvement projects, there is also money for training activities and in cooperation with regional and provincial governments there are teams of workers to do urgent, but unprofitable forest management activities.

There exists a rather complicated set of subsidies for private and public owners, parts of which are conditional on an extensive forest management plan. Meanwhile, there are four types of subsidies for all private forest owners:

a) *a one-time planting or replanting subsidy*. Plantations of more than 0.5 ha are subsidised depending on the tree species. It varies between €1,500 and €3,200 per ha.
b) *a yearly public access subsidy as a compensation for management costs*. This subsidy of maximum €50 per ha has been given to only a few owners, who seem hesitant to officially throw their estates open to the public.
c) *a yearly subsidy for ecological function*. This is granted if specific preconditions of habitat quality and natural species composition are met in a forest management plan. It varies between €50 and €125 per ha.
d) *a subsidy for the draw-up of an extensive forest management plan*. Once every 20 years a public or private owner can apply for a €200 basis subsidy when the management plan is approved. To stimulate cooperation, the amount is raised with €20 to €50 per ha subsidy if five or more owners cooperate.

Although this concerns public information, the records of how much has been paid out for these subsidies have not been converted to usable information for outside analysis. Because of this complicated subsidy structure, it is hard to estimate how much a forest owners receives on average when she/he decides to move towards more sustainable management and for instance starts converting a pine forest stand. Expert opinion estimates about €150 per ha will be received yearly when entering on a conversion path (see Section 5.4).

The forest legislation of Flanders is based on the Forest Decree ("Bosdecreet") of 1990 which has been reviewed in 1999.This base text has been completed by decrees of the Flemish government. Some important issues with regard to conversion are the selection of VEN (Vlaams Ecologisch Netwerk, Flemish ecological network)-areas by the Flemish government in July 2002, areas were a special forest management plan has to been written for. The Decree of the Flemish government of 27 June 2003 regulates the procedure for submitting and approving extensive forest management plans. For public forest an extensive forest management plan is always necessary, for private forests it's only necessary for forests more than 5 ha. Inside the VEN, this must be an extensive forest management plan. Also important is the Decree of 9 May 2003 about the exemption of inheritance tax to avoid the parcellation of forest estates.

According to the "Beheervisie voor Openbare Bossen", the main management policy document for public forest (Afdeling Bos & Groen 2001b), 30% of the basal area in homogeneous stands of Corsican pine should be indigenous broadleaved trees and at least 80% of the area of a public forest should be covered with stands of indigenous tree species. Furthermore, there is a strict stand-still principle in both private and public forests: stands of indigenous trees species mustn't be replaced by non-native species. The Criteria

Sustainable Forest Management are the legal standard in private forests within the VEN. They demand that 20% of the forest area should be indigenous forest within 20 years, the common implementation period of management plans.

2 ECOLOGICAL FEASIBILITY OF FOREST CONVERSION: Can conversion of secondary coniferous into deciduous forest enhance environmental sustainability?

2.1 A meta-analysis of forest type effects on element deposition and leaching

De Schrijver An, Geudens Guy, Staelens Jeroen & Verheyen Kris

2.1.1 Introduction

Currently, Norway spruce and Scots pine forests are distributed far beyond their assumed natural ranges in Europe. Conversion of secondary spruce or pine forests on sites naturally more suited to broadleaves is generally agreed on in Europe (Spiecker *et al* 2004). Such conversion mainly comprehends an increase in the share of broadleaves. This can range from the complete replacement of a coniferous stand by a new deciduous stand to the gradual establishment of an admixture of broadleaves in a conifer dominated stand in the long term (Gartner & Reif 2004).

The rationale for forest conversion is mainly sylvicultural. Pure spruce stands are generally considered to be highly unstable and prospects are that this will persevere in the light of climate change, especially/particularly outside the natural distribution range of Norway spruce. A decrease in profitability as compared to a pure Norway spruce forest is expected in a mixed forest, e.g. of Norway spruce and beech, but for risk-averse investors this will be reimbursed by the risk abatement (Knoke *et al* 2005). Nature conservation and protection of soil and water are further important arguments for conversion, because environmental consequences of this forest conversion are expected to be positive (Gartner & Reif 2004, De Schrijver *et al* 2004, Von Wilpert *et al* 2000). Conifers have the bad reputation of speeding up forest soil acidification (lower soil pH and lower base saturation) compared to deciduous trees because coniferous litter is more resistant to biological degradation (see Section 2.4) and more organic acids leach from it (Ranger & Nys 1994, Howard & Howard 1990, Johansson 1995). Soil biological activity and therefore nutrient turnover is reported to be lower under conifers (Binkley 1996, Saetre 1998). Furthermore, coniferous canopies more efficiently scavenge atmospheric pollution, enhancing acid deposition through higher dry deposition of SO_4^{2-}, NH_4^+ and NO_3^- (De Schrijver *et al* 2004). Also the uptake and retention of N is reported to be higher in deciduous forest (Cole & Rapp 1981). An overall N retention of 96% in a deciduous plot and 85% in a coniferous plot was found after a nine-year period of chronic N addition (Magill *et al* 2000). From the combination of higher input and lower retention of N in a coniferous forest ecosystem, higher percolation of NO_3^- to the groundwater and associated base cation losses are expected (Schulze 2000).

Contrary to this are the results of recent forest type effect studies on European and national level (Kristensen *et al* 2004, Borken & Matzner 2004). Higher NO_3^- percolation from deciduous forests was found when comparing nutrient cycling in the Level II monitoring plots of the ICP network. The cause of this phenomenon is most likely that deciduous forests, that naturally dominate a broad range of sites, were replaced at large scale during the last centuries by conifers on the poorer sites across Europe, often carrying degraded forests, heath lands or marginal farmlands (Johann *et al* 2004). The sampling scheme of the Level II sites, intended to represent the European forest situation, reflects this distribution (Fischer *et al* 2003). In Denmark, higher NO_3^- concentrations were indeed found under forests on fine textured soils as compared to coarse textured soils, irrespective of tree species (Callesen *et al* 1999).

These contrary results lead us to the question which environmental effect can be expected from converting coniferous forest to deciduous forest. The only correct approach to answer this question is by comparing deciduous and coniferous forest stands under comparable local site conditions. Climate (Erisman & Draaijers 2003), soil type (Silva *et al* 2005, Boumans *et al* 2004), land use history (Matson *et al* 2002), pollutant emission level (Matson *et al* 2002), succession phase (Aber *et al* 1989, Agren & Bosatta 1988, Cairns & Lajtha 2005) and experimental set-up (Bleeker *et al* 2003) are all known to have a significant impact on the element fluxes observed. The aim of this paper is to analyse existing research results of element stand (throughfall + stemflow) deposition flux and percolation flux to groundwater in coniferous and deciduous forests that meet the prerequisite of comparability of forest stands.

2.1.2 Methodology

Data collection

A literature survey was performed starting on the Web of Science (ISI Web of Knowledge v3.0) to obtain published studies comparing values of stand deposition and percolation fluxes of elements in pairs of forest stands solely differing in tree species composition. Afterwards the cited references of these studies were searched for other peer-reviewed publications. The forest stands in each pair had to be identical concerning mesoclimate, soil type, land use history, pollutant emission level and forest age as well as experimental set-up.

We considered 19 comparative studies analysing 25 pairs of forest stands for element stand deposition flux and 8 stand pairs for element percolation flux (List available from the authors). In these pairs, specific element fluxes were determined (i) in throughfall, sometimes (ii) in stemflow, and (iii) in wet-only or bulk precipitation in an adjacent open space. Element percolation in the soil profile was measured by different types of lysimeters at a depth assumed to be underneath the main rooting zone. In the studies considered, the sampling depth ranged between 45 and 175 cm (List available from the authors). The collected data summaries (mean annual fluxes) were recalculated in the SI-unit mol ha^{-1} y^{-1} and entered in a database.

Data analysis

To compare the results of the different studies, we performed a meta-analysis as described in Gurevitch & Hedges (2001). Because the site conditions between the stand pairs differed considerably, the parameter used from each pair was the ratio between the element flux in the coniferous forest stand and the element flux in the deciduous forest stand. We calculated these ratios both for stand deposition and for percolation fluxes.

We considered this forest type effect as random over all the stand pairs. Random variation within one stand has two possible sources: (i) space, the number and the choice of the location of collectors (e.g. Van Ek & Draaijers 1994) and (ii) time, variation between a number of measuring years (e.g. Houle *et al* 1999). Between stand pairs, the sampling effort, i.e. number of collectors and number of years of observation, can influence the observed mean. Moreover, nutrient fluxes vary considerably between years with varying meteorological conditions (Erisman & Draaijers 2003). Analytical accuracy of neither chemical analyses nor errors in water flux calculations were considered, because rarely any study provides information on these.

The lack of reporting on sample standard deviation in most studies negates the use of the response ratio metric (R_x) over the d-index for a meta-analysis (Hedges *et al* 1999). We calculated a weighted mean ratio for each element (using data from those studies that provide data on the specific element) when at least four stand pairs were available for the meta-analysis. The flux ratio of each stand pair was log-transformed and a weighted mean over all pairs was calculated using the number of sampling years as weight, since it was the only source of variation consistently reported in all studies (List available from the authors). After back-transformation, a 95% bootstrap confidence interval of this weighted mean was calculated (Gurevitch & Hedges 2001). This approach is less powerful and less accurate than the standard meta-analysis statistical procedures (Gurevitch & Hedges 2001). Calculating the weighted means without logarithmic transformation resulted in comparable results, but with broader confidence intervals (not reported).

The level of atmospheric pollution differed very much between the studies. Especially forest plots in heavily urbanised regions, near industrial plants or near intensive animal breeding farms received much more N deposition than sites in remote, semi-natural areas. To forest ecosystems, an open field deposition level of 10 kg ha^{-1} y^{-1} of total inorganic N (NH_4^+-N + NO_3^--N) seems to be a threshold above which N cycling changes (Kristensen *et al* 2004). In the studies considered, the atmospheric N pollution level remained fairly constant during the measuring period. Exceptions to this are the long-term studies at the Solling site (Matzner & Meiwes 1994) and the Šerlich site (Lochman *et al* 2004, Lochman & Mares 1995), although the open field deposition flux remained above 10 kg N ha^{-1} y^{-1}.

2.1.3 Results

Pairs of mean throughfall deposition fluxes of the following elements were reported in the studies considered: NH_4^+, NO_3^-, total inorganic N, H^+, SO_4^{2-}, Na^+, K^+, Ca^{2+}, and Mg^{2+}. Too few data pairs were available for Al(III) and HCO_3^- to draw meaningful conclusions. Mean percolation fluxes were reported for the NH_4^+, NO_3^-, inorganic N, SO_4^{2-}, K^+, Ca^{2+}, Mg^{2+} and Al(III), while H^+ and Na^+ fluxes were not reported frequently enough to be considered for meta-analysis.

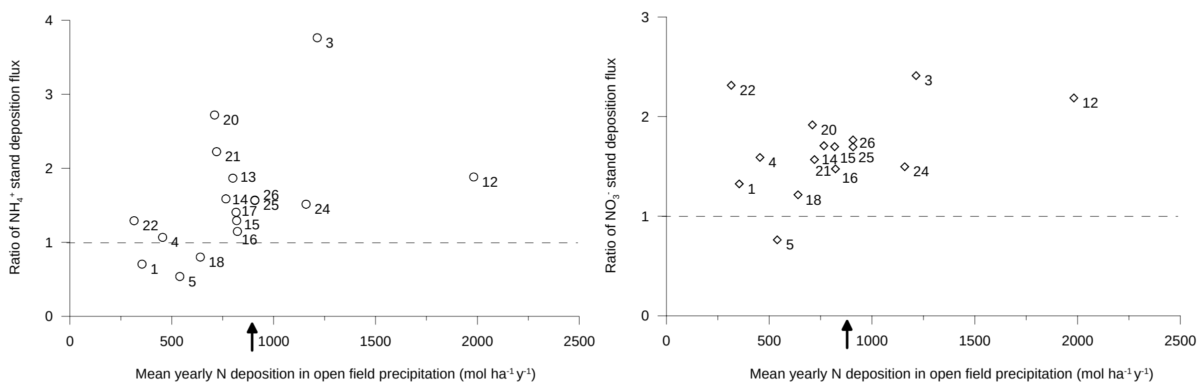
Stand deposition

For the global dataset used for meta-analysis, the ratio of stand deposition under coniferous and deciduous canopies was significantly higher than 1 for all ions other than K^+, for which the 95% bootstrap confidence interval of the mean included 1 (Table 2-1). Considering all available data, the ratio of stand deposition flux under coniferous and deciduous canopy is significantly higher than 1 for both NH_4^+ and NO_3^- and also for their sum (Table 2-1). The mean ratio is higher for NO_3^- (1.50) than for NH_4^+ (1.35), but not significantly. Distinguishing into stand pairs with a low (<10 kg N ha^{-1} y^{-1}) and a high inorganic N deposition in the open field (>10 kg N ha^{-1} y^{-1}) reveals that in the low deposition plots mean stand deposition of NH_4^+ and NO_3^- are not significantly different between the two forest types. However, there exists a clear tendency to a lower NH_4^+ stand deposition in the coniferous stands (mean ratio = 0.83) (Figure 2-1a). On the contrary, for the stand pairs with high open field N deposition, the average stand deposition flux of NH_4^+ is significantly higher in the coniferous stands (mean ratio = 1.66) (Figure 2-1a). For NO_3^-, the variability of the ratios is higher than for NH_4^+. The average ratio (1.27) indicates a higher deposition under coniferous stand, irrespective of the level of open field N deposition (Figure 2-1b). The ratios of the stand deposition fluxes of NO_3^- and of total inorganic N are significantly higher than 1 in the plots with high open field N deposition, but not for the paired stands with lower wet N deposition..

SO_4^{2-} deposition is significantly higher under coniferous canopy than under deciduous canopy (mean ratio = 1.69). H^+ deposition is on average 2.5 times higher in coniferous stands as compared to deciduous stands, but the mean ratio is very variable (confidence interval 1.77-3.57). The mean ratio of stand deposition fluxes under coniferous and deciduous canopy is significantly higher than 1 for all base cations, except for K^+. The ratios for Ca^{2+} and Na^+ are of the same magnitude (1.40 and 1.38 respectively) and both elements have a comparable confidence interval, although the number of replicates for Na^+ is only half of the number for Ca^{2+}. The mean ratio for Mg^{2+} is a little lower (1.26), while for K^+ it amounts 1.01.

Table 2-1: Weighted mean ratio between element stand deposition fluxes under coniferous forest and under deciduous forest. The 95% bootstrap confidence interval is given between brackets. n = number of studies. Results are given for: (1) all available data, (2) data with open field inorganic N deposition flux ≤ 10 kg ha^{-1} y^{-1} and (3) > 10 kg ha^{-1} y^{-1}.

Element	*n*	Mean Ratio (1)	*n*	Mean Ratio (2)	*n*	Mean Ratio (3)
NH_4^+	*17*	1.35 [1.06 - 1.70]	*5*	0.83 [0.56 - 1.09]	*12*	1.66 [1.36 - 2.06]
NO_3^-	*17*	1.50 [1.36 - 2.06]	*5*	1.27 [0.88 - 1.91]	*12*	1.87 [1.51 - 2.37]
NH_4^+ + NO_3^-	*20*	1.61 [1.31 - 1.99]	6	1.08 [0.78 - 1.35]	*14*	1.86 [1.51 - 2.35]
H^+	*15*	2.47 [1.77 - 3.57]				
SO_4^{2-}	*24*	1.69 [1.45 - 1.99]				
Na^+	*10*	1.38 [1.16 - 1.66]				
K^+	*16*	1.01 [0.83 - 1.27]				
Ca^{2+}	*20*	1.40 [1.22 - 1.62]				
Mg^{2+}	*12*	1.26 1.03 - 1.56]				



a b

Figure 2-1: Scatter plot of (a) the ratio of NH_4^+ deposition flux and (b) the ratio of NO_3^- deposition flux in coniferous paired deciduous stands for increasing mean yearly inorganic N deposition flux in open field precipitation (mol ha^{-1} y^{-1}) adjacent to each stand pair. The arrow indicates 10 kg N ha^{-1} y^{-1} open field deposition. The labels refer to the index numbers of the list of studies (available from the authors).

Percolation

The ratio of ion percolation under coniferous and deciduous stands was significantly ($p < 0.05$) different from 1 for NO_3^-, total inorganic N, and K^+, but not for the other elements considered (Table 2-2. Percolation of NO_3^- was found to be significantly and on average almost three times higher under coniferous forest stands than under deciduous forest stands. The NO_3^- percolation ratio varied strongly between stand pairs, and ranged from 0.78 to 37.5. We could not distinguish between regions with low and high atmospheric N pollution level, because (not all studies reporting on N percolation fluxes included open field N deposition data). Anyhow the number of replicates would become too low for a meaningful analysis and almost all stand pairs were located in a region where wet deposition exceeded 10 kg N ha^{-1} yr^{-1}.

Percolation of H^+ and Al(III) is not significantly different between coniferous and deciduous forest stands (Table 2-2) because the ratios for both elements show a high variability between stand pairs. The mean ratio of 1.71 for both elements may indicate higher percolation under coniferous stands. Also for SO_4^{2-}, Ca^{2+} and Mg^{2+} percolation, no significant differences were found between the two stand types and the ratios close to 1 indicate only small differences between coniferous and deciduous forest for these elements. Of the base cations, only K^+ percolation was significantly higher under coniferous stands than under deciduous stands with a mean ratio of 1.5.

Table 2-2: Weighted mean ratio between element fluxes in percolation water under coniferous forest (C) and under deciduous forest (D). N = number of studies. See Table 2 for calculations of mean ratio and 95% confidence interval

Element	*n*	Mean ratio
NH_4^+	*5*	0.50 [0.11 - 1.22]
NO_3^-	*5*	2.76 [1.17 - 6.49]
inorganic N	*8*	3.05 [1.68 - 5.44]
SO_4^{2-}	*6*	1.11 [0.85 - 1.44]
K^+	*6*	1.51 [1.20 - 1.92]
Ca^{2+}	*6*	1.15 [0.49 - 2.32]
Mg^{2+}	*6*	1.18 [0.89 - 1.59]
Al (III)	*5*	1.71 [0.88 - 4.22]

2.1.4 Discussion

Stand deposition

Atmospheric deposition can be considered as an additional source of nutrients to the 'internal' element cycles in forest ecosystems. Stand deposition flux, calculated as the sum of throughfall and stemflow deposition (fluxes), was assumed to be an adequate parameter for studying the input with the water flux to the forest floor, i.e. the net interaction between atmosphere and forest canopy. Compared to precipitation in the open field, the chemical composition of throughfall and stemflow water is generally altered, and it is widely acknowledged that this transformation results from (i) dry deposition of aerosols and gases on leaves, branches and stems, as well as (ii) canopy exchange processes such as diffusion and/or exchange between the water layer covering leaves/needles and the underlying apoplast and uptake of gases through stomata (Draaijers *et al* 1997).

In general, Na^+ is assumed to be inert with respect to the canopy, i.e. no uptake and no leakage occur (Ulrich 1983). Therefore, the stand deposition flux of Na^+ is often used as an indicator of the dry deposition capacity of a forest. Based on the meta-analysis of data on Na^+ stand deposition flux from 10 stand pairs, it can be concluded that the dry deposition capacity of coniferous forests is significantly higher than that of deciduous forests (about 1.4 times higher), implying that a coniferous stand annually intercepts more atmospheric pollutants than a deciduous stand at the same site. Several studies also consider SO_4^{2-} to be more or less inert with respect to the canopy (Stachurski & Zimka 2000, Ukonmaanaho & Starr 2002). Based on the meta-analysis of SO_4^{2-} stand deposition flux data from 20 stand pair comparisons, coniferous forest has a 1.7 times higher dry deposition capacity than deciduous forest. Important factors for lower dry deposition in deciduous than in coniferous stands are differences in vegetation structure, such as the generally lower LAI, stand and crown density, and the summergreen character of deciduous stands (Alcock & Morton 1985, Draaijers 1993, Houle *et al* 1999, Erisman & Draaijers 2003). IN addition, the leaf shape affects the amount of elements deposited. Leaves with long narrow shape (needles) are more efficient in salt accumulation than circular ones (Woodcock 1953 in Smith 1981). Nevertheless, during the growing

season, higher dry deposition fluxes to deciduous forest in comparison to coniferous forests have been observed (Cappellato *et al* 1993).
Opposite to Na^+ and SO_4^{2-}, stand deposition fluxes of the base cations K^+, Ca^{2+} and Mg^{2+} are affected by canopy exchange processes. The effect of forest type can be direct, through differences in canopy characteristics such as aboveground biomass, nutrient amount, species specific concentrations in leaves (Lovett *et al* 1989) and evergreen character (Smith 1981). Nutrient concentrations in broadleaves are higher compared to needles (Johansson 1995). Also the age distribution of leaves affects the magnitude of leaching to a large extent: young immature leaves/needles tend to lose more nutrients compared to older ones except when they are hydrophobic (Parker 1990). The type of forest can also indirectly influence canopy exchange through forest soil characteristics such as extractable amount of base cations in the soil solution (Lovett & Schaefer 1992).
In general, stand deposition flux of K^+ originates over 70% from canopy leaching (Houle *et al* 1999, Van Ek & Draaijers 1994, Parker 1983, Ragsdale *et al* 1992). The fact that K^+ stand deposition does not differ significantly between the two forest types in the meta-analysis may indicate that the higher dry deposition from the atmosphere (soil dust and sea salt) to coniferous forest stands compensates for the higher canopy exchange in the deciduous forest stands (Alcock & Morton 1985, Houle *et al* 1999, Van Ek & Draaijers 1994). Stand deposition fluxes of Ca^{2+} and Mg^{2+} are significantly higher in the coniferous forests considered in the meta-analysis. There is considerably less canopy exchange of these two elements than of K^+ (Ragsdale *et al* 1992), so this again reflects the higher dry deposition capacity of coniferous canopies.
The higher dry deposition capacity can explain the higher stand deposition of inorganic N in coniferous forest. However, this general conclusion is inconsistent with the observed lower NH_4^+ stand deposition under conifers in regions with low atmospheric N pollution. This apparent contradiction can be explained by the fact that forest canopies can take up considerable amounts of N out of the atmosphere. If only wet deposited inorganic N is considered, uptake can already range from 100 to 900 mol N ha^{-1} y^{-1} (Lovett & Lindberg 1992, Harrison *et al* 2000). Previous research indicates that N uptake rates are higher for deciduous leaves of beech and silver birch than for Norway spruce (Brumme *et al* 1992, Harrison *et al* 1991), which is attributed to a combination of thinner cuticles and higher wettability of foliage and bark of the deciduous species. However, this higher uptake rate may be counterbalanced because deciduous trees have foliage for only part of the year (Harrison *et al* 2000) and because coniferous forests have a higher leaf area index. So we hypothesize that, when open field N deposition is low, higher yearly canopy uptake of NH_4^+ by coniferous forests may keep pace with the higher dry deposition as compared to deciduous forest, resulting in the observed lower NH_4^+ stand deposition flux under conifers. In regions with high atmospheric N pollution, the canopy uptake of NH_4^+ may be obscured by elevated dry deposition, with a higher stand deposition flux of NH_4^+ in coniferous forest as a result. This hypothesis can however not be corroborated, since still no conclusive evidence exists that higher N deposition results in a higher canopy uptake of N (Bleeker & Draaijers 2002) or whether the N uptake process becomes saturated with increasing N deposition. Since NH_4^+ is taken up at a significantly faster rate than NO_3^- (Bowden *et al* 1998, Boyce *et al* 1996, Garten & Hanson 1990, Potter *et al* 1991, Schulze & Gebauer 1989, Stachurski & Zimka 2000), no such compensation process is observed for NO_3^-, and the higher dry deposition of NO_3^- onto coniferous forests therefore results in higher stand deposition flux, also in regions with lower atmospheric N pollution.
Stand deposition of protons is the resultant of on the one hand supply by dry deposited acids (NO_3^- and SO_4^{2-}) and on the other hand consumption in the canopy by canopy exchange processes, dry deposition of ammonia and bicarbonate (Ulrich 1983). The higher proton input in the coniferous forest indicates both the higher dry deposition capacity and the lower canopy exchange of potassium in coniferous stands. In addition, the higher proton input in the coniferous plots can be due to the canopy exchange of NH_4^+ for H^+ (Neary & Gizyn 1994), as coniferous forest probably retains more NH_4^+ in the canopy.

Percolation

The significant higher stand deposition flux of inorganic N in coniferous forests is reflected in an almost threefold higher percolation flux of NO_3^-. In all stand comparisons included in the meta-analysis, NO_3^- percolation under coniferous forest is higher than under deciduous forest, although the differences are highly variable. Several studies have found a close relationship between the level of N deposition and level of N percolation, at least for those sites where N saturation is evident (Matson *et al* 2002, Macdonald *et al* 2002). Apart from stand deposition fluxes, meteorological conditions explain, to a large extent, the variation in concentrations of major ions in the soil solution (De Vries *et al* 2003). Besides a higher stand deposition flux, the higher NO_3^- percolation flux under coniferous forest may also be related to species-specific N uptake and N retention capacity. For certain broadleaved species, such as ash (*Fraxinus* sp.) and oak (*Quercus* sp.), high NH_4^+ concentrations are a stimulus for NO_3^- uptake (Stadler *et al* 1993), while NO_3^- uptake by roots of coniferous trees is known to be strongly reduced in the presence of NH_4^+ (Marschner *et al* 1991, Rennenberg *et al* 1996). Also Gebauer *et al* (2000) found that young and mature conifer stands retained less than 10% of throughfall N deposition, while broadleaf trees were able to retain 70% and more.

The higher deposition load of SO_4^{2-} in coniferous forest stands was not reflected in a significant higher percolation to groundwater. The ability of many soils to retain significant quantities of SO_4^{2-} by inorganic adsorption mechanisms (Harrison & Johnson 1992, Martinson *et al* 2005) may underlie this conclusion. E.g. adsorption typically increases as the soil pH and the amount of organic matter decrease (Harrison & Johnson 1992), both parameters being influenced by the forest type.

Different mechanisms might be responsible for the higher mean percolation flux of base cations and Al(III) under coniferous stands in the meta-analysis (Meesenburg *et al* 1995, Wesselink *et al* 1995). First, a higher input of base cations through the stand deposition flux and through litterfall can result in a higher output. Secondly, differences in soil acidification due to the different proton input or the different input of base cations could be responsible for percolation differences under the forest types. Soil acidification will induce displacement of cations by protons, thereby reducing the base cation pool and increasing the proportion of Al(III) on the soil-exchange complex (Boxman *et al* 1998, Bredemeier *et al* 1998, Tietema *et al* 1998). A third possibility is that the higher percolation of anions under conifers involves a higher soluble cation fraction, making total cation percolation a function of total anion percolation (Johnson 1992). In forest soils with a base saturation over 25% or a pH-KCl level over 4.5, a strong positive relationship exists between concentrations of Ca^{2+} and strong acid anions in the subsoil (De Vries *et al* 2003), indicating that the percolation of anions in less acidified soils is mainly neutralised by the release of base cations. In forest soils with a base saturation below 25% or a pH-KCl below 4.5, the concentration of Al(III) in the subsoil is strongly related to the concentration of SO_4^{2-} and NO_3^- (De Vries *et al* 2003). Aluminium release is the dominant buffering process in acid forest soils. In a German study, a stronger acidity of the soil solution under coniferous forest than under deciduous forest was only found at the acid soil, but not at the less acidified soil (Rothe *et al* 2002). The high variability in soil conditions and the limited number of stand pairs reporting on percolation fluxes can explain why no univocal and significant differences between forest types were found in the present meta-analysis.

2.1.5 Conclusions

Anthropogenic N additions to ecosystems have been shown to affect a wide range of ecosystem properties and processes, especially when inputs are high and continuous (Matson *et al* 2002). Increased NO_3^- percolation from N saturated ecosystems drives acidification and eutrophication and alters biodiversity in downstream freshwater and marine systems (Rabalais 2002, Schindler 1994). From the comparison of pure coniferous and pure deciduous stands at comparable sites, it can be inferred that forest conversion has a good potential to reduce the N input to forest stands and N percolation and to decrease the loss of base and acid cations to the deeper soil, particularly in areas with high levels of atmospheric N pollution. As has also been shown in the NITREX and EXMAN clean rain experiments, reduction of the N input to forest soils results in a rapid and significant decrease in NO_3^- percolation, and consequently of base and acid cations (Boxman *et al* 1998, Bredemeier *et al* 1998, Tietema *et al* 1998). Therefore, the mitigation of the environmental problems of eutrophication and acidification of forest ecosystems is a valuable additional argument for forest managers to convert coniferous forests.

2.2 Effect of Norway spruce, oak and beech forest types on biogeochemical cycling

Degrave Frédéric & Carnol Monique

2.2.1 Introduction

The development of human activities has drastically changed the natural aspect of temperate forest ecosystems. Since the 19^{th} century in Belgium, open landscapes originating from ancient management practices were largely planted with easy growing coniferous tree species. Because of its high potential on poor soil and many wood qualities, Norway spruce (*Picea abies*) rapidly became the main production tree species in Wallonia, especially in the Ardenne, where Norway spruce stands are managed as even-aged monocultures. In the eighties, forest decline symptoms and concerns about ecological and environmental impact of Norway spruce monocultures have slowed down its extension in Wallonia, where Norway spruce remains the main production tree actually. Furthermore, Claessens *et al* (2001) have demonstrated that nearly half of the Norway spruce stands in Wallonia are not on adequate sites. These aspects were treated in the Section 1.6. An option to restore a balanced situation on unsuitable areas for Norway spruce stands is to convert them into pure or mixed broadleaved stands, adapted to local conditions (Spiecker *et* *al* 2004). Broadleaved trees and conifers could also be mixed at suitable places. Indeed, Cannell *et al* (1992) have shown that two or more species may use resources differently and be more resistant to stress factors if they coexist in a same stand.

Whereas tree species composition and the choice of site-adapted species appear to be fundamental in new management practices, there are still many gaps in our knowledge of tree-soil interactions. Some effects of tree species are nevertheless well documented. Soil acidification under conifers and under Norway spruce stands in particular has been investigated in many studies (Noirfalise & Vanesse 1975, Bonneau *et al* 1979, Nys & Ranger 1985). However, comparisons of tree species effects under similar environmental conditions are very rare. Without this prerequisite, measured differences between stands can be attributed to former land use or to different pedological conditions rather than to tree species (Hagen-Thorn *et al* 2004). Homogenous conditions (except tree species) are difficult to combine and it could take a long time for trees to influence soil parameters (Menyailo *et al* 2002, Priha & Smolander 1999).

In forest stands, the availability of nutrients for plant growth and maintenance is dependent of the efficiency of the biogeochemical cycle. This nutrients turnover varies between different tree species (Binkley & Giardina 1998). For example, nutrients may be differentially accessed at depth and recycled after litterfall (see Section 2.4) (Washburn & Arthur 2003). Nitrogen (N) is frequently the most limiting nutrient in forests (Prescott 2002). N is mainly located in soils but a major part is in organic forms, not directly available for plant nutrition. N cycling is thus a critical process in forest productivity. Soil microorganisms control the release of inorganic N from decomposing litter.

The main objective of this research was a qualitative and quantitative comparison of the effects of three tree species (Sessile oak, European beech, Norway spruce) on soil fertility and biological soil N transformations. Key environmental parameters such as chemical composition of throughfall, water soil solution and leachates serve as indicators to describe nutrients dynamics under each stand.

2.2.2 Material and Methods

Study site

The experimental plots (Table 2-3) are localised in the public forest 'Hertogenwald' in the Membach locality, south-eastern Belgium. Mean annual temperature and rainfall are 7°C and 1300 mm, respectively. The three neighbouring pure stands (*Fagus sylvatica, Quercus petraea, Picea abies*) are situated on stony-loamy acid brown soil with moder humus, developed on a quartzitic bedrock (Revinian – 'la Venne-Coo' formation) (Laloux *et al* 1996).

Oak and beech stands (even-aged stands) originate from a coppice with standards. The Norway spruce stand is an even-aged secondary plantation, 75 years old. By the end of the 18th century, the three sites were covered by a broadleaved timber forest. Under the oak stand, a dense herbal layer mainly composed from *Molinia cearula* and, for a lesser part, from *Pteridium aquilinum* is present. *Deschampsia flexuosa* and *Vaccinium myrtillus* are also observed at some places. In the Norway spruce stand, the moss layer is developed and is composed of *Polytrichaceae* and *Dicranaceae*. At more open places, the same herbal species as in the oak stand are growing. Nearly no herbal layer is present under the beech stand. Only some *Deschampsia flexuosa* and *Vaccinium myrtillus* have been noted.

Table 2-3: Characteristics of the three forest stands

tree species	slope (m 100m^{-1})	stem number (ha^{-1})	DBH (cm)	stand area (ha)	age (yr)	basal area (m²)	forest type
Oak	0	150	41	2	75	19.6	Luzulo-Quercetum molinietosum
Beech	<5	137	49	1	70-130	28.7	Luzulo-Fagetum
Spruce	<5	325	44	1	75	23.1	Piceetum

DBH = diameter at breast height (130 cm)

Experimental plots

Six experimental plots were installed around six randomly selected trees in each stand. Soil solution was collected continuously in each plot by tension lysimeters (PRENART soil water sampler, Denmark) at 1.5 m from the stem of the selected tree, below the forest floor (about 10 cm). Because their interception surfaces are known and allow potential input-output budget measurements (without root uptake), zero tension lysimeters were used in addition to tension lysimeters for leaching measurements. Potential soil leaching losses were quantified *in situ* using zero tension lysimeters, consisting of a 20 cm soil column in a PVC tube (20 cm diameter) in connection with a funnel which is linked to a collector flask. As zero tension

lysimeters contain no living roots, the root uptake is neglected. Throughfall water was collected by three sets of five funnels (10 cm ø) in each stand (Rodda *et al* 1985). All samples were collected fortnightly and stored at 4°C prior to analysis. Samples were analysed for pH using a glass electrode and for Cl^-, SO_4^{2-} and NO_3^- by HPLC (Merck, Hitachi). Concentrations of cations were determined by inductive coupled plasma (ICP-AES, Varian-Vista) dissolved organic N and NH_4^+ colorimetrically (autoanalyzer III, Bran-Luebbe). Dissolved organic carbon was detected as CO_2 (infrared detection) after a sodium persulphate oxidation (Labtoc, Pollution and Processes Monitoring).
On each plot, five soil cores (diameter 4 cm and height 15 cm) were extracted at 1.5 m from the stem of the central tree. Organic and mineral layers were separated and analyzed independently. The litter layer was removed from the soil samples in the field. Then the five sub-samples were mixed to produce one representative sample per plot. The fresh soil samples were sifted through 4 mm mesh prior to analysis. Soil water content was determined after drying at 105°C during 3 hours. Weight loss on ignition (450°C) was interpreted as a measure of the organic matter content of the soil. Soil pH (H_2O and KCl) was measured with a glass electrode in a soil suspension (1:1,v:v) after one hour of stabilisation. Exchangeable cations (Al(III), Ca^{2+}, Fe, K^+, Mg^{2+}, Mn^{2+}, Na^+, Zn) were extracted using a 0.1 M $BaCl_2$ solution (Henderson & Duquette 1986). Chemical analyses of the filtered and acidified (HNO_3 65%) extract were performed using ICP. An analysis of extractable NO_3^- and NH_4^+ was performed by colorimetry, after a KCl 6% extraction.

Biological activity: potential nitrification

Potential nitrification was determined by the shaken soil-slurry method (Hart *et al* 1994). This method involves shaking a sieved soil in a dilute ammonium phosphate solution and measuring NO_3^- accumulation during 30 hours. NO_3^- immobilisation by microorganisms is avoided by high NH_4^+ concentrations and denitrification is inhibited by the aeration of the soil slurry during shaking. Obscurity is maintained during the incubation because of the negative effect of light on the activity of nitrifiers. Moreover, substrate and moisture limitations are eliminated and the measured rate approximates the maximum nitrification rate. 10 g of sieved soil were placed into 250 ml Erlenmeyer flasks. 100 ml of combined solution (3 ml KH_2PO_4 0.2M, 3.5 ml K_2HPO_4, 15 ml $(NH_4)_2SO_4$, in 1 l, pH adjusted to 7.2) were added and the Erlenmeyer was covered with a vented cap. The soil slurries were shaken at 180 rpm for 30 h. Samples of homogenous slurry (15 ml) were taken after 2, 6, 22, 26 and 30 hours. These samples were filtered and stored in the freezer until analysis. NO_3^--N was determined colorimetrically with a continuous flow analyzer (Autoanalyzer III, Bran-Luebbe). Nitrification rates were calculated by linear regresion on nitrate concentrations over time.

2.2.3 Results and discussion

Soil characteristics

Results from chemical analysis are presented in Table 2-4.

Table 2-4: Mean chemical soil parameters (n = 6) in the three stands. Values are in mg 100 g^{-1} dry soil. Different letters denote significant differences between tree species ($p < 0.05$).

depth		pH_{H2O}	pH_{KCl}	C/N	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al(III)	Mn^{2+}	Fe	Zn	NO_3^--N
0-7 cm	*Oak*	4.26 a	3.10 a	19.23a	52.37a	12.63a	12.61a	4.68ab	45.18a	2.07a	0.40a	6.57a	0.47b
	Beech	4.07 b	3.14 a	18.85a	22.98b	4.29b	5.85b	3.91a	74.69b	2.31a	0.64b	4.23b	1.35a
	Spruce	3.81 c	3.17 a	22.21b	33.39b	4.69b	2.38c	5.32b	85.26b	7.03b	0.63b	3.35b	1.38a
7-15 cm	*Oak*	4.38 a	3.43 a	19.96a	4.61a	1.67a	5.68a	2.07a	65.51a	0.12 a	0.86 a	1.46 a	0.09c
	Beech	4.34 a	3.56 b	17.73b	2.55b	0.94b	2.38b	1.59a	66.20a	0.20 a	0.73 a	1.28 a	0.28 b
	Spruce	4.05 b	3.53ab	18.43b	4.05a	0.96b	0.98c	2.92b	61.11a	2.21 b	0.76 a	0.93 b	0.91 a

In the organic horizon (0-7 cm) of the oak stand, pH, exchangeable Ca^{2+}, Mg^{2+}, K^+ were significantly higher, and Al(III), Fe and NO_3^--N significantly lower than in the spruce or beech stand. Under broadleaved trees, C:N is close to 19 in the organic layer (moder humus) while it equals 22 in the spruce stand (mor humus). Only pH and exchangeable K are significantly different in the three stands (Oak > Beech > Spruce). The 7-15 cm layer of the oak stand is characterised by higher pH, Mg^{2+} and very low NO_3^--N values in comparison to other stands. Moreover the NO_3^--N content of the spruce stand is nearly three times higher than in the beech stand. Exchangeable Ca content is lower beneath European beech than beneath oak and spruce, whereas exchangeable Na^{+} and Mn^{2+} are more abundant beneath spruce.

Overall, beech and spruce seem to have a quite similar effect on exchangeable elements pools in these soil layers. In mixed stands, Sanborn (2001) showed an increase in the soil pH, Mg^{2+}, Ca^{2+}, and K^{+} contents and a decrease of the C:N ratio proportional to the broadleaved/conifer ratio of the stands. But the dissimilarities between conifer and broadleaved are not always so clear, especially in the case of beech and spruce (Binkley & Valentine 1991, Hagen-Thorn *et al* 2004, Tamm & Hallbäcken 1986). In a mixed beech–spruce stand however, Rothe *et al* (2003) have measured an increased base saturation and pH in comparison to pure spruce stand. Interestingly, tree species that improve soil fertility are secondary tree species (*Sorbus sp., Salix sp., Populus tremula, Corylus avellana*, *Betula sp.*,...) (see Section 2.4) which have often been neglected in forest management (Weissen & Michaux 1999).

Soil input and output: atmospheric deposition and soil leaching

We calculated element fluxes during one year in the 20 cm top soil by summing elements quantities collected with zero tension lysimeters (n = 6) at each sampling event. The annual element input by throughfall water measured with 5x3 collectors (funnels) per stand was also calculated and was compared to soil leaching losses in Figure 2-2.

Except for K^{+}, throughfall inputs are significantly higher in the spruce stands than in the broadleaved stands. The higher LAI (Leaf Area Index) of the spruce stand and the fact that the foliage is maintained throughout the year are likely to be the main cause for the higher input in the spruce stand (Rothe *et al* 2002). Moreover, acidity of throughfall is significantly higher under spruce stand than under beech or oak. The comparison of input and output data shows that in absence of root uptake, leaching losses in seepage water largely exceed throughfall input. This is especially remarkable for NO_3^-. In the spruce stand for example, throughfall input and soil output are 11.5 and 132.7 $kg.ha^{-1}$. NO_3^- leaching in the beech and the spruce stands were not significantly different, but significantly higher than the losses beneath oak.

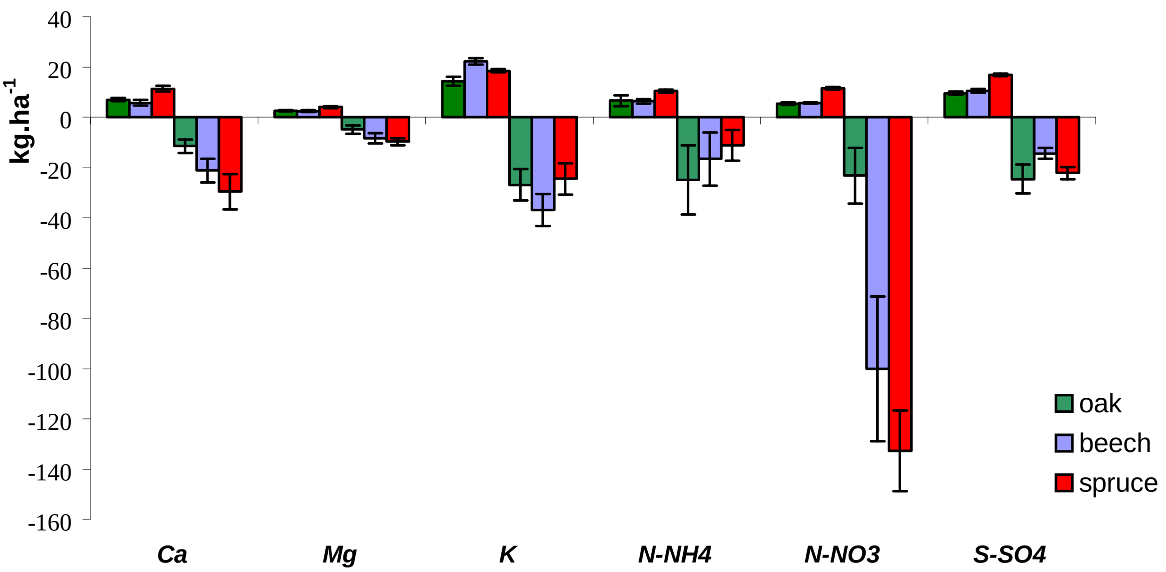
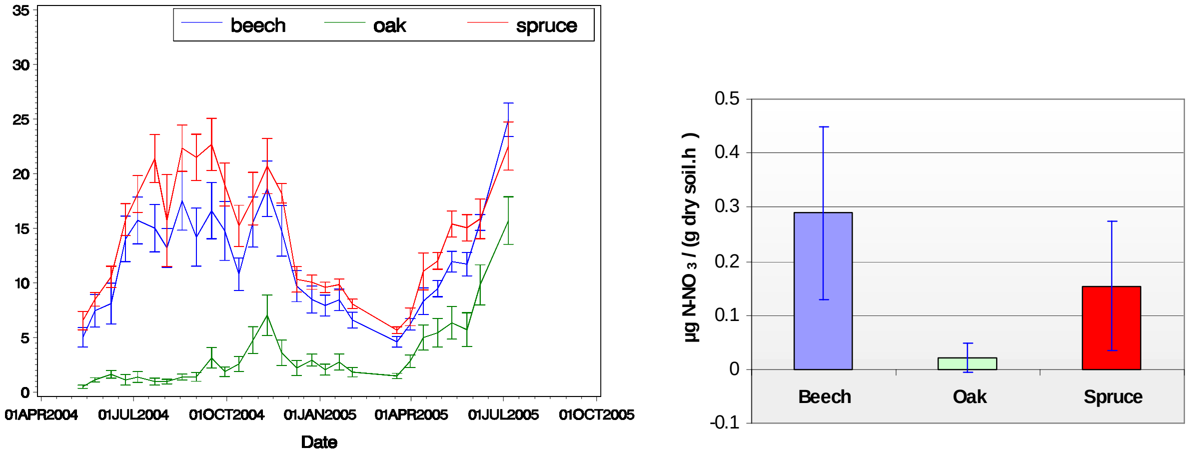


Figure 2-2: Annual elemental fluxes in the three stands (in absence of living roots). Positive values correspond to throughfall deposition fluxes and negative to percolation fluxes.

NO_3^- leaching (zero tension lysimeters, no root uptake) showed a clear temporal dynamic over the year (Figure 2-3a). In 2004, we observed a peak of NO_3^- leaching during summer-autumn in beech and spruce stands. A small peak also occurred in November 2004 under oak. However, in 2005, NO_3^- losses showed the same dynamic (summer peak) in the three stands. Zechemeister-Boltenstern *et al* (2002) also measured an increase of NO_3^- leaching during summer under beech. They attributed this peak to high precipitation events and to a release of N from microbial biomass due to a rapid decline of microbial population after a time of proliferation.

During the peak of NO_3^- leaching (July 2004), we observed a significantly higher rate of potential nitrification in beech and spruce soil organic layers than in oak soil (Figure 2-3b). This low activity of nitrifiers in the oak stand can explain the small quantities of NO_3^- in soil and soil solution. In immobilising inorganic N, the dense herbal layer under the oak stand could act as a competitor for NH_4^+ or NO_3^- and therefore lower the availability of inorganic N in this stand (Riha *et al* 1987). Vitousek *et al* (1982) observed that potential net NO_3^- production occurred only above a threshold of the mean mineral N content of the forest floor. Thus, the mineral N content of the oak stand may have been too low to allow nitrification (De Boer *et al* 1993).



a b

Figure 2-3: (a) Temporal evolution of NO_3^--N concentrations in soil leachates. (b) Potential nitrification rates (in July) in the three stands.

Capillary soil solution

There was no significant difference between tree species for soil solution pH (figure 4). However, in accord with soil analyses, the solution acidity under spruce seems to be systematically higher than under broadleaved trees. The acidity of the soil solution is responsible for the dissolution of acid cations like Mn or Al(III) (Menzies *et al* 1994). Indeed, the concentrations of Al(III) or Mn^{2+} in spruce soil solution were largely higher than in beech or oak solutions (Figure 2-4).

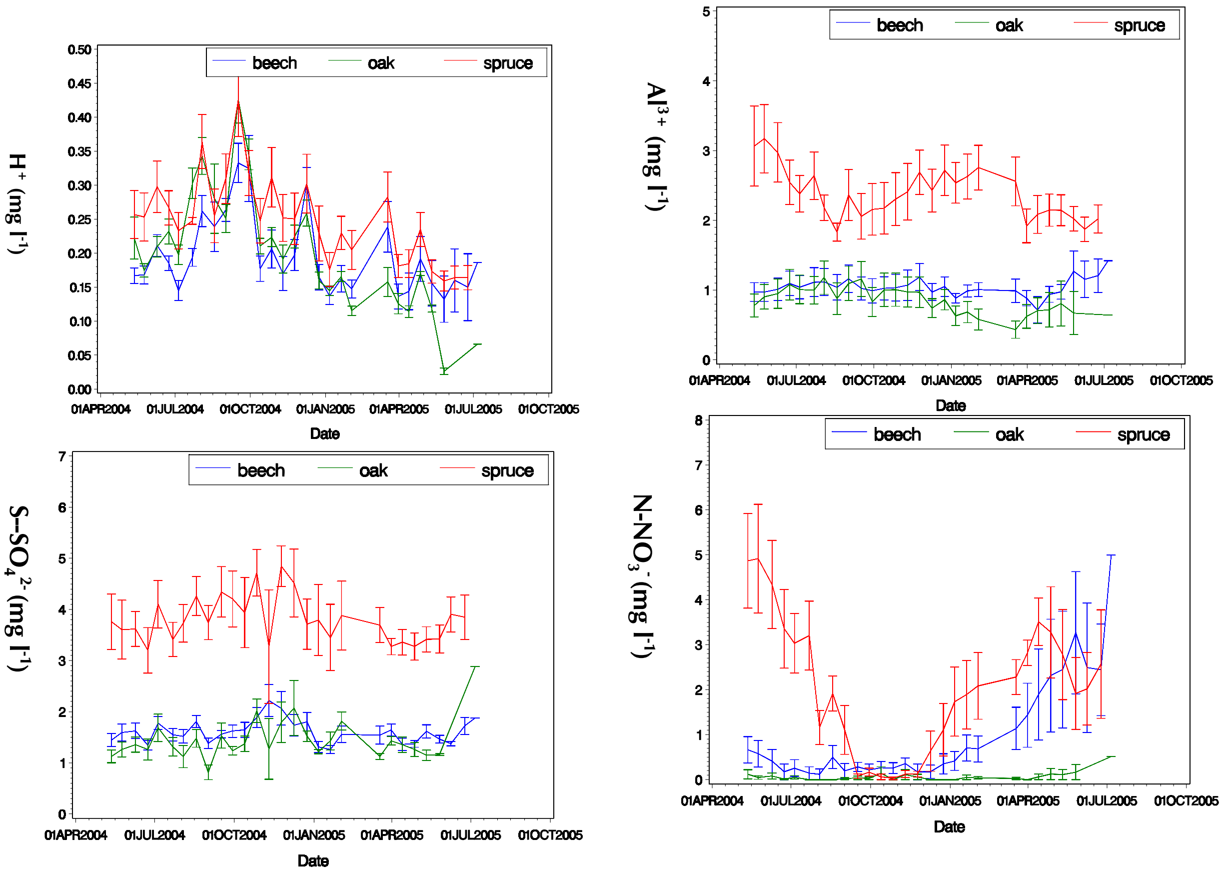


Figure 2-4: Temporal evolution of elements concentrations in soil solution of the three stands

In the spruce stand, an important Al(III) mobilisation combined with soil acidity can explain these high Al(III) concentrations. High levels of Al(III) in soil solution can have a toxic effect on roots and bring about Ca^{2+} and Mg^{2+} deficiencies, with negative consequences on tree growth (Solberg & Tørseth 1997). Moreover, the abundance of dissolved Al(III) in surface water can cause the disappearance of fish populations and other aquatic organisms (Boudot *et al* 2000).

The greater interception of atmospheric deposition by the spruce stand is reflected by the high concentrations of SO_4^{2-} and Na in comparison to the concentrations under the broadleaved stands (Figure 2-4). In acidic soils, these elements are effectively mainly of atmospheric origin (Augusto & Ranger 2001). NO_3^- in soil solution is more concentrated in the spruce stand and shows a strong seasonal trend (Figure 2-4). The minimum values for NO_3^--N concentrations in soil solution are detected during autumn and maximum in late spring. Solutions sampled in the oak stands contain very small quantities of NO_3^--N all over the year. NO_3^--N concentrations in solutions from the beech stand are intermediary between oak and spruce. As it was observed in soil analyses, Ca^{2+} and Mg^{2+} concentrations in soil solution are often lower under beech than under spruce and oak stands. Similarly, K^+ is more concentrated in solution from the oak stand than from beech and spruce stands, respectively. This could be the consequence of the 50 % higher K^+ content in beech and oak leaves as compared to spruce needles (Bonneau 1988, Hedebouw 2000).

Importance of organic N in soil solution and soil leachates

It is now well established that dissolved organic matter can significantly contribute to the cycling of soil nutrients (Park *et al* 2002). Important to our study is that dissolved organic matter may be s a major pathway for the leaching of many elements from the forest floor (Smolander & Kitunen 2002). Dissolved organic carbon (DOC) has been widely studied in forest ecosystems, but information about the importance of dissolved organic nitrogen (DON) is still lacking. In this study, we investigated the proportion of the different forms of organic and inorganic N in soil solution and soil leachates (Figure 2-5).

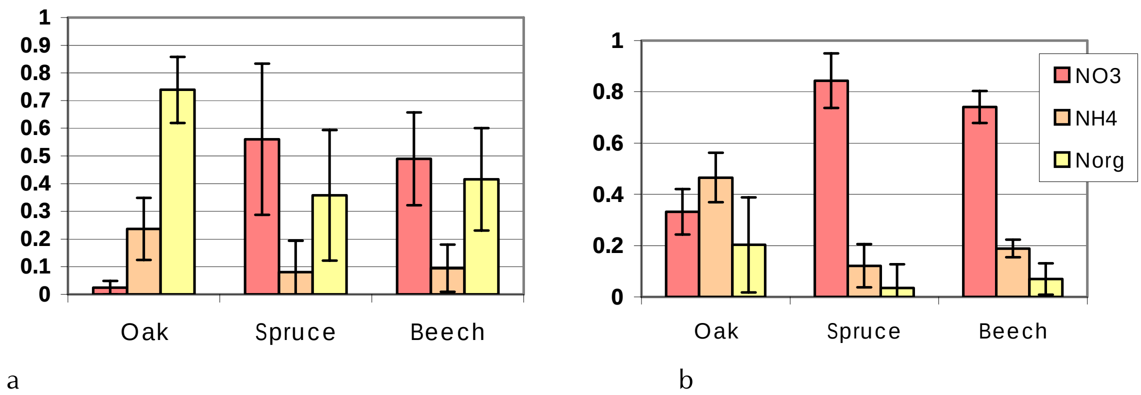


Figure 2-5: Proportion of organic and inorganic forms of N in soil solution (a) and soil leachates (b)

In both compartments, DON represents a significant part of total N (35 and 75% under spruce and oak in soil solution, less than 20% in soil leachates). NO_3^- is the main N form in soil leachates from beech or spruce stands, whereas it is NH_4^+ in leachates from the oak stand. Overall, it seems that DON and NH_4^+ are very important N forms in the oak stand as compared to spruce or beech stands.

2.2.4 Conclusions

These results clearly demonstrate the influence of the forest types on nutrient cycling. In these adjacent stands, differences were detected in soil as well as in soil solution, throughfall and soil leachates. These differences seem to originate from several factors (litter decomposition, litter chemical composition, ability to intercept atmospheric deposition, rooting pattern, phenology, physiology,...) which are in permanent interaction. It is therefore very complex to elucidate which of these factors is responsible for the measured differences.

Overall, soil analyses reveal better soil conditions (acidity, base saturation) in the soil under the oak stand. This was confirmed by the soil solution analyses. Although they were not subject of this study, the rooting patterns of the three species could partly explain these differences. Indeed, sessile oak is known to have a very deep rooting which can access to deep mineral resources, whereas beech and Norway spruce have more superficial roots which explore superior soil layers only. Due to acidic conditions, Al(III) concentrations and mobility are higher in the Norway spruce stand than in the broadleaved stands. This increased Al(III) availability under Norway spruce could have serious consequences on tree health by causing nutrient deficiencies. Mn^{2+} is also by far more concentrated in the soil under Norway spruce, and could also have a toxic effect at high levels.

Even if the Norway spruce stand has a relatively low stem density, the interception of atmospheric deposition is clearly higher than in the broadleaved stands as it was demonstrate with N or S oxides. A high input of NO_3^- in the Norway spruce stand is particularly worrying because of its negative environmental consequences. For example, NO_3^- leaching seems to enhance the leaching of Al(III) (strong correlation between Al(III) and NO_3^- in leachates). Moreover, important Al(III) losses from forested watershed can be responsible for the disappearance of aquatic organisms in rivers and lakes and might hampered the drinking water consummation. This important flux of NO_3^- in the soil profile also enhanced base cation leaching, contributing to soil impoverishment and acidification.
NO_3^- availability and leaching seems to follow seasonal dynamics, with leaching peaks in summer and autumn. These peaks might be linked with the microbial activities, also higher during this period. Nitrification rates in the soil organic layer were influenced by tree species, with a lower rate detected under the oak stand. Oak trees, with a low LAI, allow the development of a dense herbal layer which can act as competitors towards soil micro organisms. If this hypothesis was confirmed, oak stands would have an indirect effect on soil, due to its canopy structure.

Management practices are also of primary importance in determining the effect of the trees on soil parameters. The stems density and the structure of a stand for example have a major influence on the microclimatic conditions prevailing in the forest floor, and therefore on the development of herbal layers, microbial populations and decomposability of leaf litter. According to present knowledge, the increase of the proportion of broadleaved tree species in forest stands is likely to have positive consequences on soil as well as soil water quality. They are summarised below:

- A substantial decrease of atmospheric deposition reaching the forest floor (N, S), linked with a decrease of soil and soil solution acidity (lower elements inputs)
- A decrease of nitrogen losses with seepage water (NO_3^- mainly) and NO_3^- concentrations in surface and ground water quality. A diminution of base cations and Al(III) leaching losses.
- A better decomposability of litter (due to better microclimatic conditions and to a better litter quality), modifying the humus form (mor-moder to moder-mull). Better cycling of nutrients, especially in the case of oak and other improving tree species (often secondary species).
- An increase in soil pH (directly linked to soil fertility), with positives consequences some biological activities
- In the case of a conversion towards an oak stand : a decrease in the NO_3^- biological production (dependant on the importance of the ground vegetation)

2.3 Effect of conversion scenario on element deposition and leaching

Gielis Leen, De Schrijver An & Geudens Guy

2.3.1 Introduction

Stands dominated by Scots or Corsican pine in Flanders are prone to conversion management with the aim to develop well-structured forests dominated by indigenous broadleaved trees (see Chapter 1.7). In general, two conversion scenarios for homogeneous pine stands seem plausible: **continuous stand cover** and **group cutting**. Of course in practice a combination of both is possible. They can be contrasted to the two most extreme scenarios: **no intervention** and complete **clear cut** (see Section 1.7.2).

The forest type effect can be analyzed by comparing both ends of the conversion path: a pure coniferous stand, and a pure broadleaved stand as done in the previous Section 2.1 and Section 2.2. Another important aspect of ecological feasibility is the environmental impact of the conversion scenario itself. What happens with biogeochemical cycles in the period between onset of the conversion and the development of the desired broadleaved stand?

2.3.2 Material and Methods

Site description

The experimental sites are located in the northern part of the regional forest "Gewestbos Ravels" (51°23'N, 5°03'O), in the Kempen ecoregion, northeast Flanders. Gewestbos Ravels has a surface area of 850 ha and its northern part is mainly dominated by homogeneous plantations of Scots pine and Corsican pine, planted between 1906 and 1930. Following the FAO classification (FAO 1988), the coarse sandy soils were classified as Haplic podsols. After complete control of understorey of Black cherry in the 1990ies, natural regeneration arises at massive scale under the regularly thinned stand canopies. Outside fenced areas most seedlings are coniferous, since roe deer browses deciduous seedlings. Scots pine is dominant in these regenerations, but locally larch, Douglas and Corsican pine occur. Inside enclosures massive regeneration of birch (both of *Betula pendula* Roth and *Betula pubescens* Ehrh.), rowan, buckthorn, red oak and some pedunculate oak can occur. The latter species is also planted in enclosures. Some group cuttings were also performed during the last decade.

We selected a homogenous stand of Scots pine, planted around 1930, as a control plot. About 400 m apart from the control plot, two adjacent pine stands, planted in 1915, were selected that underwent a contrasting management. In the first stand half of the pine stem number was removed in 1992 and part of it was fenced (Geudens *et al* 2000). Outside the fence a homogeneous natural regeneration of Scots pine established, inside the enclosure a mixture of birch, rowan and Scots pine seedlings arose. The Scots pine seedlings within the fence withered under the fast growing broadleaves. This stand is exemplary for a shelterwood conversion scenario. In the second stand an irregularly shaped group of about tree times the height of the pines was cut in 1995, retaining the original pine canopy around it and a few Scots pines standards inside the group cut. The entire stand was fenced and a variable natural regeneration of mainly birch, Scots pine and rowan established. This stand is exemplary for a group cutting conversion scenario. Within each stand we selected parts dominated by Scots pine and by birch.

Experimental set-up

The experimental set-up consisted of three replicated plots in each stage/type of conversion: control plot (CP), shelterwood with birch regeneration (SWB), shelterwood with regeneration of Scots pine (SWP), group cutting with birch regeneration (GB) and group cutting with regeneration of Scots pine (GP). Each plot was equipped with four throughfall collectors and ceramic cup suction lysimeters at two depths (0.15 m and 0.45 m). The applied suction on the lysimeters was -50 kPa. Bulk deposition was collected using four bulk collectors placed in a clear-cut plot adjacent to the forest. Throughfall and bulk precipitation were collected using polyethylene funnels (15 cm diameter) supported by and draining into two-litre polyethylene bottles. The bottles were placed below ground level to avoid the growth of algae and to keep the samples cool. A nylon wire mesh was placed in the funnels to prevent contamination by large particles. Stemflow water was not collected because of its low contribution to nutrient fluxes in pine stands and in young birch stands.

Chemical analyses

Water fractions were collected and measured fortnightly from July 14th 2004 to July 27th 2005 on each sampling occasion, the water volume in every collector was measured in the field, and the bottles were replaced by bottles rinsed with distilled water. The four throughfall samples of each plot were pooled to one sample for the chemical analyses. All water samples were transported and stored at a maximum temperature of 5°C. After the samples had been analyzed for pH (ion-specific electrode), they were filtered through a glass microfibre filter (WHATMAN GF/A) and a nylon membrane filter (GELMAN, nyloflo) of 0.45 μm. Samples were analyzed within a week for Cl^-, NO_3^- and SO_4^{2-} (Ion chromotography), NH_4^+ (continuous flow autoanalyzer), and K^+, Ca^{2+}, Mg^{2+}, Na^+ and Al(III) (flame atomic absorption spectrophotometry). The quality of the chemical analyses was checked by including method blanks, repeated measurements of internal and certified reference samples, and by inter-laboratory tests. The methods were validated with samples from inter-laboratory profession tests and standard reference materials (CRM 100, CRM 409).

Element deposition and percolation fluxes

Element deposition was calculated by multiplying the water volume with the element concentration in that volume. Element percolation flux was calculated by multiplying the calculated water percolation volume, using the Chloride Mass Balance method, at 1 m depth with the average element concentration in the soil solution at 1m depth (De Schrijver *et al* 2004).

2.3.3 Results and Discussion

Throughfall deposition fluxes

Compared to bulk precipitation, the chemical composition of throughfall water elements is generally altered, and it is widely acknowledged that this transformation results from the washing off of dry deposition of aerosols and gases and leaching or uptake of elements in the canopy (Parker 1983). In general, Na^+ is assumed to be inert with respect to the canopy, i.e. no uptake and no leakage occurs (Ulrich 1983). The stand deposition flux of Na^+ is therefore often used as an indicator of the dry deposition capacity of a forest. Dry deposition capacity of the CP, GB, GD, SWB and SWP are compared in Figure 2-6.

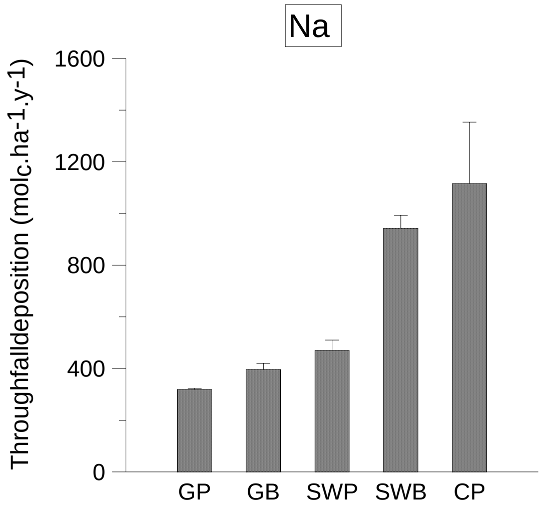


Figure 2-6: Throughfall deposition of Na^+, as indicator for dry deposition capacity, in the group cutting with pine (GP), group cutting with birch (GB), shelterwood with pine (SWP), shelterwood with birch (SWB) and the control plot with Scots pine (CP)

The control plot is receiving a higher amount of dry deposition than the regeneration plots in both the shelterwood and the group cutting. Because of the pine canopy above in the shelterwood plots, dry deposition is higher in both plots of the shelterwood compared to the plots of the group cutting.

In the group cutting, throughfall deposition of sodium is higher in the birch plot compared to the pine plot. This is contrasting with earlier results of De Schrijver *et al* (2004) who ascribed a lower dry deposition in a 40-year old silver birch plot compared to an even-aged plot of Corsican pine at differences in stand and crown characteristics, such as lower stand and crown density, lower LAI, and the deciduous character of the birch trees (Alcock & Morton 1985, Draaijers 1993, Houle *et al* 1999). Apparently other factors are influencing the dry deposition capacity of these regeneration plots. Also tree height has been reported to be of significant influence on the turbulent transport of gases and particles to forests (Erisman *et al* 2003). Both regeneration plots, although of the same age, are significantly differing in tree height. The average tree height of birch in the shelterwood cutting is 11 m, whereas the average tree height of the pine regeneration is only 4m. In the group cutting the differences in tree height are less pronounced, the birch regeneration measures 8 m, the pine regeneration 6m. We therefore hypothesize that the effect of tree height on dry deposition capacity dominates the effect of tree species. For both regeneration strategies a tree species ratio of sodium deposition (pine: birch) can be calculated. In the shelterwood cutting this ratio amounts to 0.50 and in the group cutting to 0.80. Both ratios are less than 1, which means that sodium deposition is higher for birch than for pine. Since the lowest ratio is encountered in the shelterwood cutting, we conclude that the difference in dry deposition capacity between both species is highest in the shelterwood cutting. This can be attributed to (1) the somewhat denser canopy of the overstorey above the birch plots compared to the pine plots and (2) the bigger difference in tree height between both species compared to the group cutting.

These differences in dry deposition capacity between the different management scenario's are reflected in differences in throughfall depositions of nitrate, ammonium and sulphate (Figure 2-7). Throughfall deposition of nitrogen and sulphur is highest in the control plot, lower in the plots in the shelterwood cutting and lowest in the plots in the group cutting. The difference in nitrogen and sulphur deposition between the birch and the pine plots is again much more explicit in the shelterwood cutting.

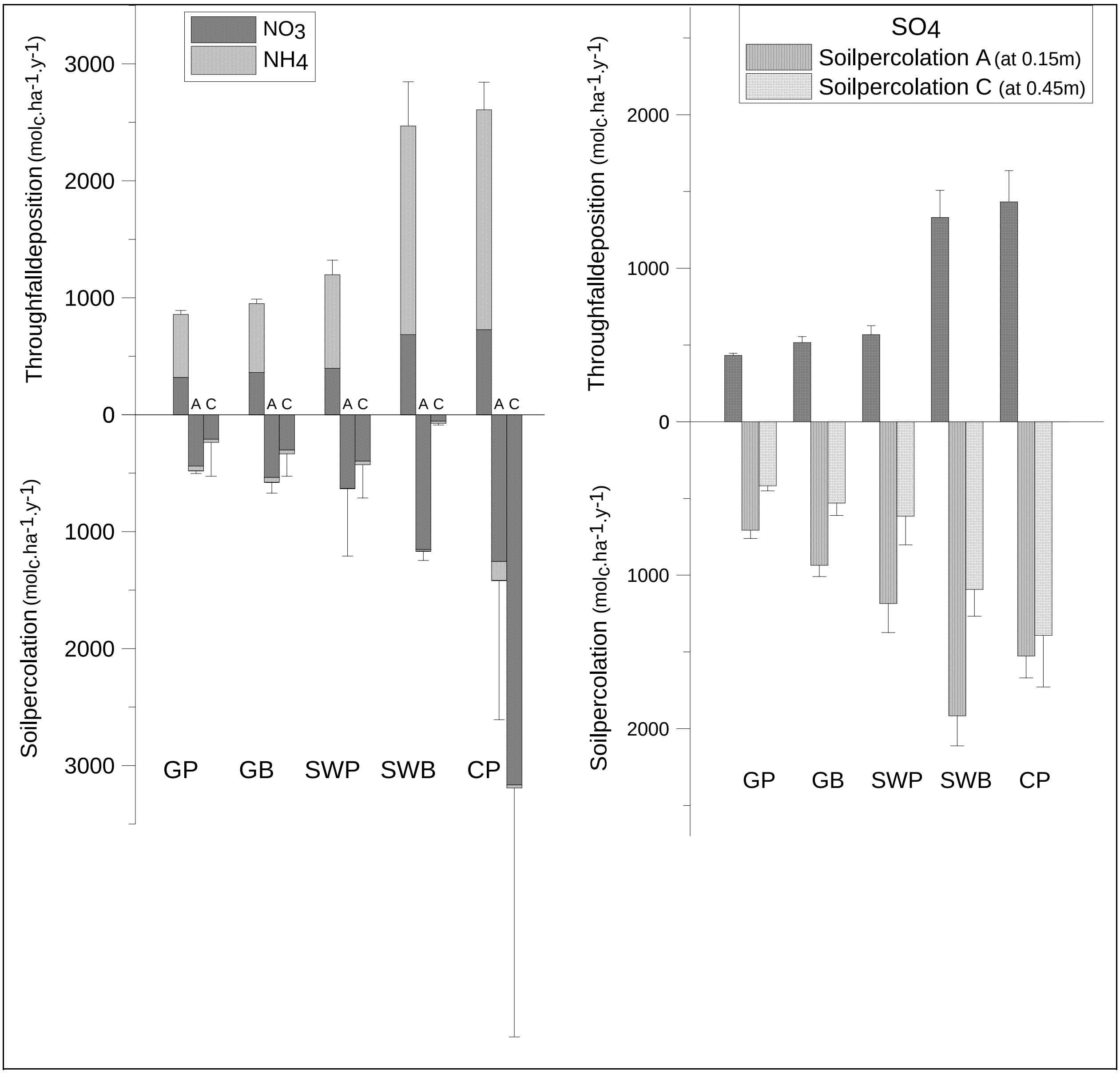


Figure 2-7: Throughfall deposition and soil percolation at 0.15 and 0.45 m depth of nitrogen and sulphur in the group cutting with pine (GP), group cutting with birch (GB), shelterwood with pine (SWP), shelterwood with birch (SWB) and the control plot with Scots pine (CP)

Percolation fluxes

Comparing N throughfall input and percolation at 0.15 m depth (Figure 2-7), we can conclude that the higher the input of nitrogen, the higher the output. Several other studies have indeed found a close relationship between the level of N deposition and level of N percolation, at least for those sites where saturation of the ecosystem with N is evident (Matson *et al* 2002, Macdonald *et al* 2002). At 0.45 m depth, this relationship between N input and N output disappears. Differences in NO_3^- percolation are probably determined by N uptake and retention capacity of each of both tree species. In all regeneration plots, N is retained between 0.15 and 0.45 m depth, while in the control plot NO_3^- percolation increases with depth. When expressing the N percolation at 0.45 m depth as a percentage of the N input via throughfall deposition, the difference between the control and the regeneration plot becomes very clear. For the regeneration plots this percentage varies from 2.3 to 33.2% (SWP 33.2%, SWB 2.3%, GP 24.5%, GB 31.9%), whereas for the control plot the percentage amounts to 121.4%! The N uptake and retention capacity of each regeneration plot can be calculated as the difference between nitrogen input and nitrogen percolation at 0.45m. Both the pine and the birch regeneration in the group cutting (GP and GB) retain 647 mol N $ha^{-1}y^{-1}$. In the shelterwood the N uptake and retention capacity of the birch regeneration (SWB) is 2413 mol N $ha^{-1}y^{-1}$. This is much higher than that of the pine regeneration (SWP) 799 mol N $ha^{-1}y^{-1}$. Up till now, the birch regeneration has grown much larger than the pine regeneration under the shelterwood. It may therefore have a higher N demand. Otherwise, the pine shelter is a little denser above the birch regeneration and therefore also be responsible for a higher N demand. In the group cutting, the pine regeneration is much denser than the birch and the (height) growth difference is less expressed. N demand may therefore be similar between both species. NH_4^+ is not entirely nitrified at 0.15 m depth in the control plot, while in all regeneration plots NH_4^+ is almost completely oxidized to NO_3^-.

For SO_4^{2-}, the same pattern in throughfall deposition could be seen as for nitrogen. Furthermore, the output at 0.15 m depth is higher than throughfall deposition input and than percolation at 0.45 m depth. Previously adsorpted SO_4^{2-} is probably desorpted in the upper horizons and then taken up by vegetation or leached and adsorpted again in the deeper soil layers. Several factors are influencing the adsorption capacity of soils (e.g. pH, organic matter, quantity of Al and Fe oxides, ...). More intensive research is needed to explain the ongoing sorption and transformation processes of SO_4^{2-}.

Throughfall deposition of base cations K^+, Ca^{2+} and Mg^{2+} (Figure 2-8) are determined by both the process of dry deposition and canopy exchange. Throughfall deposition of K^+, which originates over 70% from canopy leaching (Houle *et al* 1999, Van Ek & Draaijers 1994, Parker 1983, Ragsdale *et al* 1992), is obviously higher in the shelterwood cutting with birch regeneration than in the control plot and this despite its lower interception capacity. This means that the external input through dry deposition is indeed of minor importance than the internal cycling as a consequence of canopy exchange processes. This can be attributable to thinner cuticles and higher wettability of birch foliage. Houle *et al* (1999), Van Ek & Draaijers (1994) and Alcock & Morton (1985) also found that deciduous canopies leached significantly more K^+ than coniferous canopies. Also in the group cutting, higher K^+ deposition is found in the birch plot compared to the pine plot.

In all plots, percolation flux of cations is dominated by percolation of Al(III). All plots are clearly so acidified that Aluminium hydroxides, originating from weathering products of primary silicates (mainly clay minerals), dissolve into the soil solution and leach into the ground water (Ulrich 1983). Different mechanisms might be responsible for the highest mean percolation flux of Al(III) in the control plot. A high acidification of the soil due to a high proton input can be responsible. Soil acidification will induce displacement of cations by protons, thereby reducing the base cation pool and increasing the proportion of Al(III) on the soil-exchange complex (Boxman *et al* 1998, Bredemeier *et al* 1998, Tietema *et al* 1998). Furthermore, a higher percolation of anions in the control plot involves a higher soluble cation fraction, making total cation percolation a function of total anion percolation (Johnson 1992).

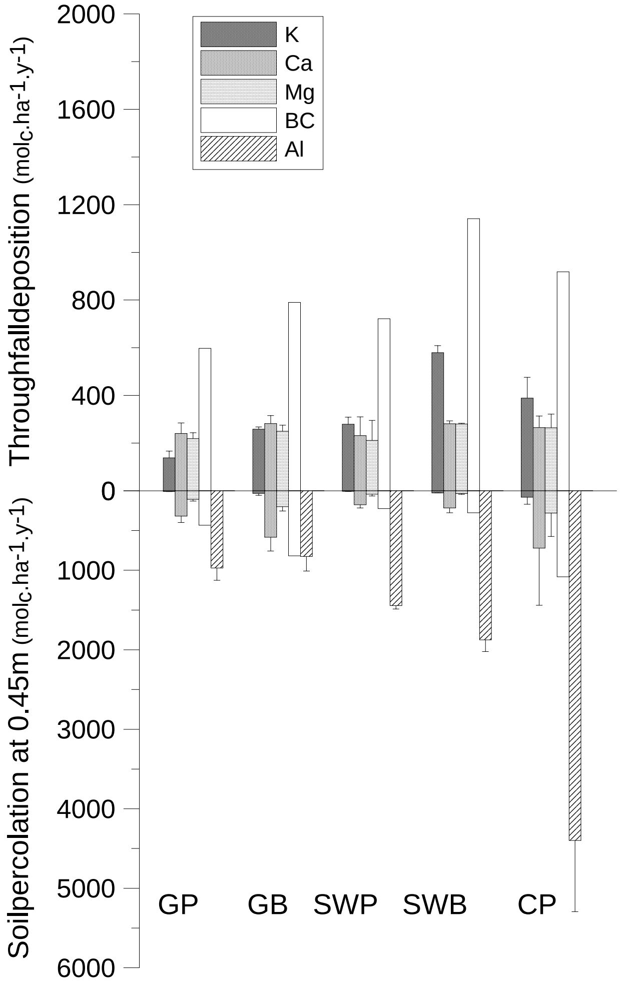


Figure 2-8: Throughfall deposition of base cations K^+, Ca^{2+} and Mg^{2+} and soil percolation at 0.15 and 0.45 m depth of the same elements and Al (III), in the group cutting with pine (GP), group cutting with birch (GB), shelterwood with pine (SWP), shelterwood with birch (SWB) and the control plot with Scots pine (CP)

2.3.4 Conclusions

The main differences in nutrient cycling between the conversion scenarios, can be linked both to tree species in the regeneration and to the vertical and horizontal structural characteristics of the stands. In general dry deposition (interception efficiency) of a stand decreases after thinning, but increases from the moment the regeneration reaches a certain height and eventually grows into the pine canopy.

Based on the input and output balances measured for the different scenarios, the best way to reduce the input of acidifying elements, may be to cut groups in Scots pine stands and promote the regeneration of Scots pine. But the lower interception in a group cutting or in a shelterwood where pine seedlings grow is very timely. At the moment, the pine regeneration is much lower as compared to the young birches, which have their maximal height increment within the first 20 years. Scots pines have a modest maximal yearly height growth, but it continues steadily for several decades. This relative advantage of the pine regeneration will decrease over the next decades. Moreover, the end result will be a new conifer stand, comparable to the control stand, but possibly with more than one canopy layer. As we know from the control plot and the findings in Section 2.1, the interception capacity for atmospheric pollution of a conifer stand is higher than that of a deciduous stand.

Looking at the element output to the ground water (percolation), the relative advantage of the pine regeneration isn't noticeable any more. Although the input of acidifying and eutrophicating elements in the shelterwood with birch regeneration is much higher, the percolation at 0.45 m depth of basic cations, Al(III) and NO_3^- is comparable to that under the shelterwood with pine regeneration. This points at the much higher retention and uptake capacity of birch.

An important remark is that our comparison of input and output balance of acidifying and eutrophicating elements is incomplete, since it compares snapshots in time. To be able to compare the entire impact of a chosen conversion scenario all development phases must be considered. Both the element cycling in each phase and the duration of the phase have an impact:

- Immediately after the cutting of a group, there may be high losses of N and other elements through percolation, but this phase only lasts about a year or three. A shelterwood (continuous cover) scenario may avoid such high initial losses.
- The development of an understorey from natural regeneration -with lower interception and throughfall deposition- may only take about 10 years, while the phase were the second generation grows into the pine overstorey may last 40-50 years.

An important research need is therefore an entire life cycle analysis of a conversion scenario with all development phases and management steps (see Appendix Forest Conversion Scenarios).

- first strong thinning of pines or group cut
- reaction phase to this thinning or cut
- establishment of a regeneration
- ingrowth of regeneration into the pine canopy
- removal of the remaining pine canopy
- pure broadleaved stand.

One other consideration is that at the boundaries of a group cutting there may be an internal forest edge effect (De Schrijver *et al* 1998). This may cause higher element depositions at the edges of a group. Because we avoided the group boundaries when selecting the throughfall and percolation plots, we do not have data to confirm or reject this possibility.

2.4 Mass loss and nutrient dynamics during three year litter decomposition of seven tree species after conversion of a Norway spruce plantation

Carnol Monique

2.4.1 Introduction

European forests have been influenced by human activities over the centuries and, in Belgium, planted forests dominate (see Section 1.5). Atmospheric pollution, climate change and intensive management are some of the many factors causing stress to forest ecosystems. Already in the early studies of ecology, concerns were raised about soil degradation resulting from raising fast-growing woodlands on poor soils (e.g. Ovington 1962). Eventually, forest dieback observed in the 1980's has lead to the concept of 'sustainable forest management', including the forest's economic (production), ecological (forest health, soil quality, biodiversity) and social (leisure) functions. For example, the improved Pan-European indicators for sustainable forest management (MCPFE Expert Level Meeting, Vienna, Austria, October 2002) include: 'Maintenance of Forest Ecosystem Health and Vitality', 'Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems' and 'Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably Soil and Water)'. This chapter deals with soil quality, which is of is of particular importance through its roles in filtering pollutants, in buffering acidity, in plant nutrition (connected to organic matter mineralization) and water protection (Pankhurst *et al* 1997).

In addition to their impact on biodiversity, tree species may influence forest ecosystem functioning. Their impact on biogeochemical cycles can be seen at three levels: (1) interception of pollutants (de Schrijver *et al* 2004) (2) leaching of elements and (3) composition and decomposition of litter. The litter decomposition process is fundamental to nutrient recycling in ecosystems, as nutrients released by decomposition can reflect up to 70-90% of the yearly nutrient demand of essential elements of forest species (Huang *et al* 1998). In poor soils, litter decomposition can be the process that limits nutrient cycling and forest productivity (Flanagan & van Cleve 1983). In the Walloon region, and particularly in the Ardenne region, a large proportion of forest soils present a low pH, associated with calcium and magnesium deficiencies (Buldgen 1984, Claessens *et al* 2001, Lambert *et al* 1990). In these areas, the nutrient supply to forest plantations is largely dependent on the recycling of mineral nutrients from organic matter in the upper soil horizons.

The litter decomposition process is controlled by the physico-chemical environment, the decomposer organisms and the resource (litter) quality (Swift *et al* 1979). In the case of forest conversion at one site, the physico-chemical environment is identical and litter chemical composition is thought to dominate the process at a local scale. Furthermore, recent research did not provide support for the notion that woodland plants encourage the development of soil communities that rapidly decompose their litter (Ayres *et al* 2006). Several authors indicate that the quality/composition of litter may influence soil fertility (Augusto *et al* 2002), however quantitative estimates comparing nutrient release of different forest species are scarce.

The objective of this study was to investigate mass loss and release of some essential plant nutrients from different leaf litters decomposing at the same site, to suggest their possible impacts on the nutrient economy of the forest ecosystem after conversion of Norway spruce.

2.4.2 Material and Methods

Study site

The decomposition experiment was performed within the 81 ha catchment 'Robinette', situated in the 'Hertogenwald' forest (50°33'50''N, 6°4'24''E) of the Haute-Ardenne region, south-eastern Belgium (Budgen 1984). It is located in the 'Massif de Stavelot', on Cambrian geological bedrock consisting of quartzites, quartzo-phyllades and phyllades, covered by pleistocenic (quaternary) eolian loess loam. Soils in the Haute Ardenne are naturally poor in base cations, with a base saturation of 10-15% in the mineral soil horizon (Delecour 1978). At the 'Robinette' site, soils are characterised by the presence of pseudogley with moder to dysmoder humus type and with a soil depth varying between 0.35 and 2 m. They correspond to the reference soil group 'Gleysol dystrique' (World Reference Base for soil resources).
The altitude ranges from 470 to 530 m (declivity 8%). The annual rainfall is 1300 mm and mean annual air temperature is 7°C. The catchment was completely covered with *Picea abies* (L.) Karst. But by 1995 the forested area was reduced to 80% (mainly due to windthrow) with only 43% coverage of mature trees. End of 1996, a further 22 ha were clearcut, followed by an extensive afforestation program in 1998. The objective was to develop a mixed plantation, favouring deciduous species adapted to site conditions (Weissen & Michaux 1999, Weissen *et al* 1991, Weissen *et al* 1994), planted at low density. *Alnus glutinosa* (L.) Gaertn, *Fagus sylvatica* (L.) (at the borders of the catchment), *Betula pendula* Roth, *Populus tremula* L., *Quercus petraea* L., *Sorbus aucuparia* L., *S. caprea caprea* L; *Abies procera* Rehder, *Picea sitchensis* (Bong.) Carr were planted with individual protections in the catchment and in four fenced 2-ha plots. In these plots, trees were planted in rows with a spacing of 2.5 m. Ground vegetation was composed of the grasses *Molinia caerulea* (L.) Moench and *Deschampsia flexuosa* (L.) Trin and of the dwarf shrub *Calluna vulgaris* (L.) Hull. The moss layer was composed of *Polytrichum formosu*m and *Sphagnum* sp. The decomposition experiment was performed within one of those fenced plots. Selected soil characteristics can be found in Table 2-5.

Table 2-5: Characteristics of the underlying soil at the decomposition site. Exchangeable cations were extracted with 0.1 M $BaCl_2$ (Henderschot & Duquette 1986).

Soil layer (cm)	pH_{H2O}	Exchangeable cations ($cmol_c$/kg)				
		Al	Ca	K	Mg	Na
0-10	4.3	6.46	5.59	0.33	0.97	0.31
10-20	4.4	2.65	0.27	0.02	0.05	0.07
20-40	4.3	2.53	0.11	0.01	0.03	0.06
40-60	4.7	1.56	0.09	0.03	0.03	0.06

Litterbags and experimental design

Newly fallen leaf litter of *A. glutinosa*, *F. sylvatica*, *B. pendula*, *P. tremula*, *Q. petraea*, *S. aucuparia*, *S. caprea* and *P. abies* was collected in autumn 1999 from nylon nets placed under mature trees situated within 2 km of the experimental site on similar soils. They were pooled to one composite sample for each species and air-dried. Litter (4 g) was then placed in nylon net bags (Solana NV, Schoten, Belgium), sized 20x20 cm and with 1.4 mm mesh size (2 g in 10x10 cm bags with mesh size of 0.7 mm for *P. abies*). For *S. aucuparia*, leaflets were placed in the litterbags; stalks were only analysed for the fresh litter. Initial element content of the litter was analysed on seven sub-samples for each species of the initial composite sample, after drying at 85°C. To facilitate sampling, one litterbag of each species was linked by a wire. Lines were placed in the field in seven blocs and litterbags were fixed on the ground by small stainless steel pins. Seven replicate lines (one randomly chosen line from each block) were sampled after 1, 2 and 3 years in the field. Litter was cleaned manually to remove non-original plant material and soil. The cleaned samples were oven dried (85°C), weighed and ground (0.8 mm) for chemical analyses.

Analytical methods

Litter (0.2 g) was digested using a sulphuric acid-hydrogen peroxide procedure, including lithium sulphate and selenium (Allen 1989). A boiling stage was included for optimal recovery of Fe and Mn (results not shown). Digests were analysed for Ca, K, Mg, P, Al, Na, by ICP-AES (Varian – VISTA). C and N were analysed on a CHN Carbon Nitrogen analyser (Carlo-Erba NA 1500).

Data analysis

The ratio air dry/oven dry of each species for the initial samples was used to correct air dry mass placed in each litter bag at the beginning of the experiment. The difference between species for each sampling time was analysed using Analysis of Variance procedures followed by Duncan's post-hoc test (SAS 1989). Nutrient release was calculated as the difference between the nutrient content at sampling (taking into account the mass remaining) and initial nutrient content for 1 g of litter.

2.4.3 Results and discussion

Initial nutrient contents

Table 2-6: Initial nutrient contents of the litters (mg g^{-1}). Values are mean and standard deviation of 7 replicates (n=7), except for *Picea abies* (n=4) and *Sorbus aucuparia* stalk (n=5). Data in the same columns with different letters are statistically different at P < 0.05 using one-way ANOVA.

		Ca	K	Mg	P	Na	C	N	C/N
Alnus glutinosa	**mean**	9.98^{c}	3.08^{b}	2.87^{b}	0.55^{c}	0.31^{b}	506.86^{ab}	22.19^{a}	22.97^{e}
	sd	*1.67*	*3.19*	*0.24*	*0.11*	*0.09*	*28.15*	*2.18*	*1.79*
Betula pendula	**mean**	8.20^{d}	2.98^{b}	1.67^{c}	0.55^{c}	0.14^{c}	506.14^{ab}	10.55^{d}	48.39^{c}
	sd	*1.35*	*0.43*	*0.25*	*0.14*	*0.07*	*28.77*	*0.93*	*5.77*
Quercus petraea	**mean**	5.16^{e}	3.22^{b}	0.74^{d}	0.35^{d}	0.30^{b}	481.86^{bc}	9.17^{de}	53.45^{c}
	sd	*0.52*	*1.16*	*0.06*	*0.19*	*0.03*	*25.14*	*1.44*	*7.38*
Picea abies	**mean**	2.97^{f}	1.95^{b}	0.33^{e}	0.67^{c}	0.23^{b}	521.95^{ab}	10.65^{d}	49.11^{c}
	sd	*0.06*	*0.11*	*0.00*	*0.03*	*0.05*	*49.50*	*1.02*	*3.60*
Fagus sylvatica	**mean**	5.87^{e}	3.02^{b}	0.96^{d}	0.26^{d}	0.27^{b}	517.73^{ab}	8.41^{e}	61.55^{b}
	sd	*0.70*	*0.68*	*0.14*	*0.04*	*0.07*	*35.09*	*0.57*	*1.43*
Salix caprea	**mean**	20.25^{a}	7.94^{a}	1.56^{c}	1.66^{a}	0.71^{a}	463.21^{c}	18.18^{b}	25.70^{e}
	sd	*1.83*	*0.68*	*0.16*	*0.19*	*0.07*	*15.19*	*1.86*	*2.62*
Sorbus aucuparia	**mean**	14.28^{b}	2.18^{b}	2.88^{b}	0.95^{b}	0.31^{b}	535.17^{a}	12.49^{c}	43.15^{d}
	sd	*0.71*	*0.42*	*0.24*	*0.07*	*0.04*	*44.44*	*1.45*	*4.11*
Sorbus aucuparia (stalk)	**mean**	15.65^{b}	2.87^{b}	3.20^{a}	0.37^{d}	0.67^{a}	483.90^{bc}	5.07^{f}	95.58^{a}
	sd	*0.69*	*0.68*	*0.17*	*0.04*	*0.10*	*20.55*	*0.15*	*4.92*

Litters from the seven tree species differed greatly in their nutrient contents (Table 2-6). For example, Ca contents ranged from 3 (*P.abies*) to 20 (*S. caprea*) mg g^{-1} and Mg contents from 0.3 (*P. abies*) to 3 (*A. glutinosa*, *S. aucuparia*) mg g^{-1}. Coniferous species are generally assumed to have lower nutrient contents than broadleaved species (Augusto *et al* 2002), which was confirmed for Ca and Mg in *P. abies* litter. *S. caprea* showed highest contents of Ca, K, P and Na and *S. aucuparia* was also rich in Ca, Mg, P and Na. Main forest species (*Q. petraea*, *P. abies*, *F. sylvatica*) showed lowest contents for Ca, K and Mg. C contents ranged from 463 (*S. caprea*) to 535 mg g^{-1} (*S. aucuparia*), with few significant differences between species (Table 2-6), so that differences in C/N ratios were due to different N contents. *A. glutinosa* and *S. aucuparia* litter showed highest N contents and lowest C/N ratios, whereas *F. sylvatica* showed the highest C/N ratio (62), followed by *Q. petraea*, *P. abies* and *B. pendula*.
Total base cation content was highest for *S. caprea* (Figure 2-9), attaining 1.37 $mmol_c$ g^{-1}, followed by *S. aucuparia*, *A. glutinosa* and *B. pendula*. Again, main forestry species (*Q. petraea*, *P. abies*, *F. sylvatica*) had the lowest base cation content (below 0.46 $mmol_c$ g^{-1}). For all species, Ca was the main base cation (62-74%), followed by Mg (9-29%) and K (5-21%).

Differences in nutrient contents between leaf litters are generally explained by site conditions and species. In this study, although litters were not collected at the same site, soil conditions were similar and the main factor controlling litter nutrient content was thought to be species identity. Such differences between species and preferences for certain ions are considered to be inherent species characteristics (Larcher 2003) and can be explained by the rooting depth and assimilation mechanisms, such as enzyme or organics production (Barnes *et al* 1986, Larcher 2003). Furthermore, data from Weissen & Michaux (1999), studying 8 species across 21 sites (minimum 5 sites/species), indicated that the impact of species identity may be greater than the impact of the site. This author also reported highest nutrient cation contents in litter from secondary forest species (Acer, *S. aucuparia*, Populus) and lowest contents for main deciduous forest species (*F. sylvatica*, *Q. petraea*). Literature data comparing litter nutrient contents of more than 2 species growing on similar soils are scarce. For example, Berg & Staaf (1987) reported higher concentrations of nutrients in *B. pendula* compared to Pinus. However, it is generally assumed that foliage nutrient content is higher for deciduous species than for conifers.

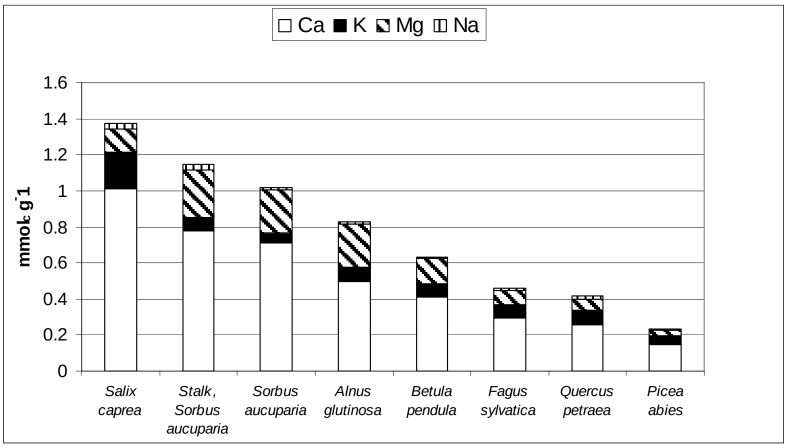


Figure 2-9: Base cation content of seven tree leaf litters.

Mass remaining

Mass loss was highest during the first year of decomposition, with species clustering into 3 significantly different groups ($P<0.05$) with 27 % (*S. aucuparia*), 54% (*A. glutinosa*, *B. pendula*, *S. caprea*) and 73% (*Q. petraea*, *P. abies*, *F. sylvatica*) mass remaining. The same grouping was observed for the second and third year of decomposition (Table 3). After 3 years decomposition, remaining mass attained 18% (*S. aucuparia*), 35% (*A. glutinosa*, *B. pendula*, *S. caprea*) and 56% (*Q. petraea*, *P. abies*, *F. sylvatica*).

Figure 2-10: Mass remaining (%) after 1 to 3 year of decomposition in the field of seven tree leaf litters. Values are means and standard deviations (sd) of seven replicates, except for *Picea abies* (n = 6) and *S. aucuparia* (n = 3-6), na: not available.

		years		
		1	**2**	**3**
Alnus glutinosa	**mean**	55^b	42^b	30^b
	sd	*12*	*13*	*17*
Betula pendula	**mean**	53^b	39^b	37^b
	sd	*13*	*7*	*9*
Quercus petraea	**mean**	68^a	48^{ab}	52^a
	sd	*5*	*5*	*7*
Picea abies	**mean**	77^a	58^a	55^a
	sd	*3*	*6*	*10*
Fagus sylvatica	**mean**	73^a	56^a	61^a
	sd	*4*	*8*	*8*
Salix caprea	**mean**	53^b	42^b	38^b
	sd	6	9	8
Sorbus aucuparia	**mean**	27^c	*na*	18^c
	sd	9	*na*	4

As the seven leaf litters were decomposing at the same site, differences in litter decomposition rates are mainly related to resource quality. Species initially rich in N (*A. glutinosa*, *S. caprea*, *S. aucuparia*), with generally lowest C/N ratios, decomposed more rapidly than N-poor litters. N content and C/N ratios are generally accepted as factors influencing decomposition rates (McClaugherty & Berg 1987, Aber *et al* 1990). However, other factors may play an important role, as indicated by the rapid decomposition of *S. aucuparia*. The C/N ratio of this species is indeed in the same order of magnitude as the ratio of slow decomposing species. Lignin content and lignin/N ratio are also often cited as factors important in controlling litter decomposition (Berg 1984, McClauerty & Berg 1987, Cotrufo *et al* 1984), especially in the later stages (Berg 1984). The slow decomposition of *P. abies*, compared to other species with similar N content, may be explained by the high polyphenol and lignin content of conifers (Berg & Staaf 1980).

Nutrient release

The amount of nutrient released by the litters reflects their initial nutrient content, combined with their decomposition rate. For most elements and species, the major amount of the nutrient was released during the first year of decomposition (Figure 2-11), as also noted for *B. pendula* by Berg & Staaf (1987).

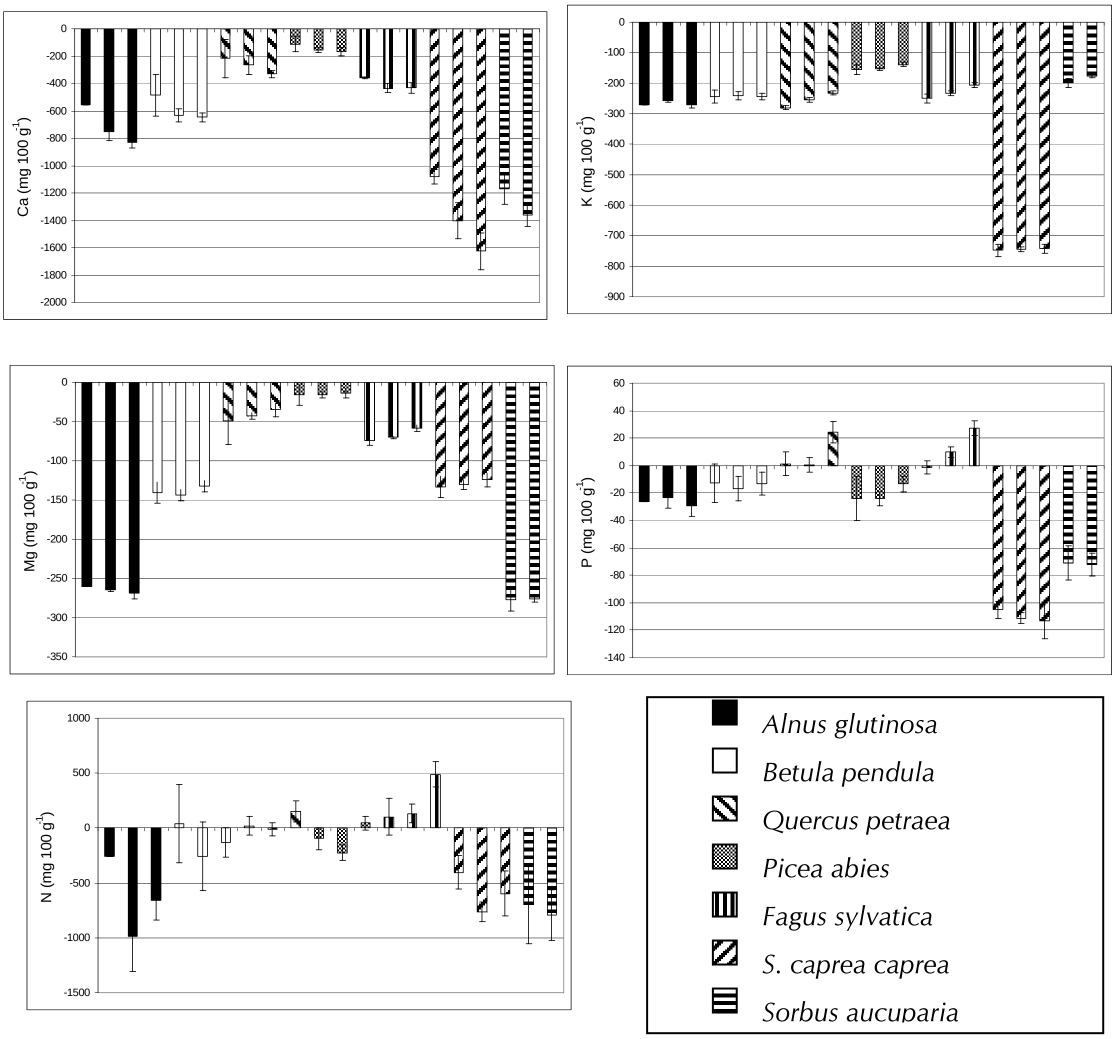


Figure 2-11: Cumulative mean nutrient release (negative values) or immobilisation (positive values) from seven tree litters during 1, 2 and 3 (successive bars) years of decomposition (except *S. aucuparia*: 1 and 3 years). Vertical bars indicate standard deviation of the mean.

S. caprea and *S. aucuparia* released the highest amounts of Ca (above 1000 mg g^{-1}), followed by *B. pendula* and *A. glutinosa* (between 500 and 800 mg g^{-1}). *Q. petraea*, *P. abies* and *F. sylvatica* released low amounts (between 100 and 400 mg g^{-1}). P release was also highest for *S. caprea* and *S. aucuparia* (70-110 mg g^{-1}), whereas *A. glutinosa*, *B. pendula* and *P. abies* released low amounts (around 20 mg g^{-1}). *Q. petraea* and *F. sylvatica* immobilised P, indicating that P is possibly a limiting nutrient for decomposing microorganisms of these species (Berg & Staaf 1987). Mg release was highest for *A. glutinosa* and *S. aucuparia* (around 260 mg g^{-1}), followed by *B. pendula* and *S. caprea* (around 130 mg g^{-1}). As for Ca, lowest Mg release was measured for *Q. petraea*, *P. abies* and *F. sylvatica* (below 70 mg g^{-1}). K release was only higher for *S. caprea* (745 mg g^{-1}), compared to other species (225 mg g^{-1}). N release occurred for *A. glutinosa*, *S. caprea* and *S. aucuparia* (above 500 mg g^{-1}). For *A. glutinosa*, the release occurred mostly during the second year of decomposition. *F. sylvatica* showed highest N immobilisation (500 mg g^{-1}), especially during the third year of decomposition.

In view of improving the soil nutrient status, *S. aucuparia* seems to be interesting with regard to Ca, P and Mg. *S. caprea* could provide an improvement in Ca, P and K whereas *A. glutinosa* released more Mg. Nutrient release by the main forest species (*Q. petraea, F. sylvatica, P. abies*) is significantly lower. *S. caprea*, *S. aucuparia* and *A. glutinosa* might therefore be interesting species for the improvement of the nutrient status of poor forest soils. However, these species also show net N mineralization which might be linked to N leaching on N saturated sites.

Besides litter quality, the effective input of nutrients to the upper forest soil horizons depends on the area planted with these species and their litter quantity. In closed-canopy temperate forests, the amount of litterfall is only slightly influenced by species (Augusto *et al* 2002) and tree density (Bray & Gorham 1964). During conversion or in mixed stands, however, planting pattern and species proportions will influence the amount and spatial distribution of leaf litters with different chemical qualities. Thus the actual effect of tree species through litterfall during conversion and in mixed stands will be mainly influenced by litter chemical composition in interaction with forest management.

2.4.4 Conclusions

This study demonstrated the impact of litter quality on the decomposition seven tree litters at the same site, after conversion from a mature Norway spruce stand. Litter from main forest species (*P. abies*, *F. sylvatica*, *Q. petraea*) are characterised by lower decomposition rates than litter from secondary species (*A. glutinosa*, *B. pendula*, *S. caprea*, *S. aucuparia*). These lower rates may be explained by initially lower N content, higher C/N ratios and several other factors (contents in lignine, polyphenols, decomposing organisms,...). The secondary species studied showed higher initial contents in Ca, Mg, K, highest decomposition rates and highest nutrient release. They may therefore play an important role in restoring the nutrient status in poor sites.

3 ECOLOGICAL FEASIBILITY OF FOREST CONVERSION: Can conversion of secondary coniferous into deciduous forest enhance biodiversity?

Geudens Guy, Verheyen Kris, Degrave Frédéric & Carnol Monique

3.1 Effect of forest conversion on species diversity

3.1.1 Introduction

A literature review was performed on the effects of forest conversion (change in the dominant tree species from coniferous to deciduous) on biodiversity, highlighting pine and spruce forests in Belgium. Although we acknowledge that forest management influences the diversity at genetic, interspecific, ecosystem and landscape level (Decocq 2002), the definition of biodiversity was restrained to the species level for this review. Particularly important to the biodiversity value of Belgian forests are true forest species, in particular ancient forest species (for plants: Hermy *et al* 1999). Secondly, we distinguish between plant and animal diversity. Plant diversity is relatively easy to assess in forest inventories (Rondeux 1994, Dirkse & Martakis 1998) and can then be linked to tree species composition (De Roo 2005). But this still doesn't assure an easy comparison between forests or stands of different tree species composition based on forest inventories, because of confounding factors. For animal diversity we distinguish between species directly associated with a forest tree species and indirectly related species. Diversity of fungi is discussed under both plant and animal diversity. Data on microbial diversity are still too scarce to be included in this literature review.

3.1.2 Effects on diversity of vascular plants and bryophytes

The abundance and the diversity of the herbal vegetation in a forest is dependent on several factors (i) site characteristics like solar radiation reaching the forest floor, soil temperature, topography and soil fertility (Pitkänen 2000), (ii) management regime (Decocq *et al* 2005), isolation from and distance to colonization sources (Dzwonko & Gawronski 1994) and (iii) land use history (Verheyen *et al* 2003). The dominant tree species influence some of the site characteristics directly and therefore determine plant species diversity (causal factors). But the relationship between dominant tree species and site characteristics and between site and herbal vegetation is complicated. What's more, several confounding factors blur these relationships. Land use history, internal forest succession, management regime and exotic broadleaves are all mentioned in literature for their effect on diversity of the herbal layer. Each of them is relevant to the secondary pine and spruce plantations under consideration. In other words, it is not possible to simply compare the plant diversity of a coniferous and a deciduous forest stand and attribute all the observed differences to effects of the tree species composition. Even if direct effects are found through meticulous research, these will not allow predicting the diversity change in a stand after conversion, without knowledge about the confounding factors.

An important note is that the potential or natural plant species diversity is relatively low on a major part of the sites under pine and spruce plantations in Belgium. The soils in these areas have been acidified and lost most of their buffering capacity through centuries of exhaustive agricultural use (see Section 1.5). The prevailing natural forest types of pine plantation sites in Flanders are birch oak forest and acid oak-beech forest. Both are characterized by relatively few higher plant species, be it with a somewhat higher number of bryophyte species (De Keersmaeker *et al* 2001, Dirkse & Martakis 1998). By this fact alone, a strong increase in the species composition after conversion to the level of diversity that would be found in a virgin deciduous forest on these sites, is not to be expected, not even in the long term (A in Figure 3-1). The same note applies to large surfaces in the Walloon Ardennes were naturally an acid beech forest would prevail.

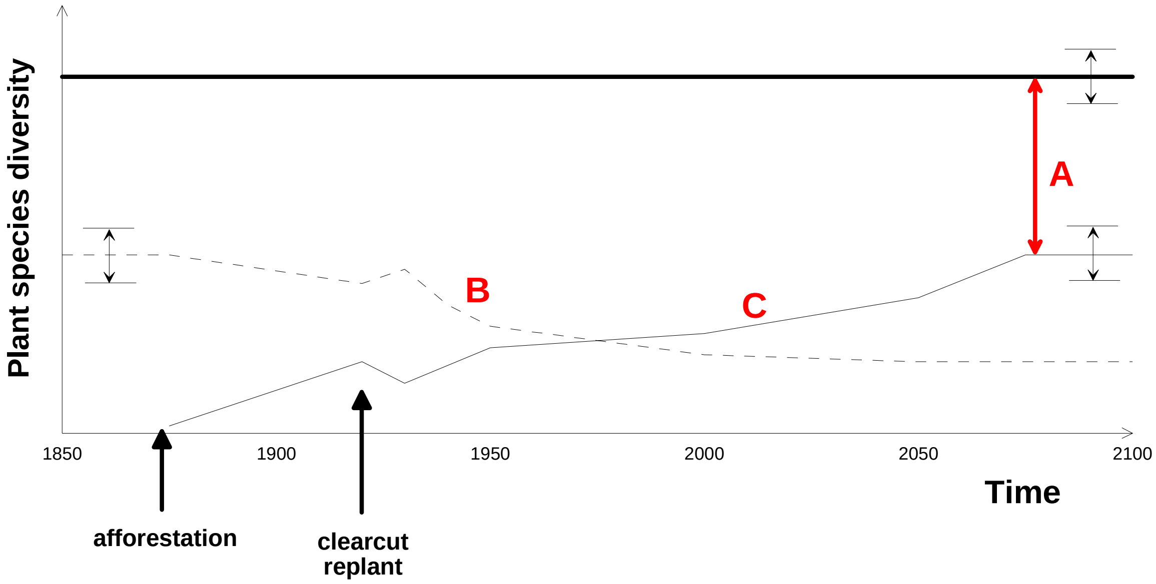


Figure 3-1: Evolution of plant species diversity in secondary conifer plantations on former heathland (dashed line: heathland plants, full line: true forest plants) and in an imaginary virgin forest on an undisturbed site (bold line: true forest plants)

Causal factor: light

The light penetration under the canopy is one of the main limiting factors to the development of the herbal layer (du Bus de Warnaffe *et al* 2004). The quantity and quality of the sub-canopy light depends strongly on the canopy tree species but also on the developmental stage of the forest and on the thinning regime. Phenology of leaf sprouting in spring and leaf shedding in autumn can influence the microclimate in the understorey (Gosselin 2004). Canopy cover of Scots pine is less dense than that of oak and beech at comparable sites in Western Europe, which promotes a greater cover of all understorey layers (Augusto *et al* 2004). Under selectively cut high forest the amount of light is less than 5% of full sunlight (Simmons & Buckley 1992). Under pole stages of most tree species and especially of beech and conifers this can decrease to 1% (Schmidt *et al* 2004). Simmons and Buckley (1992) have shown that the diversity and abundance of bryophytes (mosses) in a mixed spruce-oak stand was positively correlated with the percentage cover of Norway spruce. The moss stratum is very tolerant to shading and seems to find optimal growing conditions under spruce. However, the diversity of bryophytes within a pure spruce forest is rapidly reduced after the canopy closure in a young plantation (Wallace & Good 1995).

Causal factor: litter

The litter quality is tree-species dependent (see Section 2.4) and has a strong impact on the characteristics of the top soil layer, which is the main rooting zone of the herbal layer. Apart from the chemical composition (see 2.1.2.), also the structure of the leaf litter is important. Red oak (*Quercus rubra* L.) for instance has large leaves that decompose slowly. In fall, these leaves cover the forest floor and impede plant colonization. On the contrary for invertebrates, like ground beetles and Isopoda, such a litter structure can provide a suitable habitat (Barkman 1992).

Under poor forest types (*Quercetea robori-petraea* on sandy soils in the Netherlands), the influence of the independent site factors (soil parent material) decreased with time of afforestation, while the variable factors (tree species and humus type) became more important. Moder and more humus types show a self-reinforcing process of acidification. The tree species seems to matter especially in gradient zones between richer and poorer forests that are basic cation leached, but still have some buffer capacity left (Hommel *et al* 2002). Of the ancient forest plants in the research of Hommel *et al* (2002), three species preferred the poor sites, four were indifferent between poor and rich sites, eight were mainly found on the richer side of the gradient and nine were restricted to the rich forest plots. Poorer forest types were also more prone to invasion of brambles and bracken fern. In Flanders a negative effect of a low pH on forest plant diversity was found in ancient forest patches on dry sandy soils (Dumortier *et al* 2000).

Admixture of accompanying broadleaved species in beech forest may ameliorate humus quality and with that biodiversity of the soil microorganisms (Weissen 1986). This in turn can influence the diversity of predator species feeding on the soil organisms, like ground beetles (du Bus de Warnaffe *et al* 2004).

Augusto *et al* (2004) studied the differences in species diversity at a wide range of forests on dry acidic soils. As compared to oak and beech, Scots pine forests had a deeper litter layer, a higher C/N ratio (0-10 cm), a lower pH (0-10 cm), and higher Al and Al-oxide concentrations (0-10 cm). Nevertheless these authors found no significant difference in biodiversity of the herbal layer between forests under oak and pine at comparable sites.

Causal factor: root system

Gosselin (2004) found many references that proved root competition was a main factor of influence by the dominant tree species on ground vegetation. This effect was most pronounced in stands that had since long been dominated by certain species, in stands that had received few management or in very dense stands (pole stages). A clear example is the intense rooting of the soil surface layers by beech that impedes the development of a herbal layer.

Causal factor: bark

Epiphytic mosses and lichens can be specific to certain bark characteristics of a tree species, like texture, colour, amount of stem flow and pH (Humphrey *et al* 2004, Kiessling *et al* 2004). Oak, beech, alder, ash and maple have a richer epiphytic community than other species (see under in Figure 3-2).

Causal factor: atmospheric deposition

Changes in both herbal vegetation and mycoflora of Dutch forests during the last decades are mainly due to the eutrophicating effect of atmospheric nitrogen deposition, which is now considered as the greatest threat to forest biodiversity on sandy soils (van Tol *et al* 1998). Nitrogen-intolerant species (especially lichens of the genus *Cladonia*) have strongly declined, while N-demanding plant species increased: *Deschampsia flexuosa, Molinia caerulea*, *Corydalis claviculata*, *Rubus sp.* and *Dryopteris dilatata*. In Flanders, of the nitrogen-demanding vascular plant species, 13% are on the Red list of endangered species. Of the nitrophobe species 40% are endangered (MIRA 2003). However, except in the case of lichens (Aptroot *et al* 1998), eutrophication through atmospheric N-deposition has not yet resulted in a loss of species. What's more, the total plant species densities in Dutch forests have increased over the last decades. This applies particularly to Scots pine forests (Samsen 1995 in Dirkse & Martakis 1998, van Dobben *et al* 1994). Over the period 1960-1980, Arnolds (1988) showed a general decline of ectomycorrhizal fungi in the Netherlands, e.g. of the well-known Yellow Chanterelle. Meanwhile parasitic and saprophytic fungi tended to increase (Arnolds & Jansen 1992). Taylor *et al* (2004) found that morphotype diversity of ectomycorrhizal fungi in spruce and beech stands decreases from north to central Europe, along with increasing atmospheric nitrogen deposition. This was attributable to the loss of stress-tolerant species at the expense of ruderal morphotypes.

Conifer canopies increase nitrogen deposition rates to the forest floor (see Section 2.1) so the changes in plant species composition from eutrophication may be directly attributed to the dominant tree species. But, especially on sandy soils in Flanders atmospheric N-deposition rates are so high, that even in deciduous forest stands they result in changes in the vegetation composition (MIRA 2003). This may mask beneficial effects of conversion on plant diversity, especially if N-emission does not decrease faster than it does today.

Confounding factor: land use history of the conifer plantations

The land use of the present day forest stands in Belgium has evolved strongly during the last two centuries (see Section 1.5). It is one of the main keys to the present-day plant diversity. Plant communities with the associated fauna typical of heathlands and of drift sands have declined under the vast pine plantations in Flanders, apart from short revivals after clear cut and before stand closure (Rogister 1955, B in Figure 3-1). They have generally become rare, and contain many red-listed species (Hens *et al* 2005). The true forest plant species (and mosses, fungi and animals) still seem restricted to the few ancient forests and to small landscape elements associated with historical agricultural use. They do not seem to spread spontaneously into the younger forests (Bijlsma 2002) (B in Figure 3-1). Ancient forest plant species are very slow colonizers (less than 0.1 m a year), and they are very vulnerable to environmental changes (Brunet & Von Oheimb 1998, Bossuyt *et al* 1999). Similarly, in plantations of Scots and Corsican pine and Sitka and Norway spruce in Britain diversity of vascular plants, bryophytes and mycorrhiza depends on the distance to ancient semi-natural woodland (Humphrey *et al* 2004).

Comparably to the situation on the sandy soils in Flanders, on the one hand the typical vegetation of the historical mires, heath- and grasslands became very rare in Wallonia (Branquart *et al* 2003), and the true forest plants do not seem to colonize the young forests planted at these sites (Herault *et al* 2005). Furthermore, in conifer plantations in former ancient mixed oak forests or beech forests the diversity of the herbal layer has decreased. The typical ancient forest plants do not produce a persistent seed bank. Once the canopy closes in a conifer plantation, the ancient forest vegetation disappears, probably because the lack of light, the build up of thick humus layers and accelerated acidification of the top soil. In the Ardennes, du Bus de Warnaffe (2001) found a maximum diversity of forest plants in ancient oak forests and a minimum diversity in Norway spruce and Douglas fir stands. Beech forests had intermediate plant diversity. In Basque Country, the diversity of the vegetation is lower in coniferous plantations (*Larix kaempferi* and *Pinus radiata*) than in the native woodland. On the contrary, the diversity in the seed bank is higher under secondary conifers, but consists mostly of non-forest species, since true forest species rarely produce seed banks (Amezaga & Onaindia 1997).

Confounding factor: internal forest succession

The present-day management of pine forests on sandy soils favours natural succession processes (see Section 1.6). Effects of atmospheric deposition may be confounded with effects of succession because both usually entail soil acidification and increased nitrogen availability (Fanta 1986). Nevertheless, for sandy soils under forest in Flanders it was found that atmospheric deposition causes faster deposition acidification than expected under natural conditions (De Schrijver *et al* in press).

An important expression of succession in pine plantations is the maturation of the forest floor (organic layer, root layer and vegetation), especially as rotations are lengthened, large clear cuts avoided and deep soil preparation at the time of regeneration, litter raking and sod cutting stopped. This should promote true forest species within the stands, while typical pioneer plants survive in areas managed for open habitat (e.g. heather) and along forest edges (e.g. shoulders of forest roads). Such maturation should lead to higher biodiversity at a landscape level as species number, but most of all naturalness and specificity, increase. Bijlsma (2002) opposes to this general hypothesis. Most ancient forest plants considered typical to mature forests on the sandy region survived in hedgerows, roadsides, in very open, coppiced and overgrazed forests and edge situations. In the absence of traditional management regimes, they suffer from thick humus layers, a lack of light, erosion of human-induced gradients and a lack of human seed vectors.

Confounding factor: management regime

Dense plantations of conifers in former broadleaved forests lead to the disappearance of true forest species (Augusto *et al* 2001). However Decocq *et al* (2005) observed that these true forest plant species are in fact "coppice-woodland species ". Even the mere establishment of a selectively cutting system in a broadleaved forest in northern France that used to be a coppice with standards for centuries, lead to a fast (within 20 years) and major shift in herbal species composition, and specifically a decrease of true forest species (Decocq *et al* 2005). In Danish beech forests, management related factors like stand age, canopy structure and the cutting cycle explained more vegetation variation than did microclimate and soil factors. 30 years of non-management changed vegetation dramatically, at least on a local scale (Aude & Lawesson 1998). Van Dort *et al* (1999) observed a decline of ancient forest plants in Dutch strict forest reserves, established in the 1980's. They point at the spontaneous darkening of the formerly thinned stands. This may however be a scale effect, resulting from both the lack of time and the lack of large areas to incorporate natural disturbances and forest development stages in these forest reserves. To overcome this, managers of some forest reserves in Flanders, actively diversify the initial stand structure, e.g. by mimicking a natural disturbance event, before allowing a strictly spontaneous development. To avoid such temporary negative effects, it may thus be necessary during a conversion process to not only allow for spontaneous processes, but to combine this with an active diversification management.

Van Gossum (2000) and Dumortier *et al* (2000) found that tree species and habitat diversity of forest fragments can predict the forest plant species diversity on sandy soil in Flanders. The tree species diversity for its part is dependent on the forest stand development (Iida & Nakashizuka 1995, Lust *et al* 1998). This means that in the managed forest landscapes in Western Europe, the correlation of forest plant species diversity with tree species diversity can be considered as an indirect relation between diversity and (historical) management (Gosselin 2004). Many authors (e.g. Becker 1979, Barkham 1992) confirm the importance of management for diversity.

Confounding factor: exotic broadleaves

Two exotic broadleaves, Black cherry (*Prunus serotina* Ehrh.) and Red oak, are very common in the understorey of forests on sandy soils in Flanders (Afdeling Bos & Groen 2001). Red oak can also dominate as a canopy species. Both species are considered to be a major problem to forest management and more specifically to biodiversity (Peterken 2001, Lust *et al* 1998, du Bus de Warnaffe *et al* 2004). Recent research puts some nuances to this pessimistic view. Presence of Black cherry in the understorey of pine or oak stands on sandy soils in Flanders conditions light and moisture regime for the herbal layer. Light demanding plant species (like Heather or Blueberry) have a lower presence as compared to stands without Black cherry, but there is no evidence that typical forest plants are threatened by Black cherry (Stock 2005). Nevertheless, the presence of these exotic broadleaves may frustrate conversion management, impeding the establishment of indigenous woody species and creating other site characteristics (light, litter, bark, etc.) than the natural tree species composition..

3.1.3 Effect on diversity of animals

The diversity of animal species in a forest depends to a great extend on the diversity of (woody) plant species. This effect is clear for nesting birds, invertebrates and fungi (Bibby *et al* 1989, Young *et al* 1992). However management regimes may also be the actual factor affecting animal species diversity rather than forest tree species (du Bus de Warnaffe & Lebrun 2004, Humphrey *et al* 1999).

Directly associated animal species

The number of species of animals and fungi that depend on the presence of a specific tree species determines its biological value. The biological potential of certain indigenous broadleaved species is markedly high (Kennedy & Southwood 1984, Brändle & Brandl 2001). Every tree species has a specific biological potential according to different functional groups of animals and fungi (see Figure 3-2).
According to Branquart & Dufrène (2005), *Salix*, *Quercus*, *Fagus*, *Prunus*, *Betula*, *Alnus*, *Sorbus* and *Populus* all rank high. Among the conifers *Pinus* ranks much higher than *Picea*. Exotic broadleaved tree species have a much lower biological potential (Gosselin 2004).

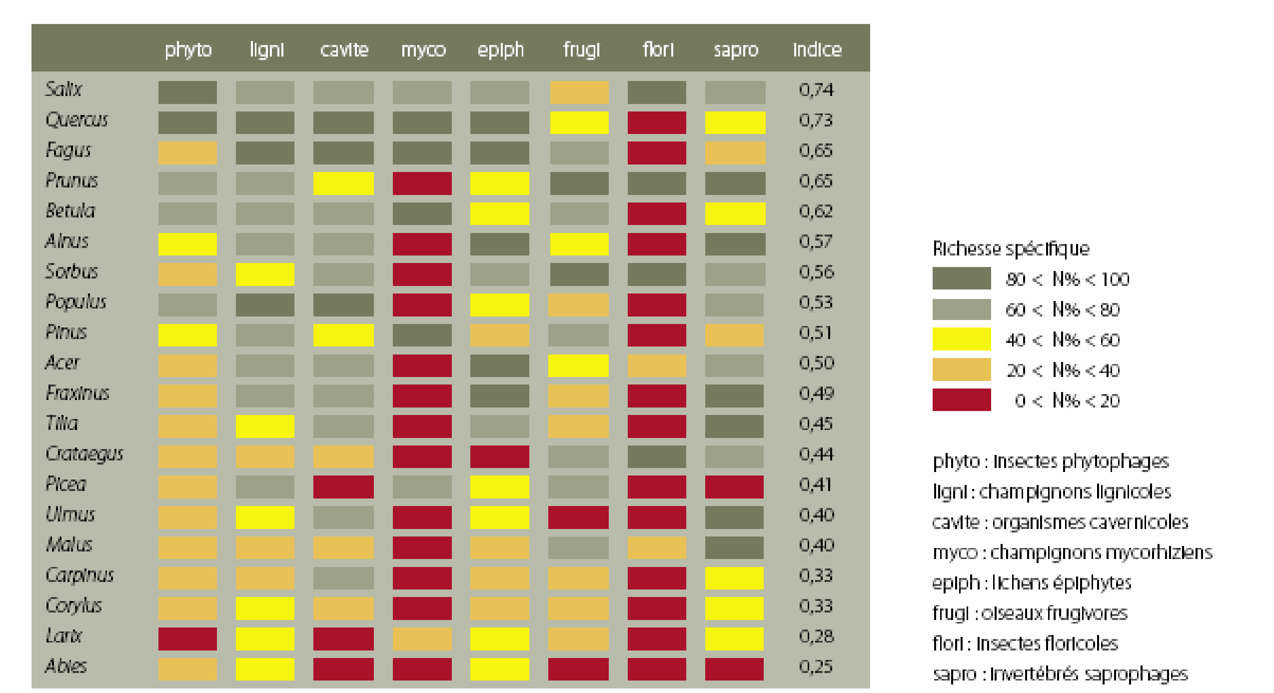


Figure 3-2: Ordering of the principal woody genera of Western Europe according to a weighted index of their biological potential for different functional groups (Branquart *et al* 2005).

Indirectly associated animal species

The changes in forest type and associated herbal vegetation cause secondary changes in animal populations. For instance, ant populations in Dutch forests declined as a result of the increase in grass cover (*Deschampsia flexuosa* and *Molinia caerulea*) under conifer forests. This in turn led to the decline of the Green woodpecker (van Swaay & van Halder 1993). De Jong *et al* (2002) evaluated forest and stand features that determine habitat quality for fauna. Based on the effect of different stand features on the habitat suitability, forest conversion on sandy soils in the Netherlands was evaluated (see Table 3-1, De Jong *et al* 2002). The bird species that are affected very negatively (last column of Table 3-1) are associated with larger open spaces, common in the traditional clear cutting system of pine stands. It is not the change of tree species, but of forest structure that causes these effects. This does not so much question stand conversion, but stresses a diversified management at the forest and landscape level.

Table 3-1: Expected effects on indicator animal species of conversion of conifer forests on sandy soils in the Netherlands (De Jong *et al* 2002)

	Very positive	Rather positive	No effect	Rather negative	Very negative
Birds	Wood Warbler Hawfinch Nuthatch March tit Blue tit Garden Warbler Chaffinch	Tawny owl Blackcap Whitethroat Great tit Willow tit Tree creeper Great Spotted Woodpecker		Tree pipit Sparrowhawk Woodlark	Nightjar Yellowhammer Goldcrest Crested tit Coal tit
Mammals	Natterer's bat Nathusius's pipistrelle Noctule bat Whiskered bat Brown long-eared bat Pine marten Badger Common shrew Bank vole	Hedgehog	Field vole	Red squirrel	
Ants			Red wood ant Southern wood ant		Black-backed meadow ant
Reptiles				Slow worm	

The most specialized ground beetle communities in the Walloon Ardennes are found in ancient beech forests. Nearly all of the ground beetles of Norway spruce and Douglas fir forests were generalist species (du Bus de Warnaffe 2001). Beech and spruce stands differ in the community of epigeic and trunk-living arthropod fauna in Bavaria, Germany (Engel & Ammer 2004). The average number of mite species in a forest soil sample was higher in the case of pine forest converted 30 to 50 years earlier into oak stands as compared to the surrounding pine stands. The dominant species of mites from adjacent pine stands still remain dominant species in the oak stands after conversion. But in the oak stands, the species composition of mites was more balanced with several dominant species (Skorupski 2004). Earthworm communities had a higher species richness and density in mixed oak-beech-pine forest as compared to pine forest. Remarkable were the high shares of *Lumbricus terrestris* and *Aporrectodea caliginosa* in the biomass, indicators of a rich soil life (Kautz & Topp 1998). Advance plantings of oak and beech under pure pine stands made the parasitic wasp community change to one with a significantly larger proportion of effective pest control agents: *Scelionidae* among the egg parasites, *Pteromalidae* among the larval and pupal parasites. This effect is larger with older understoreys (40 years as compared to 5-8 years old). Oak is better than beech in this respect, because of a more complex crown architecture, probably more admixed species and a greater variety of phytophagous host insects which promotes a stable and more efficient parasitic wasp community (Jäkel & Roth 2004). Advance plantings of oak and beech under pine resulted on the long run in a strong promotion of the dominant predatory arthropod group living on the soil surface (ground beetles or spiders). Also for these groups, oak was better (Bräsicke *et al* 2005). In pure spruce and in mixed spruce-beech forests the invertebrate decomposer communities were dominated by *Nematoda* (roundworms), *Enchytraeidae* (potworms), *Lumbricidae* (earthworms) and *Diptera* (flies). Conversion of pure spruce to mixed beech forest made the biomass of saprophagous flies decrease. Fly species composition shifted from *Sciaridae* and *Tipulidae* dominating spruce monocultures, to *Lonchopteridae*, *Lauxaniidae* and *Fanniidae* in mixed beech stands. With a rising share of beech in spruce forest, *Lumbricus* sp. increased. This earthworm genus is indicative of a good trophic structure of the soil community (Elmer *et al* 2004, Kautz & Topp 1998).

3.1.4 Conclusion

Question: A homogeneous pine or spruce plantation will be converted over the next decennia. Will species diversity after conversion be higher than the actual or at least remain at the current level?
In general, yes, because (i) in our regions the direct effects of deciduous tree species on the site characteristics favour more diverse plant and animal communities and (ii) the biological potential of the main indigenous deciduous tree species is superior as compared to conifers (see also conclusions of literature reviews by du Bus de Warnaffe *et al* 2004 and Gosselin 2004). But the actual outcome in the field depends strongly on several factors, other than the dominance of indigenous deciduous trees in the stand.

To draw this conclusion, we considered the species level. Holding firmly to this restriction when taking management decisions, could lead to the mystification of an intensively mixed stand of indigenous deciduous trees and shrubs. Creating this stand type in all current secondary conifer plantations would have a homogenizing effect that could be detrimental to specific plant and animal species. Therefore, management strategies should consider the forest and landscape level and forest conversion should be put into a wider forest management perspective. This may result in the delineation of priority zones for conversion, e.g. on more buffered soil types and close to ancient woodland sites. It may also mean that for biodiversity reasons, conifers have to be preserved as individual trees, groups or even large stands in an otherwise converted forest.

3.2 Is the herb and moss layer of coniferous forests less diverse? A case-study from Flanders

Verheyen Kris & Geudens Guy

3.2.1 Introduction

From the conclusions of the previous Section 3.1 it is clear that there is no straightforward answer whether (plant) species diversity is (potentially) higher under native deciduous compared to coniferous tree species, as a lot of confounding factors are in play. From the current distribution of pine plantations and from their history (Section 1.3 and Section 1.5) it can be seen that they dominate the forests of the poor sandy regions in the Kempen and Vlaamse Zandstreek. Forests on richer, loamy soils in other regions of Flanders are mainly deciduous. In general, richer forest soils bear more diverse herbal layers (van der Werf 1991). From this, a general first impression could arise that deciduous forests in Flanders have a more diverse herbal layer. Nevertheless, it would be erroneous to compare diversity of the herbal layer of any forest on a rich soil with that of any forest on a poor, sandy soil and attribute this to the forest type. Such comparison would be irrelevant to judge the ecological impact of forest conversion. The only correct approach is to compare forest stands dominated by different tree species on comparable sites, as was also stated for the comparison of biogeochemical cycling between forest types (Section 2.1).

The aim of this study was to test the hypothesis that the species richness of the herb and moss layer in forests on sandy soils in Flanders is higher under deciduous than under coniferous stands.

3.2.2 Material and Methods

Available data

For this study, data from the Flemish Regional Forest Inventory (Afdeling Bos & Groen 2001a) were used. Between 1997 and 1999, 3047 plots were laid out on a 1km x 0.5km grid in which a dendrometric assessment of the forest stand was performed. In half of the plots (1564 in total) the herb and moss layers were recorded in 16m x 16m plots using a Braun-Blanquet scale.
Apart from stand related variables such as dominant tree species, total canopy cover, stand age and development stage, the following additional variables were available for each plot:

- soil texture, drainage class and type according to the Belgian Soil Map (IWT 2001);
- forest age following De Keersmaeker *et al* (2001);
- the area of forest within a 500m buffer around the plot derived from the Flemish Forest Map (Afdeling Bos & Groen 2001b);
- the ecoregion in which the plot was located. The Kempen covers the northeast of Flanders, whereas the Vlaamse Zandstreek lies in the north-western part of Flanders.

More details about these variables can be found in Table 3-2.

Data-analyses

Given the objectives of this study, only forest plots occurring on poor sandy soils were selected for further analysis. Poor sandy soils are hereby defined as soils with a sandy or loamy sand texture (Z, S, X), that are not too wet (X, a, b, c, A, B, d, e, D) and that are either Podsols, Anthrosols or Arenosols (FAO nomenclature). A second selection criterion dealt with the stand structure and development. To be able to make comparisons between deciduous and coniferous stands, mixed deciduous-coniferous stands were omitted. Furthermore, only high forest stands, that were not too open (> 33% crown cover) nor too young (minimum pole or tree stage) were retained. This left us with 474 plots.
However, to be able to make valid interspecific comparisons, it was decided to retain only those canopy species for which a minimum of ten plots were available. Hence the data-set was further reduced to 359 plots containing five different canopy species: oak (*Quercus robur* and *Q. petraea*), poplar (*Populus x canadensis*), birch (*Betula pendula* and *B. pubescens*), Scots pine (*Pinus sylvestris)* and Corsican pine (*Pinus nigra*).

The following five response variables were derived: the number of moss species, the number of herb layer species, the number of typical forest species, the number of species of edges and clearings and the number of non-forest species. The latter three variables were derived based on the list of Stieperaere & Franssen (1982) in which mosses are not included.

Relationships between the response and explanatory variables were assessed by means of General Linear Modelling implemented in SPSS 11.0 (SPSS Inc. 1998-2002). Only the main effects of the explanatory variables were included in the model.

Finally, Indicator Species Analysis (Dufrêne & Legendre 1997) using PcOrd 4.0 (McCune & Mefford 1997) with canopy tree species as the grouping variable was performed to assess whether understorey species are associated with overstorey dominants.

3.2.3 Results

The mean species richness of the understorey community was 19.04 (min: 3; max: 43), while for the herb layer separately this was 11.73 (min: 1; max: 31) and for the moss layer 7.31 (min: 0; max: 22). Although significant, species numbers in the herb and moss layer were only poorly correlated ($r^2 = 0.23$, $p < 0.001$). The nature of the dominant tree species was the most important variable to explain the variation in the five richness variables (Table 3-2).

Table 3-2: Relationships between species numbers and local and regional explanatory variables assessed by means of General Linear Modelling (N = 359)

Explanatory variables	Explanatory variable description	Response variables°				
		#Moss	#Herb	#F Herb	#E Herb	#NF Herb
Ecoregion$	Kempen (90%); Vlaamse Zandstreek (10%)		**	***	(*)	(*)
Buffer500£	Area of forest in a 500m buffer (ha)	*** +		(*) +	*-	
Forest Age€	Eight classes ranging from >230y to <25y					
Soil texture€	Sandy (83%); Loamy Sand (17%)					
Soil drainage€	Very dry (11%); Dry (67%); Moist (22%)					
Soil type$	Podsols (78%); Anthrosols (8%); Arenosols (13%)				*	
Stand age$	<20y (10%); <40y (58%); <60y (24%); <120y (4%); uneven aged (4%)	(*)		**		
Cover €	Between 33% and 66% (28%); >66% (72%)	(*) +		*** +	* +	
Dominant tree species$	Oak (6%); Poplar (3%); Birch (3%); Scots pine (62%); Corsican pine (25%)	***	***	***	***	***

$: Nominal variable; €: Ordinal variable; £: Continuous variable.
°: #Moss: number of moss species; #Herb: number of species in the herb layer; #FHerb: number of forest species; #EHerb: number of species of edges and clearings; #NFHerb: number of non-forest species.
(*) P <0.1; * P <0.5; ** P <0.01; *** P <0.001; The trend (+ or -) is given for relationships with the ordinal or continuous variables.

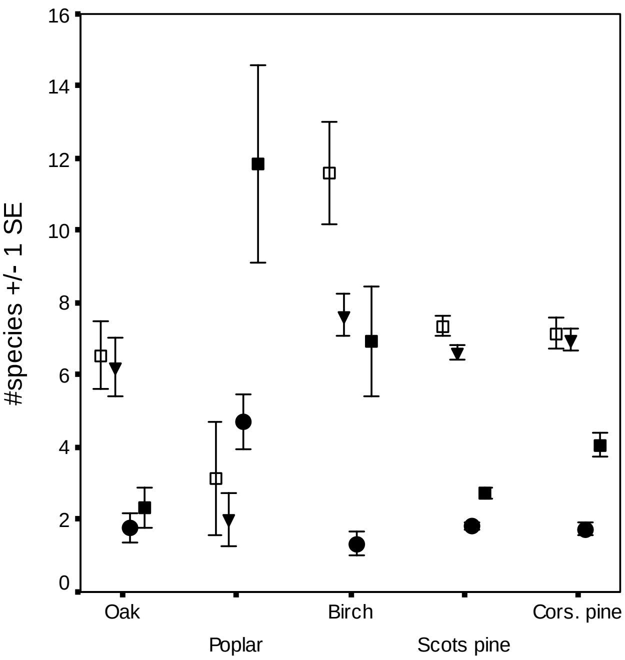


Figure 3-3: Mean (+/- 1 Standard Error) number of species of mosses (empty squares), forest herbs (black triangles), herbs of edges and clearings (black circles) and non-forest herbs (black squares) in stands dominated by the five selected tree species

The number of moss species was highest in the birch plots and lowest in the poplar plots (Figure 3-3), while no differences existed between the oak and pine plots. Significantly less forest herbs and more species of edges and clearings occurred in the poplar plots, but no differences exist between the other tree species. Finally, significantly more non-forest herbs were found in the poplar and birch plots and, again, no differences exist between the oak and pine plots. With respect to the total richness of the herb and moss layer, the tree species ranked in the following order: birch > poplar ≥ Corsican pine ≥ Scots pine ≥ oak, but only birch differed significantly from the other species. Apart from dominant tree species, other important explanatory variables were the ecoregion, the degree of crown cover, the area of the surrounding forest and the stand age (Table 3-2). For all variables, species richness was consistently higher in the Kempen compared to the Vlaamse Zandstreek. The number of moss species exhibited a strong positive relationship with an increase in forest area in the surroundings, while the number of herb species from edges and clearings exhibited the opposite trend. Total cover crown cover had a consistent positive effect on the number of moss species, forest herbs and species of edges and clearings. Effects of stand age displayed no consistent trend (Table 3-2).

Table 3-3: Understorey species that are significantly ($p < 0.05$) associated with one of the five tree species determined by means of Indicator Species Analysis (Dufrêne & Legendre 1997). Species are ranked according to decreasing p-value and moss species are underlined.

		Dominant tree species		
Cors. pine	**Scots pine**	**Oak**	**Birch**	**Poplar**
Pinus nigra	*Pinus sylvestris*	*Mnium hornum*	*Juncus spp*	*Cirsium arvense*
		Dicranella heteromalla	*Sphagnum spp*	*Convolvus arvensis*
		Maianthemum bifolium	*Calypogeia spp*	*Urtica dioica*
		Dicranoweisia cirrata	*Peucedanum spp*	*Sambucus nigra*
			Brachythecium spp	*Galium spp.*
			Alnus glutinosa	*Arrhenaterum elatius*
			Aulacomnium spp	*Ranunculus spp*
			Campylopus spp	*Trifolium spp*
			Betula spp	*Humulus lupulus*
			Salix caprea	*Ajuga reptans*
			Cardamine spp	*Angelica sylvestris*
			Aulacomnium palustre	*Glechoma hederacea*
			Eurhynchium praelongum	*Alopecurus spp*
			Poa trivialis	*Heracleum sphondylium*
			Erica tetralix	*Poa pratensis*
			Hieracium spp	*Dactylis glomerata*

Athyrium filix-femina	*Lysimachia spp.*
Orthodontium lineare	*Eupatorium cannabium*
	Leucanthemum vulgare
	Plagiothecium spp.
	Lychnis flos-cuculi
	Symphytum officinale
	Stachys spp
	Moehringia trinervia
	Filipendula ulmaria
	Lythrum salicaria
	Holcus spp
	Polygonum spp
	Galeopsis tetrahit
	Phalaris arundinacea

Finally, large interspecific differences were found with respect to the number of indicator species (Table 3-3). For the two coniferous species, only their juveniles were characteristic. Whereas 4, 18 and 30 species were associated with oak, birch and poplar, respectively. Relatively many moss species were associated with oak and birch, while many tall growing herbs typical for poorly shaded habitats were associated with poplar.

3.2.4 Discussion

In the literature review on effects of conversion on biodiversity, a number of factors were listed that possibly confound any causal relationship between forest type and plant diversity values. From the results in Table 3-2 it seems that the selection of plots from the available dataset was successful. Forest age, which reflects aspects of land use history, and soil variables were not significant in explaining variation of species numbers, while dominant tree species was the most important explanatory variable.
The fact that the number of forest herb species is related to stand age and cover, but not to forest age, may indicate that apart from colonization, competition with other, non-typical herbs is important.

From our results, one can not make a unequivocal distinction between broadleaved and coniferous forest stands on sandy soils. Nevertheless, there are important interspecific differences.

Poplar stands on sandy soils are on younger, moister and more heavily textured soils. Our model did not give a decisive answer about this, probably because interactions between explanatory variables were not tested. In combination with higher light availability, the richer soil under poplar stands explains the high number of typically tall growing, resource demanding herbs (ruderals). The low number of typical mosses in poplar stands can be expected from the high cover of tall herbs. Mosses can escape from this by growing on stems of living trees or on dead wood, but epiphytic mosses were not recorded in the plots (Afdeling Bos & Groen 2001). These poplar stands are not a typical result of conversion of pine stands, contrary to birch and oak stands.

Striking is the absence of indicator species in stands of both pine species. Pine and birch seeds are anemochorous and, especially inside forest stands, the seed rain extinguishes exponentially with distance of the mother tree. This explains why the presence of pine and birch seedlings can distinguish vegetations under pure stands of Scots pine, Corsican pine and birch from those under pure stands of other tree species. Acorns are heavy but spread over large distances by Gay (*Garrulus glandarius)*, mice and voles. Oak seedlings are therefore not typical for pure oak stands (Table 3-3).

As a target species for the conversion of pine plantations in Flanders, especially birch exhibits good potentials for improving plant diversity. According to phytosociological literature, the natural forest plant communities at the sites currently under pines fall under the *Quercetea roboris-petraeae*. They are generally negatively characterized for herb species. This means that many plant species that grow in other forest plant communities are typically absent in forests of the *Quercetea roboris-petraeae*. Diversity is mainly sustained by moss species (Van der Werf 1992). Our results confirm that especially mosses act as indicator species and show that they are most numerous under birch (Table 3-3). In birch stands there seems to be a combination of (i) a diversity of forest herb species comparable to pine and oak forests with (ii) a diversity of non-forest herb species that is higher than in pine and oak forests and with (iii) a diversity of mosses that is also higher than in pine and oak forests (Figure 3-3). One explanation might be that plots under white birch (*Betula pendula*) and downy birch (*B. pubescens*) were not distinguished in our analysis.

Those comprise quite divergent site types (Atkinson 1992). On the other hand the beneficial effects of birch on deteriorated soils are well documented (Emmer *et al* 2000, Gardiner 1968, Perala & Alm 1990a and b). The introduction of birch (and rowan) in acidified Norway spruce stands or clear-cuts in Central Europe causes an increase in pH, plant-available elements, and biological activity in the humus form, and concordantly a higher variability in humus form properties. Emmer *et al* (1998) found an increase in site diversity and biodiversity after the establishment of broad-leaved pioneer trees, among which birch.

4 SOCIAL FEASIBILITY OF FOREST CONVERSION: The attitude of forest owners towards forest conversion

Van de Steene Karolien & Van Herzele Ann

4.1 Introduction

Since in Flanders 70 % and in Wallonia 50% of the forest area is privately owned, it is obvious that for any policy towards forest conversion the support and co-operation of forest owners are prerequisites of success. In this respect, the attitude of the forest owners - whether they are supportive to or resistant against forest conversion - is at the centre of our study. As we expect this attitude to be dependent on a number of specific forest owner characteristics and motivations, it is our study's aim to gain a better understanding of those characteristics and motivations that underlie forest owners' attitudes towards forest conversion in particular, as well as some related issues of importance. Such an understanding would then enable to assist in formulating effective and efficient policy instruments and communication strategies.
According to the overall objective of the FEFOCON study, our research population is the private owners of forests on poor acid soils. In Flanders, these largely encompass the pine plantations on sandy soils in the Kempen region in Antwerp and Limburg, and in restricted sandy regions in the north of East- and West-Flanders. In Wallonia the spruce plantations are concerned. Because of the expected complexity of forest owners' attitudes in relation to different socio-economic contexts, we restricted our research population to Flanders. Nevertheless, we paid continual attention to relating our findings to the Walloon situation, by comparing with studies such as Feremans (2004).

The study followed a three step approach (see Figure 4-1). First, we analyzed the full range of forest policy instruments with emphasis on those directed at private owners. We specifically approached the forest groups, as they represent a unique source of knowledge in the context of our study. We conducted in-depth interviews with eight coordinators of forest groups who work with our research population. Together with the findings from previous studies in different countries, this has led to a preliminary typology of forest owners.
In a second step, the above information has served to design a mail questionnaire to the research population. With this, apart from testing and adapting the forest owners' typology, it was the purpose to predict – following the Theory of Planned Behaviour (Ajzen 1991) - the Behavioural Intention of the forest owners towards forest conversion by looking at their Attitude, Subjective norm, and Perceived Behavioural control.
Thirdly, in order to gain a deeper understanding of our findings from the mail questionnaire (typology of owners and predicted Behavioural Intentions), we organised in-depth interviews with six focus groups. These focus groups have led to a deeper understanding of the characteristics and motivations of forest owners, and hence, their Behavioural Intention.

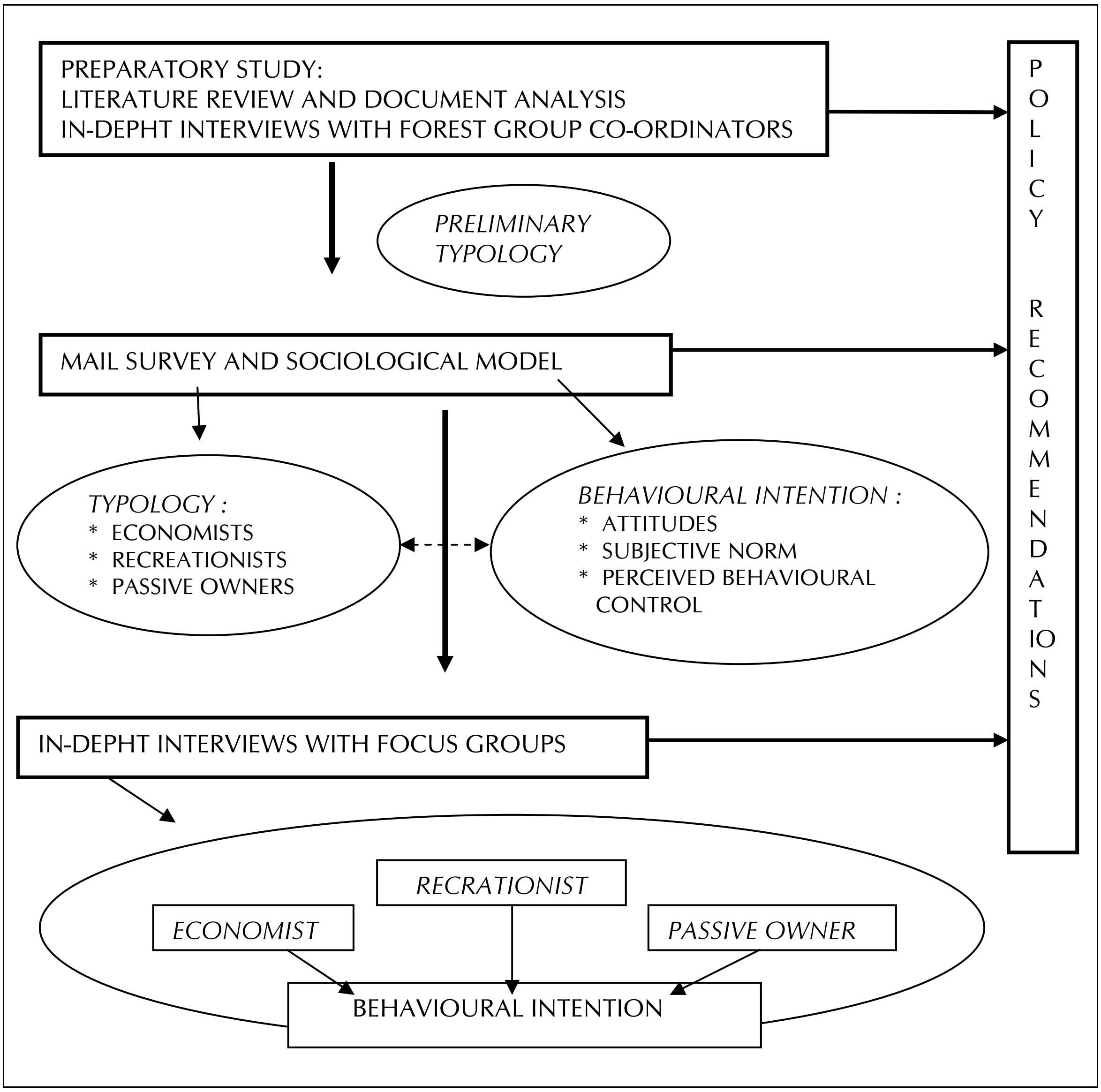


Figure 4-1: Methodological steps of the research

4.2 STEP 1: Preparatory study

Besides an essential review of the forest policy and ownership situation (see Chapter 1), and an exploration of our research population, it was our purpose to create a preliminary typology of forest owners. Both of these objectives were dealt with through analysis of legislative documents, analysis of the literature on typologies of forest owners in different countries and in-depth interviews with forest group coordinators.

4.2.1 In-depth interviews with forest group coordinators

The forest group is a voluntary cooperation liaison between forest owners (both public and private) within a working area of 4,000 to 15,000 ha of forest. As a relatively independent body, the forest group actually takes a 'mediating' position between the Flemish administrations and the forest owners of the working area. One of the main objectives is to promote sustainable forest management. However, the owner's free choice of management is highlighted. Another objective is to inform forest owners on financial and regulative policy instruments.

Between March and April 2004 we held in-depth interviews with eight forest group coordinators whose working area encompasses the pine plantations on sandy soils. Their daily contacts with the owners make them experts of the field.

First, it was the aim to extend our insight into the management practices in private forests, the problems and the actual influence of current policy and legislation. Second, the aim was to get an insight into how a forest group approaches and communicates with the forest owners. Moreover, we wanted to investigate the way coordinators perceive the attitude of the forest owners with whom they are in contact. The eight interviews were held at the offices of the forest group coordinators, and lasted between half an hour and one hour. The interviews were semi-structured. A number of selected themes were addressed, the order of the questions being adjusted to the course of each interview. All of the interviews were tape recorded, transcribed (about 150 pages in total), and analyzed using the cut-and-past-technique (Stewart & Shamdasani 1990).

In the next sections we summarize how forest group coordinators generally perceive forest owners' attitudes, and how they think different types of owners can be distinguished. We then integrated this information with the findings from literature in order to create a preliminary typology of forest owners.

4.2.2 General information on forest owners

Taking the forest owners back into their forests is the first precondition to enable any forest management (and conversion). This will also allow the coordinators to share their knowledge and experience with the owners. This is important because forest group coordinators feel that they have a strong influence on the behaviour of most forest owners.

Government subsidies are considered as a welcome support in compensating the costs of any intervention, but are unlikely to encourage forest owners' behaviour in a direct way. On the one hand, forest management, let apart forest conversion, is not a real concern to most forest owners. Moreover, in cases where conversion is ongoing this is often perceived as a situation of neglect. Many forest owners accept thinning operations as they feel their forest will benefit from that. At the same time, however, such an intervention may initiate spontaneous processes and initiate a forest conversion path (see Appendix Conversion Management Scenarios).

Forest group coordinators share the experience that in most cases forest owners have little knowledge about forest legislation and policy. Forest owners are often faced with social pressure from other people with a particular interest in their forest: neighbours, vacationers, nature organizations, etc. According to the coordinators information brochures about government subsidies and management plans have no effect, partly because of the specialist terminology. Personal contact in combination with non-technical language is the best way to contact the forest owners and influence their Behavioural Intention.

4.2.3 Preliminary typology of forest owners

The forest group coordinators identified what could be called an 'intuitive typology' of the different forest owners they know. In Table 4-1, we sorted this information under a number of key forest owners' types as derived from previous studies in Germany (Becker *et al* 2000, Volz & Bieling 1998, Bieling 2004), Finland (Karppinen 1998, Kuuluvainen *et al* 1996), Denmark (Boon *et al* 2004) and United States (Kline *et al* 2000a+b).

Table 4-1: Preliminary typology of forest owners

General typology from literature	'Intuitive' typology from forest group coordinators in Flanders
Economist	**TRADITIONAL FOREST OWNERS** Most of them have inherited their forest, which size is higher than average. The family estate has been managed in the same way for years. The financial aspect is still important. **(SPECULATOR)** It was the speculator's initial objective to invest in forestland, so as to sell it as a building lot later on. In the context of current legislative restrictions this option has become less realistic so that most of them could be classified elsewhere.
Multi-objective owner	**OWNERS WITH A LOT OF TIME** A large share of the Flemish owners has already retired. They spent a lot of time in their forest. There aim is a well-maintained forest, and they firmly follow their interventions.
Recreationist	**THE NATURE LOVER** These people have or buy a forest because of its nature values. They are often member of nature organizations.

	OWNERS WITH A HOLIDAY COTTAGE IN THE FOREST They bought a small forest lot in de seventies and built a little cottage in it. They manage it as a garden, and like exotic species and flowers. **FOREST IS PART OF THE GARDEN** They have their residence in the forest; it is part of their garden. Aesthetic enjoyment is the most important value for them.
Self-employed	**'FOREST PEOPLE'** These 'men' like to work in their forest: gathering firewood, cutting and planting trees. They don't have a lot scientific knowledge, but are very practical.
Passive/resigning owner	**PASSIVE OWNERS** These are often young people who inherited or bought their forest. They are interested in forestry, but have no time to think about it or to work in it. They trust professionals to maintain their forest.

4.3 STEP 2: Mail survey and sociological model

In the second step of our study we built a typology of owners of pine plantations on sandy soils. In order to get knowledge of the behavioural intention of the owners to converse their forest, we applied the Theory of Planned Behaviour (Ajzen 1991) (Figure 4-2, see Appendix The Theory of Planned Behaviour Model).

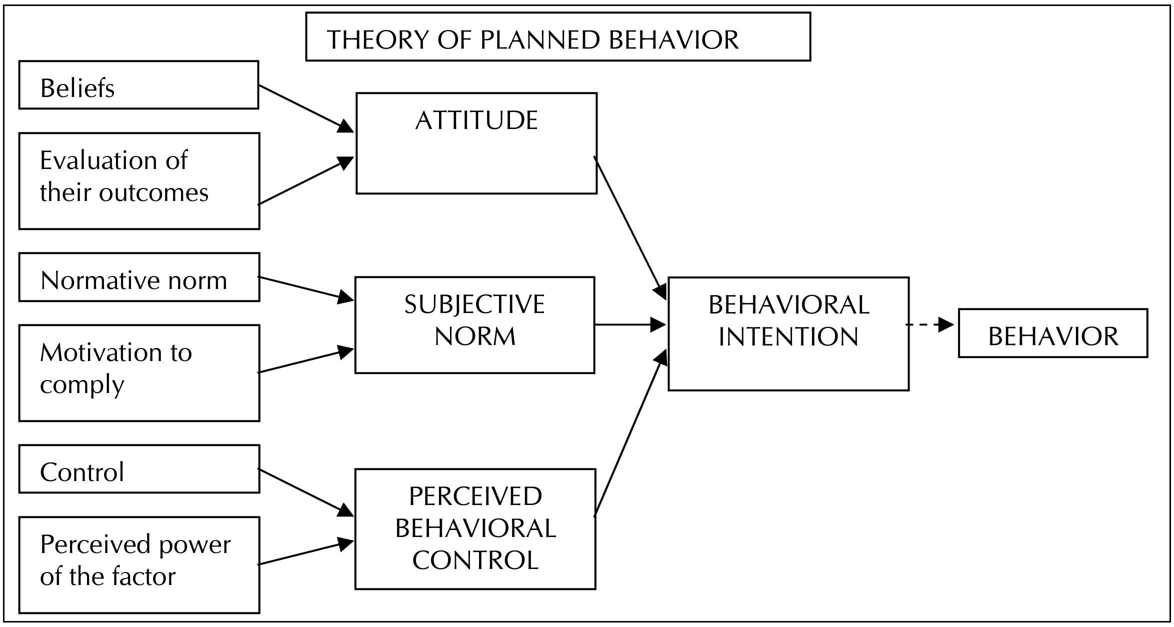


Figure 4-2: Theoretical framework: the Theory of Planned behaviour (Ajzen 1991)

We selected seven forest complexes of importance on poor acid soils that mainly consist of pine forests. The complexes are spread over the working areas of three forest groups (Table 4-2).

Table 4-2: Characteristics of the forest complexes

Forest complex	Forest group	Years of activity	Ecoregion°	Forest area ha	# of owners
Olen	Kempense Heuvelrug	>5	Kempen	>100	>100
Heidehuizen	Zuiderkempen	2	Kempen	139	?
Eindhout	Zuiderkempen	4	Kempen	116	226
Bel	Zuiderkempen	10	Kempen	180	?

De Ster	Oost-Vlaanderen Noord	no	Vlaamse Zandstreek	124	162
Puivelde	Oost-Vlaanderen Noord	3	Vlaamse Zandstreek	166	297
Lembeekse bossen	Oost-Vlaanderen Noord	2	Vlaamse Zandstreek	298	159

° ecoregion: see Chapter 3.2

With help of the information from our preparatory study, we designed a questionnaire (see Table 4-3). It was tested during a meeting of forest owners (forest group West-Limburg). The questionnaire was sent to 1,003 randomly selected owners by the end of October 2004. In November 2004 we sent a reminder. The response rate was 33.3%. Owners of deciduous forestland were excluded from the sample. The data (276 owners) were analyzed using SPSS.

Table 4-3: Structure of the survey questionnaire

Structure of the inquiry
Part 1: General characteristics of the forest and the forest owner.
Part 2: Motivation to own a forest and the owner's commitment to the forest.
Part 3: Forest management: knowledge, use and interest/necessity of it
Part 4: Behavioural intention towards conversion (Theory of Planned Behaviour).

4.3.1 Empirical typology of forest owners

Methods

Forest owner typology studies are almost exclusively based on ownership objectives (for an overview: see Boon *et al* 2004). We used the motivations for ownership as derived from the survey data to build a typology. Survey respondents were asked to rate on a five-point scale the importance of possible reasons for owning forest land (see the list in

Table 4-4). Firstly, respondents' importance ratings were analyzed using PCA (principal component analysis) (Legendre & Legendre 1998). The reliability of the PCA was evaluated using Carmines' theta $\theta = (N/N-1)*(1-1/\lambda_1)$ where N is the number of variables in the total PCA and λ_1 is the first eigenvalue (Carmines & Zeller 1979). The Carmines' theta must be greater than 0.70. Only components with an eigenvalue greater than 1 were considered. Secondly, based on the principal component scores obtained from the PCA, a K-means clustering analysis (Legendre & Legendre 1998) was performed to categorize respondents into separate groups. Finally, logistic regression was performed to identify the explanatory variables describing characteristics of the forest owner: sex (dichotomous scale), age (three-point scale), work situation (three-point scale), inherited the forest (dichotomous scale); the forest property: distance of the forest from the home (three-point scale), frequency of forest visits (three-point scale); the owner's relation to government services and the forest group (dichotomous scales).

Results

The PCA condensed the 12 motivations into four principal components (PC). Because the eigenvalue of the fourth PC (containing the motivations recreation for others and wildlife habitat) was lower than 1, it was rejected. The Carmines' theta of 0.72 indicates that the solution was reliable. The three retained PC's explain 46% of the variation in importance ratings for forest ownership.

Table 4-4: Loadings of the motivations on the three principal component axes (N = 276)

Motivations for ownership (*)	PC 1	PC 2	PC3
Timber to sell		0.620	
Forest is part of garden	0.498		
Relaxation	0.823		
Family estate	0.342		
Personal recreation	0.878		
Place for working	0.675	0.269	
Eventually sell at profit			0.900
Enjoy own forest	0.627		
Recreation for others			

Providing wildlife habitat	0.292		
Land investment		0.245	0.602
Firewood	0.285	0.879	
(*) The motivations regarding enjoy beauty of the forest, preserving untouched nature, and place for hunting, were excluded from the analysis because importance ratings could not be classified under any specific PC			
Eigenvalue	2.859	1.353	1.286
Proportion explained	24%	11%	11%

The interpretation of the three components included only those variables with loadings exceeding 0.25 on the PC (

Table 4-4). The first component (PC1) has highly positive loading coefficients for 'recreational' motivations (personal values and amenities). PC2 and PC3 are both characterized by economic motivations for ownership. PC2 describes the 'traditional' motivation for production: wood to sell on the timber market as well as firewood for household consumption. PC3 describes financial or 'speculative' motivations for forest ownership. The factor loading coefficients were used to calculate a set of standardized factor scores for each respondent (Legendre & Legendre 1998). A K-means cluster analysis (Legendre & Legendre 1998) was performed on the standardized factor scores to categorize respondents into three separate empirical owner types (Table 4-5). As the principal scores were orthogonal in structure, the problem of multicollinearity was avoided in the cluster analysis (Serbruyns & Luyssaert 2004).

Table 4-5: Mean of standardised cluster values of the cluster centres for the three-group solution (N = 276)

Owner type	**n**	**PC1**	**PC2**	**PC3**
Economist	62	0.273	0.856	0.636
Recreationist	73	0.728	-0.548	-0.368
Passive owners	69	-1.016	-0.189	-0.182
F-value		183	69	28
Significance (ANOVA)		0.00	0.00	0.00

The empirical owner types were named after the PC for which the higher score was obtained. 204 out of 276 respondents represent a specific owner type (62 'economists', 73 'recreationists' and 69 'passive owners'). The first group tends to score highly positive on the traditional (PC2) and speculative motivations (PC3) and was therefore called economists. It also scores positive on the recreational motivation (PC1), but not as high as on the other motivations. The second group was called the recreationists because of their highly positive score on recreational motivations (PC1). Recreationists score negative on traditional (PC2) and speculative (PC3) motivations. Based on their negative scores on the recreational (PC1), traditional (PC2) and speculative motivations (PC3) we called the third group the passive owners. Figure 4-3 provides an overview of the empirical typology of forest owners.

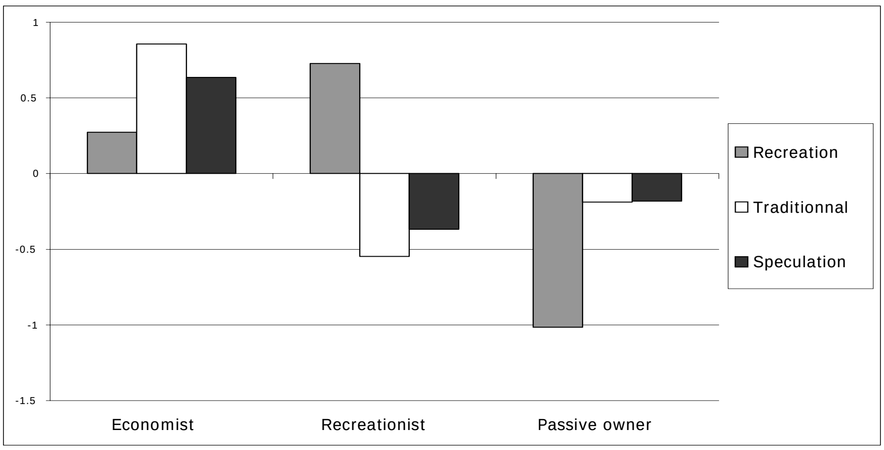


Figure 4-3: Three types of forest owners and their motivations for ownership (standardized factor scores on the PC's in Table 4-5)

The empirical typology of forest owners as it was derived from PCA and K-means cluster analysis was related to a number of explanatory variables describing owner and property characteristics (Table 4-6), and the owner's relation to government services and the forest group (Table 4-7). The relationships – calculated as regression coefficients (odds ratio) in a logistic regression – enabled us to describe the separate owner types as identifiable categories (
Table 4-8).

Table 4-6: Characteristics of owner and property for each owner type (N = 276)

	OWNER TYPES		
	Economist	**Recreationist**	**Passive owner**
Model significance	*0.033**	*0.000***	*0.003***
Variables			
Constant	1.626 n.s.	-1.519 n.s.	-3.744*
OWNER CHARACTERISTICS			
Sex			
(female)		1.131 (3.716)*	
Age			
(56-75, retired owners)	-1.601 (0.202)*	1.099 (3.001) n.s.	
Work situation			
(retired)		-1.351 (0.259)**	
(not working, not retired)	1.555 (4.737)*		
Inherited the forest			
(none)		2.641 (14.024)*	
PROPERTY CHARACTERISTICS			
Distance of the forest from the home			
(5-20 km)	1.514 (4.543)*		
Frequency of forest visits			
(a few times a week - a few months a year)		-1.284 (0.277)*	
(never – almost never)			3.461 (31.841)**

(* p< 0.05, ** p< 0.01, n.s. = not significant)

Table 4-7: Owner's relation to government services and forest group for each owner type (N = 276)

	OWNER TYPES		
	Economist	**Recreationist**	**Passive owner**
Model significance	*0.061 n.s.*	*0.002***	*0.000***
Variables			
Constant	-7.136 n.s.	-8.599 n.s.	-19.500 n.s.
GOVERNMENT SERVICES			
Ever used subsidies for the forest			
(none)			-3.658 (0.026)*
Would make use of general information on forest management			
(none)		2.108 (8.234)**	
Would eventually hand over the management of the forest to government			
(none)		3.191 (24.316)**	-3.022 (0.049)**
FOREST GROUP			
Ever heard of the forest group			
(none)			2.526 (12.508)**
Ever had contact with the forest group			
(none)	-2.557 (0.078)*		
Ever attended information meeting			
(none)		-1.664 (0189)*	

(* p< 0.05, **p < 0.01, n.s. = not significant)

Table 4-8: Characteristics of owner types

Owner type	**Characteristics**

ECONOMIST	❖ For a typical economist the forest has to be profitable, as a financial investment, but also in a productive way (timber and firewood). ❖ He/she is probably a person who doesn't work and isn't yet retired. ❖ He/she lives at a distance of 5-20 km from the forest. ❖ He/she knows government subsidies and was already in contact with the forest group.
RECREATIONIST	❖ Recreational motivations are very important for owning forestland. He/she hasn't got any speculative or traditional motivations. ❖ He/she is often a working person and isn't yet retired. The forest was probably not inherited. ❖ He/she visits the forest on a daily base, frequently works in it. ❖ The typical recreationist would not use general information about forest management, and neither tends to hand over the management to government. He/she has probably heard of the forest group and/or has attended an information meeting.
PASSIVE OWNER	❖ A typical passive owner has no clear motivations for ownership. ❖ He/she rarely visits the forest or works in it. ❖ He/she is probably willing to hand over the management to government. He/she has never heard of a forest group or at least has no contact with the forest group in the region.

4.3.2 Predicting Behavioural Intention

Methods

Following McKee & McClendon (1998) and Moore & McCabe (2001) we used a multiple regression analysis to evaluate the effects of the independent predictors (Attitude, Subjective Norm and Perceived Behavioural Control) on the dependent variable 'Behavioural Intention towards forest conversion' by the model of Planned Behaviour (see Appendix The Theory of Planned Behaviour Model). Firstly, we performed a univariate analysis of the answers provided by the survey respondent's for the questions about Attitude, Subjective Norm, Perceived Behavioural Control and Behavioural Intention towards conversion. Secondly, we modelled the relationships between the predictors and the dependent variable (e.g., a forest owner having a positive attitude towards conversion: does he/she also have a positive Behavioural Intention?). We used a bivariate regression analysis where Pearson's correlation coefficients (r^2) will reveal any effects between the predictors and dependent variables. Finally, we used a stepwise multivariate regression analysis to show how each independent variable in itself could explain the changes in the dependent variables (e.g., the effect of the Subjective Norm on the Behavioural Intention when controlling for Attitude and Perceived Behavioural Control). We performed two multivariate analyses: (1) with as dependent variable, the chance that the owner will engage in management activities towards conversion in the following ten years and (2) with as dependent variable the chance that the owner has a positive intention towards conversion given that he/she has any knowledge about some conversion aspects. In each of these two multivariate regression analysis we built three models. A first model showed the separate influence of each predictor on the dependent variable. A second model shows the changes in the results of the first model when socio-demographic variables are included and controlled for. In a third model, we looked at the changes in the results of the first model when we bring in and control for the policy management variables. In the three models we looked at the standardized regression coefficients (ß), we gave the explained variation (R^2) and the significance (p) of the model.

Results

The Behavioural Intention is predictive for the likelihood of exhibiting the behaviour in question (forest conversion). After the PCA and K-means cluster analysis the sample of forest owners was reduced to 204, which is too small for performing multivariate regression analysis per type of owner. We first describe the Behavioural Intention towards forest conversion of the total research population, and next, the effects of the predictors on Behavioural Intention.

The Behavioural Intention captures the motivation factors that may influence conversion, that is, how much of an effort respondents are willing to exert (Ajzen 1991). In our study, the Behavioural Intention was measured by two questions: (1) "How likely is it that you would carry out the following management activities in your forest over the next ten years?" (five-point-Likert scale: certainly not - certainly yes) and (2)

"Suppose that you could gradually convert your coniferous forest into a mixed or deciduous one quite easily, and moreover, that it costs you nothing. How likely is it that you would convert your forest if you know the following: ... " (five-point Likert-scale: certainly not - certainly yes). To assess the Behavioural Intention we constructed scale variables by reliability analysis based on the summed scores of owners' responses on each question. (1): Cronbach's alpha=0.71 and item-total correlations -0.02-0.58; (2): Cronbach's alpha=0.72 and item-total correlations 0.39-0.57). Bivariate analysis revealed a strong relationship ($r^2=0.500$, $p<0.01$) between both variables. The results suggest that forest owners have a moderately positive Behavioural Intention towards conversion: the response to question (1) (management activities favouring conversion) was moderately positive (Mean=27.41, standard deviation sd=6.00, Max=40 en Min=12), and the response to question (2) (conversion when he/she has knowledge of some conversion aspects) was rather positive (Mean=16.38, sd=4.03, Max=25 en Min=5).

Subjective Norm

The Subjective Norm was conceptualised as the perceived social pressure to perform or not to perform forest conversion (Ajzen 1991). In our study, it was measured by two questions: (3) (motivation to comply, Ajzen 1991): "To what extent do you agree with the following statements. When I make any decision related to my forest, I take into account:..." (five-point Likert scale: totally disagree-rather agree), and (4) (normative beliefs, Ajzen 1991): "When thinking of different people in the surroundings, what is your overall impression? Most of them... " (five-point Likert scale: totally disagree-rather agree). We constructed by reliability analysis a scale variable based on the responses on question (3) (Cronbach's alpha= 0.71 and item-total correlations 0.28-0.51). The standardised item alpha was too low for question (4) (0.27) to enable further analysis.

Univariate analysis of the scale variable revealed that the average forest owner takes the opinion from others into account when making decisions (Mean=24.14, sd=5.80, Max=35 en Min=7). Especially, the opinions of family members (43.5% < > 20.6%) and the forest group (39.1% < > 17.8%) are being considered. Univariate analysis also pointed to a rather negative Subjective Norm towards forest conversion when those others consider coniferous forest as being part of the cultural heritage of the region (38% < >11.7%). Some respondents do not agree with the statement that most people in their surroundings want conifers to be converted into broadleaves (28.8% < > 19.6%). However, it was also thought that these people like a mixed forest (46% < > 8.3%).

Bivariate regression analysis shows some correlations between the Subjective Norm and the Behavioural Intention: the more the owner takes the opinion of others into account, the more he/she will have a positive Behavioural Intention following question (2) (when he/she has knowledge of some aspects of forest conversion) ($r^2=0.238$, $p<0.01$). This effect results from the influence of the opinions of the forest group ($r^2=0.282$, $p<0.01$), the wood industry ($r^2=0.236$, $p<0.01$), nature associations managing forests ($r^2=0.155$, $p<0.05$) and other forest owners ($r^2=0.144$, $p<0.05$). When the owner thinks that others prefer coniferous over deciduous forest, there is a smaller chance that he/she will carry out management activities favouring conversion (question 1) ($r^2=0.312$, $p<0.01$). Conversely, when the owner thinks that others find that coniferous forests should be converted into deciduous ones, there is a greater chance that he/she will carry out such management activities (question (1)) ($r^2=0.430$, $p<0.01$), and will have a positive Behavioural Intention following question (2) ($r^2=0.478$, $p<0.01$). A positive intention following question (1) ($r^2=0.287$, $p<0.01$) and question (2) ($r^2=0.230$, $p<0.01$), also becomes more likely when others prefer mixed forests.

When controlling for the effects of the Attitude and the Perceived Behavioural Control, we can see the unique effect of the Subjective Norm on the Behavioural Intention towards conversion. The first model ($R^2=0.60$, $p<0.01$) reveals that when owners take the opinion of others into account, there is a smaller chance that they will have a positive intention following question (1) (ß= -0.172, $p<0.01$). This effect doesn't show up in the bivariate analysis and in the second model ($R^2=0.81$, $p<0.01$) where we control for the socio-demographic variables (ß = -0.072, p= n.s.). So the effect can be partly explained by the socio-demographic characteristics of the owner. In the third model ($R^2=0.67$, $p<0.01$), which maintains the management variables unchanged, this effect is even stronger (ß = -0.185, $p<0.01$). The first model ($R^2=0.44$, $p<0.01$) also reveals that when the owner takes the opinion of others into account, the chance will be greater that he/she will have a positive Behavioural Intention following question (2) (ß = 0.204, $p<0.01$). This means that the effect that we already found in the bivariate analysis resists when we control for the effects of the Attitude and Perceived Behavioural Control. This effect can be explained a little by the socio-demographic variables: when we control for it in the second model ($R^2=0.51$, $p<0.01$), the result remains the same although it is a little weaker (ß = 0.174, $p<0.05$). Also the management variables may explain a little bit of the effect: when the management variables were held constant (ß = 0.227, $p<0.05$) in the third model ($R^2=0.51$, $p<0.01$), the result is also a little weaker.

In conclusion we suggest that the Subjective Norm has a significant effect on the Behavioural Intention of the forest owners towards conversion. The opinions of family members and the forest group may influence them the most. The greater the owner takes the opinion from others into account, the greater the chance that he/she will convert the forest (given that it costs nothing) when he/she has any knowledge about some conversion aspects. Otherwise, when the owner takes the opinion from others into account, there is a smaller chance that he/she will carry out management activities over the next 10 years that favour conversion. Additionally, the following weaker relationships (only significant on the bivariate level) need to be considered. When the owner thinks that others prefer mixed over coniferous forests, there is a smaller chance that he/she will carry out these management activities. Otherwise, when the owner thinks that others find that conifers should be converted into broadleaves, there is a greater chance that the intention to convert the forest is very positive. The same relation occurs when the owner thinks that others prefer mixed over coniferous forests.

Attitude

The Attitude was conceptualised as the degree to which a person has a favourable or unfavourable evaluation or appraisal of forest conversion (Ajzen 1991). The Attitude was measured by three questions: (5) "When choosing a particular tree species, what is your most important reason?" (five possible responses); (6) *Beliefs* (Ajzen 1991): "Do you think it would be wise to carry out the following management measures in a coniferous forest? (five-point Likert scale: totally unwise-very wise). By reliability analysis we constructed a scale variable (Cronbach's alpha= 0.55 and item-total correlations 0.03-0.60); (7) *Evaluation of their outcomes* (Ajzen 1991): "How important for your forest are the following management measures?" (five-point Likert scale totally unimportant-very important),). By reliability analysis we constructed a scale variable (Cronbach's alpha= 0.71 and item-total correlations 0.10-0.71).

The univariate analysis reveals that forest scenery (41.7%) and naturalness (27.5%) are the most important reasons for owners to choose a particular tree species. From the first scale variable it was shown that the average forest owner finds management measures that are positive for conversion rather wise (Mean=32.38, sd=5.93, Max=46 en Min=20). Owners are especially positive towards natural regeneration of broadleaves (41.5% < > 19.9%), sparing spontaneously growing young oaks (56.1% < > 10.5%), thinning trees for one time (40.9% < > 17.8%), thinning trees regularly, e.g., every tree years (51.1% < > 9%) and fighting brambles (59.1% < > 11.2%). From the second scale variable we conclude that the average forest owner considers management activities that are positive for conversion rather important for his/her forest (Mean=27.37, sd=5.99, Max=40 en Min=15). Forest owners are especially positive towards fighting American bird cherry (57.2% < > 10.5%), making space for broadleaves when thinning (41% < > 20.6%), thinning (52.9% < > 14.9%) and sparing spontaneously growing broadleaves (51.4% < > 10.1). Instead, owners are rather negative towards clear-cutting and replanting with broadleaves (12.7% < > 45.9%).

Bivariate regression analysis shows some correlations between the Attitude and the Behavioural Intention: the more the owner considers positive management activities towards conversion as a wise option ($r^2=0{,}579$, $p<0.01$) or/and important for his/her forest ($r^2=0.728$, $p<0.01$), the more likely it is that he/she will carry out management activities favouring conversion (question (1)). When the owner considers possible management activities towards conversion as a wise option ($r^2=0.488$, $p<0.01$) or/and important for his/her forest ($r^2=0.595$, $p<0.01$), the chance for a positive intention towards conversion - when he/she has any knowledge (question (2)) - will increase.

When controlling for the effects of Subjective Norm and Perceived Behavioural Control, we find a small effect of the justification of the owner of management activities on question (1). We see that in the first model ($R^2=0.60$, $p<0.01$) a positive Attitude towards conversion, measured as the justification of management activities leads independently of the Subjective Norm or the Perceived Behavioural Control to a greater intention towards conversion (ß = 0.160, $p<0.05$). In the second ($R^2=0.81$, $p<0.01$) and third model ($R^2=0.67$, $p<0.01$) this relationship doesn't hold. So the positive influence of the justification of positive conversion management activities on a positive Behavioural Intention is likely to be influenced by socio-demographic characteristics (ß = 0.126, p= n.s.) and owners' management variables (ß = 0.091, p= n.s.). In contrast to the first Attitude variable, the Attitude measured as the importance of management activities in the owner's forest, has a strong influence on the chance that the owner would carry out management activities favouring conversion (question (1)). The more the owner considers these activities important for his/her forest, the greater the chance that he/she has a positive Behavioural Intention (model 1: $R^2=0.60$, $p<0.01$ and ß = 0.576, $p<0.01$). The socio-demographic characteristics or owners' management variables do not influence this relationship (model 2: $R^2=0.81$ $p<0.01$ and ß = 0.675, $p<0.01$ resp. model 3: $R^2=0{,}67$, $p<0.01$ and ß = 0.537, $p<0.01$).

For the intention towards conversion when owners have knowledge about some conversion aspects (question (2)), the first model ($R^2=0.44$, $p<0.01$) shows that there is no unique effect of the owners'

Attitude towards management activities in a coniferous forest on their Behavioural Intention (ß = 0.024 , p= n.s.). Similarly, the second (R^2=0.51, p<0.01 and ß = 0.129 , p= n.s.) and third model (R^2=0.52, p<0.01 and ß = 0.044 , p= n.s.) show no effect. By contrast, a strong relationship exists between the extent owners find management activities important for their own forest and their Behavioural Intention towards conversion following question (2). The first model (R^2=0.44, p<0.01) shows that the more the owner finds management activities favouring conversion important, the greater the chance that he/she will have a positive Behavioural Intention towards conversion (ß = 0.465, p<0.01). This relationship is not influenced by socio-demographic characteristics or owners' management variables in the second (R^2=0.51 p<0.01 and ß = 0.435, p<0.01) and third model (R^2=0.52, p<0.01 and ß = 0.544, p<0.01).
To conclude, the Attitude is a significant predictor of the owners' willingness to convert their forests. The forest scenery together with naturalness, are most important reasons for owners to choose a particular tree species. Owners find management activities favouring conversion generally wise and important for their forest, especially thinning, fighting brambles and American bird cherry and spontaneous regeneration of broadleaves. When the owner finds management activities towards conversion very wise, there will also be a greater chance for a positive Behavioural Intention. However, this relationship is not very strong (e.g., the effect on question (2) stands only on the bivariate analysis level). Otherwise, when the owner finds management activities favouring conversion important for his/her forest, there will be great chance that the owner will have the intention to convert the forest, as well as to carry out management activities favouring conversion. This relation is very strong on all the levels of analysis.

Perceived Behavioural Control
Perceived Behavioural Control is conceptualized as the perceived ease or difficulty of performing forest conversion and it is assumed to reflect past experience as well as anticipated impediments and obstacles (Ajzen 1991). We measured Perceived Behavioural Control by the question: (8): "Which is an important barrier for carrying out management activities in your forest?" Several responses were possible: I have no time (27.2%); Managing a forest costs too much money (13.0%); I know too little about it (29.0%); I am not interested (12.3%); I don't know where to find help (7.2%); Other (22.8%).
Bivariate analysis revealed two significant relationships. When there is a barrier because of lack of interest, there is a smaller chance that the owner will have the intention to carry out management activities favouring conversion (question (1)) (r^2=0.172, p<0.05). However, this relationship is not very strong. Interestingly, when the owner points to 'other' barrier than those listed in the question, the chance will be greater that he/she has a positive Behavioural Intention towards carrying out management activities favouring forest conversion (question (1)) (r^2=0.242, p<0.01).
When controlling for the effects of the Attitude and the Subjective Norm on Behavioural Intention, we found that the barriers have some effects on question (1). The first model (R^2=0.60, p<0.01) shows indeed that when the owner points to another barrier, there will be a greater chance that he/she has a positive Behavioural Intention (ß = -0.141, p<0.05). It is a weak relationship. When we control for the owners' socio-demographic characteristics and management variables, this effect disappears (second model: R^2=0.81, p<0.01 and ß = -0.075 p= n.s.; third model: R^2=0.67, p<0.01 and ß = -0.127 p= n.s). So these characteristics may partly explain the first effect. The second model shows two additional effects. When there is a lack of time, there is also a greater chance that the owner has a more negative Behavioural Intention (ß = -0.136, p<0.05). When an owner indicates that he/she doesn't know where to find help, a negative Behavioural Intention becomes more probable (ß = -0.121, p<0.05). The barriers have no effect on question (2).
In conclusion, there are a number of significant barriers for managing the forest. However, the effects of these barriers on the Behavioural Intention are relatively weak. The strongest effect does appear for the 'other' barriers. Removing these, could possibly encourage forest owners to put into practice their positive intentions.

Conclusions
Attitude, Subjective Norm and Perceived Behavioural Control all explain a part of the forest owner's Behavioural Intention. From the bivariate regression analysis we conclude that the relations between the three independent variables are rather weak (see
Table 4-9). As each of these variables has an independent effect on the Behavioural Intention, there is no danger for multicollinearity. Only the normative norms, including the opinion of others on different tree species, correlate with the owner's Attitude. The effect of these two variables cannot be considered separately.
Attitude and Subjective Norm have the greatest effect on the behaviour intention. The opinion of family members and the forest group have the greatest impact. When forest owners take the opinion from others into account, there's a greater chance that they will convert their forest (given that it costs nothing), when

they have knowledge about positive aspects of conversion. But, surprisingly, there is a smaller chance that they will carry out management activities favouring conversion over the next 10 years. Maybe this could be explained by particular difficulties or resistances related to management activities. When owners think that others are positive towards conversion (e.g., they find that coniferous forests should be converted into broad-leave forests), the chance will be greater that they have a positive Behavioural Intention towards conversion.

This finding cannot be considered separately from the Attitude of the owner (see
Table 4-9).
The Attitude of the owner has a major impact on his/her Behavioural Intention. The owner's beliefs (justification of management activities) have a rather small effect. But the extent into which they attach importance to management activities has a major effect on their Behavioural intention. When owners find these activities important for there forest, they will have a positive Behavioural Intention towards conversion. The relationship between the owner's Attitude and the importance attached to the forest scenery remains unclear.
The effects of the barriers for conversion (Perceived Behavioural Control) on the Behavioural Intention are not very strong. However, it was also noted that 'other barriers' are important compared with those listed in the questionnaire.

Table 4-9: Bivariate regression analysis between the independent variables Attitude, Subjective Norm and Perceived Behavioural Control.

	SN	MTC	36a	36b	36c	36d	36e	36f	PBC	31a	31b	31c	31d	31e	31f	A	Bel	Out
SN	/																	
MTC	/	1.00 197																
36a	/	.035 192	1.00 212															
36b	/	-.090 193	.349** 212	1.00 214														
36c	/	-.088 189	.340** 208	.299** 210	1.00 214													
36d	/	.079 194	.204** 212	.253** 214	-.024 213	1.00 219												
36e	/	-.103 193	-.195** 211	-.077 213	.036 209	-.258** 214	1.00 216											
36f	/	.112 191	-.004 209	-.124 210	-.045 206	.000 210	.092 210	1.00 210										
PBC	/	/	/	/	/	/	/	/	/									
31a	/	.063 187	.058 198	-.038 199	.065 199	.079 204	-.064 201	-.115 196	/	1.00 216								
31b	/	-.065 187	.013 198	-.070 199	-.010 199	-.021 204	.137 201	.117 196	/	-.117 216	1.00 216							
31c	/	-.119 187	.111 198	.028 199	-.022 199	.082 204	-.057 201	-.077 196	/	-.076 216	-.009 216	1.00 216						
31d	/	.060 187	-.146* 198	-.014 199	.011 199	.025 204	.162* 201	.110 196	/	-.155* 216	-.091 216	-.147* 216	1.00 216					
31e	/	-.097 187	.065 198	.053 199	.037 199	-.002 204	-.035 201	-.073 196	/	-.032 216	.114 216	.053 216	-.094 216	1.00 216				
31f	/	-.039 187	-.045 198	.082 199	008 199	-178* 204	.060 201	-.012 196	/	-.318* 216	-041 216	-.302** 216	-.165* 216	-.029 216	1.00 216			
A	/	/	/	/	/	/	/		/	/	/	/	/	/	/			
Bel	/	.025 165	.345** 171	.490** 171	.270** 171	.392** 172	-.130 171	-.027 170	/	-.008 168	-.049 168	.034 168	.160* 168	-.014 168	-.166* 168	/	1.00 177	
Out	/	.135 182	.300** 195	.543** 196	.225** 193	.305** 196	-.078 195	-.021 194	/	-.003 186	-.017 186	.060 186	.143 186	.053 186	-.156* 186	/	.670** 165	1.00 199

(SN=Subjective Norm, MTC=motivation to comply, 36=normative norm; PBC= Perceived behavioural control; 31= barriers; A=Attitude, Bel= beliefs, Out=evaluation of outcome, * p<0.05, ** p<0.01)

4.4 STEP 3: In-depth interviews with focus groups

4.4.1 Methods

To gain a better understanding of the findings from the mail survey, and to deepen our knowledge of the forest owners' Behavioural Intention towards conversion, and how this may differ among the distinct types of owners, we used focus groups. We organised six focus groups in April and May 2005: two with 'economists', two with 'recreationists', and two with 'passive owners' (see the empirical typology in Step 2). Three focus groups were organised in Sint-Niklaas (for owners having their forest in the working area of the Oost-Vlaanderen-Noord forest group), three in Geel (Kempense Heuvelrug and Zuiderkempen forest groups). The research population was the same as in the mail survey. We selected 250 forest owners from address-files (available at the municipalities) in proportion to the selected forest complexes.
The forest owners were sent an introductory letter and were then asked over the telephone if they were willing to participate. If yes, we asked them a few questions as to characterise them according to the empirical typology. The owners who agreed for participation (35%) were sent a second letter with further details about the event and asked to confirm their participation in the focus group (and the lunch we offered).
We made a semi-structured topic list (see Appendix Topic List of Sociological Focus Groups). The order of the questions was adjusted to the course of the focus group, but all the topics were discussed. We checked again for typology with help of a mini-questionnaire. Notes were taken throughout the conversations (non-verbal information) and shortly after (our impressions). All focus groups were taped-recorded and transcribed. We performed a Content Analysis (Stewart & Shamdasani 1990, Gibbs 2002, Bloor *et al* 2001, Morgan 1997). For this purpose, all the data (including the written notes) were coded using Nvivo (qualitative software programme from the QSR-NUD*IST). In order to sort out the information, we constructed 'tree-nodes' based on the questions of the topic list.

4.4.2 Results

Appraisal of the focus group typology

**The mini-questionnaire, together with how the participants located their forest during the introductory session of the focus group, enabled us to perform an appraisal of typology for each focus group. The results (see Table 4-10) confirm that the typology of the focus groups fits with the characteristics we found in the mail survey (see
Table 4-8).**

Table 4-10: Appraisal of the owner typology

Characteristics	Groups of Economists (SN : N=14, GE : N=12)	Groups of recreationists (SN : N=12, GE : N=9)	Groups of passive owners (SN : N=10, GE : N=7)
Visiting the forest	Regular (SN : 64.2%, GE : 75%)	Very often (SN=66.7%;GE=88.8%)	Seldom (SN=20%, GE=42.9%)
Working in the forest	Regular (SN=57.1%; GE=75%)	Regular (SN=41.7%; GE=77.7%)	Seldom (SN=40%, GE=14.3%)
Contacted the forest group	Yes (much owners) (SN=57.1%; GE=75%)	Yes (much owners) (SN=66.7%; GE= 88.9%)	Yes (GE), No (SN) (SN= 20% yes - 80% no; GE=71.4% yes – 28.6% no)
* information leaflet	Yes (SN=85.7%, GE=66.7%)	Yes (SN=66.7%, GE=55.6%)	Yes (GE), No (SN) (SN=30%, GE=71.4%)
* information meeting	Some owners (SN=35.7%, GE=50.0%)	Some owners (GE), No owners (SN) (SN=0%, GE=55.6%)	Few (SN), some (GE) owners (SN=20%, GE=57.1%)
* collective wood sale	Some owners (SN=21.4%; GE=41.7%)	Few owners (SN=0%; GE=22.2%)	Few (SN), some (GE) owners (SN=10%; GE=57.1%)
* participating in activities	Few owners (SN= 21.4%; GE=25.0%)	Few owners (SN= 25%; GE=22.2%)	Few owners (SN= 10%; GE=14.3%)
Age	Old (SN= $\bar{x}$=67.7, sd=10.69; Ge=$\bar{x}$=60.91, sd=7.07)	Middle age (SN= $\bar{x}$=52.92, sd=9.58; Ge= $\bar{x}$=56.44, sd=9.41)	Old (SN= $\bar{x}$=56.90, sd=18.59; Ge= $\bar{x}$=63.60, sd=14.91)

Working condition	Retired (SN=71.4%; GE= 50.0%)	Working or housewife (-man) (SN=33.3%; GE=55.6% resp. SN=16.7%; GE=11.1%)	Retired (Ge +1/2 SN) and working (1/2 SN) (working: SN= 40%; GE=14.3%, retired: SN= 40%; GE=85.7%)
Speculation	Not very important (SN=14.2%, GE= 25% selling ground, SN=21.4%, GE=16.7% investment)	Not very important (SN=16.7%, GE= 11.1% selling ground, SN=16.7%, GE=22.2% investment)	Rather important (SN=30%, GE=42.9%, selling ground, SN=30%; Ge=28.6%, investment)
Wood production	Important GE, Little important SN (SN= 28.6%, GE= 41.7%)	Important GE, Not important SN (SN=8.3%; GE=44.4%)	Not important (SN), little important (GE) (SN=10%; GE=28.6%)
Fire wood	Important (SN=50%; GE=50%)	Important (SN=50%; GE=44.4%)	Not important (SN=10%; GE=14.3%)
Recreational motivations	Important	Very important	Rather unimportant
Hunting in the forest	Not important (SN= 64.3%; GE= 83.3%)	Not important at all (SN=83.3%; GE=100%)	Not important at all (SN=80%: GE=85.7%)
Location of the forest	Clear localisation, close to the home	Close to the home: 50% has a holiday cottage in it, 30% has forest as part of the garden	Difficult to localise for some Often far from the home

($\bar{x}$=mean, sd=standard deviation, SN=St-Niklaas, GE=Geel)

Main results of the focus groups based on 'tree-nodes'

In the next sections, we summarise the main findings with regard to the Behavioural Intention towards forest conversion of the different focus groups. We describe the Behavioural Intention and next, we attempt to interpret this looking at the Attitude, Subjective Norms and Perceived Behavioural Control.

Economists

The two groups (SN and GE) show a rather positive Behavioural Intention. However, an important precondition is that conversion costs are low and the benefits high. Economists do not tend to work for the future generations. For this reason, conversion is seen as a gradual process (thinning and giving space to broadleaves).

Economists are strongly influenced by the forest group's view. For them, the forest group is an excellent communication instrument between the private forest owners and government policies. They especially like its independent character. They think it is very important to have the feeling that their opinion is taken seriously and that they themselves can take the final decisions. When planning management activities, however, economists take the opinion of neighbour owners into account.

Economic values and the naturalness of the forest are very important, as well as the ownership of the forest. They are very interested and actively involved in their forest. Many economists are also emotionally attached to their forest. Their Attitude towards forest conversion is rather positive. They know from their own experience that many conifers are "sick" and need to be replaced by broadleaves. They carry out - often with the help of the forest group - management activities that favour conversion: thinning, giving space to broadleaves and even planting broadleaves into thinned stands.

Apart from the rather positive Attitude towards conversion, economists face important difficulties or barriers when managing their forest: aging, increased recreation, illness of trees, high costs, vandalism, rubbish, inappropriate and unclear legislation. For economists also difficult accessibility to their forests and problems when public access is given, are main barriers. They are not positive about the future of the forests in general. Because of the high costs and low benefits they think that forests will disappear.

Economists think actively about the solutions they see for their problems with the management: proper control of public access, government subsidies for management and for public access, financial favours (e.g., lifting death duties and land register costs) and better access to their property. Economists recognise the high value of forests for society and don't want them to disappear. This could be guaranteed by giving more responsibility to the forest groups in the management, rather than involving government, which is being associated with politics. Economists are very positive about the information they get from the forest group, but would like to have more information about the administrative tasks related to the forest. Economists do not plan to buy more forest as a solution against deforestation, because they don't see the benefits for themselves. They neither see 'handing over the forest management to anyone else' as a solution for their problems. In this, they make no difference between the handing over to the government, another forest owner or the forest group. They just want to control their forest themselves. When given the opportunity to sell their forest, economists have no univocal opinion. Many of them are personally attached to their forest, but for those who would sell their forest the financial benefits are very important.

Recreationists

Both recreationist groups showed a rather negative Behavioural Intention towards conversion. When thinking of conversion, they find clear-cutting an easier way of working than a gradual conversion through thinning. This because (some of them talk from experience) trees may grow crooked as they search for light between the conifers. Generally taken, recreationists prefer to observe what happens without interfering in the forest. Much of their Behavioural Intention can be explained by their attitudes, norms and barriers.

When they plan to undertake radical management activities, they ask the advice of the forest group and/or nature associations. They follow their opinions, although recreationists are not as enthusiastic as economists about the forest group. They are less convinced about the benefits from it. They often tend to confront the information and opinions given by the forest group with those from nature associations. Recreationists also take the opinion from neighbour owners into account.

Recreationists attach most importance to the recreational and nature (ecological) values. Their forest is often an extension of their garden or they have a holiday cottage in the forest. The ownership value is also very important for the recreationists. When thinking of the future of the forests more generally, the combination of ecology and recreation is an important topic for discussion. Recreationists are divided about the societal value of forests. They subscribe the importance of forests for society but are reluctant towards opening up their forest to the public. Their Attitude towards conversion is rather negative. They have the impression that conifers are part of the cultural heritage of the region and, therefore, should not disappear. They have a conservative Attitude, and are reluctant towards changing the forest, even through thinning. For them, it is important that the forest scenery does not change.

Recreationists are faced with several barriers to manage their forest: increasing recreation of others, vandalism, rubbish, inappropriate and unclear legislation. Additionally, the lack of knowledge and the need for help, including the high costs of it. Recreationists think negative about the future, they believe that forests will only survive when recreation and ecology go hand in hand. They are especially negative about the fact that many forest grounds are turned into building lots. Government should take responsibility and start with establishing more forests.

Recreationists do not actively think about possible solutions to the barriers they face. They are very negative about government. They believe that the government could help the forest owners with the management by liberalising legislation while taking the owners' opinion into account. Furthermore, more information and financial benefits to decrease the costs would be welcome. Recreationists experience a serious lack of information. Although they see the forest group as a partially solution for their information problem, they also want the government to distribute more information via the local authorities. Forest groups should work out one vision on managing the forest that all kinds of owners can agree with. More control of recreation of others in their forest by forestry officials is necessary and recreation should be restricted to a limited number of forests. Recreationists also tend to be very positive about buying more forest ground. However, such ground should be adjacent to their actual property. Conversely, they do not want to sell their own forest. Financial profit is not one of their aims as they are too much attached to their forest. They neither like the idea of 'handing over the management of the forest to others' to ease the management. The forest is their property and nobody else has a say in it.

Passive Owners

From the two focus groups with passive owners (SN and GE) we can conclude that passive owners have no intention to convert their forest. For them, their forest is often a burden and they are not really interested in it. They do not like great changes in it, and do not want to carry out management activities that influence the forest scenery. The Behavioural Intention can be explained by the norms, attitude and barriers.

When passive owners undertake management activities, they sometimes take the advice from the forest group and other tree experts into account. However, they are divided about the qualities of the forest group. Those who use the forest group, that is who leave their forest in the care of the forest group, are very positive about it. But those who don't use their services find the forest group rather unnecessary (and possibly linked to politics). They prefer to find any information on their own by the time they need it. The forests of those non-users were often left unmanaged. Passive owners also count on the advice of local authorities and they find that information should also be available there.

That passive owners consider the forest as a burden (or have no interest in it) is often a result of the negative experiences they have with holiday-makers when public access was provided or when forest visitors 'think' that the forest is open for the public. They tend to believe that a forest is not a place for

recreation. Passive owners want to generate financial benefits from their forest. The ownership is very important and they do not want government telling them what to do. Their negative image of government often results from their frustrations with changes in the zoning plans that affect the value of the forestland. When they entrust their forest to the forest group, they expect to get earnings from collective wood sales. Passive owners are divided about their Attitude towards conversion. On one hand, they find that conifers are part of the cultural heritage of the region, but on the other, they find that conifers become sick and must replaced by broadleaves. Passive owners are not interested in management activities that favour conversion. Such activities (i.e. thinning) are only undertaken where owners have handed over the management to the forest group.
Passive owners are also frustrated because of the many problems they face: aging, increasing recreation, rubbish, inappropriate and unclear legislation (e.g., changes in the zoning plan, permissions for tree-cutting), high costs for the management, lack of knowledge and conflicts with neighbours. Passive owners are rather negative about government. They are especially negative about changing zoning plans and perceived pressure as to provide access to the public. Passive owners aren't positive about the future of forests more generally. They expect all forests to become public or in hands of nature associations because of the high costs and low benefits of forests nowadays. Nevertheless, passive owners have possible solutions in mind that could help them managing the forest: control for recreation by forestry officials, cleaning-up actions, a reduction on the price of admission to waste collection sites for owners collecting garbage. They also want government to raise subsidies, make clearer legislation, create more public forests and provide information to owners. They especially need information on how to solve the problems caused by increasing recreation (a.o. rubbish), the main problem they face. Passive owners do not tend to buy more forestland because of the poor financial benefits and the ongoing changes in the zoning plan. Only when they could extend their property, (so that it could be divided into small lots and/or they could build a holiday cottage in it), they would eventually consider to buy (adjacent) forest land. Conversely, passive owners are very open for the idea to sell their forest. A major reason that they don't do it is because of the low prices of forestland (as compared to the price they originally bought it for).

Integrated findings from the focus groups

Generally taken, e*conomists* and *recreationists* have great attachment to their forest and they have much to say about it. Forests have a high nature value for both types of owners. A main difference between them is that *economists* are more likely to see their forest rather as a resource of timber and firewood while personal recreation and relaxation are more important for *recreationists*. To change their Behavioural Intention, they should probably be offered different benefits of conversion. By contrast, *passive owners* are not much involved with the forest. For them, the forest is likely to be a burden and they are not interested in it. So, with exception of the financial benefits, they find forest management not a big issue for discussion. Therefore, it could be very difficult to convince them of the benefits of conversion.
Only *economists* seem to have a positive Behavioural Intention towards conversion and are already active with positive management activities. By contrast, *recreationists* and *passive owners* have a rather negative Behavioural Intention. Both owner types do not like to change the forest scenery and often see conifers as the cultural heritage of the region. *Recreationists* like to recreate in their forest and do not want to disturb the wildlife habitat. Many *passive owners* leave their forest unmanaged, they are not much interested in positive management strategies for conversion.
The forest group influences all types of owners. *Economists* find the forest group an excellent policy instrument. If it is the aim to influence their Behavioural Intention, it should taken serious that they do not want government to take decisions for them. Moreover, there is a realistic chance that they would distrust any of the government's ideas. By contrast, they have no problem with following the advice of the forest group. For *recreationists* more persuasiveness will be needed to convince them of the value of the forest group's advice, although many recreationists consider the forest group as a good initiative to help them with the management. *Passive owners* who have handed over the management to the forest group follow its ideas, although they aren't always positive about it. When the forest group has a longer active working (e.g. Zuiderkempen and Kempense Heuvelrug, GE), *passive owners* are more likely to use their services, but they tend to entrust the whole management to the forest groups. Neighbours (*economists* and *recreationists*), nature associations (*recreationists*) and tree experts (*passive owners*) also influence the Behavioural Intention. So we conclude that the possibilities for influencing the Attitude of those people towards conversion should also be considered.
All of the owner types share many barriers of importance for managing the forest: increasing recreation, high costs, vandalism, rubbish, inappropriate and unclear legislation, aging of the forest, lack of knowledge, and need for help. To solve these, all find that government should liberalise the forest legislation and encourage them by providing them higher financial favours (e.g. subsidies). We conclude that solving these

barriers is an important precondition for encouraging forest owners to carry out positive management activities towards conversion.
Generally taken, *economists* and *passive owners* do not want to buy more forest land. By contrast, *recreationists* would consider buying more forest land adjacent to their property, but they do not want to sell their own actual property. By contrast, *economists and passive owners* would consider this option, although *economists* are much more emotionally attached to their forest than *passive owners*. *Economists* and *recreationists* do not want to hand over the management of the forest. Handing over the management could be a solution for the unmanaged forests of some passive owners, however, this would imply a greater engagement for the forest groups.

4.5 Overall conclusions

In this study, we investigated the social feasibility of the conversion of privately owned pine plantations on sandy soils. We found three owner types – labelled as *'economists', 'recreationists'* and *'passive owners'* - who clearly differ in their characteristics and motivations underlying their Behavioural Intention to convert the forest. It could be suggested, therefore, that any policy strategy or instrument should realistically be adapted to the particularities of each type of forest owner.
Overall, forest owners show a moderately positive intention towards conversion. The owner's attitude towards (any) management activities, which could possibly favour conversion, appears to be a significant predictor for the owner's intention to convert. Family members and the forest group influence the decisions of the owners the most. When owners take these opinions into account, they probably have a positive intention to convert their forest while by contrast, there is a smaller chance that they will carry out management activities favouring conversion. Owners who have a positive intention to convert the forest are faced with a number of barriers, which constrain them from undertaking such management activities. From the mail survey we could not find a significant effect from the barriers listed in the questionnaire to the owners' intention. From the focus groups, however, we found that partly due to the many 'other' barriers owners have to face, forest conversion is not their actual concern.
The *'economists'* - for whom the earnings from marketable timber and firewood, some financial aspects and the appreciation of the nature values of the forest are important motivations – show great interest and attachment to the forest. They are rather positive towards conversion and they – often with help of the forest group – already carry out management activities favouring conversion. As the forest group is attentive to their concerns and allows them to take their own decisions, the two have a positive relationship. Despite the adequate knowledge of this type of owners – thanks to the good contacts with the forest group – we found that still more support through information, subsidies and practical help would be effective.
The *'recreationists'* - who love their forest most because of personal recreation and relaxation values - feel much attached. The forest can be a part of their garden, used as a setting for their holiday cottage or just being loved for its nature values. They tend to have a rather negative intention towards conversion because of their resistance against any changes of the forest scenery and wildlife habitats. A forest is a place for recreation and it belongs to the cultural heritage of the region. Conversion is often perceived as a situation of neglect. Nevertheless, they consider any recommendations from the forest group seriously, along with those from nature organisations. Given the critical Attitude of this type of owners, much persuasiveness is needed to convince them of the benefits of conversion.
'*Passive owners*' are not so much emotionally involved with their forest and hardly pay any visit to it. This type of owners often became frustrated from negative experiences, especially a wrong appraisal of activities allowed (e.g., building a holiday cottage) or of earnings from the forest. As a result, the forest is often considered as a burden while they still keep an interest in financial benefits. Many of the passive owners' forests are left unmanaged and conversion is not a real concern. Compared to the other types of owners they have a clear intention to sell their forest. Passive owners also seem to be more willing to hand over the management to the forest group, especially where it has a longer working history.
We conclude that for policy measures towards forest conversion having any chance of success, these should deal with the many barriers that forest owners face. Only by finding solutions for these problems – together with the owners - it would be possible to convince forest owners to carry out management activities, which gradually lead to forest conversion. Special attention should be given to adapt legislation to owners' needs and build up solutions for the many problems with increasing recreation and rubbish. As the scenery of the forest is also an important issue for many forest owners, 'profile diagrams' could decrease the negative feeling they have about changes in the forest (Nielsen & Nielsen 2005). Furthermore, the results from this study suggest a clear need for critical reflection and 'image building' on the government's side (Van Woerkum 2000). Forest owners do have the feeling that the government is 'against them'. It is high time to stop considering the private forest owners as a problematic group but instead to show appreciation for their societal role. As our study points to a great influence of the forest group on the

owner's intention to convert, we conclude that forest groups should play a major role in encouraging forest conversion.

5 ECONOMIC FEASIBILITY OF FOREST CONVERSION: Forest rent and cost benefit analysis

Schram Albert, Verbeke Tom & Bouma Jan Jaap

5.1 Introduction

The main objectives of the socio-economic part of the FEFECON research project are, first to evaluate existing forest policy, and then to propose a mix of policy instruments which should be both efficient and effective towards achieving an increase in the forested area, a more sustainable mix of tree species in Belgian forests, and a more widespread implementation of sustainable management practices.

For this purpose, the socio-economics group in the FEFOCON project carried out four types of analysis:

- Firstly, an examination of existing forest policies pointed towards certain internal contradictions and regulatory blank spots.
- Secondly, a survey among 320 forest owners was analysed as to the questions pertaining revenues from forests.
- Thirdly, a cost benefit analysis (CBA) was carried out. This is the more substantive part of the report.
- Finally, economic experiments were done with forest owners to calibrate the parameters in the CBA and help interpret the results.

On the basis of these results, some conclusions were formulated following each analysis. This chapter summarizes these analyses.

5.2 Existing forest policy

In Chapter 1.5.1 the economic motivations that made people plant pine forests in Flanders are given. Nowadays, forests are mostly valued for their recreational, landscape, ecological and other functions. In Flanders, a large part of the private forest owners doesn't do any effective forest management. Natural processes induce a spontaneous development towards a more mixed forest with an increasing share of broadleaves. Forest conversion is the effort to speed up and direct this transformation process.

From this analysis of the policy environment (see Section 1.8), the following conclusions follow:

- If the current style of detailed and specific forest policies is maintained, a complete forest land register census should be drawn up so that effectiveness of the policy can be increased and locational aspects can be taken into account. Colson *et al* (2002) also mention the lack of this information for Wallonia.
- Conversion goals should be formulated in terms of % of forest converted by certain dates, for instance 33% in 20 years. The policy instruments are in place, but goals are vague and only qualitative. It is probably most cost effective to target the relatively few large owners (estates larger than 10 ha) who own about 85% of the private forest land. Forest groups show promising results.
- Depending on the conversion goals, the resources allocated to extending the coverage of forest groups should be determined, in comparison to targeting the large owners.
- A comprehensive study on simplifying the subsidy structure should be commissioned to enhance transparency and build up trust among forest owners.
- The recreational subsidy should be redesigned, because it is hardly used in its actual form.

5.3 Brief analysis of the forest owner survey

Here we will analyse only the answers to the economic questions in the survey. For a full discussion of the survey we refer to Section 4.3. We were very prudent when asking for quantitative economic information in the questionnaire for risking a high non-response rate.

Remarkable with regard to the externalities of forest ownership, is that almost 60% of owners state that they do not consider it important that others can walk in their forests. This becomes more explicable when considering that about 50% of the owners has never heard of subsidies, which could compensate them for their provision of externalities. It is remarkable that the efforts of forest groups to provide information about subsidies has not resulted in a much broader awareness of forest subsidies. In the VLINA research project in 2001 around 40% of small owners knew about subsidies, while around 70% of larger owners had heard about them. But while the research population of the VLINA project was all private forest owners, ours was restricted to (small) owners in pine forests on sandy soils.

About 75% is aware of the existence of a forest group, but about 25% of all owners does not want any contact, and slightly less than 50% has never attended a forest group info meeting. We should remember however that about 50% of all owners are passive owners who never visit their forest patches, and some even do not know where it is located (VLINA 2001). Personal interviews with small forest owners during the experiments showed that the most difficult aspect of membership of a forest groups is the commitment to a management plan.

About 25% of the owners thinks it is important to keep the forest because one day they can sell it for a higher price. Almost 20% considers forest land as an investment. Regarding possible sources of revenue from their forests, less than half finds wood revenues important for being a forest owner. It is noteworthy that only 20% considers the possibility to hunt important.

From the survey, we can conclude the following:

- Raising awareness about existing subsidies and rules, can improve progress towards forest goals.
- The passive attitude of most forest owners makes rational management difficult.
- Forest groups should communicate more clearly about their goals so at to take away fears that management plans are too rigid and costly to execute.

5.4 Cost Benefit Analysis

5.4.1 Methods and Results

One appropriate framework for evaluating the results of forest conversion policies, is Cost Benefit Analysis (CBA). The maximization of net social benefits is generally regarded to be the appropriate criterion for selecting a project. The challenges of expressing the intangible benefits of forest conversion policies in monetary terms, however, are still enormous, so this study must be regarded as a first attempt. The CBA first evaluate the private net benefits for the forest owners through a Forest Rent Model (see Appendix The Forest Rent Model), and secondly added values for society at large through Benefit Transfer and Public Pricing methodologies.

In contrast to the description in the initial project proposal, the FEFOCON research team decided not to carry out a Contingent Valuation (CV) survey for three reasons. First, the added value of carrying out a similar study was deemed to be small after the study done by Moons *et al* (2000) that contains a state of the art application of CV, and travel costs (TC) methods for Flanders.

Secondly, despite all methodological sophistication of this study, error margins associated with CV method were roughly 150%, while minimum and maximum values for TC method differed more than 1.000%. In case a CV survey would have been passed among forest owners a Willingness to Accept Compensation (WTA) question instead of a Willingness to Pay (WTP) question would have been intuitive appeal, but lead to strategic bidding and distortions (see Reference list: Valuation literature). For the TC method the problem of combined trips seems insolvable. These methods obviously still generate very imperfect results, and it is not expected that further methodological improvements will lead to lower error margins. We chose therefore to use the imperfect results of the Moons *et al* (2000) study, modify and apply them, which is called "adjusted unit benefit transfer" (Bateman *et al* 2000).

Thirdly, it was deemed impossible to develop a plausible CV scenario that subjects could understand within a CV survey. Interviewed subjects were assumed to have hardly any knowledge about the values associated with the benefits of a "converted forest", which in any event might arise after several decades. Valuing a good (a converted forest) that might come into existence in say 20 or 30 years is asking too much from the current imperfect valuation techniques.

Private Costs and Benefits

Most forestry models start with considering the simplest case of a forest plantation: an even aged stand. First, technically optimal rotation period (TORP) or in this case bedrijfstijd as determined by Dienstencentrum voor

Bosbouw (2000) is presented. As in many countries the TORP is based rather loosely on a mixture of biological, technical forestry and ecological considerations. Secondly, sustainable biological yield (SBY) is determined on the basis of the tree growth functions or tables. This biological approach does not take into account any economic consideration, like the price of wood or the interest rate, but maximizes the biological timber production over time. Thirdly, the optimal rotation resulting from an economic model, called the Fisher-Hotelling (FH) model, is shown. This model has the limitation that it is valid only for a limited number of plantation cycles and that opportunity costs are left out. Finally, the Faustmann-Pressler-Ohlin (FPO) model is discussed. This last model gives the correct optimisation framework for an infinite number of plantation cycles, and takes into account the opportunity costs of selling or using the land for other purposes, and loosing future revenues like thinnings and subsidies. The Economically Optimal Rotation Period (EORP) is determined through this model. The Samuelson equivalent formulation (FPO-S) explicitly takes land values into account, and yields the same results.

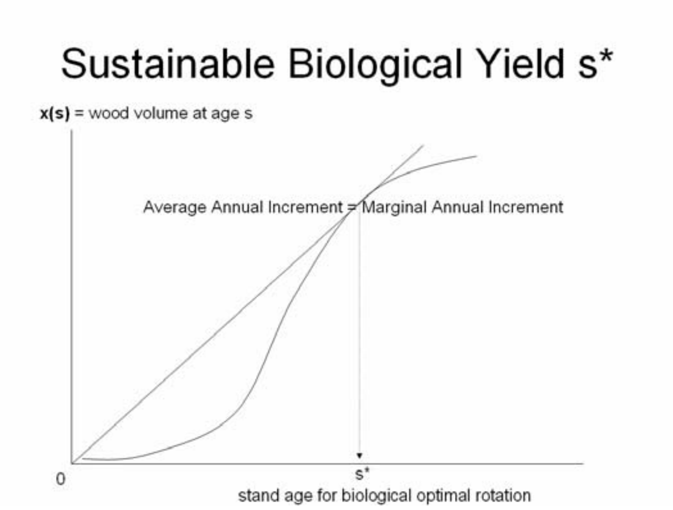


Figure 5-1: Sustainable Biological Yield

When the average annual increment (total production over the stand age) equals the marginal or current average increment curve, the physical timber production curve is maximized over the plantation cycle (Figure 5-1). After this period, the stand should be replaced by younger trees if maximal timber production is the goal.

In forestry publications usually the technically optimal rotation period (TORP) or some other "conventional" rotation period is taken. Although this gives approximations of the economically optimal management, a preferable approach takes into account interest and discount rates, land prices, tree growth, and the development of wood prices. The latter approach is by far superior for the case of Belgium, where the land prices between Flanders and Wallonia are very different. The interest rate and the land price both increase the length of the EORP. The wood price and the growth rate lower the length of the rotation period. In this paper we show that these variables do not complicate modelling unduly, and lead to more accurate results. The rotation period for oak, for example, turns out to be considerably shorter than the officially recommended one.

For a private cost-benefit analysis modelling the EORP is a necessary step. First, for the private CBA the economically optimal rotation period is estimated with a Faustmann-Pressler-Ohlin model (FPO) for a discount rate of 2.5% and 5% for Corsican pine and Scots pine, the main forest species concerned for conversion in Flanders, and for Pedunculate oak, one of the main target species after conversion of pine forests.

Furthermore we took a land value of €6,000 and of €12,000 for Flanders. From these values a land rent is imputed, using the forestry rate of 2.5% and a commercial interest rate of 5%. For a broader discussion of the forest land price issue, we refer to Section 5.5.5 below on public pricing.

For the ease of calculations and interpretation, we considered evenaged, homogeneous stands of Corsican and Scots pine. Moreover, this is the archetype of the undesired forest stand structure subject to conversion. The growth rates of these species were estimated using the Jansen's yield tables for every 5 years, which present total volume, thinning volumes and growth rates for each five year period (Janssen *et al* 1996). The values for the intermediate years were obtained by linear extrapolation. For Corsican pine we chose a wood increment level of 14m^3 per ha per year, for Scots pine 8 m^3 per ha per year, which is representative for the sandy soils. Alternatively we took the oak tables for good soils with an increment of 5 m^3 per ha per year. These tables assume regular thinning every 5 years, which we averaged each year of the intervening period. For the FH-modelled rotation for oak no rotation period can be calculated since this particular tree species never reaches a 5% growth rate.

As can be seen in Table 5-1, however, a rotation period of more than 90 years for none of these species maximizes biological production.

Table 5-1: Optimal Rotations at Different Interest Rates

Optimal rotation (years) at 2,5% interest rate					
Species	**Growth class ($m^3ha^{-1}ya^{-1}$)**	**BT**	**SBY**	**FH**	**FPO**
1- Corsican pine	14	80	**77**	34	--
2- Scots pine	8	85	**34**	32	--
3- Oak	5	180	**89**	--	--
Optimal rotation (years) at 5% interest rate					
Species	**Growth class ($m^3ha^{-1}ya^{-1}$)**	**BT**	**SBY**	**FH**	**FPO**
1- Corsican pine	14	80	77	70	**35**
2- Scots pine	8	85	**53**	*68*	*73*
3- Oak	5	180	**89**	50	*117*

Notes: BT BedrijfsTijd Vlaamse Hoge Bosraad
SBY Sustainable Biological Yield
FH Fisher Hotelling
FPO Faustmann Presler Ohlin

Firstly, it can be observed that the two of the FPO rotation periods (73 and 117 years) at 5% interest rate are not biologically relevant. When FPO exceeds the SBY rotation, the SBY rotation will be chosen instead, since by definition it will be more profitable to replace the stand by younger trees. The reason for this depends on the parameter values chosen in the model, particularly the discount rates, land rents, but also the price of the final cut and the thinnings. In our calculations constant prices were used, given by Dienstencentrum voor Bosbouw (2000). In fact, a large part of the optimization is driven by wood prices. Secondly, it must be noted that at 2,5% no optimization results are obtained at all. With these given parameters the model simply fails to identify an economic optimum within the 90 years time horizon chosen in the model. At lower interest rates than 2,5% the economic optimum lies beyond 90 years, and therefore is longer than the SBY rotation. This means SBY should be chosen as optimal rotation period.

We did not estimate a growth function as most forest economist try to do, but instead used a linear interpolation between the five year periods. Instead of exact mathematical optimization we used approximate optimization using yearly tree growth tables. This allowed us more compatibility with the approaches in forestry, and to have a better feel for the data and compare them more easily with the annuities.

Integrating Private and Social Net Benefits

For the determination of costs and benefits of a converted forest to society, we tried to combine the results of the Forest Rent Model for private costs and benefits, and the results of Benefit Transfer (BT) and Public Pricing (PP). In order to do so, we had to make a number of simplifying assumptions.

With regard to forest rent, we assumed that the rents of the converted stands, whatever the exact species composition, will be similar to those of a pure Pedunculate oak stand. The rent before conversion was set to one applicable for pure Corsican pine. Using Scots pine would result in marginally more positive B/C ratio of conversion. Taking other tree species than these, or mix of species would probably not substantially change the results.

Private costs were assumed to be zero, since technical assistance for conversion is available through the forest group or the local forester of afdeling Bos & Groen. For calculating *private benefits*, linear extrapolation from the yield tables for different soil and forest management types, was used to produce more realistic approximations for TORP and EORP than the long rotation periods from Dienstencentrum voor Bosbouw (2000). For the financial benefits of the forest owners, we were able to calculate the forest rent at EORP. In reality, during the transition path depending on the state of the forest at the onset of conversion, private rents tend to be higher due to revenues from cutting more pines than in usual thinning management.

In general, the difference between TORP and EORP is just as relevant as the choice of interest rates or land values for calculating private forest rents. In this particular case, however, calculating EORP did not lead to very interesting results, but at even higher interest rates, rotation periods would be substantially shorter and forest rents even lower. A value of €-45 and €-96 can be found for private forest rents from a Corsican pine stand, with zero land value and a rotation period of 77 years (2.5%) and 34 years (5%) (Table 5-2). The annual forest rents calculated with this model are shown below:

Table 5-2: Forest rents with existing conversion policy for different tree species

	EORP 2,5%	Forest rent	EORP 5%	Forest rent
Corsican pine	77	-45 €	35	-96 €
Scots pine	53	-6 €	53	-82 €
Oak	98	-4 €	98	-88 €

Taking these negative forest rents and combining them with two different discount rates (2.5% and 5%) and two different land values, we obtained the implicit subsidies of the intervention of the administration in the forest land market, as shown in Table 5-3.

Table 5-3: Implicit subsidies calculated using public pricing at EORP

Discount Rate (1)	Corsican Pine Yearly net revenue ha^{-1} y^{-1} (2)	Corresponding land value converted forest (3) = (2) / (1)	Current land value forest (4)	Difference (5) = (4) - (3)	Yearly deficit or Implicit Subsidy (6) = (5) * (1)
2,5%	-45 €	-1.800 €	6.000 €	7.800 €	***-195 €***
5%	-96 €	-1.920 €	6.000 €	7.920 €	***-396 €***
2,5%	-45 €	-1.800 €	12.000 €	13.800 €	***-345 €***
5%	-96 €	-1.920 €	12.000 €	13.920 €	***-696 €***

The most important market players for buying up forest land is the Flemish government (Afdeling Bos & Groen, Afdeling Natuur and the Vlaamse Landmaatschappij). From a sample of price data taken between 199 and 2003 in a part of the Kempen region, where many pine forests are we found an average a price around €12,000. This represents an implicit yearly subsidy to forest owners of €345 at 2.5% discount rate, and €696 at 5% discount rate. This conclusion is inevitable, since forest revenue is negative and therefore the underlying asset, in this case forest land, would also have a negative value. As we saw when discussing the economic Forest Rent Model, a higher price of forest land and the consequent high land rents, will lead to shorter rotation periods. This could urge forest conversion because pine stands are cut earlier. But is might also work against it, because it promotes reinitiating a new (Corsican or Scots) pine stand after cutting the existing one.

With regard to the *costs to society* of the conversion policy, we will assume that during the conversion path the current subsidies and the income from hunting on average will amount to €150 annually, net of transaction costs and extra management costs. The costs of this policy are represented by direct subsidies as well as by indirect subsidy of maintaining an artificially high land price. Between 1999 and 2003, a total of 1,440 ha of forest land was bought by afdeling Bos & Groen, around 1.4% of the total of about 105,000 ha of privately owned forest. At the average price of €12,000 per ha, on a yearly basis the administration spent €1,920,600 or about €18 per ha of existing privately owned forest (Table 5-4).

Table 5-4: Calculating implicit subsidy from forest purchases

Forest Purchases Vlaams Gewest	
Year	**Forest (ha.)**
1994-1999	
2000	436
2001	434
2002	571
Total (1)	1.440
Average price (2)	12.000 €
Total Cost over 9 years (3) = (1) x (2)	17.285.400 €
Total Cost per year (4) = (3)/9	1.920.600 €
Total privately owned forest in Flanders (ha) (5)	105.000
Annual implicit subsidy (6) = (5) / (4)	18,29 €

Concerning the *benefits to society*, the recreational or use-values were taken from Moons *et al* (2000) for the reference forests (Meerdaalwoud and Heverleebos). Two different cases are presented: the high and the low land and recreational value. In the High Land and Recreational Value (HLRV) case, a forest land value of €12,000 was taken. The recreational value after conversion was estimated by halving the lowest value, obtaining €500 per ha per year. The recreational value of pure pine forest was taken to be €250 per ha per year. Due to the geographical fragmentation of ownership, the full recreational values of the reference forests (over 2000 ha large) will probably never be achieved. In the Low Land and Recreational Value (LLRV) case, a forest land value of €6,000 was taken. Recreational values of €125 for converted and €100 for unconverted forest was taken, assuming only a marginal increase in recreational values.

Similarly, from the study of the reference forests, non-use values corresponding to an addition to the forest capital of €2,000 per ha where deduced, obtaining €50 per ha per year at a 2.5% discount rate, and €100 per ha per year at a 5% discount rate. For the unconverted forest, a non-use value of €500 was taken, leading to a €12.5 per ha per year at 2.5% and €25 at 5%. To determine which of these cases is the most realistic, will require a considerable improvement in the methods of measuring recreational values.

All this leads to the cost/benefit ratios in Table 5-5 for the Low Land and Recreational Value (LLRV) case.

Table 5-5: B/C Ratio for forest conversion in Flanders with Low Land and Recreational Values

Cost and benefits per year of 1 ha. of converted forests in Flanders (rounded values)

		No policy (Corsican pine)		Policy (guaranteed land price, oak with € 150 subsidy)		Difference	
Discount rate		**2,5%**	**5%**	**2,5%**	**5%**	**2,5%**	**5%**
Costs to private owner	FRM Wood and thinnings	0 €	0 €	0 €	0 €	0 €	0 €
Benefits to forest owner	FRM Wood and thinnings	-45 €	-96 €	-4 €	-88 €	41 €	8 €
	PP Land value €6.000	0 €	0 €	196 €	396 €	196 €	396 €
Net Private Benefits		*-45 €*	*-96 €*	*192 €*	*308 €*	*237 €*	*404 €*
Costs to society	OD Conversion subsidies	0 €	0 €	150 €	150 €	150 €	150 €
	OD Expropiation costs	0 €	0 €	18 €	18 €	18 €	18 €
Benefits to society	BT Recreational (TC)	100 €	100 €	125 €	125 €	25 €	25 €
	BT Non-use values (CV)	13 €	25 €	50 €	100 €	38 €	75 €
Net social benefits		*113 €*	*125 €*	*7 €*	*57 €*	*-106 €*	*-68 €*
Total Private and Social Benefits		68 €	29 €	199 €	365 €	300 €	504 €
Total costs		0 €	0 €	168 €	168 €	168 €	168 €
B/C ratio of conversion						**1,8**	**3,0**

Note that although the total B/C ratio of the conversion policy is higher than one, with only a marginal increase in recreational value, the net social benefits in this case are negative.

For the High Land and Recreational Value (LLRV) case, Table 5-6 summarizes the results:

Table 5-6: B/C ratio for forest conversion in Flanders with High Land and Recreational Values

Cost and benefits per year of 1 ha. of converted forests in Flanders (rounded values)

		No policy (Corsican pine)		Policy (guaranteed land price, oak with € 150 subsidy)		Difference	
Discount rate		**2,5%**	**5%**	**2,5%**	**5%**	**2,5%**	**5%**
Costs to private owner	FRM Wood and thinnings	0 €	0 €	0 €	0 €	0 €	0 €
Benefits to forest owner	FRM Wood and thinnings	-45 €	-96 €	-4 €	-88 €	41 €	8 €
	PP Land value €12.000	0 €	0 €	345 €	696 €	345 €	696 €
Net Private Benefits		*-45 €*	*-96 €*	*341 €*	*608 €*	*386 €*	*704 €*
Costs to society	OD Conversion subsidies	0 €	0 €	150 €	150 €	150 €	150 €
	OD Expropiation costs	0 €	0 €	18 €	18 €	18 €	18 €
Benefits to society	BT Recreational (TC)	250 €	250 €	500 €	500 €	250 €	250 €
	BT Non-use values (CV)	13 €	25 €	50 €	100 €	38 €	75 €
Net social benefits		*263 €*	*275 €*	*382 €*	*432 €*	*119 €*	*157 €*
Total Private and Social Benefits		218 €	179 €	723 €	1.040 €	674 €	1.029 €
Total costs		0 €	0 €	168 €	168 €	168 €	168 €
B/C ratio of conversion						**4,0**	**6,1**

5.4.2 Discussion

Models are simplifications of the truth, they reduce a complex problem to a few essentials and illustrate the relationships between them. A good model is wide in scope and unexpected in implications (Kay 2004: 11). The Forest Rent Model showed that wood price, land price, management subsidies, and discount rate together determine the Economically Optimal Rotation Period. This influences the speed at which forest conversion (stand replacement) takes place and the distribution of costs and benefits between private owners and society at large. One unexpected result is the observation that the forest groups by increasing timber prices actually lengthen EORP and therefore inadvertently slow down conversion.

The results of this model are indicative and highly debatable. The discussions about the "true values" for use-values, land values, discount rate, and even wood prices seem to be never ending (references). We tried to make reasonable choices based on the limited evidence we were able to obtain. Recreational values are the biggest question mark, because travel costs studies are unable to determine them with an acceptable degree of accuracy. Next, the forest land value in a market strongly influenced by government intervention is hard to determine. The discount rate debate is unsolvable. So we took both a low, conventional 2.5% discount rate, and a high 5% discount rate to satisfy both sides, the forestry scholars and the economists, in the debate. Experimental evidence seems to suggest that in reality even higher discount rates are used.

Comparing the different B/C ratios, for both cases it can be concluded that the interest rate makes a difference to the financial rents of the forest owners, but not so much to forest management (rotation periods). As we saw in the Forest Rent Model, rotation periods held constant, higher land prices off-set lower interest rates exactly. When interest rate increases from 2.5 to 5%, the B/C ratio goes up for the LLRV case from 1.8 to 3 and for the HLRV from 4 to 6.1, mainly due to high share of costs attributed to the subsidized land price and caused by the relatively high land price of €6,000 or €12,000. Taking a lower forest land value, however, has other drawbacks. Lower land values will lead to longer rotation periods for the pine stands, and consequently slower conversion. Further work is needed to acquire more realistic data about subsidies, wood prices and fuel wood prices. Forestry research about the price increment of different timber types in unmanaged forests would also be welcome to improve our calculations.

The B/C ratios are all over 1, ranging from 1.8 to 6.1, depending on assumptions about discount rates, land prices and recreational values. At higher interest rate, implicit subsidy for land values is higher, because alternative investment would generate more income In rounded values, we can conclude that forest conversion of pure pine stands generates a benefit to the private owner and to society of between €350 and €1,030 per ha per year, at a cost to society of about €170 per ha per year. This implies a policy leverage factor of between 2 and 6.

In effect, however, the partitioning of this benefit between private owners and society differs dramatically between the LLRV and HLRV cases. In the LLRV case, net social benefits are negative, while net private benefits remain positive. In the HLRV case, net social benefits become positive, but still a factor 3 to 4 smaller than private benefits. The difference between the LLRV and HLRV hinges on the effects of government intervention in the forest land market and the changes in use-values. Non-use values do not play a critical role.

It can be noted that at the preferred 2.5% discount rate the current level of subsidies leads to B/C ratios between 1.8 and 4, in any case higher than 1. These results suggest that current direct and indirect subsidies exceed the benefits by a comfortable margin. It might also suggest that only by slightly increasing subsidies, owners of oak stands could be compensated for the negative forest rent of their oak forests of €-4 . This interpretation would however attach too great a significance to these results, and overestimate their accuracy. Given the insecurity about the price of forest land, the many other assumptions, and the wide error margins of valuation of non-use and use values not too great an importance should be given to this exact number. The social costs were determined using a general estimate of average subsidies for desired forest type using public pricing. Social benefits were estimated using results from other studies, a procedure called Benefit Transfer. For use values of the converted forest, results from a travel cost study was used, while for non-use or passive use values result from a contingent valuation study were employed. These procedures do not allow for great accuracy.

In this section, we showed how forest stand yield tables can be integrated with economic models of forest rent to determine Economically Optimal Rotation Periods. Subsequently, knowing management costs and the EORP, private forest rents can be maximized.

According to the FPO solution of the optimization problem, harvest takes place when timber volume growth rate is equal to or smaller than the interest rate plus a stock effect. This stock effect is the ratio of all opportunity costs over the value of the timber. the higher interest rate plus stock effect, the shorter the rotation period, because relative wood increment decreases over time. Rotations will also be shorter when land values are high, as is the case in Flanders. On the other hand, shorter rotation periods will lead to higher forest rents, and more opportunities for forest conversion (stand replacement). Conversely, when land values are relatively low, like in Wallonia, the rotation periods will be relatively longer. In most cases, for Flanders the EORP found were similar to the Sustainable Biological Yield, though far shorter than the rotation periods prescribed by Dienstencentrum voor Bosbouw (2000). These differences in rotation period influence the results for forest rents models substantially, particularly when higher discount rates are chosen.

In brief, the critical issues when evaluating costs and benefits of forest conversion turn out to be how to (i) evaluate the effect of the government's intervention in the forest land markets and (ii) how to value the changes in recreational benefits. According to our calculations, the benefits for private owners of market intervention in forest land were substantial in comparison to the direct conversion subsidies. The implicit subsidy of intervening in the forest land market turned out to be a highly cost effective policy measure, with a cost of around €18 per ha generating benefits for the forest owners between 10 and 35 times as high. Moreover, this measure shortens EORP, and therefore speeds up forest conversion, with the remark that it might stimulate reinitiation of pine stands where legally tolerated. With regard to recreational benefits, travel cost studies produced unsatisfactory results, and alternative approaches to achieve a more accurate valuation of these benefits as a function of landscape values and amenities of different forest types should be developed.

With regard to conclusions on policy, this study produced some indications, but it can not yet form the basis for a scientifically based argument for a policy change. Although the current policy is commendable because of its goal-specific subsidy instruments, its low transaction costs, and its enlightened participatory approach through the forest groups, a large majority of owners still does not practice sustainable forest management. We suggest therefore that it should be a first priority to extend the participation of the forest owners in forest groups, in order to achieve some established goal for forest conversion within a given time frame, for example, 33% of the pine forests converted within 20 years.

From the CBA analysis follow these conclusions:

- Although not enough data on forest land values are available to draw statistically valid conclusions, the government programme for buying up forest land should continue and not be scaled down. It is probably the most cost-effective instrument.
- Data on implicit land values and implicit discount rates used by forest owners could be obtained from experimental methods, but are not available now.

- A small study on compensating owners who have converted aggressively should be carried out, in order to avoid negative forest rents for these owners.

5.5 Economic experiments to calibrate the Cost Benefit Analysis

5.5.1 Introduction

During the CBA a number of unresolved issues remained for which conventional data is not available:

1. *How do forest owners approach opportunity cost i.e. dissimilar discount rates in the different conversion scenarios that take several decades?*

The choice of a discount rate has far reaching implications for the Cost Benefit Analysis of forest conversion policies. In order to interpret the CBA correctly it was critical to establish which discount rates were used by the forest owners. Forest owners can be seen as a unique group that has to make decisions about forest management with an impact in periods of 20 or more years. This long-time horizon makes the discount rate in this CBA even more critical. Some authors argue that in taking these decisions, owners use extremely low discount rates. As a consequence, optimal rotation periods will lengthen if a conventional Faustmann model for optimal rotation of a forest plantation is used. This may slow down the forest conversion process

2. *Is the hampered cooperation among forest owners in forest groups due to their distrustful attitudes, or to more objective factors related to the incentives?*

Trust is important when people interact in economic life. We tried to find evidence that trust levels were low among forest owners. Lack of trust among other forest owners who do not participate in forest groups could also be a motive for not participating. Further questioning of participants gave reasons to believe the inflexible nature of the regulations on forest management plans were the main reason for forest owners not to participate or cooperate.

3. *How do forest owners react to forest policy incentives? Are they willing to choose a faster conversion path, even if incentives are for a moderately fast conversion?*

The survey had shown that forest owners are not greatly concerned about the uses other people make of their forests, or other externalities. The question whether moral pressure to choose for a larger than optimal provision of public goods was experimentally tested.

These unresolved issues brought us to an experimental approach, where (i)forest owners, (ii)forest group coordinators and (iii) university students as a control group were used as experimental subjects.

Conventional economic data are derived from observing ongoing, and uncontrolled processes. It is still conventional wisdom for most economists that happenstance field data is the only type of data they can work with, but unfortunately this turns out to be wrong (Table 5-7). For almost 50 years economic experiments have been conducted, which have proven to be useful for environmental economists (Kagel & Roth 1997).

Table 5-7: Types of economic data

		Data type	
		Happenstance	**Experimental**
Data source	**Field**	inflation rate	fundraising experiments
	Laboratory	discovery of penicillin	double auction experiments

In 1994 the Nobel Prize in Economics was awarded to two game-theorists and experimenters John C. Harsanyi, John F. Nash Jr., and Reinhard Selten for "for their pioneering analysis of equilibria in the theory of non-cooperative games". In 2002, again this prize was awarded to Daniel Kahneman, a psychologists, and Vernon L. Smith respectively, "for having integrated insights from psychological research into economic science, especially concerning human judgment and decision-making under uncertainty", and "for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms". (http://www.nobel.se) It is no exaggeration to state that during the last half century economics apparently too has seen the emergence of serious experimental activity flanking traditional theoretical practice (Friedman & Sunder 1994: 1).

Environmental economists have become interested in economic experiments for two principal reasons. First, markets tend not to work well for public goods and in the presence of large externalities. A major source of market failure is environmental externalities. Subjects' behaviour might respond to the externalities rather than to market incentives. In those cases, economic experiments can shed light on implicit attitudes to risks, trust, and discount rates. If subjects use very high implicit discount rates, for example, taking a low discount rate in a cost-benefit analysis will most likely not lead to realistic predictions of subjects' behaviour. Secondly, environmental policy instruments often require some degree of cooperation. Fine tuning policy instruments and institutions can not occur when incorrect behavioural assumptions are used. Test-bed experiments can therefore help to develop policy instruments.

Economic experiments are commonly divided into several thematic categories depending on the discipline or theory that inspired them:
- psychology, e.g. individual decision-making, risk, trust;
- game theory, e.g. coordination, bargaining;
- market organization and competitive equilibrium, e.g. double auction;
- public goods, e.g. cooperation, voluntary provision of public goods and
- policy instrument testing, e.g. alternative fine mechanisms.

An experimenter is successful in provoking real life decisions in subjects when three conditions are met:
- *Monotonicity*. Subjects must prefer more reward medium to less, and not become satiated. This condition is easily satisfied when domestic currency is used as a reward medium.
- *Salience*. Subjects must base their choices on the different rewards for each choice.
- *Dominance*. Changes in subject's utility stem mainly from the reward medium and other considerations are negligible.

The subjects' pools for the experiments and the framing or contexts can also differ. The most commonly used, are pure laboratory experiments with students as subjects, which are usually context free and heavily scripted. Some experimenters, however, deny that experiments with students have any external validity, i.e. the results can not be generalized. Artefactual field experiments, are the same as conventional lab experiments but use a non-standard subject pool, i.e., non-students. The purpose of taking these particular subject groups is to increase validity of the experiments. Our experiments with forest owners can be classified as framed field experiments, which are identical to artefactual field experiments but with field context in either the commodity, task, or information set that the subjects use. An example would be work that elicits valuations for public goods that occur naturally in the environment of the subjects. The danger of introducing even more realism, e.g. not informing the subjects that they are in an experiment, is that one looses control. But in principle if control issues are addressed carefully no such loss need occur (Harrison 2004). The issue of control arises in all types of experiments and has to be addressed carefully anyway.

5.5.2 Methods

In the FEFOCON research we conducted artefactual field experiments with real decision-makers (forest owners) and with policy makers. Students acted as a control group. These experiments were set up as small scale exercises, in order to formulate some hypotheses about the existence of peculiar behaviour among the forest owner group.

We chose a sequence of three experiments, all closely linked to the unanswered questions in the CBA. First, an individual decision experiment elucidated the implicit discount rates forest owners actually apply. Given the insecurity about inter-temporal choices among forest owners in the cost benefit analysis, this was an obvious issue suitable for an experimental approach. In principle, this subject pool should be used taking decisions that extend their own life span. The analysis of the result focused on the average discount rate employed and the differences between gain and loss scenarios.
Secondly, we did a pure trust experiment without context. Subjects alternated the role of sender and receiver. Contrary to some literature, we found that this alternation enhanced cooperation and we observed high levels of efficiency. The analysis of the result focused on the share of total Pareto efficiency achieved and the dynamics of the several rounds.

Thirdly, voluntary provision of public goods and cooperation was measured, first in a pure form without context, and then with a similar marginal payment in a context rich environment, including the net social benefits for each decision. The analysis of the results focused on the frequency of the occurrence of the

Nash equilibrium achieved, the dynamics over the several rounds and the similarities in strategies with the second game between the same subjects.

Experiments were held on May 21st 2005 in Bokrijk with 6 forest owners (Owners 1 experiment), on June 7th 2005 with 6 students at Ghent university (Students), on July 16th, 2005 in Sint Michiels with 14 forest owners (Owners 2), and, finally in Brussels on September 9th, 2005 with forest-group coordinators (Forest Group Coordinators).

5.5.3 Discount Rate Experiments: Results

In some environmental or forest economics literature the hypothesis is advanced that a low discount rate of 1% or 2% must be employed in natural resource management for evaluating opportunity costs. This experiment added to the burden of evidence that implicit discount rates are high and not always hyperbolic. Hyperbolic discounting means subjects use high discount rates for the short term, but decrease them for longer term. Discount rates rather differ almost randomly depending on the time period under consideration. The results also falsified the hypothesis that forest owners employ starkly different discount rates from other groups, in this case students. It also falsifies the hypothesis that differences among forest owners are insignificant.

Our specific experiment was modelled on the study by Harrison *et al* (2002). For each of a 1, 2, 5, 10 and 25 year time interval we showed subjects a table. There were two different treatments. One a pure gain, and the second a compensation after incurring costs. At the beginning of the session we stated: "One person in this room will be randomly chosen to receive a substantial sum of money. For this individual we will randomly choose one of the tables, and pay out the amount in the manner indicated by the subject."

An average discount rate in the two groups of owners is hard to determine, since many owners indicated a rate higher than the maximum rate in the table of 35%. In general, it can be said they indicated rates between 10% and 20% and in no case can the average be said to lie under 10%. These results confirm former results that discount rates elicited by this method are above 10% and often in the 20-30% range (Harrison *et a*l 2002). Students follow a similar pattern, although rates are somewhat lower, 6-8%.

We also analyzed whether a longer time span would lead to a lower, higher or equal discount rate. Around 50% of the responses showed a higher discount rate when time periods became longer, which is opposite of what you expect with hyperbolic discounting. With regard to the difference between the gain scenario and compensation for loss scenario results were more mixed with about half the subjects choosing the same or a very similar discount rate.

The hypothesis of hyperbolic or decreasing discount rate was not confirmed by these experiments. In fact, a majority of the subjects used increasing discount rates. No explanation for this behaviour is advanced. No evidence for the hypothesis that compensation for loss would lead to higher discount rates was found. The difference between students and forest owners was minimal.

5.5.4 Trust Experiments: Results

In the trust experiment we tried to measure trust levels among groups of forest owners as well as a group of students. Attitude surveys of forest owners found them particularly distrustful (VLINA 2001). Using students as a control groups it was possible to see whether there is any basis for such a hypothesis. We were also particularly interested in seeing whether reciprocal behaviour in fact enhances trust. The mechanism we used was that of alternating roles. In contrast to other experimental results, this enhanced levels of trust (Burks *et al* 2003). Trust is understood as an expectation or a reliance on the reciprocity of others where a return is made for something done or given (Berg *et al* 1995: 126). Conversely, trustworthiness is a reputation for reliability in responding fairly to trust offered. Reciprocity is different from trust or trustworthiness, and should be seen as a strategy in the game-theoretical sense. Reciprocity implies that people respond to acts that are perceived as kind in a kind manner, and to acts that are perceived as hostile in a hostile manner (Fehr and List 2004: 745). In this sense, reciprocity is similar to a tit-for-tat strategy.

A more accurate idea about forest owners' tendency for trusting or trustworthy behaviour is a precondition for designing policies requiring a certain willingness to cooperate or invest in a public good. These experiments show that there is no reason to believe forest owners are particularly untrusting or fail to reciprocate.

Two hypotheses were formulated with regard to alternating roles in a trust game (Burks *et al* 2003: 196). The golden rule hypothesis states that both the degree of trust (sending) and reciprocity (sending back) are enhanced when partners play alternating roles. In contrast the reduced responsibility hypothesis states that each participant feels less responsibility for the well being of his/her partner, and feels less guilty about acting selfishly. The authors used an experimental design in which in one case participants were informed about the fact they would play both roles, and in the other that in which they did not know this. They found no evidence for the golden rule hypothesis, so did not reject the reduced responsibility hypothesis.

We argue that these results depend on the one-shot nature of this game. One shot games seldom occur in real life situations, so we decided to play this game repeatedly with alternating roles. Participants were informed that they would play anonymously with a fixed partner during at least ten rounds. The end of the experiment would be determined by the flipping of a coin in order to avoid end effects. Each participant, sender and receiver was endowed with 100 points each round, and was informed that this corresponded to about 0.50 euro. This was done so that the point received would have a relative value in respect to the initial endowment.

The sender would decide to send an amount between 0 and 100 to the receiver, which the experimenter would triple. The receiver would than decide to send an amount back of between 0 and 400. The next round would start with the sender and receiver role reversed, and so on.

With the forest owners 1,833 (92%) points of a total of 2,000 in case of total trust and reciprocity. In the role of senders these subjects had an average of 814 (44%) points and in the role of receivers 1,019 (56%). With the forest group coordinators only 3 test rounds and 4 valid rounds were played. They achieved on average 745 (93%) of a total o 800 points. In the role of senders these subjects had an average of 349 (47%) points and in the role of receivers 396 (53%). There seems to be no significant difference between the groups.

In all, these experiments yielded no evidence that forest owners have significantly different attitudes and would be particularly distrusting. It seems the reasons for some of their uncooperative behaviour should be sought in the measures themselves, not in the attitudes of the forest owners.

5.5.5 Public Goods Experiments: Results

In view of the original research proposal of FEFOCON, it was thought interesting to compare private and public costs-benefit structures (net benefits or pay-offs in game theoretical language). It was also considered interesting to see whether forest owners had a specific style of decision-making or were sensitive to policy goals and broader context.

We gave subjects instructions for a standard 4 x 4 matrix public goods game. To see if forest owners and policy makers show different sensitivities to context we conducted a separate experiment with forest group coordinators.

To our surprise, these groups behaved very similarly and showed the same percentage of Nash play. It does seem however clear from all three experiments that the forest owners' decisions are not likely to be very different from other people's decisions. Moreover, the experiments stressed the importance of incentives to influence behaviour.

There are no direct conclusions for policy following from these experiments, since they were used to calibrate the CBA. They do however reinforce some of the conclusions of the CBA, namely

- Discount or interest rates do matter, and are not likely to be close to 0% even over long periods such as 25 years.
- The lack of participation in forest groups is not due to lack of trust among forest owners, but are more likely to be sought in the conditions and inflexibility of the policy measures themselves.
- Forest owners, but also forest group coordinators do not automatically incorporate social benefits into their private decision making. Like other subject groups they do respond to incentives.

6 RESEARCH SYNTHESIS AND POLICY RECOMMENDATIONS FOR FOREST CONVERSION

6.1 Synthesis and recommendations from the ecological research

6.1.1 Forest conversion improves the environmental quality of the forest ecosystem

A quantitative literature review was performed on published studies comparing pure coniferous and pure deciduous stands at comparable sites. It can be inferred that forest conversion has a good potential to

- reduce the NO_3^- and NH_4^+ input to forest stands (ammonium and nitrate)
- reduce input of acidifying pollutants
- reduce NO_3^- percolation to the ground water
- reduce the loss of base and acid cations to the deeper soil.

These positive effects are particularly promising in areas with current high levels of atmospheric N pollution. The sandy regions in Flanders, where most pine plantations grow, are an extreme example of this. But also the Ardenne region, with most of the Norway spruce forests, has high levels of atmospheric N pollution, typical for the whole of Central Western Europe.

A comparison study of three homogeneous forest types (Norway spruce, beech and sessile oak) in Wallonia confirmed these general findings from literature. Soil conditions (acidity, base saturation) are better under the oak stand. The input and output of NO_3^- are high in the Norway spruce stand. Due to acidic conditions, Al and Mn concentrations and mobility are higher under the Norway spruce stand than under the broadleaved stands. This increased Al availability could cause nutrient deficiencies and high Mn concentrations could have toxic effects. Moreover, important Al losses from forested watershed can be responsible for the disappearance of aquatic organisms in rivers and lakes and might hampered the drinking water consummation.

Nitrification rates in the soil organic layer were influenced by forest type, with a lower rate detected under the oak stand. The relatively light oak canopy allows the development of a dense herbal layer which may act as a competitor towards soil microorganisms for N consumption. The experimental set-up did not allow proving this hypothesis, but it would mean that an oak stand also has a indirect effect on soil, through its canopy structure. This would mean that the oak stand, through its canopy structure, has an indirect effect on soil processes. This highlights the importance of the stand structure, together with the dominant tree species. The stem density and the layer structure of a forest stand also have a major influence on the microclimatic conditions prevailing in the forest floor, and therefore on the development of herbal layers, microbial populations and decomposition of leaf litter. According to present knowledge, the augmentation of broadleaved tree species like sessile oak and beech in Norway spruce stands will probably have positive consequences on soil as well as soil water quality:

- a substantial decrease of atmospheric deposition reaching the forest floor (N, S);
- a decrease of NO_3^-, aluminium and base cation losses with seepage water;
- a better litter decomposition: a moder-mull in stead of a mor-moder humus form;
- a better cycling of nutrients, especially in the case of oak and other improving tree species (often secondary species);
- an increase in soil pH and soil fertility;
- a decrease in the biological NO_3^- production if converted towards an oak forest.

A litter decomposition study showed highest nutrient contents in litter from secondary forestry species (*Salix caprea*, *Sorbus aucuparia*, *Alnus glutinosa*, *Betula pendula*) as compared to the main forest species (*Quercus petraea*, *Picea abies*, *Fagus sylvatica*) growing on similar soils in the Walloon region. Different rooting pattern and nutrient acquisition mechanisms may explain these differences. The nutrient-rich species also decomposed more rapidly and released the highest amounts of the more frequently limiting nutrients (Ca, Mg, K). The major amount of these nutrients was released during the first year of decomposition. The introduction of secondary forest species on poor soils may therefore be a potential management tool for maintaining/improving the nutrient status of these sites. Besides the nutrient content of the litters, their actual impact on soil fertility will also depend on the management scenario chosen, in particular with regard to the percentage of broadleaved trees and their spatial distribution.

Choosing a different scenario of conversion (see Appendix Forest Conversion Scenarios) implies a specific sequence of stand development phases, each with its own vertical structure. Apart from the tree species in the regeneration, this vertical structure has an important effect on the input of atmospheric deposition and the losses of base cations and aluminium in seepage water. The promotion of broadleaved species for the regeneration (i.e. conversion) seems to be the best choice, although in certain development phases this can imply temporarily higher input of atmospheric deposition. It seems that even in such a phase, the nitrate and cation losses with seepage water are lower in broadleaved regeneration.

As a conclusion, the mitigation of the environmental problems of eutrophication and acidification of forest ecosystems is a valuable additional argument for forest managers to convert coniferous forests. Furthermore, the introduction secondary species (willow, mountain ash and alder) may be a useful tool for improving the nutrient status of poor forest soils.

6.1.2 Forest conversion probably improves forest biodiversity

In general, conversion will improve species diversity or at least keep it at the current level, because (i) in our regions the direct effects of deciduous tree species on the site characteristics favour more diverse plant and animal communities and (ii) the biological potential of the main indigenous deciduous tree species is superior as compared to conifers. But the actual outcome in the field depends strongly on several "confounding" factors, other than the dominance of indigenous deciduous trees in the stand.

A case study for forests on sandy soils in Flanders confirmed that no unequivocal distinction can be made for the herbal species diversity between broadleaved and coniferous forest stands on these sites. However it confirmed that there are important differences in plant species diversity between homogeneous Scots pine, Corsican pine, indigenous oak and birch stands. Both oak and birch stands have associated plant and especially moss species, whereas both pine forest types don't. These specialized plant and moss species add much to the nature value of forests. As a target species for the conversion of pine plantations in Flanders, especially birch exhibits good potentials for improving plant diversity.

Policy must however avoid the mystification of an intensively mixed stand of indigenous deciduous trees and shrubs. Creating this stand type in all current secondary conifer plantations would have a homogenizing effect that could be detrimental to specific plant and animal species.
Priority zones for conversion, e.g. on more buffered soil types and close to ancient woodland sites, must be defined. Maintaining biodiversity also implies the preservation of conifers as individual trees, groups or even large stands in an otherwise converted broadleaved forest. In order to have ad differntial choice and to reach conversion goals, a combination of different management scenarios is needed.

6.1.3 Forest conversion goals, priorities and management scenarios

Both in Wallonia and Flanders, the actual homogeneous conifer forest types that are candidates for conversion are well defined. However, the workable definition of the desired stand types to aim at, must be more exact than the reference to (ancient) broadleaved forest stands that have a completely different management history. At a practicable scale (regional level or at forest complex level) the forest policy should define general priorities and goals, but nonetheless include quantitative objectives in space and time. Of course, when choosing conversion management scenarios, these general rules will be confronted with the field situation by the forest managers.

The main differences between the scenarios are indeed the speed of change, the resulting variation in horizontal and vertical stand structure and the balance between the different tree species. The parameter % broadleaved trees in the forest will increase whatever scenario chosen and will in the long term not differ very much between the different scenarios. The resulting forest will however differ strongly. The % broadleaved trees is therefore insufficient as the only quantitatively defined parameter of conversion policy.

A general conclusion on sylvicultural scenarios for the conversion of homogeneous pine stands on sandy soils can be that:

- Awaiting spontaneous regeneration of broadleaved trees and shrubs (rowan, buckthorn, pedunculate oak and birch) while continuing thinning management of pine stands is an easy and cheap way of conversion. But it might result in homogeneous two storied stands over large areas, with an uncertain timber quality of the broadleaved trees.
- Group cuttings can speed up the conversion, resulting in the fast establishment of new broadleaved stands of pioneer species (birch) and in the desired small-scale mosaic structure. For

the feasibility of practical stand management and future timber quality, groups should be rather large (0.5 - 1.5 ha).

- A combination of the regeneration of broadleaved species under variably thinned pine cover with the regeneration in rather large group cuttings, seems feasible from a sylvicultural point of view and can be adjusted to the goals and priorities set by the forest policy.
- Planting broadleaved trees for conversion is an expensive alternative to spontaneous regeneration, although it might well be justified. The protection against deer browsing is a major cost for both alternatives that should be addressed by the forest policy.

6.2 Synthesis and recommendations from the socio-economic research for Flanders

6.2.1 Different types of forest owners

ECONOMISTS

Economists are often carrying out management activities that promote conversion. Economists who are not busy with management strategies favouring conversion at the moment can be easily be encouraged to work out such activities with policy instruments that convince them of the benefits of it. Economists in general have good contacts with the forest group that can have a central role in supplying them with more information about several conversion aspects, practical help and optimal use of subsidies. Simplifying the subsidy structure should be commissioned to enhance transparency and build up trust among forest owners. From the economical point of view it's important that the recreational subsidy should be redesigned because it is hardly used in its actual form. There is no balance between the (small) subsidy and the extra costs cause of increasing recreation and public access. Raising the awareness of owners about existing subsidies and rules can improve progress towards forest goals.

RECREATIONISTS

Recreationists are often not carrying out management activities that favour conversion. They have a rather negative intention towards conversion, because they dislike changes in the forest scenery and wildlife habitats (see Section 6.2.3). They really believe conversion stands for neglect and damage to the cultural heritage landscape. We have good reasons to believe that conversion is possible in forests of recreationists in the long term, but persuasiveness and caution is needed to convince them of the benefits. There is a great need for information to increase their knowledge about (conversion) management. An important step will be to convince them of the benefits of the forest group, about which they are sceptical. By communicating clearly their goals, the forest group can take away the recreationists fears. Recreationists are the owner group that is most likely to buy more forest in the future, although preferably adjacent to their actual property. Moreover, they are least likely to hand over management of their forest (or sell it) to the government. They are opposed strongly to interference in the management of their property, possibly because many of them have a holiday cottage in it or the forest is an extension of their garden.

PASSIVE OWNERS

Passive owners often don't manage their forests at all, so forest conversion is not a concern for them. Neither is there an indication that they will do conversion management in the future. Obviously their passive attitude makes rational management difficult. They rather want to sell their forest or handle over the management to the forest group, especially when the forest group has been active for several years and is locally acknowledged. Providing management information to passive owners is useless. More effective will be a well-organised forest real estate market with recreationist owners and the government at the demand side. A parallel option is the forest group taking over all management activities.

6.2.2 Forest groups

Although quite young, the forest groups already have a great influence on private forest owners. They will play a crucial role for the conversion of private and public conifer forests in the future. A key factor is the highlight free choice of the owner, but also the supply of information through personal contact. A clear communication can take away most owners' fears that management plans are too rigid and costly to execute. The most effective promotion of conversion management by the forest group is (i) helping economists with good technical management, (ii) cautiously, but steadily convincing recreationists of the benefits of forest (conversion) management and (iii) be a trustworthy and complete manager of the forests of the passive owners or inform them about the demand side of the estate market. The current specifications of the forest groups and their capacity does not allow this last task. It is moreover not certain that such tasks are compatible with a forest group that must be trustworthy to the recreationist and the economist. Forest policy should think of extending the definition and capacities of a forest group, or finding other policy instruments to accomplish the management of the passive owners' forests, whether or not after buying them, which seems to be a cost-effective instrument that should continue and not be scaled down (see Section 5.4). Non-participation of owners can rather be sought in the conditions and inflexibility of the policy measures than it has to do with a lack of trust among forest owners (see Section 5.5).

From the economic experiments, it is clear that the lack of participation in forest groups is not due to lack of trust among forest owners. The reasons are more likely to be sought in the conditions and inflexibility of the policy measures themselves and in other barriers owners face.

Depending on the conversion goals and priorities in a certain area, the resources allocated to extending the coverage of the local forest group should be determined, in comparison to targeting the large owners.

6.2.3 Scenery and wildlife habitats of the forest (profile diagrams)

The scenery of the forest and the existence of certain animals seem to be a great concern for forest owners, especially for recreationists. To take away uncertainty about the future evolution, it would be very useful to convince private forest owners of the benefits of conversion by showing them diagrams of the different development phases they will encounter. This may contrast the evolution in the different management scenarios chosen, inclusive of a non-intervention scenario. By looking at such diagrams (on posters or even on a computer screen), forest managers and owners confront this with their own mental images and experiences. The implementation of new management paradigms, as is forest conversion to many managers/owners, will become easier (Nielsen & Nielsen 2005). And it will also be easier to formulate conversion goals within a certain time frame, for example 33% of the pine forests converted within 20 years. A possible next step that is being proven in forest complexes where forest groups are active for 5-10 years is that the changed scenery examples can be shown and discussed in real.

6.2.4 Barriers and recommendations to solve them

As important as convincing forest owners of management activities that favour conversion, is the solving of the numerous barriers and problems owners face. Many forest owners are now not concerned with conversion because they have other things to deal with. Owners of all types face the following problems: expanding recreation resulting in rubbish and vandalism, high costs, inappropriate and obscure legislation, lack of knowledge, need of help. Owners formulate the following solutions to these own problems:

- Liberalize the forest legislation so that it becomes clear and transparent and an owner can manage without wondering if his strategy is allowed or not.
- Provide higher financial favours to decrease the high management costs (more subsidies or better information about the different existing subsidies). An example: decrease the waste deposit costs for rubbish collected by forest owners when they bring it to a recycling unit. The subsidy for public access doesn't work.
- Distribute more information about forest management.
- Do NOT ignore the problems associated with the increasing forest recreation.

Besides these general problems, there are specific barriers for each type of owner.
Economists face problems with (i) the difficulty to reach their forest, (ii) their high age, (iii) the troubles with public access to their forest. They want permissions to improve the private (!) forest roads. Apart from other benefits and services, they expect the forest group to arrange accessibility plans at forest complex level for them and the other forest users.

The main concerns for the recreationists are (i) a lack of technical knowledge, (ii) a lack of time for management and (iii) vandalism in and around holiday cottages. They think they need more (costless) help than the forest group can offer. They ask more surveillance in the forest with public access and a restriction of public access to a limited number of forest complexes, e.g. those with a low natural value. A very good solution for their specific situation would be the parallel distribution of problem-specific information by the local government as well as by the forest group.

Passive owners are concerned with the negative effects of forest recreation. They feel a pressure to open up all the forests to the public, while in fact they prefer not to. A good and frequent cleaning service would already help a lot and like the recreationists they believe in better surveillance, e.g. by forest rangers.

For all the types of owners it seems to be very important in a first step to start from the own experience that forest owners have with their forests and to solve their first concerns. In a second step they can be encouraged to work out good forest (conversion) management. The economists, and some of the recreationists, will be the first group that can be informed with conversion management by the forest group.

6.2.5 Government

All forest owners have the strong impression that the forest authority, that is Bos & Groen, does not take into account the problems associated with forest recreation when implementing the general forest policy of encouraging recreational use of the forest!

The government should make a critical reflection about the actual forest legislation. The opinions and concerns of the (small) private forest owners have clearly not been integrated so far and there is a lack of transparency. An important step towards a transparent policy is a clear terminology: terms should have only one meaning, an exhaustive explanation must be given and terms must be used consequentially in all policy documents and in legislation (Van Woerkum 2000). It is not good that as we saw in our review of current policy that the need of forest conversion is stressed in policy documents, while in the recent advice of the Hoge Bosraad it is hardly mentioned (Bossenverklaring, Van Langenhove & Spaas 2003). The expectations of the government towards forest owners should be crystal-clear and the link with other policy instruments as forest groups, subsidies and legislation should be explained.

Government should implement two changes in its current attitude towards forest owners: 1° do something about the negative 'image' of the forest authority and 2° stop considering private forest owners as a problematic group, inferior to the public forest owners and managers, but stress their positive societal role and the services they deliver to the public.

'Image-building' of the government

Even without encouragement from the researchers' side, the forest owners in the FEFOCON focus groups expressed a very negative image of the authorities in general and of the forest authority in particular.

As Van Woerkum (2000) points out, government institutions often use 'instrumental thinking' for policy building, which means that they take up the working field as "to be influenced" and strive for a pointed aim with certain instruments. From the moment these instruments give a friction, citizens don't accept the policy of the government and they build up a negative image of it. If this evolution is not recognized, this image becomes worse and citizens begin to think that policy makers are 'against them (Van Woerkum & Aarts 1998).

From our findings, we think that an 'image-research' is urgently needed for the government organisations that work out and implement forest policy, that is AMINAL and the local authorities. This will give clues for improving the image. At this moment the negative image is a barrier, a handicap for the real concern: implementing good forest policy in all forests.

Important components of this problem are given by Van Woerkum (2000: 27-):

- *the gravity of the problem* Forest owners have to be convinced of the urgency of good (conversion) management. A lot of them do like pine plantations and do not see a species change as an aim for their forests.
- *is it necessary that there is government intervention?* Government should know the limits of interference in owner's decisions.
- *effective instruments* To accept the forest policy it's necessary that forest owners see the benefits of the conversion activities that government promotes.
- *realistic and practical instruments* Many technical management activities that the government supports, are not possible for forest owners in practice, e.g. because of the high costs.
- *fair instruments* Owners will only accept policy instruments when they find them fair. e.g. efforts towards conversion should be balanced between all owners (public and private) and also restrictions should be balanced.

'Negative images' are often the result of a lack of interaction between the forest owners and government. Van Woerkum (2000) and Van Woerkum & Aarts (1998) formulate preconditions for communication and negotiation with an interactive approach:

- Flexibility of government institutions towards problem solving in the field.
- Transparency: not only the general aims, but also the intentions in the field and the procedures should be clear. E.g. is private forest ownership encouraged in a certain forest complex or does the government want to buy it up to extend a public forest.
- The media are very good to give information to the forest owners but also for interactive debate!
- The theme must be accessible for forest owners.

Forest owners are NOT a problem, they play a positive societal role.

In their communication, forest authorities should stress the positive societal role that private (and public) forest owners play. Especially economists and recreationists know the role they play for the basic environmental quality (water, air, landscape, biodiversity) and for the forest recreation, but never get the impression that the government or the general public appreciate their role. It would be a good idea to honour the (small) private forest owners for their efforts towards society. A possibility we suggest is choose the small private forest and its owners as the topic of the 'Week van het Bos" in one of the following years. Curiously, for more than 20 years this event has been successfully used by the forest authority to introduce various forest policy aspects to the general public, but always from the perspective of public or even domanial forests (only covering 30 or a bit over 10% of the Flemish forest area). This approach does however not mean that the situation of the private forests has to be propagated as ideal. It will only help to bring both partners, government and private owners, to a joint level, after which progress can be made with forest management and more specifically conversion. And maybe this can lead to the incorporation of social benefits into the private decision making of the forest owners instead of only responding to incentives, the way most forest owners act nowadays.

6.2.6 Current financial policy instruments

Although the current forest policy in Flanders is commendable because of its goal-specific subsidy instruments, its low transaction costs, and its enlightened participatory approach through the forest groups, a large majority of owners still does not practice sustainable forest management. The following recommendations can be formulated:

- If the current style of detailed and specific forest policies is maintained, a complete forest land register census should be drawn up so that effectiveness of the policy can be increased and locational aspects can be taken into account. This is both the case for Flanders and Wallonia.
- The policy instruments are in place, but goals are vague and only qualitative. It is probably most cost effective to target in the short term the relatively few large owners (estates larger than 10 ha) for conversion management. Most of these belong to the economist group (VLINA 2001) and can be approached well by the forest groups. Forest groups should however communicate more clearly about their goals so as to take away fears that management plans are too rigid and costly to execute.
- A comprehensive study on simplifying the subsidy structure should be commissioned to enhance transparency and build up trust among forest owners.
- Raising awareness about existing subsidies and rules, can improve progress towards forest policy goals.
- The recreational subsidy should be redesigned, because it is hardly used in its actual form. The owners do not feel a balance between the (small) subsidy and the extra costs involved. From the sociological research the clear problems associated with public access to forests (rubbish etc) need to be solved, through surveillance, cleaning services and accessibility planning at forest complex level.
- Although not enough data on forest land values are available to draw statistically valid conclusions, the government programme for buying up forest land should continue and not be scaled down. It is probably the most cost-effective instrument sustaining private forest ownership, although it is not specific and thus not directly promoting conversion.
- A small study on compensating owners who have converted aggressively should be carried out, in order to avoid negative forest rents for these owners.

6.3 A shortlist of policy recommendations

Promote forest conversion, it is good for the forest ecosystem! – Forest conversion certainly mitigates eutrophication and acidification (lower N input and N output, lower acidifying input, lower losses of cations to the deeper soil and ground water, increased nutrient input through litter, improved litter decomposition) and it probably improves biodiversity as compared to the situation in homogeneous conifer stands.

Consider several conversion management scenarios (including the promising group cutting scenario) and develop an optimal combination of scenarios to reach the conversion goals. These goals must be defined in terms not only of share of deciduous species, but also of desired quantities of each species and of desired horizontal and vertical forest structure.

(in Flanders)

Take private owners seriously in their diversity – (At least) three divergent types of private forest owners need to be addressed properly by forest policy: economists, recreationists and passive owners. As an example, the distribution of any information must be differentiated to reach each type properly.

Honour small private owners for their societal role, do not consider them as a problem for good forest policy.

The forest authority must (re)build its image among private forest owners.

Policy must take away obscurity and uncertainty in legislation for private (and public) forest owners. The policy instruments to sustain recreational use of private forests by the public should be reconsidered: individual subvention is inefficient, the associated inconveniences must be taken seriously and be tackled at forest complex level. These are now barriers to good management practices like conversion.

The strength, but also the limits of the forest groups in Flanders, must be considered by the forest policy. Raising the number of owner's participation in forest groups is a first priority. But other policy instruments, like the buying-up of forest land from the passive owners should be fully considered.

An urgent tool for good forest policy in private forests in Belgium is a forest land register.

APPENDIX: FOREST CONVERSION SCENARIOS

1. Conversion scenarios of pine forests in Flanders

In general two conversion scenarios for homogeneous Scots and Corsican pine stands on sandy soils in Flanders seem plausible: **continued thinning** and **group cutting**. Of course in practice a combination of both is possible, where the remaining forest stand in between the groups is being thinned and the groups are not extended to replace the entire stand in the mid term. These reasonable scenarios can be contrasted to two extreme scenarios: **no intervention** and complete **clear cut** (Figure I).

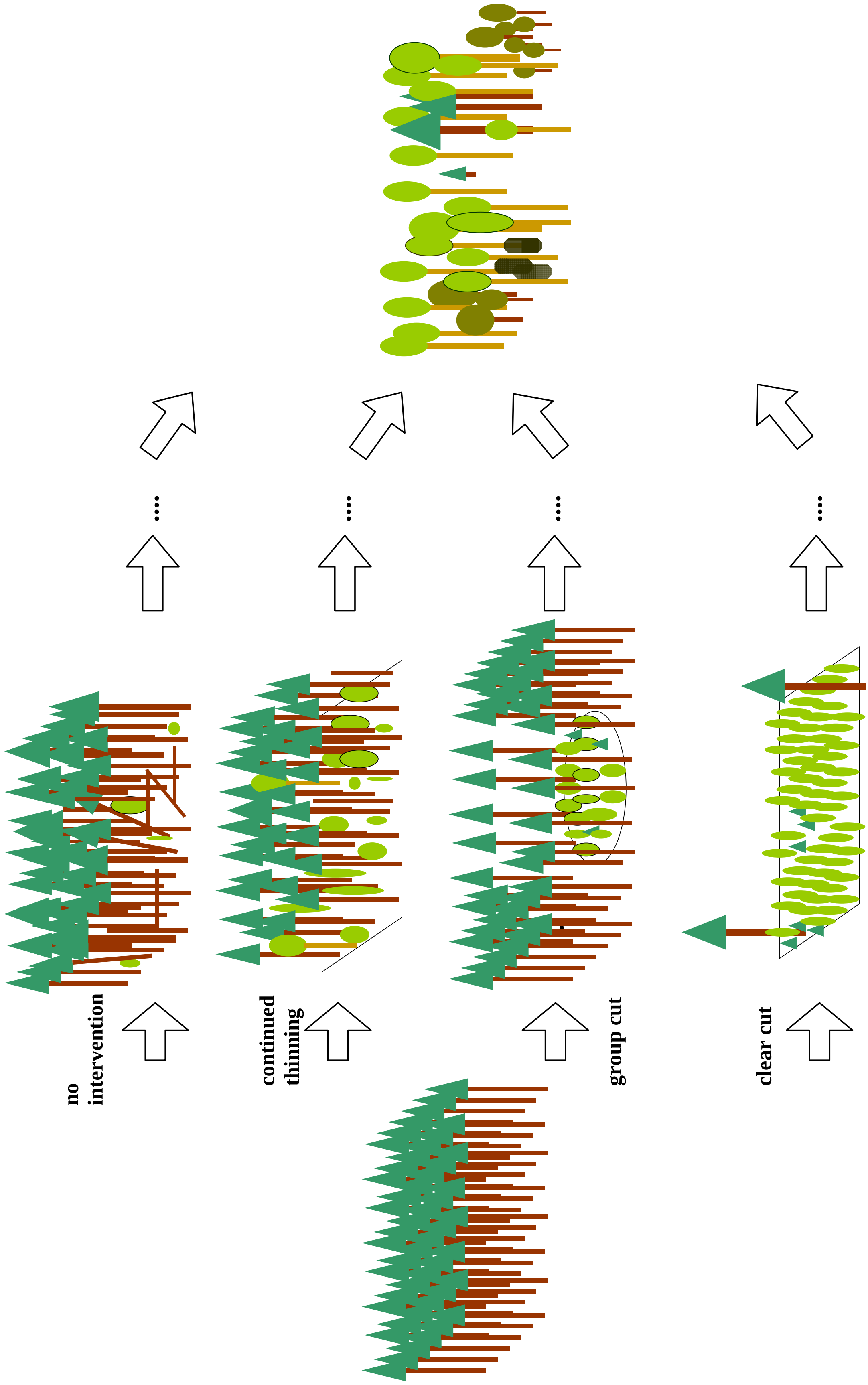


Figure I: Basic forest stand structures that develop in the first years after starting four different management scenarios to convert a homogeneous pine stand (left image) on sandy soil in Flanders

A. Continued thinning

Lust *et al* 1998 describe a long transformation period for pine plantations with (natural) regeneration of indigenous tree species under the pine cover. Large clear cuts should be avoided. The main principle is delaying the final cut of the pine stands, i.e. lengthening the rotation period (over 100 years) or even giving up the idea of a rotation period, since the new forest generation will have taken over by that time. This is a continuous cover system. In Central-European Scots pine forests, active underplanting of broadleaved trees is common practice (Oleskog *et al* 2005). Geudens *et al* (2000) investigated the feasibility of spontaneous regeneration under pine cover in Flanders. Birch, pedunculate oak and beech can all regenerate successfully under a canopy of Scots pine. Each of these species has adaptation mechanisms to the shady circumstances (Van Hees & Clerkx 2003).

Practical implications

STEP 1: thinning the pine canopy

- This may be a strong thinning at once or a gradual thinning to create stable pine individuals with rather large crowns, before opening up the canopy to a basal area well under 20 m²/ha).

Loewenstein (2005) introduces the management concept of converting homogeneous even aged stands into multistorey, multi-aged forests with a simple 1-2-3 rule. In the ideal situation 50% of the available growing space is occupied by the overstorey (3/6th), one third is reserved for the substorey (2/6th) and 1/6th must be available for the regeneration (seedlings and saplings). Applying this recipe to an initial pine stand were the overstorey occupies all growing space: (1) a strong thinning to less than 50%, (2) a regeneration establishes and grows for about 20 years after which (3) the pine cover is thinned again to less than 50% (it has grown in this period, extending its crowns to 50% or more of the available space), while in the substorey (30 year old) good elements are promoted by cutting down inferior elements until the substorey occupies less than 1/3rd of the growing space. (4) Then a new seedling regeneration will establish profiting from the available growing space. (5) After another 30 years a multilayered stand has developed with three age classes and at least three stories. This recipe abstracts from the availability of seed trees of the desired species and the absence of pest species and excessive herbivory.

STEP 2: induction of spontaneous regeneration under pine cover

- pest control of black cherry and red oak,
- proximity of seed trees of the desired native species of trees and shrubs,
- control of game browsing (roe deer),
- top soil disturbance from extraction of thinned pines or through active soil scarification.

OR

STEP 2: planting of advance regeneration under pine cover

- As for induced spontaneous regeneration under pine cover but in cases where the desired species will not regenerate spontaneously or if spontaneously a non-desirable species (pest species or conifers) will dominate, e.g.:
    - few to no seed trees around of oak or beech,
    - bracken fern present,
    - massive regeneration of red oak expected .
- Oak, beech, lime (*Tilia cordata*) and hornbeam (*Carpinus betulus*) are normally planted at pine stand age 80-120 in Germany. That is 10-30 years before the final cut, sometimes much earlier (Kenk & Guehne 2001).
- seeding of oak as imitation of natural seeding by jays "Hächereichen" (Fischer 1993)

STEP 3: management of a two-storied stand

- gradual further thinning in the pine canopy, with the aim of a regulation of the light climate and the root competition for the regeneration, cf. the 3-2-1 distribution of growing space by Loewenstein (2005)

STEP 4: final cut of the remaining pines

- When the broadleaved regeneration grows into the remaining canopy of old pines, the manager will choose which pines to retain "forever" to create mature ecologically valuable trees and which to harvest in favour of broadleaves.

Disadvantages

sylvicultural drawbacks

- light demanding species birch, trembling aspen (Populus tremula) (and pine) can regenerate with high density but are hampered in growth within the first 5 years
- (semi-) shadow tolerant species oak and beech regenerate mostly at too low density to produce quality timber ("Hächereiche", Peters & Bilke 2004)
- repeated thinning operations in pine canopy damage the understorey
- the previous tree points concern the 3° practical implication, i.e. the complicated management of two-storied stands of (semi-)light demanding species
- quality of the pine stems is moderate to low; the further increment of these stems will lead to thicker stems, with saw timber, but only of a moderate to low price (10 to max 25 euro per m³ if sold standing).

ecological drawbacks

- continuous impact of the pine canopy
    - efficient scavenging of atmospheric deposition by coniferous canopy (see Section 2.3)
    - majority of the litterfall consists of slowly decomposing needles, which hamper the soil biotic community and slow down nutrient cycling and from which organic acids leach to the mineral soil (see Section **Error! Reference source not found.**)
- limited chances for light demanding fauna and flora (relics of historical heathland) (see Section 3.1.2)

Advantages

sylvicultural advantages:

- In the short term (first decennia) this is an easy system, suitable for both skilled (public) managers and for private owners.
- Costs (investments in regeneration) are postponed, the thinning operations are mostly self-financing or give a return, only pest control and fencing against deer browsing can pose a cost. The cost-benefit of an oak forest in 250 years for spontaneously regenerated oaks under thinned pine cover is at least as good as for oak planting and tending in groups. There is few to no production of quality timber, but most costs are avoided (Peters & Bilke 2004).
- Spontaneous regeneration can be very good: Table I displays the frequency of the species in the regeneration under homogeneous Scots pine stands (plots of the Flemish regional forest inventory) and the mean seedling number per ha. 61% of the Scots pine stands has regeneration

Table I: Characteristics of (spontaneous) seedlings under homogeneous Scots pine stands in Flanders (Bos & Groen 2001a)

species		frequency (%)	mean nr/ ha
rowan	*Sorbus aucuparia*	23.3	4165
black cherry	*Prunus serotina*	21.4	4465
pedunculate oak	*Quercus robur*	17.9	10060
buckthorn	*Frangula alnus*	12.1	3270
red oak	*Quercus rubra*	6.7	1759
Scots pine	*Pinus sylvestris*	6.1	2458
birch	*Betula sp.*	5.9	1987

- The creation of a broadleaved shrub layer with birch, rowan, buckthorn and pedunculate oak poses few problems at most sites. Only domination of black cherry and red oak is problematic. Even at sites with much deer browsing within a decade or two such shrub layer can settle spontaneously. Of the homogeneous Scots pine stands 67% percent has some kind of shrub layer (Table II).

Table II: Characteristics of (spontaneous) seedlings under homogeneous Scots pine stands in Flanders (Bos & Groen 2001a)

species		frequency (%)	mean nr/ ha
rowan	*Sorbus aucuparia*	23.1	1187
black cherry	*Prunus serotina*	17.9	1206
birch	*Betula sp.*	17.2	696
buckthorn	*Frangula alnus*	14.0	490
pedunculate oak	*Quercus robur*	13.7	655
red oak	*Quercus rubra*	5.6	336
Scots pine	*Pinus sylvestris*	4.1	1342

ecological advantages:

- Strong disturbances are avoided, natural succession is promoted.
- There is a build up of biomass.
- Pine trees can become old and the vertical stand structure develops.

From forest model simulations, Jorritsma *et al* (2001) found that continuous and low density of herbivores (roe deer) prevent red oak and beech to regenerate in Scots pine forest. Spontaneous development leads to dominance of beech and red oak (if herbivory is not limiting). Group cutting promotes birch and even enables pine to persist through a century. Wamelink *et al* (2001) modelled the effects on expected biodiversity when converting a Scots pine stand on sandy soil in the Netherlands through a continued thinning regime (10% of the pines cut down every 10 years) and found that the modelled result, a homogeneous pedunculate oak forest, did not gain very much in biodiversity. Reasons were both the poor structure of the resulting oak forest and the negative effects of eutrophication (high N-stock in litter and soil) from historic N-deposition. In section 3.2.3 we showed that some increase in the herbal diversity is to be expected when developing an oak stand. However in the scenario of continued thinning birch, that seems to have a much more beneficial effect on herbal diversity, does not have an important place.

B. Group cutting

Lust *et al* 1998 note that small-sized clear cuts can be valuable. The main principle is removing the pine canopy in patches of various sizes, between 0.25 and 0.5 to 1 ha, and initiating a one-storied regeneration within the group. By spreading the groups in space and time a shifting mosaic of species and development phases is created. In principle this relates to the conversion method of Koop (1991). Wieman (1999) calculated the economic consequence of a groupwise conversion scenario for one example forest estate in the Netherlands.

Practical implications

STEP 1: planning of the groups in space and time

- As an example the Dutch Forestry Service (Staatsbosbeheer) gives the general guidelines from Table III.

Table III: Distribution of patch sizes for forest conversion in Dutch state forests with a final stand height of about 25m (Staatsbosbeheer 2002)

dimension	reference	diameter (m)	area (ha)	number / 100ha
small	1 x final stand height	25	0.05	50
medium	2 x final stand height	50	0.20	16
large	3 x final stand height	75	0.44	4

STEP 2: cutting the group

- choice of diameters between 20-120 meters (0,05 – 1.5 ha)

STEP 3: induction of spontaneous regeneration in the group or planting

- pest control of black cherry and red oak
- proximity of seed trees of the desired (native) tree and shrub species
- control of game browsing

STEP 4: management of a patchy forest

- spatial layout of skid trails, combined with timing of fellings
- decisions on enlargement of patches, joining of regeneration groups

Disadvantages

sylvicultural drawbacks

- high cost if combining groups with fencing, planting and tending for quality timber
- difficulties of keeping old pines on the long run. If groups are extended or many groups are being cut, than the old stand can disappear faster than intended.
- In the short term this requires extra planning and management input.
- Costs (investments in regeneration) are spread over time. This means that in some stands costs are made very early. The cutting operations are mostly self-financing or give a return, but the pest and game control, planting and tending of the regeneration and the extra planning efforts can pose a cost.

Advantages

sylvicultural advantages

- Spontaneous regeneration of birch, pine, rowan, buckthorn and oak can be very good in the groups. And moreover the growth conditions in the first decades can be much more favourable than under pine cover.
- Good growth of birch or pine regeneration into productive forest patches with commercial thinnings and timber sale on much shorter time horizon than oak (under cover). Jorritsma *et al* (20001) found that group cutting promotes birch and even enables pine to persist in the future species composition.

ecological advantages

- fast reduction of the (negative) impact of the pine canopy and litterfall (Chapter 2)
- promotion of fauna and flora of open pioneer habitat (relics of heathland, internal forest edges)
- creation of a mosaic of different successional stages. Differentiation in ecological conditions (litter quality, light quantity and light quality). Grgic & Kos (2004) state that since small-scale heterogeneity within a forest stand enhances the local species richness and supports viable populations of specialized species, maintenance of this heterogeneity should be the key focus of forest management.

sociological advantages

- In Finland, small clear cutting had a positive effect on scenic beauty, as perceived by the forest visitors. It did not reduce the recreational value even though the preconceptions against clear cut were very negative. Attitudes towards small clear cut areas are usually more positive than towards larger areas. In this study, clear cut areas were small and logging residue, which has been found to decrease scenic beauty was removed. These facts have probably contributed to the valuation of clear cutting. In fact, openings in a forest may increase its variability and make it more beautiful and suitable for recreation.

C. No intervention

Practical implications

- In the short term, this requires no planning and management input.

Disadvantages

silvicultural drawbacks

- slower growth of the thickest pine trees, loss of valuable crown depth and growth capacity
- no control of undesired species, or quality of regeneration of desired species. In Dutch circumstances (mainly the Veluwe), Jorritsma *et al* (2001) found that spontaneous development in pine forests on sandy soils leads to dominance of beech and red oak, if herbivory is not limiting.In Flanders seed sources of beech are rather rare in the sandy regions, but red oak seed trees are very frequent.
- There is no return from timber sales

ecological drawbacks

- Pest species may dominate, especially red oak.
- few structural differentiation, until natural disturbances (storm, pests) occur
- no chances for species of open habitats, until major disturbances occur

Advantages

silvicultural advantages

- no costs
- very easy system on the short run, no skills needed

ecological advantages

- If no exotic species dominant, natural succession can take place.
- fast increase of small-dimension dead wood

D. Clear cut

Practical implications

- on the short term this requires major planning and management input
- stands at the size of parcels 1-5 ha are cut and replanted or seeded with broadleaved trees

Disadvantages

silvicultural drawbacks

- loss of forest climate,
- no control of desired species, or quality of regeneration, unless planted
- difficulties of keeping old pines on the long run
- large and early investments (removal of residues, fencing, planting)

ecological drawbacks

- loss of forest climate, succession is turned back
- few structural differentiation
- limits chances for late successional species to settle and develop
- nutrient loss

In sociological studies, clear cutting has been found to be one of the least acceptable silvicultural measures (Tahvanainen *et al* 2001).

Advantages

silvicultural advantages

- fairly easy, can be very satisfactory for the untrained manager
- If tended well the objective of quality timber production can be strived for, but this requires investments.
- Great return from timber sale at the moment cash is needed for investments (which are partly subsidized).

ecological advantages

- fast conversion, eradication of the negative impact of pine cover
- good, be it timely, habitat for heathland species

2. Conversion scenarios in Norway spruce forests in Wallonia

Depending on the expected stability of the Norway spruce stand, Baar (2005) proposes two major scenarios for conversion of Norway spruce stands.

1. Norway spruce stands that have a considerable number of stable individuals. These exhibit a good balance between the crown / root system dimensions and the total height. They will resist strong winds, even when the canopy is opened up by thinning. In these stands beech will be advance planted in small cells of 25-50 plants under canopy gaps in the Norway spruce stand, with a maximum of 30-40 cells per ha. Each of the cells will produce one crop tree in the final stand. Normal thinnings and harvest in the Norway spruce stand continue, placing harvest tracks in between the cells.
2. At wind exposed sites or where soil conditions prevent the building of a good root system or where a lack of thinning has resulted in high trees with small crown dimensions, small clear cuts or bandwise cuttings must be made. After 5-15 years of spontaneous development in these clear cuts

regeneration of Norway spruce, birch, rowan, black alder, etc. is expected. Within this young stand beech or oak is planted in small cells.

In France the conversion scenarios for homogeneous Norway spruce stands also include (i) clear cut and replanting or natural regeneration, (ii) advance planting and promotion of broadleaved species admixture in Norway spruce stand and gradual removal of the spruces (Di Placido 2002, Di Placido *et al* 2002). At low productive sites Norway spruces are kept for a prolonged period of time as frame trees above the spontaneous regeneration of oak, birch and Scots pine. At productive sites, the spruce canopy is opened fast and only kept as to avoid excessive development of the herbal layer. Spontaneous regeneration is expected of ash, oak, maple, cherry, black alder, birch and hornbeam.

Baar (2005) draws much attention to any spontaneous regeneration of secondary broadleaved species and of Norway spruce that develops during the conversion process. Neruda (2000) points out for conversion of Norway spruce stands in Central Europe that:

1. Even if the planting density of beech (or oak) is low, stem quality will be good because the beech and oak plants will have to compete with the secondary species (mainly rowan and birch).
2. The spontaneous shrubs and tree seedlings might avert browsing of planted beech or oak.

Nilsson *et al* (2002) studied 6-year-old spontaneous regeneration under different densities of Norway spruce cover (Table IV). Birch survival and height growth was negatively affected by dense Norway spruce canopies. However, birch seedlings were much less affected by removal of the remaining Norway spruce canopy after 4 years. Norway spruce and Scots pine seedlings showed a relatively high mortality when the spruce canopy was removed.

Table IV: Effect of Norway spruce canopy density (clear cut - 96 - 155 - 277 stems ha^{-1}) and soil scarification (yes or no) on spontaneous regeneration of different species in stands under conversion (Nilsson *et al* 2002)

species	spruce stem density			soil scarification		
	emergence	survival	height growth	emergence	survival	height growth
Norway spruce	+	(*)	-	+	+	0
Scots pine	?	0	-	+	0	?
birch	0	-	--	+	0	?

0 = no effect, ? = no data, (*) = maximum survival at 155 stem ha^{-1} density

APPENDIX: THE THEORY OF PLANNED BEHAVIOUR MODEL

1. Theoretical framework

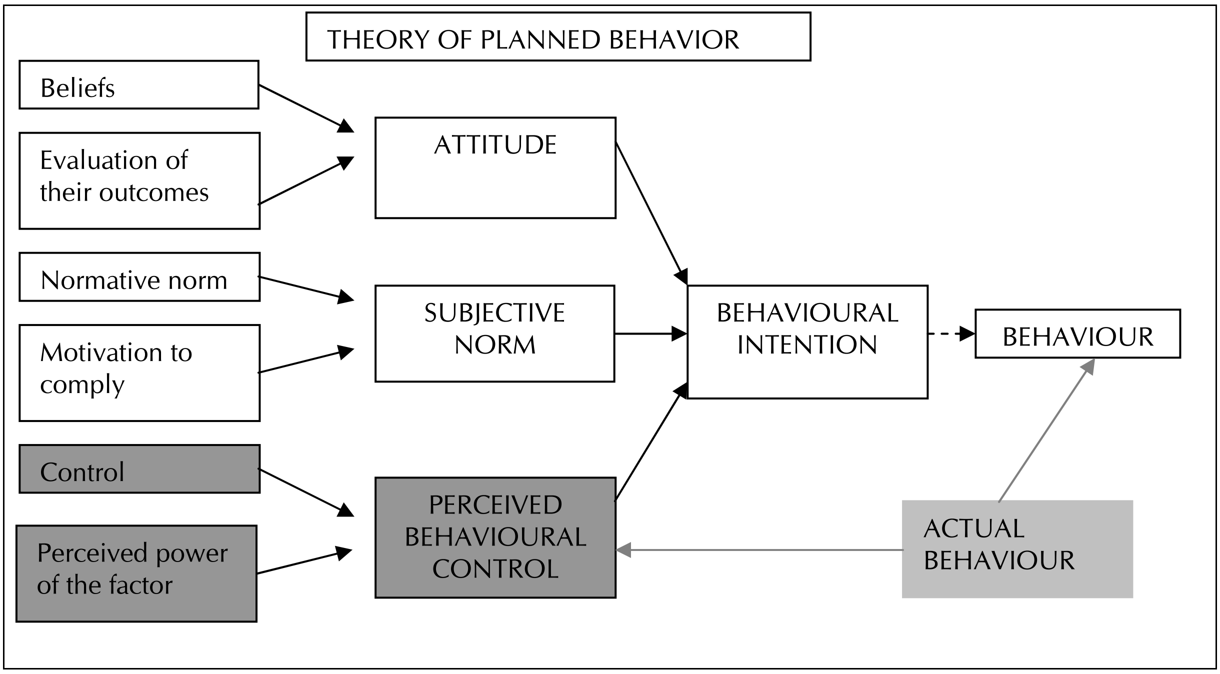


Figure II: Theory of Planned Behaviour (Ajzen 1991). white boxes= Theory of Reasoned Action, grey boxes= the extension of the Theory of Reasoned Action

The Theory of Planned Behaviour (TPB) is a theoretical framework, a model that can be used for instance to analyse the results of a sociological questionnaire. For applications in forestry, see: Schulting (1998), Pouta & Rekola (2001), Karppinen (2005) and Van Gossum *et al* (2005). It is an extension of the Theory of Reasoned Action (TRA) (Ajzen & Fishbein 1980, Fishbein & Ajzen 1975, both in Ajzen 1991). Just as the TRA, the TPB-model wants to predict actual behaviour using Behavioural Intentions. The Behavioural Intention captures the motivation factors that may influence the Behaviour, that is, how much of an effort respondents are willing to exert. An important precondition is that a person can freely decide to perform or not perform: the Behaviour in question must be under volitional control. This also means that a person should have control over the situation. Because there is much behaviour in life where people don't have volitional control, Ajzen (1991) added a new explanatory factor to the model of TRA, the Perceived Behavioural Control (Figure II). In the TPB-model, Ajzen (1991) distinguishes three independent predictors of the Behavioural Intention. He points out that the more favourable the Attitude and the Subjective Norm with respect to certain Behaviour and the greater the Perceived Behavioural Control (when people face less obstacles), the stronger the individual's intention should be to perform the Behaviour. The relative importance of each predictor will vary across behaviour and situation.

The Perceived Behavioural Control is conceptualized as the perceived ease or difficulty of performing the behaviour of interest and it is assumed to reflect past experience as well as anticipated impediments and obstacles (Ajzen 1991). The Perceived Behavioural Control can best be compared with Bandura's term self-efficacy which "is concerned with judgements of how well one can execute courses of action required to deal with prospective situations" (Bandura 1982: p 122 in Ajzen 1991: p 184). As we see in Figure II, Perceived Behavioural Control is composed of (i) the control beliefs and (ii) the perceived power of the particular control factor to facilitate or inhibit Behaviour (Karppinen 2005). The control beliefs may be based in part on past experience with the behaviour, but they can also be influenced by the experiences of acquaintances and friends or by other factors that increase or reduce the perceived difficulty of performing the Behaviour in question (Ajzen 1991: p 196). Ajzen (1991) believes that the more resources and opportunities individuals believe they possess and the fewer obstacles or impediments they anticipate, the greater their perceived control over the behaviour should be.

The Attitude and Subjective Norms are both predictors of the Behavioural Intention of a person (Figure II). The Attitude is conceptualised as the degree to which a person has a favourable or unfavourable evaluation or appraisal of the behaviour in question. In the scheme we see that the Attitude is composed of (i) the beliefs which concern the specific behaviour and (ii) the evaluation of their outcomes which concerns their own experiences with this behaviour. Beliefs were defined by Ajzen (1991) as the subjective probability that a given behaviour will produce a certain outcome.

As we see in Figure II, the Subjective Norm is composed of (i) normative beliefs and (ii) the motivation to comply. Ajzen (1991) conceptualized the Subjective Norm as the perceived social pressure to perform or not to perform the behaviour. Normative beliefs measure the likelihood that important referent individuals or groups approve or disapprove of performing a given behaviour. The strength of each normative belief is multiplied by the person's motivation to comply with a certain referent.

Ajzen (1991) also considered the actual behavioural control in his TPB-model. In this study we don't consider the actual behaviour because that would be too complex. We neither put it in the reports scheme.

2. Methodology and operationalisation

The Theory of Planned Behaviour can be formulated as the following mathematical model (Ajzen 1991, Pouta & Rekola 2001, Beedell & Rehman 2000, see also Figure II):

$$B \sim BI \sim w_1A + w_2SN + w_3PBC = w_1 \sum bs_i \, oe_i + w_2 \sum nb_j mc_j + w_3 \sum cb_k pb_k$$

B	Behaviour or action
BI	Intention to perform the Behaviour
A	Attitude – a person's positive or negative evaluation of performing a behaviour
SN	Subjective Norm – a person's perception of the social pressures upon him to perform or not perform a behaviour
PBC	Perceived Behavioural Control – perceived ease or difficulty of performing a behaviour
bs	belief strength – a person's perceived probability that performing the behaviour will lead to a particular outcome
oe	outcome evaluation – a person's subjective evaluation of how good or bad a particular outcome of performing the behaviour is, that is what is the utility of the outcome to the decision maker
nb	normative belief – a person's assessment of whether important referents he should or should not perform a behaviour
mc	motivation to comply – a person's assessment of how much he wants to comply with the important referents, utility from complying with referents
cb	control belief – a person's assessment of the probability of the belief affecting behaviour
pb	power of the control belief – a person's subjective evaluation of the power of the control belief to affect performance of the behaviour.

(based on Beedell & Rehman 2000)

w_i weighting factor

Most studies have found that between 50% and 70% of the variation in behaviour could be explained by using this research model (Beedell & Rehman 2000). For statistical inferences about the model, most studies used Correlation techniques and Multiple Regression (Ajzen 1991, Beedell & Rehman 2000, Karppinen 2005). These parametric analyses require that scales are on the interval level. This means that it should be possible to order the points according to some criterion and there is an equal difference between any two successive points in the scale. We used the standardized scaling procedure 'Likert scaling' (Ajzen 2002) for the questions about the three predictors (Attitude, Subjective Norm and Perceived Behavioural Control), but we also scaled the dependent variable Behavioural Intention in this manner. We tested the internal consistency of the scale for each variable (Item-Total-Correlations) and the reliability of it (Cronbach's alpha). In the following sections we show the different scales we formed for the evaluation of the respondents.

Attitude

$w_1 A = w_1 \sum bs_i \ eo_i$

The Attitude was measured as the product of a person's evaluation of how good or bad the outcomes associated with a behaviour (the 'oe') are, indexed by the person's perceived probability or likelihood that the behaviour will lead to the outcome consequence in question (the 'bs') (Beedell & Rehman 2000). As a prediction factor of the Behavioural Intention we made the summation of all the possible Attitudes (bs and oe), and weighted it with a factor w_1.

The Attitude was measured by the following questions:

1. When choosing a particular tree species, what is your most important reason? (choose just one reason)

   - ❑ The recreational advantage
   - ❑ The economic advantage
   - ❑ The scenery of the forest
   - ❑ The naturalness
   - ❑ Other: ....

2. Do you think it would be wise to carry out the following management measures in a coniferous forest? **Beliefs** (It is important that you give your own opinion, there are no wrong answers!)

(Give each management activity a score between 1 and 5, score 1 means that you find this management activity not at all sensible and score 5 means that you find it very sensible.)	complete nonsense	rather unwise	wise nor unwise	rather wise	very wise
Planting broadleaves	1	2	3	4	5
Clearcut a part of the forest and grow a new conifer stand	1	2	3	4	5
Clearcut a part of the forest and plant a broadleaved stand	1	2	3	4	5
Cut down conifers to have natural regeneration of broadleaves	1	2	3	4	5
Let nature go it's own way, no cutting nor planting	1	2	3	4	5
Thinning the stand once	1	2	3	4	5
Promote spontaneous young oaks	1	2	3	4	5
Control brambles	1	2	3	4	5
Cut down young birch seedlings	1	2	3	4	5
Thinning the stand regularly, e.g. every three years	1	2	3	4	5

3. How important for your forest are the following management measures? **Evaluation of the outcomes**

(Give each proposition a score between 1 and 5, where 1 means that you find that sort management activities totally unimportant to work out in your forest and 5 means you find it very important to work out in your forest)

	totally unimportant	rather unimportant	important nor unimportant	rather important	very important
Work out a thinning	1	2	3	4	5
Cut down a pine stand and replant it with broadleaves	1	2	3	4	5
Control Black cherry	1	2	3	4	5
Plant Broadleaves	1	2	3	4	5
Do nothing, let nature go his own way	1	2	3	4	5
Promote broadleaves	1	2	3	4	5
Cut down an pine stand and replant it with conifers	1	2	3	4	5
Leave broadleaves that grow spontaneously	1	2	3	4	5

Subjective Norm

$w_2SN = w_2 \sum nb_j mc_j$

The Subjective Norm was measured as a person's evaluation of whether groups (or individuals) important to him think he should or should not carry out a behaviour (the 'nb') multiplied with and assessment of how much he wants to comply with those important referents (the 'mc') (Beedell & Rehman 2000). We made a summation of the different Subjective Norms (normative norms and motivations to comply) and weighted it with a factor w_2.

The Subjective Norm was measured with the following questions:

1. To what extent do you agree with the following statements? When I make any decision related to my forest, I take into account: ... **Motivation to comply**

(Give each of the following propositions a score between 1 and 5, score 1 means that you disagree with the proposition, score 5 means that you totally agree with the proposition.)

	totally disagree	rather disagree	disagree nor agree	rather agree	totally agree
People living in the forest's neighbourhood	1	2	3	4	5
Family members	1	2	3	4	5
Forest users	1	2	3	4	5
The forest group	1	2	3	4	5
Other forest owners	1	2	3	4	5
Nature associations	1	2	3	4	5
The wood market	1	2	3	4	5

2. When thinking of different people in the surroundings, what is your overall impression? Most of them... Normative Beliefs

(Give each item a score between 1 and 5, where score 1 means that you totally disagree with the issue and score 5 means that you totally agree with the given issue)	totally disagree	rather disagree	disagree nor agree	rather agree	totally agree
…find conifers nicer than broad-leaves.	1	2	3	4	5
…find that conifers should be converted into broadleaves.	1	2	3	4	5
…find that coniferous forests are a part of the cultural inheritance of the region.	1	2	3	4	5
…prefer a mixed forest of both conifers and broadleaves.	1	2	3	4	5
…don't like it when trees are being cut down.	1	2	3	4	5
…are not interested in forests.	1	2	3	4	5

Perceived Behavioural Control

$w_3 PBC = w_3 \sum cb_k pb_k$

We measured the Perceived Behavioural Control by the product of a person's assessment of the probability of the belief affecting behaviour (the 'cb'), indexed by a person's subjective evaluation of the power of the control belief to affect performance of the behaviour (the 'pb') (Beedell & Rehman 2000). We made a summation of these two factors that predict the Perceived Behavioural Control (control belief and perceived power of the factor) and weighted it with a factor w_3.

Perceived Behavioural Control was measured by the following question (we only measure the obstacles that respondents experience):

Which is an important barrier for carrying out management activities in your forest? (Several answers are possible)

- ❑ I don't have time for it
- ❑ Managing a forest costs to much money
- ❑ I know to little about it
- ❑ I'm not interested
- ❑ I don't know where I can find help
- ❑ Other: ....
- ❑ Other: ....

Behavioural Intention

The Behavioural Intention was calculated as the summation of the evaluation of the respondents' Attitude, Subjective Norm and Perceived Behavioural Control.

The Behavioural Intention was measured by the following questions:

1. How likely is it that you would carry out the following management activities in your forest over the next ten years?

(Give each issue a score between 1 and 5, where score 1 shows that you certainly shouldn't do this management and score 5 that you should certainly do it.)

	certainly not	rather unlikely	maybe, maybe not	rather likely	most certainly
Work out a thinning	1	2	3	4	5
Leave spontaneous broadleaved trees	1	2	3	4	5
Plant broadleaves	1	2	3	4	5
Promote broadleaves when thinning a conifer stand	1	2	3	4	5
Cut down pine trees and replant conifers	1	2	3	4	5
Control Black cherry	1	2	3	4	5
Cut down part of a stand and plant broadleaves	1	2	3	4	5
Leave young spontaneous oaks	1	2	3	4	5

2. Suppose that you could gradually convert your coniferous forest into a mixed or deciduous one quite easily, and moreover, that it costs you nothing. How likely is it that you would convert your forest if you know the following: ...

(Give each issue a score between 1 and 5, where score 1 means that you certainly shouldn't convert your forest and score 5 means that you certainly should convert your
forest)

	certainly not	rather likely	maybe, maybe not	Rather unlikely	Certainly wel
A broadleaved forest improves the quality of the ground- and drinking water	1	2	3	4	5
A broadleaved forest earns more	1	2	3	4	5
A broadleaved forest contains a greater variety of animal species	1	2	3	4	5
Your neighbours prefer broadleaves above conifers	1	2	3	4	5
The natural vegetation on the site was broadleaved forest	1	2	3	4	5

APPENDIX: THE FOREST RENT MODEL

1. Methodology

Any model is a simplification of reality, but some models are more informative than others. In forestry economics sometimes reality can not be captured by even the most complex models, and consequently solutions achieved by models are hardly instructive. In those cases simulations can be more helpful, but these tend to require complicated software able to handle large quantities of variables (Jacobsen, in Spiecker 2004: 225). The Forest Rent Model (FRM) used here is based on several simplifications, and does not take into account the transition path or the exact initial situation. In order to study the effects of different forest management interventions, interaction between tree species, the influence of soil types, climatic effects etc. more sophisticated scenario studies are needed (Eid 2001: 214). In the case of Flanders, however, these studies have not yet been carried out and the necessary data are still being collected. Despite the limitations of simple forestry economic models, practical conclusion can be drawn. The net benefits, expressed in annuity values, can be used in "model forests" approaches, where for instance a mixture of species for a 100 ha. "representative" forest holding is taken as a unit of analysis. A draw back of similar scenario studies is that the mechanics are difficult to understand, and consequently the results are hard to interpret, particularly for policy makers.

The technically optimal rotation period is determined when the average physical productivity, or the productivity per year over the stand aged **s**, is maximized. From this we derive that average forest productivity is maximized when marginal productivity is equal to average productivity:

$$x'(s) = \frac{x(s)}{s} = \bar{q} \quad \Leftrightarrow \quad \frac{x'(s)}{x(s)} = \frac{1}{s}$$

Note that if we would draw a typically wood production function an S shaped logistic function would be obtained (Figure III). All lines that go through the origin of the graph, will have a tangent of which is the average productivity. Consequently, we can find the technically optimal rotation period (TORP) graphically by drawing a line through the origin and maximizing .

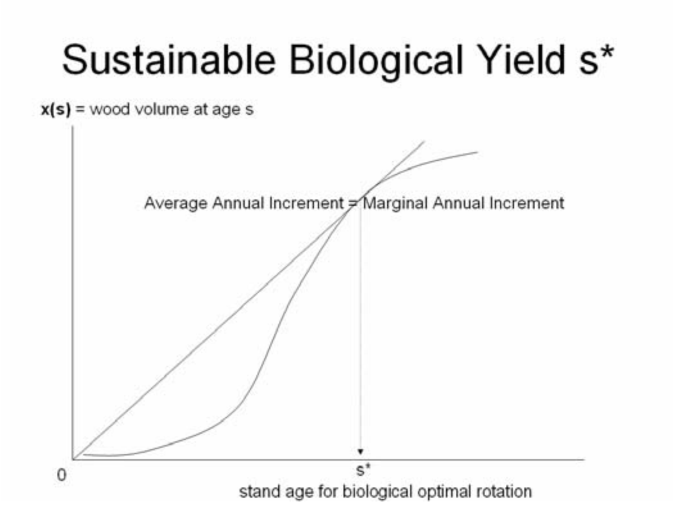


Figure III: Sustainable biological yield

When Average Annual Increment (AAI) over the stand age equals the Marginal or Current Average Increment (CAI) curve, the physical timber production curve is maximized over the plantation cycle (Figure III). In other words, what is maximized is the biological production of the stand. After this period, the stand should be replaced by younger trees if biological production is the goal. In practice, however, older logs fetch are relatively expensive and scarce, so extending stand age beyond TORP can make sense when higher prices for older logs are clearly documented. At this point another difference between the two disciplines should be noted. In some forestry studies long rotation periods are chosen, sometimes even longer than TORP. In natural resource economics text books, on the contrary, rotation periods of less than 40 years are usually chosen, because with shorter periods the results are less sensitive to the choice of interest rates. Even in the Finnish forest literature, which is of a high level of sophistication, these TORP continue to be used in economic

optimization models, although they sometimes differ quite substantially from EORP (Hyytiäinen& Tahvonen 2003: 457). Often no reasons are given for this practice.
The first economic model, the Fisher-Hotelling (FH) model, introduces the interest rate **r**, the price of the wood **p**, and **K** the cost of the plantation or the size of the investment. The idea is the net benefits flow of the investment should be maximized:

$$\text{Max } NPV = px(s)e^{-rs} - K$$

In the simulations values are not discounted continuously by $\mathbf{e^{-rs}}$ but by $\mathbf{(1+r)^s}$, expressed discontinuously per year, more in line with the table wise presentation. Both expressions generate very similar results
Taking the derivative with regard to stand age:

$$p'x(s) - rpx(s) = 0 \quad \textbf{(3)}$$

This corresponds to:

$$\frac{x'(s)}{x(s)} = r \quad \textbf{(4)}$$

Equation (7) says that when the relative growth of the commercial value of the timber volume, or just the growth of the timber volume, is equal to the interest rate, the stand should be cut. In other words, at this point, the owner is indifferent between investing in a numerary asset or in a timber plantation. Comparing with equation (4) we can conclude that when the interest rate is higher than **1/s***, the TORP will be longer than the FH rotation. As a consequence, with very fast growing species, like poplar, or species that continue to grow substantially in old age, like Scots pine, the TORP can be shorter than the FH rotation, depending on the interest rate.

Using the FH model to derive the economically optimal rotation period, however, is incorrect for being insufficient. The opportunity cost for the farmer of renting the land to another farmer, or selling it and investing the capital also need to be taken into account. There are two equivalent solutions to this problem. The first one, is based on the problem formulated by Martin Faustmann in 1849, specified the economic model to make decisions about optimal rotation, taking into account an infinite cycle of plantation cycles. This we will call the Faustmann-Pressler-Ohlin (FPO) rotation, after the other two authors who solved the optimization problem. Implicitly the opportunity costs of the land, or rents, are considered. This is a relatively simple control problem and no welfare losses or social optimality are considered. The model was long unknown in economics, leading some economists in the 20th century - as we saw above in the FH model - to specify it wrongly or incompletely.

The second approach, named after Samuelson (FPO-S), takes land rents into account implicitly and is more useful for our purposes. It assumes that the forest owner initially has bare land after clear cutting. The land rent **R** is simply the value of the land times the interest rate. If payments **R** exist for the rent of the land, the basic equation becomes:

$$\text{Max } VAN = px(s)e^{-rs} - K - R\int_0^s e^{-rs}\,ds \quad \textbf{(5)}$$

Equivalent to:

$$\text{Max } VAN = px(s)e^{-rs} - K + \frac{R}{r}(e^{-rs} - 1) \quad \textbf{(6)}$$

Differentiating and simplifying it leads to the equality for the FPO or FPO-S rotation period:

$$\frac{x'(s)}{x(s)} = r + \frac{R}{px(s)} \quad \textbf{(8)}$$

It can easily be seen that the FPO and FPO-S rotation will always be shorter than the FHO rotation, when the extra term is positive. This difference will larger the higher the rent of the land (or opportunity cost) and the lower the price of the wood. The optimal rotation is determined when the increase in terms of percentage in the volume (and value) of the timber becomes equal or smaller than the interest rate *plus* the rent of the land. In other words, harvest when timber volume growth rate is equal or smaller than the interest rate plus a stock effect. This stock effect is the ratio of the value of the land through the interest rate and the value of the timber. This is always earlier in the growth cycle of the stand, since later timber volume growth rates have begun to slow down. It will also be larger when land values are high, as is the case in Flanders, leading to shorter rotation times. When land values are low, like in Wallonia, the rotation times will be relatively longer.

Contrary to the land rent, other opportunity costs, such as subsidy payments (S) or revenue from thinnings (B) are actually lost when the forest is harvested, so the equation becomes:

$$\frac{x'(s)}{x(s)} = r + \frac{R - B - S}{px(s)} \quad \textbf{(9)}$$

At equality the optimal rotation period is reached, which takes into account all opportunity costs. The difference between TORP and EORP becomes even larger when all opportunity costs, such as future revenues from thinning and subsidies, are taken into account. Since subsidies and revenue from thinnings are the policy variable, this underlines the relevance of our approach.

The left hand side is the relative increase in value of the wood, or capital. Higher interest rates **r** will lead to shorter rotations. The term after **r** can be thought of as a correction of the interest rate for opportunity costs. Note that if revenue from thinnings and subsidies is higher for the term after **r** longer rotation periods will result. Paradoxically, forest groups' efforts to obtain subsidies and get higher prices for burning wood, will cause longer rotation periods and slower conversion. Conversely, we can see how higher wood prices will lengthen the rotation period. Quicker tree growth will also lead to shorter rotations.

Comparing equation (12) above with (7) showing the FH optimal rotation, we note that higher land values will shorten rotation periods, while higher thinning revenues or subsidy revenues will lengthen it. This last effect can be less desirable, since sustainable management can increase revenues from thinnings, and forest transformation subsidies can lengthen rotation period, thus increasing the time in which full transformation can be achieved.

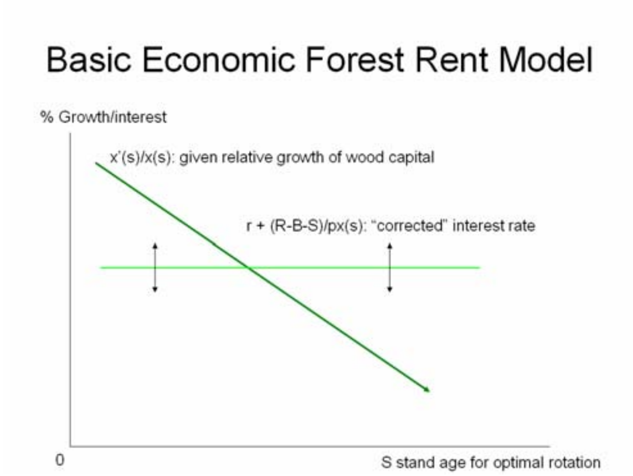


Figure IV: Economically Optimal Rotation Period (EORP)

From an economic point of view, however, what must be maximized are the discounted benefits of the stand, taking account of the interest rate, timber price, planting costs and the extraction costs. In the FPO equation the opportunity costs of clear cutting the land and renting it to another farmer are also taken into account.

With regard to choice of the proper interest rate in cost benefit analysis, there is a long standing debate on this issue. Some say that for long periods, a long term interest rate of 2.5% should to be used. Others will sustain that a commercial interest rate of 5% should be applied. Since this issue is unsolvable, the consequences of adopting either point of view are shown in the tables with results. The resulting TORP, the one prescribed by the VHBR and maximum sustainable yield for Corsican pine, Scots pine and Oak and their EORP (FH and FPO rotations) at 2.5% and 5% are listed in Table V.

Table V: Optimal Rotations at Different Interest Rates

Optimal rotation (years) at 2,5% interest rate					
Species	**Growth class ($m^3ha^{-1}ya^{-1}$)**	**BT**	**SBY**	**FH**	**FPO**
1- Corsican pine	14	80	**77**	34	--
2- Scots pine	8	85	**34**	32	--
3- Oak	5	180	**89**	--	--
Optimal rotation (years) at 5% interest rate					
Species	**Growth class ($m^3ha^{-1}ya^{-1}$)**	**BT**	**SBY**	**FH**	**FPO**
1- Corsican pine	14	80	77	70	**35**
2- Scots pine	8	85	**53**	*68*	*73*
3- Oak	5	180	**89**	50	*117*

Notes: BT BedrijfsTijd Vlaamse Hoge Bosraad
SBY Sustainable Biological Yield
FH Fisher Hotelling
FPO Faustmann Presler Ohlin

Firstly, it can be observed that the two of the FPO rotation periods (73 and 117 years) at 5% are not biologically relevant. When FPO exceeds the SBY rotation, the SBY rotation will be chosen instead, since by definition it will be more profitable to replace the stand by younger trees. The reason for this depends on the parameter values chosen in the model, particularly the discount rates, land rents, but also the price of the final cut and the thinnings. In our calculations constant prices were used, given by Dienstencentrum voor Bosbouw (2000). In fact, a large part of the optimalisation is driven by wood prices. Secondly, it must be noted that at 2.5% no optimalisation results are obtained at all. With these given parameters the model simply fails to identify an economic optimum within the 90 years time horizon chosen in the model. The lower interest rate means the economic optimum lies beyond 90 years, and therefore is longer than the SBY rotation.

2. Result

The Forest Rent Model is too large to be printed, but is provided separately in electronic format. Here we present a summarizing Table VI.

Table VI: The Forest Rent Model

A- Optimal rotation (years)

Species	Growth class ($m^3ha^{-1}ya^{-1}$)	SBY	FH	FPO (2,5%, €6000)	FPO (5%, €6000)	FPO (2,5%, €12.000)	FPO (5%, €12.000)
1- Corsican pine	14	*77*	34		**35**		**34**
2- Scots pine	8	*53*	32				
3- Oak	5	*89*	--				

B- Annuities with FHO rotation and standard parameters (euros)

Species	Calculated Rotation Period	2,5%; €6.000	Calculated Rotation Period	5%; €6.000	Calculated Rotation Period	2,5%; €12.000	Calculated Rotation Period	5%; €12.000
1- Corsican pine	77	-45 €	**35**	-96 €	77	-45 €	**34**	-96 €
2- Scots pine	53	-56 €	53	-108 €	53	-56 €	53	-108 €
3- Oak	89	-4 €	89	-8 €	89	-4 €	89	-8 €

APPENDIX: THE OWNER SURVEY

I. *General questions*

In this first part, we will ask you some general questions about yourself and your forest. It is important that you fill in all the questions. Please don't skip any question.

1. You're...

- ❑ male
- ❑ female

2. Can you give us your year of birth? ....

3. What is the highest diploma that you ever achieve?

- ❑ Primary education
- ❑ Lower secondary education
- ❑ Higher secondary education
- ❑ Higher education short term
- ❑ Higher education long term
- ❑ University

4. Wat doet u op dit ogenblik? Ik ben...

- ❑ Student
- ❑ Housewife or -man
- ❑ Working or employed
- ❑ Retired
- ❑ Job-seeking
- ❑ For specific circumstances unemployed (career interruption, pregnancy leave)
- ❑ In chronic sick leave or invalidity
- ❑ Other: ....

5. How big do you think is the forest area you own?

.... ha .... are

6. Is it a continuous forest?

- ❑ Yes
- ❑ No

> - **When you own *several forests*, You should answer the following questions for your forest with the most *coniferous stands* in it.**
> - **When you only own deciduous forests, you should answer the following questions for the biggest deciduous stand you have.**

7. Can you give us the name and postal code of the municipality who contains your forest?

Postal Code: ....
Municipality: ....

8. Who is the owner of the forest?

- ❑ You personally
- ❑ You and other members of the family
- ❑ You and other non-related persons
- ❑ A company or partnership
- ❑ Other: ....

9. For how long are you the owner of the forest? .... **years**

10. How did you became the owner of your forest?

- ❑ I bought it as a forest
- ❑ I inherited it as a forest
- ❑ I planted it
- ❑ Other: ....

11. What sort of forest is it?

- ❑ *Coniferous forest:* almost all the trees are conifers.
- ❑ *Mixed coniferous:* particularly conifer trees, mixed with more than 20% broad-leaved trees.
- ❑ *Mixed forest:* almost just as much conifer trees than deciduous trees.
- ❑ *Mixed broad-leaved trees:* particularly deciduous trees, mixed with more than 20% conifer trees.
- ❑ *Broad-leaved forest:* almost all the trees are broad-leaved trees

12. Is the forest a part of a bigger forest area?

- ❑ Yes
- ❑ No

13. How far do you live from your forest?

- ❑ I live in my forest
- ❑ Less than 1 km
- ❑ 1-5 km
- ❑ 5-10 km
- ❑ 10-20 km
- ❑ More than 20 km

14. Are there inhabited houses close or in the sight of your forest?

- ❑ Yes
- ❑ No

2

15. How often do you visit your forest?

- ❑ Every day
- ❑ A few times a week
- ❑ A few times a month
- ❑ A few times a year
- ❑ Almost never
- ❑ Never

16. To what extend are the following items a motivation or a reason for you to own this forest?

(Give every item a number from 1 to 5. If you choose 1, that means that you find the item not important at all and 5 means that the item is very important for you)

	Not important at all	Rather unimportant	Not important and not unimportant	Rather important	Very important
The wood production brings up	1	2	3	4	5
The forest is a part of my garden	1	2	3	4	5
The forest gives me rest	1	2	3	4	5
The forest is a family patrimonium for yaers and I want to keep it like that	1	2	3	4	5
I like walking in my forest	1	2	3	4	5
I like to work in my forest	1	2	3	4	5
I hope ever to sell the groud at a higher price	1	2	3	4	5
I like to be a forest owner	1	2	3	4	5
I'll enjoy the beauty of the forest	1	2	3	4	5
I like to preserve a peace of untouched nature	1	2	3	4	5
I want to hunt in my forest	1	2	3	4	5
I like others walking or byking in my forest	1	2	3	4	5
I like to give plants and animals a fitted environment	1	2	3	4	5
My forest is an investing or a moneyinvestment for me	1	2	3	4	5
The forest gives me firewood	1	2	3	4	5

17. Have you ever heard of the existence of subventions for forest management?

- ❑ Yes
- ❑ No

3

18. How often do you work or are you doing management actions in your forest?

- ❑ Every day
- ❑ A few times a week
- ❑ A few times a month
- ❑ A few times a year
- ❑ Less than one time a year
- ❑ Never

19. People are hunting in some of the forests in Flanders. Which situation counts for your forest?

- ❑ There 's no hunting in my forest
- ❑ People hunt in my forest and I get an allowance for it (money)
- ❑ People hunt in my forest and I get an allowance in nature for it
- ❑ People hunt in my forest and I get no compensation for it

II. *Forest policy*

The following questions are about the ongoing forest policy in Flanders. We're interested in your personal opinion. There also doesn't exist wrong answers. Please fill in all the questions, don't leave any question unanswered.

20. If the government should offers the following services, would you use them? And for which services would you pay a contribution for the costs?

	Would you use this service?		Would you pay for this service?	
	Yes	No	Yes	No
Supply general information about forest management	❑	❑	❑	❑
Giving personal advice (about your own forest)	❑	❑	❑	❑
Giving support with administrative work	❑	❑	❑	❑
Giving support for work in the forest	❑	❑	❑	❑
Placing forest workers at disposal for work in the forest	❑	❑	❑	❑
Offering the possibility to hand over the forest to the government	❑	❑	❑	❑

21. Have you ever heard of a forest group?

- ❑ Yes
- ❑ No

4

III. Forest Management

In the following part, we will ask you some questions about managing a forest. WE'RE ASPECIALLY INTERRESTED IN YOUR PERSONAL OPINION. SO THERE ARE NO WRONG ANSWERS. May we ask you to fill in all the questions, please don't leave any question unanswered.

27. Wich sort of forest do you like most?
(Give each of the following sorts of forests a score between 1 and 5. Give 5 points to the forest you like the most, the forest that you don't like at all gets 1 point)

A coniferous forest	
A coniferous forest with some broad-leaves	
A mixed forest (as much conifers than broad-leaves	
A broad-leave forest with some conifers	
A broad-leave forest	

28. To what extend do you agree with the following propositions. If I take decisions about my forest, I'll take the following issues in account…

(Give for each of the following propositions a score between 1 and 5, score 1 means that you totally disagree with the proposition, score 5 means that you totally agree with the proposition)

	Totally disagree	Rather disagree	Don't agree and don't disagree	Rather agree	Rather disagree
Neighbouring of my forest	1	2	3	4	5
Family members	1	2	3	4	5
Users of my forest	1	2	3	4	5
Forest group	1	2	3	4	5
Other forest owners	1	2	3	4	5
Nature associations who manage forests	1	2	3	4	5
Wood industry	1	2	3	4	5

6

22. Do you know the forest group in your region?

- ❑ Yes ……go to the next question……
- ❑ No ……go to question 26……

23. Do you ever have contact with the forest group in your region??

- ❑ Yes ……go to the next question……
- ❑ No ……go to question 25……

24. For what purpose do you have contact (have you got) with the forest group?
(several answers are possible)

- ❑ I joined an informational meeting
- ❑ I participated in a collective wood sale
- ❑ I participate in a collective management plan
- ❑ I'll contacted the forest group for advice and information
- ❑ The forest group contacted me (send me a letter, telephoned,…)
- ❑ I participate in the making of an accessibility regulation
- ❑ Fight against American bird cherry
- ❑ Other: ……………………………………………………

……Go to question 26……

25. Why haven't you have any contact yet with the forest group?
(several answers possible)

- ❑ They've never contact me
- ❑ I'm not interested
- ❑ I don't find it necessary
- ❑ I just don't know enough about it
- ❑ I don't have time for that
- ❑ Other: ……………………………

26. Have you ever make use of subventions for your forest?

- ❑ Yes
- ❑ No

Are you the owner of a coniferous forest or a mixed coniferous forest?
An important part of our research goes about managing coniferous forests. We would like to ask you some further questions on the following page (page 6). Would you please fill in all the questions, they are very important for our research.

Are you the owner of a mixed forest or a deciduous forest?
You don't have to fill in any question anymore. If you have any questions or recommendations after answering the questions above, please note them on page 10

29. **What is the most important reason when you choose a certain kind of tree?** (choose just one reason)

- ❑ The recreational advantage
- ❑ The economical advantage
- ❑ The view and sphere of the forest
- ❑ The naturalness
- ❑ Other: ....

30. **The following table sums up some possible management actions. To what extend do you think it's sensible to work out the following management activities in coniferous forests?** (It is important that you give your own opinion, there are no wrong answers!)

(Give each management activity a score between 1 and 5, score 1 means that you find that management activity not at all sensible and score 5 means that you find it very sensible.)

	Totally unsensible	Rather unsensible	Not sensible and not unsensible	Rather sensible	Very sensible
Planting young broad-leaves	1	2	3	4	5
Cut down a part of the forest and let grow conifers again	1	2	3	4	5
Cut down a part of the forest and plant it with broad-leaves	1	2	3	4	5
Take away conifers to let grow natural regeneration of broad-leaves	1	2	3	4	5
Let nature goes it's own way, not cutting down or planting	1	2	3	4	5
Just one time thinning in trees	1	2	3	4	5
Leave young oaks that grows spontaniously	1	2	3	4	5
Fight brambles	1	2	3	4	5
Take away young birches that grows spontaniously	1	2	3	4	5
Thinning regularly, for example every tree years	1	2	3	4	5

31. **Which is an important barrier to work out some management activities in your forest?** (several answers are possible)

- ❑ I don't have time for it
- ❑ Managing a forest costs to much money
- ❑ I know to little about it
- ❑ I'm not interested
- ❑ I don't know where I can find help
- ❑ Other: ....
- ❑ Other: ....

7

32. **How likely is it for you to work out the following management activities in your forest for the next 10 year?**

(Give each issue a score between 1 and 5, where score 1 shows that you certainly shouldn't work that sort of management activities and score 5 shows that you should certainly work out that management strategie.)

	certainly not	Rather unlikely	Maybe yes, maybe not	Rather likely	Certainly yes
Working out a thinning	1	2	3	4	5
Leave young broad-leaves who grows spontaniously	1	2	3	4	5
Planting young broad-leaves	1	2	3	4	5
Give broad-leaves space by a thinning conifers	1	2	3	4	5
Cut down an area of trees and replant it with coniferous trees	1	2	3	4	5
Fight against American bird cherry	1	2	3	4	5
Cut down an area of trees and replant it with broad-leaves	1	2	3	4	5
Leave young oaks who grows spontaniously	1	2	3	4	5

33. **To what extend do you find the following management activities important for your forest?**

(Give each proposition a score between 1 and 5, where 1 means that you find that sort management activities totally unimportant to work out in your forest and 5 means you find it very important to work out in your forest)

	Totally unimportant	Rather unimportant	Not important, but also not unimportant	Rather important	Very important
Working out a thinning	1	2	3	4	5
Cut down an area and replant it with broad-leaves	1	2	3	4	5
Fight American bird cherry	1	2	3	4	5
Planting Broad-leaves	1	2	3	4	5
Doing nothing, let nature goes his own way	1	2	3	4	5
By working out a thinning, make place for broad-leaves	1	2	3	4	5
Cut down an area and replant it with conifers	1	2	3	4	5
Leave broad-leaves who grows spontaniously	1	2	3	4	5

8

34. Would you manage your forest differently when you should receive a yearly compensation (for example a subvention) for it?

- ❑ Yes
- ❑ No

35. Would you manage your forest differently when you should receive free help for it as there are: administrative help, workers, personal advice,...?

- ❑ Yes
- ❑ No

36. If you think of several people in your environment, what is than your general impression? Most people in my environment...

Most people in my environment... (Give each item a score between 1 and 5, where score 1 means that you totally disagree with the issue and score 5 means that you totally agree with the given issue)	Totally disagree	Rather disagree	Don't agree and don't dis	Rather agree	Totally agree
...find conifers nicer than broad-leaves	1	2	3	4	5
...find that conifers should be converted into broad-leaves	1	2	3	4	5
...find that coniferous forests are a part of the cultural inheritance of the region	1	2	3	4	5
...houden van een gemengd bos (loof-en naaldbomen)	1	2	3	4	5
...don't like cuttings going on in the forest	1	2	3	4	5
...are not interested in forests	1	2	3	4	5

9

37. Suppose that its very easy to convert a coniferous forest gradually into a mixed coniferous / deciduous forest and that you don't have to pay anything for it. Than how probable is it that you should convert your coniferous forest if you have knowledge about the following:

(Give each issue a score between 1 and 5, where score 1 means that you certainly shouldn't convert your forest and score 5 means that you certainly should convert your forest)	Certainly not	Rather likely	Maybe yes, maybe not	Rather unlikely	Certainly yes
A deciduous forest improves the quality of the ground- and drinking-water	1	2	3	4	5
A deciduous forest earns more	1	2	3	4	5
A deciduous forest contains a greater variety of animal species	1	2	3	4	5
Your neighbours prefer broad-leaves above conifers	1	2	3	4	5
The original vegatation are broad-leaves on that ground	1	2	3	4	5

If you have some recommendations by this questionnaire, please note them here.

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____

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____

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Finally, we wanted to thank you for your engagement!!!

Every answered questionnaire is a great help for our research! We guarantee you that all the personal issues are only used for researchpurposes! If you have some more questions about these questionnaire, please contact Christel Sabbe, christel sabbe@Ugent.be, 09/264.90.26. Even if your interested in the results of this questionnaire, don't hesitate to contact us! Don't forget to fill in the red fiche than you have chance to win one of the 30 book cheques we raffle of.

YOU CAN SEND BACK YOUR QUESTIONNAIRE WITH THE ADDED ENVELOPE. A STAMP IS NOT NECESSARY.

10

APPENDIX: TOPIC LIST OF SOCIOLOGICAL FOCUS GROUPS

Topiclijst Fefocon (Focus group – sociological research)

1. OPENINGSVRAAG
   Naan Plaats Bos Betekenis bos
2. BEELD BOS
   Belangrijkheid bossen Betekenis bossen (Maatschappelijke betekenis)
3. BOSBEHEER
   - Hoe kan overheid beheer vergemakkelijken
   - Mate van overheidsinmenging
   - Toekomst van de bossen
   - Bos in beheer geven: Bosgroep ⟷ Privé-boseigenaar
   - Bos verkopen Overheid ⟷ Privé-boseigenaar
4. SUBJECIEVE NORM
   Stel bomen moeten worden gekapt.
   - Hoe aanpakken
   - Wie/Wat raad vragen
   - Met wie/wat rekening houden
   - Wie/Wat kan uitvoering beheerwerken tegenhouden
5. ATTITUDE
   Wat zou je NIET willen veranderen aan je bos?
   - DUNNINGEN (bosbouwdeskundige) Waarom wel/niet
   - OMVORMING Naaldbos ⟷ Loofbos Waarom wel/niet?
   - SNELLE ⟷ GELEIDELIJKE omvorming Waarom wel/niet?
6. DREMPELS
   - Moeilijkheden bij onderhoud?
   - Oplossingen voor problemen?
   - Tijd, geld, kennis en hulp vormen GEEN probleem. Wat houdt uitvoeren dan nog tegen?
7. BOSGROEP
   Gekend? JA:
   - Motivatie gebruik diensten?
   - Ervaring bosgroepenwerking?
   - Daar terecht kunnen met problemen?
   - Geven voldoende advies?
   - Waar wordt te weinig informatie over gegeven?

   NEE:
   - Waarom geen gebruik? / Reden geen contact?
   - Situatie waar wel gebruik zou worden gemaakt?
   - Tips voor verbetering van het contact
   - Ervaring bosgroepenwerking?

   Positieve punten bosgroep
   Negatieve punten bosgroep
8. INFORMATIE / COMMUNICATIE
   Voldoende informatie van de overheid?
   - Andere kanalen nodig? Welke?
   - Waarover informatie nodig? Op welke manier? Via welke kanalen?
9. SLOTVRAAG

   Wat wordt gezegd over omvorming tegen de minister van leefmilieu?
   Hoe ideeën concreet realiseren?

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