Contemporary beech forest management in Europe

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Contemporary Beech Forest Management in Europe

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Contents of report

1. INTRODUCTION 6

2. HISTORY AND MANAGEMENT OF BEECH IN NORTHWEST EUROPEAN LOWLAND 7

GREAT BRITAIN 7

2.1 INTRODUCTION 7
2.1.1 Present Status of Beech Woodland in Britain 7
2.1.2 British Beechwoods in a European Context 8
2.1.3 British Classification of Beechwoods 9
2.2 PRE-INDUSTRIAL PERIOD (5,000 BC – 1800 AD) 11
2.2.1 Changes in Woodland Cover and Composition 11
2.2.2 Management of Woodland 12
2.2.3 Management of Beech Woodland 14
2.3 INDUSTRIAL PERIOD (1800 AD – 1980 AD) 15
2.3.1 General Changes in Woodland 15
2.3.2 Management of Beech Woodland 17
2.3.3 Silvicultural Systems 18
2.3.4 Establishment and Aftercare 19
2.4 MODERN CHANGES 23
2.4.1 Changes in Objectives, Policies and Regulations 23
2.4.2 Management of Beech Woodland 25
2.4.3 Ancient Beech Woodland 26
2.5 SUMMARY 29
2.5.1 Pre-Industrial Period (5,000 BC – 1800 AD) 29
2.5.2 Industrial Period (1800 AD – 1980 AD) 30
2.5.3 Modern Changes 31
2.6 IMPACTS ON BIODIVERSITY 33
2.6.1 Pre-industrial impacts 33
2.6.2 Industrial impacts 34
2.6.3 Modern changes 35
2.6.4 Distinctive features of beech and beechwoods in Britain 35
2.7 REFERENCES 36
2.8 MANAGEMENT OF BEECH IN BRITAIN: A CASE-STUDY ON THE CHILTERN HILLS 41
2.8.1 Introduction 41
2.8.2 Chiltern site characteristics 42
2.8.3 History 42
2.8.4 Silviculture overview 46
2.8.5 Case study Rumerhedge Wood 48
2.9 INTERVIEW 50
2.9.1 General description 50
2.10 REFERENCES 51
2.11 APPENDICES 51
2.11.1 Overview of broadleaved forest (Appendix 1) 51
2.11.2 Forestry Commission Grant schemes in operation since 1947 (Appendix 2) 51
2.11.3 Key Legislation since 1914 (Appendix 3) 52
2.11.4 Forestry Guidelines and Standards (Appendix 4) 52

3. HISTORY AND MANAGEMENT OF BEECH IN NORTH EUROPEAN LOWLAND 53

DENMARK, SOUTH SWEDEN, NORTH POLAND AND NORTH GERMANY 53

3.1 INTRODUCTION TO BEECH FORESTS IN NORTH EUROPEAN LOWLAND 53
3.1.1. Beech forest vegetation 54
Calcareous beech forests 54
Circum-neutral beech forests 54
Acid beech forests 54
3.1.2 Climate 55
3.2 PRE-INDUSTRIAL PERIOD (12,000 BC – 1800 AD) 55
3.2.1 Changes in woodland cover and species composition 55

3.2.2 Social changes ... *58*
3.2.3 Management of woodland ... *59*
Unaffected forests ... *61*
3.3 INDUSTRIAL PERIOD WITH ORGANIZED FORESTRY (1800 AD – 1980 AD) ... 61
3.3.1 Land reforms and forest regulations ... *61*
3.3.2 Forest functions ... *62*
3.3.3 Changes in woodland area and species composition ... *63*
3.3.4 Organized beech forest management ... *64*
3.3.5 Silvicultural aspects of beech forestry ... *65*
3.3.6 Damaging agents ... *67*
3.4 THE CONTEMPORARY SITUATION – MODERN CHANGES (1980 -) ... 68
3.4.1 Present beech forest conditions ... *68*
3.4.2 Changes in forest functions ... *70*
3.4.3 Changes towards nature-based forestry ... *72*
3.4.4 Beech forest reserves and research programmes ... *74*
3.4.5 Public participation in forestry ... *74*
3.5 CASE STUDY: TRADITIONAL BEECH FOREST MANAGEMENT, 'SORØ AKADEMI FOREST DISTRICT' 1800-2000 ... 75
3.5.1 Description of the area ... *75*
3.6 SUMMARY ... 78
3.7 IMPACTS ON BIODIVERSITY ... 80
3.7.1 Pre-industrial impacts ... *80*
3.7.2 Industrial impacts ... *81*
3.7.3 Modern changes ... *82*
3.8 REFERENCES ... 83

4. HISTORY AND MANAGEMENT OF BEECH IN CENTRAL EUROPEAN UPLANDS ... 90

SOUTHERN GERMANY, CZECH REPUBLIC, SLOVAKIA ... 90

4.1 INTRODUCTION ... 90
4.2 PRE-INDUSTRIAL PERIOD (FROM THE NEOLITHIC PERIOD TO 1700) ... 90
4.3 BEECH FORESTS IN THE INDUSTRIAL PERIOD (FROM 1700 TO 1980) ... 91
4.4 BEECH FORESTS IN THE MODERN PERIOD (SINCE 1980); TRENDS TOWARDS FUTURE ... 93
4.5 COUNTRY REPORT: BADEN-WÜRTTEMBERG ... 94
4.5.1 General description ... *94*
4.5.2 Historical background ... *94*
4.5.3 Beech forest communities, forest typology ... *95*
4.5.4 Beech forest functions; management concepts and aims ... *96*
4.5.5 Forest reserves programmes ... *97*
4.5.6 Summary ... *97*
4.5.6 References ... *98*
4.6 CASE STUDY: KARLSBAD ... 100
4.6.1 Description of the area ... *100*
4.6.2 History of the mixed beech forest management in the area ... *100*
4.6.3 Contemporary management of mixed forests of beech and conifers ... *101*
4.6.3 The tending scheme ... *102*
4.6.4 Natural regeneration ... *103*
4.6.5 Conclusion ... *103*
4.6.6 References ... *104*
4.7 COUNTRY REPORT: CZECH REPUBLIC ... 105
4.7.1 General description ... *105*
4.7.2 Historical background ... *105*
4.7.3 Beech forest communities; forest typology ... *106*
4.7.4 Beech forest functions; management concepts and aims ... *107*
4.7.5 Nature conservation and nature reserves programme ... *108*
4.7.6 Summary ... *109*
4.7.7 References ... *110*
4.8 CASE STUDY MASARYKUV LES ... 112
4.8.1 Description of the area ... *112*
4.8.2 History of beech forest management in the area ... *112*
4.8.3 Principles and methods of beech forest management; management techniques ... *113*
4.8.4 Conclusion ... *115*

4.8.5 References ... *115*
4.9 CASE STUDY JIZERSKOHORSKÉ BUCINY ... 116
4.9.1 Description of the area ... *116*
4.9.2 History of beech forest management in the area ... *116*
4.9.3 Principles and methods of beech forest management; management techniques ... *117*
4.9.4 Conclusion ... *118*
4.9.5 References ... *119*
4.10 SLOVAKIA ... 120
4.10.1 General description ... *120*
4.10.2 Historical background ... *120*
4.10.3 Beech forest communities; system of forest typology ... *121*
4.10.4 Beech forest functions; management concepts and aims ... *121*
4.10.5 Nature conservation and nature reserves programme ... *122*
4.10.6 Summary ... *123*
4.10.7 References ... *123*
4.11. CASE STUDY: BOHUNICE ... 126
4.11.1 Description of the area ... *126*
4.11.2 History of beech forest management in the area ... *126*
4.11.3 Principles and methods of beech forest management; management techniques ... *127*
4.11.4 Conclusion ... *128*
4.11.5 References ... *128*
4.12 IMPACT ON BIODIVERSITY ... 129
4.12.2 References ... *132*

5. HISTORY AND MANAGEMENT OF BEECH IN SOUTHEAST EUROPEAN MOUNTAINS ... 133

SLOVENIA, AUSTRIA, CROATIA, ROMANIA ... 133

5.1 INTRODUCTION ... 133
5.2 SLOVENIA ... 133
5.2.1 Soils134
5.2.1 Phytogeographic areas in Slovenia and their climate ... *134*
5.2.2 Beech forests ... *136*
5.3 CROATIA ... 137
5.3.1 Climate ... *137*
5.3.2 Soils137
5.3.3 Beech forests ... *137*
5.4 AUSTRIA ... 139
5.4.1 Climate ... *140*
5.4.2 Relief and substrate ... *140*
5.4.3 Beech forests ... *140*
5.5 THE PREINDUSTRIAL PERIOD (12,000 BC – 1800 AD) ... 141
5.5.1 Social changes ... *141*
5.5.2 Landscape changes ... *142*
5.5.3 Use and structure of the remaining woodland ... *143*
5.5.4 Impacts on biodiversity ... *143*
5.6 THE INDUSTRIAL PERIOD (1800 AD – 1950 AD) ... 144
5.6.1 Social changes ... *144*
5.6.2 Landscape changes ... *145*
5.6.3 Use and structure of the remaining woodland ... *146*
5.6.4 Impacts on biodiversity ... *147*
5.7 THE MODERN PERIOD (1950 AD -) INTO THE FUTURE ... 148
5.7.1 Social changes ... *148*
5.7.2 Landscape changes ... *149*
5.7.3 Use and structure of the remaining woodland ... *149*
5.7.4 Impacts on biodiversity ... *151*
5.8 SUMMARY ... 152
5.9 REFERENCES ... 153
5.10 CASE STUDY BREZOVARA REBER, SLOVENIA ... 156
5.10.1 General description of the area ... *156*
5.10.2 Beech forest communities and types ... *156*
5.10.3 History of beech forest management in the area ... *157*

5.10.4 Principles and methods of beech forest management; management techniques *158*
5.10.5 Conclusion *160*
5.10.6 References *160*
5.11 CASE STUDY: SAMOBOR, CROATIA 161
5.11.1 General description *161*
5.11.2 History of beech forest management in the area *161*
5.11.4 Principles and methods of beech forest management; management techniques *162*
5.11.5 Conclusion *163*
5.11.6 References *163*
5.12 SILVICULTURAL AND ECONOMIC CONSIDERATIONS OF BEECH IN ROMANIA 164
5.12.1 Introduction *164*
5.12.2 Distribution of beech in Romania *164*
5.12.3 The main climatic and site requirements of beech *165*
5.12.4 Flowering, seed production and nursery conditions *165*
5.12.5 Growth, production and productivity of beech *166*
5.12.6 Silvicultural aspects: Regeneration, silvicultural systems and tending operations *167*
5.12.7 Economic importance of beech in Romanian forestry *171*
5.12.8 References *172*
6. LIST OF INTERVIEWS CONDUCTED FOR THE REPORT 173
6.1 NORTHWEST EUROPEAN LOWLAND 173
6.2 NORTH EUROPEAN LOWLANDS 173
6.3 CENTRAL EUROPEAN UPLANDS 174
6.4 SOUTHEAST EUROPEAN MOUNTAINS 174
7. LIST OF CASE STUDIES IN THE REPORT 175

1. Introduction

J. Fanta, Alterra, The Netherlands

This report forms part of the Nat-Man project, which is concerned with the sustainable management of European beech forests. These forests cover a large part of the European landscape and are a major resource for timber production, biodiversity conservation, amenity, and watershed protection. The project is undertaking various new studies and combining these with reviews of existing information to provide a scientific platform for the improved management of beech forests.

This report presents a review of the management of beech forests down through the ages. It covers the earliest historical period, the Middle Ages, the Industrial period, and concludes with the present situation. During this span, the extent, status and usage of beech forests have changed considerably.

Literature has been collected from all parts of Europe along a NW – SE transect, based on the following regions and countries:

? Northwest European Lowland: Great Britain

? North Central European Lowlands: Denmark, South Sweden, North Germany & North Poland

? Central European Uplands: Baden-Württemberg, Czech Republic & Slovakia

? Southeast European Mountains: Austria, Slovenia, Croatia & Romania

In addition to reviewing the literature on beech forest management in these countries, a range of complementary case studies and interviews were undertaken. The case studies were based on particular regions/countries and the interviews were with well-known and experienced forest practitioners. These gave detailed insights and specialised knowledge of the broad span of theoretical, practical and political problems facing contemporary beech forest management. In addition, there are specific sections on how management has affected biodiversity and the measures used to conserve and enhance wildlife and natural features in European beech forests today. Although not every country in Europe could be included, the aim was to give a representative review of past and present management in beech forests in Europe. To this end, a supplementary section was added covering Romania.

The information in this review will be used in other parts of the Nat-Man project, and specifically as a reference in the development of guidelines for the sustainable management and multifunctional use of beech forests in Europe.

2. History and management of beech in Northwest European Lowland Great Britain

T.J. Clements and E.P. Mountford, Oxford Forestry Institute, UK (2.1-2.7)
R. A. Pakenham, UK (2.8-2.11)

2.1 Introduction

2.1.1 Present Status of Beech Woodland in Britain

Beechwoods are an important component of the British landscape. They are valued not only for timber production, but also for their landscape appeal, historical, cultural and wildlife values, recreational usage, and for game and livestock production. Semi-natural beech woodland is frequent in some parts of southern Britain (Figure 1), where it is characteristic, though not solely associated with, outcrops of limestone and chalk and light to medium textured soils. However, within this area and elsewhere there are many recent beechwoods that have been planted or promoted for ornament or timber, and in places beech these have naturalised (Selmes and Peterken 1997). Beech woodland occupies about 58,000ha or 14% of the high forest area in England (Forestry Commission 1983). About half of this has been classified as ancient, semi-natural beech or yew woodland in lowland Britain. Beech is second to oak as one of the main broadleaved timber trees.

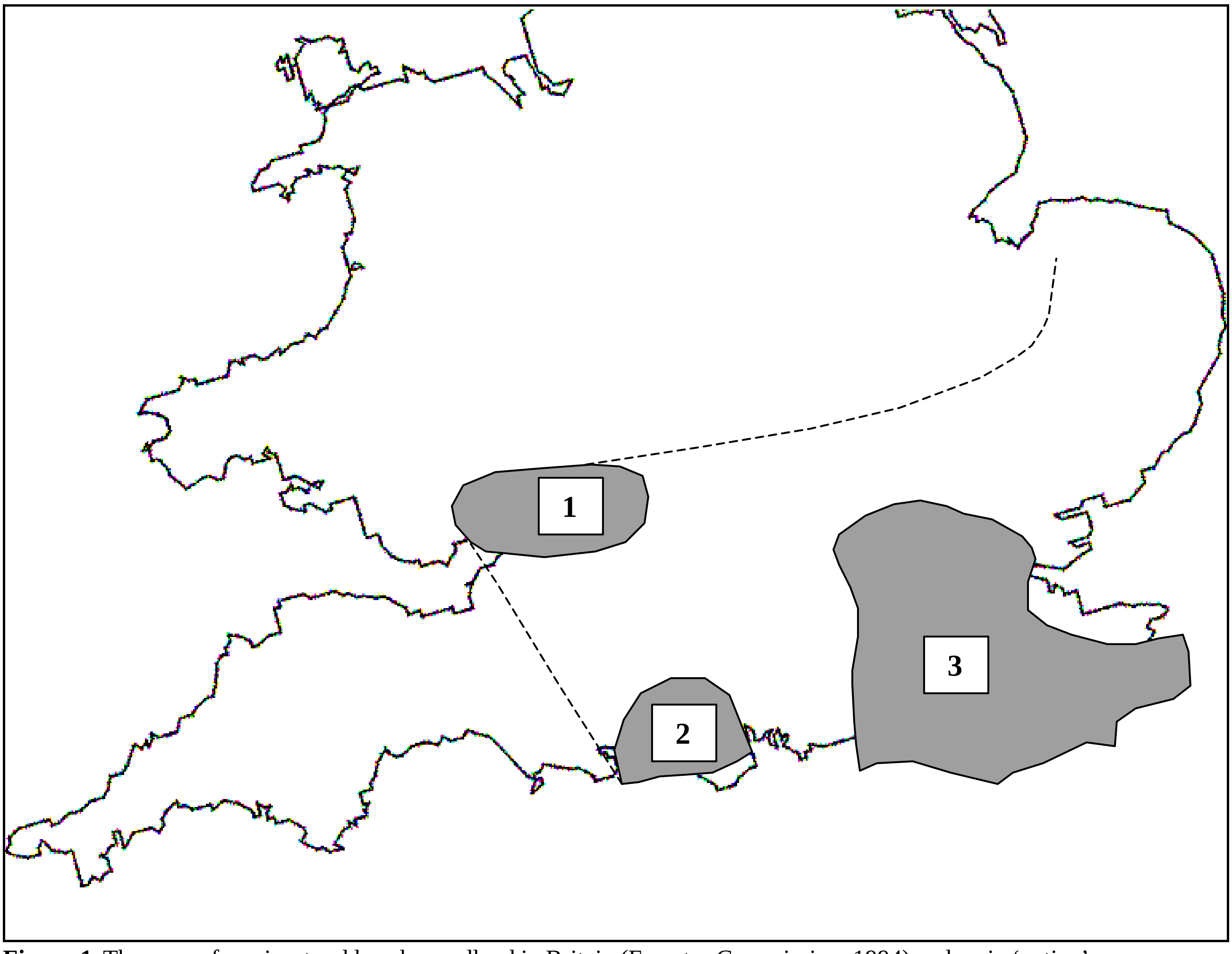

Figure 1. The zone of semi-natural beech woodland in Britain (Forestry Commission, 1994) and main 'native'

concentrations within this (Rackham 1997). 1=South Wales Coalfields, Lower Wye Valley, and Cotswold Hills, 2=New Forest, 3=North and South Downs,Weald, London Basin and the Chilterns.

Much of the beech woodland in England is in private ownership, either non-governmental organisations or private individuals or bodies. The state forestry service, the Forestry Commission, own about 30% (Forestry Commission 1983). Numerous sites are protected for wildlife conservation, notably those designated as National Nature Reserves, Sites of Special Scientific Interest, and Ancient Semi-Natural Woodland. Many form important components of areas designated for their scenic appeal, notably several Areas of Outstanding Natural Beauty in southern England.

2.1.2 British Beechwoods in a European Context

Beech woodland occurs at the edge of its European range in Britain. These woods belong to the Atlantic phytogeographic province of north and west France, Britain, Belgium, the Netherlands, and west Denmark (Jahn 1991). They are grouped under the *Endymio-Fagenion* sub-alliance, which is differentiated from other European beechwoods by the frequency/abundance of *Blechnum spicant, Endymion non-scriptus, Hedera helix Holcus mollis, Ilex aquifolium, Lonciera periclymenum, Pteridium aquilinumn, Rubus fruticosus* and *Ruscus aculeatus* (Dierschke 1990).

Table 1. Average monthly temperate and precipitation levels for main areas of native beech woodland in Britain (south-east, south-central and west-central England, see Figure 1), and for comparison north-central England, north France and central Belgium.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temp. °C													
South-east England	4.7	4.1	6.4	8.1	11.5	14.1	16.7	16.6	14.4	11.8	7.8	6.1	10.2
South-central England	3.7	4.2	5.8	8.4	11.7	14.9	16.6	16.2	13.8	10.1	6.4	4.4	9.7
West-central England	4.1	4.4	6.0	8.5	11.7	14.7	16.4	16.0	13.7	10.0	6.6	4.7	9.7
North-central England	3.1	4.0	5.6	8.1	11.6	14.4	15.8	15.6	13.4	10.1	6.1	4.3	9.3
North France	3.0	3.1	6.3	8.3	11.9	14.7	17.4	17.0	14.6	11.3	6.5	4.5	9.9
Central Belgium	2.2	3.1	5.6	9.0	13.0	16.1	17.7	17.4	14.8	10.6	5.9	3.1	9.9
Precip. mm													
South-east England	94	41	61	44	37	38	41	41	53	103	69	76	695
South-central England	53	41	42	43	52	55	61	59	61	66	62	55	649
West-central England	86	64	62	59	63	63	77	95	84	98	90	92	933
North-central England	71	59	58	52	62	71	87	93	82	93	85	87	900
North France	59	47	46	47	52	54	58	61	57	66	66	64	677
Central Belgium	68	56	58	56	61	67	80	74	66	72	71	69	797

South-east England site is Herstmonceux, 50.87°N 0.30°E, data from 1981-90; south-central England site is Oxford, 51.70°N 1.20°W, data from 1828-1980 (temp.) and 1767-1988 (precip.); west-central sites are Ross-on-Wye (temp.), 51.90°N 2.60°W, data from 1877-1975, and Barrow Gurney (precip.), 51.40°N 2.70°W, data from 1860-1976; north-central England site is Manchester Airport, 53.35°N 2.20°W, data from 1786/94-1990; north France site is Rouen, 49.38°N 1.10°E, data from 1981-1990 (temp.) and 1845-1973 (precip.); and central Belgium site is Uccle, 50.80°N 4.30°E, data from 1833-1990.

The climate in Britain (Table 1) differs from much of continental Europe because of the strong influence of the Atlantic Ocean (Fairburn 1968, Goudie and Brunsden 1994). Summers are relatively cool, winters mild, and the annual growing season is moderately long at 260-280 days. The lack of warm summers means that beech produces seed abundantly only every two to ten and most often in the south (Jones 1952, Matthews 1955, Hilton and Packham 1997, Pfetscher 1999). The average total rainfall ranges from 650-950mm, but patterns are variable and irregular summer droughts occur which impact strongly on mature beech trees especially on dry shallow soils (e.g. Peterken and Mountford 1996). Little precipitation falls as snow and relatively few days have freezing temperatures, though frosts are common and in late spring often cause damage to young beech (Brown 1953, Aldhous 1981). There is some geographic variation in climate: south-east England is generally warmer, drier and has more seasonal rainfall; central England is cooler (especially in winter) and has more even rainfall; west and north-central England are wetter in most months, though the latter is also cooler throughout the year. Compared to the nearest parts of continental Europe (i.e., north France and central Belgium), average temperate and rainfall are closest to south-east England, though winters are as cold as in north-central England and summers are noticeably warmer.

2.1.3 British Classification of Beechwoods

Several types of beech woodland are recognised in Britain (Tables 2 and 3), others being characterised principally by oak or ash. They occur on three principle substrates, in various mixtures, and mainly in the south. The main associates are ash and sycamore on calcareous substrates; ash, birch, oak and sycamore on mesotrophic substrates; and birch, oak and sycamore on acid substrates.

Table 2. Main deciduous woodland types in Britain in relation to soils, climate and possible phytosociological affinities. Based on the National Vegetation Classification (Rodwell 1991).

ALNO-ULMION	QUERCION ROBORI-PETRAEAE		
W9 *Fraxinus-Sorbus-Mercurialis* woodland	W11 *Quercus-Betula-Sorbus* woodland	W17 *Quercus-Betula-Dicranum* woodland	**COOL, WET, NORTH-WESTERN SUB-MONTANE ZONE**
CARPINION BETULI			
W8 *Fraxinus-Acer-Mercurialis* woodland	W10 *Quercus-Pteridium-Rubus* woodland	W16 *Quercus-Betula-Deschampsia* woodland	**WARM, DRY, SOUTH-EASTERN LOWLAND ZONE**
FAGION SYLVATICI			
W12 *Fagus-Mercurialis* woodland	W14 *Fagus-Rubus* woodland	W15 *Fagus- Deschampsia* woodland	**SOUTHERN ZONE NATURALLY DOMINATED BY BEECH**
W13 *Taxus* woodland			**LOCALLY IN SOUTH**
RENDZINAS & BROWN CALCAREOUS EARTHS	**BROWN EARTHS OF LOW BASE-STATUS**	**RANKERS, BROWN PODZOLIC SOILS & PODSOLS**	

Table 3. Main beech woodland types in Britain, and their associated soils and main vegetation elements. After [1]Rodwell (1991), [2]Peterken (1993), and [3]Forestry Commission (1994).

NVC communities[1]	**Main Peterken Stand Types**[2]	**FC Semi-Natural Woodland Types**[3]	**Main soils**[1/2]	**Extent and Description of main vegetation elements**[1/2]
W12 *Fagus sylvatica-Mercurialis perennis* woodland (with 3 sub-communities)	8C Calcareous pedunculate oak-ash-beechwoods (with three variants)	Lowland beech-ash woods	Calcareous, free-draining, brown earths and rendzinas on limestone or chalk	About 40% of native beech woodland. Associated with limestone and chalk outcrops on the North and South Downs, the Chilterns, Cotswolds, Wye Valley and south Wales coalfield. *Fagus sylvatica* often dominant. *Fraxinus excelsior, Acer pseudoplatanus, Corylus avellana* and/or *Taxus baccata* frequent and occasionally abundant. Usually includes a minority of many species of calicole and other trees and shrubs from *Quercus robur/petraea, Tilia cordata, Acer campestre, Cornus sanguinea, Crataegus monogyna, Daphne laureola, Euonymus europaeus, Ligustrum vulgare, Sambucus nigra, Sorbus aria, Viburnum lanata,* and *Ilex aquifolium*. Most frequent ground flora species *Mercurialis perennis, Rubus fruticosus* agg., and *Hedera helix.* Other characteristic species include *Brachypodium sylvaticum, Clematis vitabla, Galeobdolon luteum, Geum urbanum, Mycelis murialis, Melica uniflora, Sanicula europea, Tamus communis,* and *Viola riviniana/ reichenbachiana.* Characteristic uncommon or rare plants include *Buxus sempervirens, Cephalanthara rubra, Cardamine bulbifera*, and *Neottia nidus-avis*.
W14 *Fagus sylvatica-Rubus fruticosus* woodland	8D Acid pedunculate oak-ash-beechwoods 8E Sessile oak-ash-beechwoods (with two variants)		Mesotrophic, often poorly-drained, base-poor, circum-neutral to mildly acid, brown earths and clays	About 45% of native beech woodland. Common in the High and Low Weald, Chilterns plateau, New Forest, Cotswolds and Wye Valley. *Fagus sylvatica* mostly dominant. *Ilex aquifolium* frequent and occasionally abundant, and usually some *Quercus robur* and a few other trees and shrubs from *Betula pendula/pubescens, Fraxinus excelsior, Tilia cordata, Acer pseudoplatanus, Prunus avium, Acer campestre, Ulmus glabra, Sorbus aria/aucuparia, Taxus baccata, Corylus avellana, Crataegus monogyna, Sambucus nigra, Salix caprea,* and *Ligustrum vulgare.* Most frequent ground flora species *Rubus fruticosus* agg., *Pteridium aqulinium, Mnium hornum,* and *Milium effusum,* Other characteristic species include *Deschampsia cespitosa, Dryopteris felix-mas, Endymion non-scriptus, Galium odoratum, Hedera helix, Holcus mollis, Lonicera periclymenum, Luzula pilosa, Lysimachia nemorum, Melica uniflora, Oxalis acetosella, Poa nemoralis,* and *Ranunculus ficaria.* Characteristic uncommon or rare plants include *Epipactis purpurata*.
W15 *Fagus sylvatica-Deschampsia flexuosa* woodland (with 4 sub-communities)	8A Acid sessile oak-beechwoods 8B Acid pedunculate oak-beechwoods	Lowland acid beech and oak woods	Acid, infertile, free-draining, brown earths, rankers and podzolics	About 15% of native beech woodland. Found in the High Weald, Hampshire and London basins, and Chilterns plateau. *Fagus sylvatica* mostly dominant. *Quercus robur/petraea, Ilex aquifolium* and *Betula pendula* generally frequent and occasionally abundant. Usually with a minority of other trees and shrubs, typically including *Taxus baccata, Acer pseudoplatanus, Betula pubescens, Corylus avellana,* or *Sorbus aucuparia.* Most frequent ground flora species *Deschampsia flexuosa, Pteridium aqulinium, Blechnum spicant, Dicranella heteromalla,* and *Mnium hornum.* Other characteristic species include *Agrostis capillaris, Anthoxanthum odoratum, Carex pilulifera, Deschampsia cespitosa, Digitalis purpurea, Holcus mollis, Leucobryum glaucum, Lonicera pericylmenum, Luzula sylvatica, Melampyrum pratense, Oxalis acetosella, Rubus fruticosus agg., Tuecrium scorodonia,* and *Vaccinium myrtillus.*

2.2 Pre-Industrial Period (5,000 BC – 1800 AD)

Woodland in Britain has been greatly altered and no truly-natural sites remain (Godwin 1975a, Rackham 1986). Beech arrived late to the British Isles after the last ice age and was consequently affected by greatly by management and changes to the landscape. By the time it started to increase in dominance, much of the landscape had been cleared of woodland and many remaining sites had been brought into regular management.

2.2.1 Changes in Woodland Cover and Composition

Changes from 5,000 – 3000 BC

The woodlands of the Atlantic period represent the last natural forests of Britain, in that human activities though widespread were apparently inconsiderable. This period was the warmest since the last glaciation, with a mean summer temperature perhaps 2.5?C higher than now. Woodland covered most of the landscape and the broad distribution of many species was similar to that in extant semi-natural woodland, though there were major differences in composition. In the lowlands, lime, oak, hazel, ash, alder and elm were abundant and widespread, whereas beech was scarce (Godwin 1975a, 1975b, Birks *et al.* 1975, Greig 1982, Birks 1989). Most woodland was probably dominated by old-growth, mixed-species, high forest stands which included some old, large trees, some accumulations of dead wood, some temporary open spaces, and a high degree of structural and spatial complexity (Peterken 1996). There were several types of large mammalian herbivores and carnivores present, and at least some areas were probably open and heavily grazed. Mesolithic people were widespread and at least locally used fires to increase food plants and create openings to attract deer and pigs (Simmons 1988). Hunting contributed to the early extinction of bison, elk, giant deer, lynx, mammoth, reindeer and wild horses (Corbett and Harris 1991).

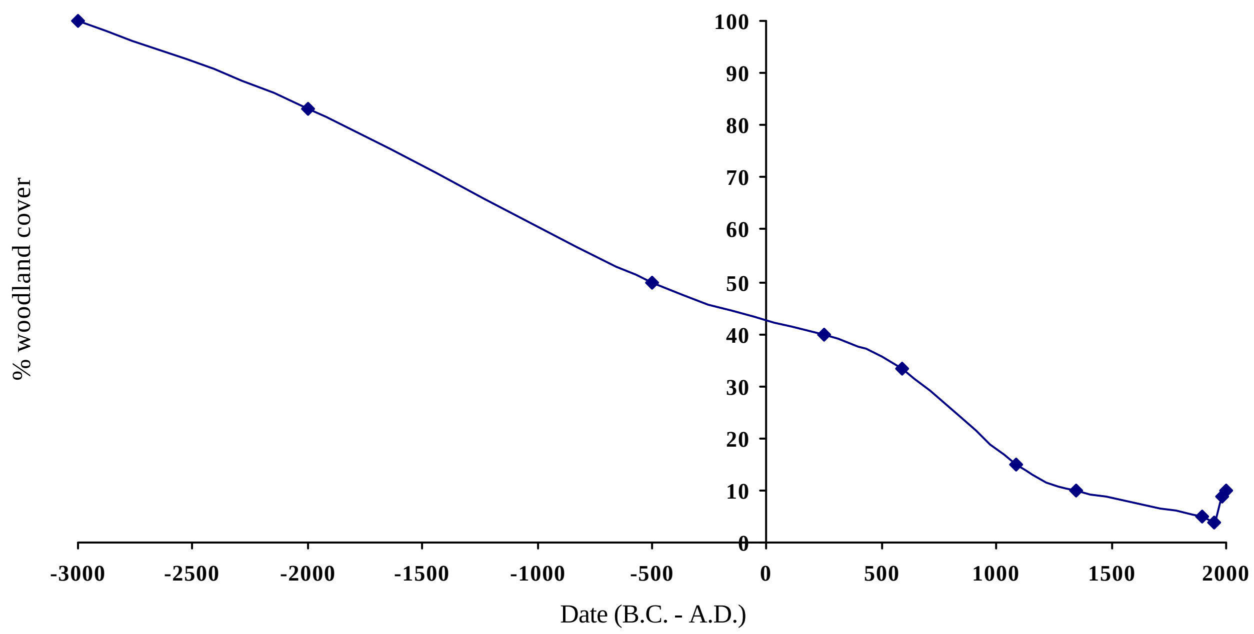

Figure 2. Likely changes in Forest Cover of Britain 3000 BC – present (based on information in Rackham 1986, and Peterken 1996).

Changes from 3000 BC – 0 AD

The proceeding millennia are marked by the start of Neolithic agriculture and the first clearance of large tracts of woodland. Initially the climate was cooler and drier, and then around 800 BC it became wet and even cooler. By the late Bronze Age (500 BC) perhaps half the original woodland of lowland England had been cleared (Figure 2), probably including most on the more-fertile sites. Most notable was the decline in elm and lime. Elm declined early and abruptly, probably because it was much affected by Elm fungus disease (Rackham 1986). Lime declined gradually and at various dates around the country (Table 4 of Baker *et al.* 1978), probably reflecting clearance of woodland from fertile soils, increased use of surviving woodland for fodder and pasture, and possibly confounded by climate change (Turner 1962, Godwin 1975a, 1975b, Baker *et al.* 1978). Beech and hornbeam expanded in range in southern Britain but remained minor species (Godwin 1975a, 1975b, Birks *et al.* 1975, Birks 1989, Waller 1993). Hunting and persecution of large woodland animals increased and probably resulted the loss of aurochs (wild cattle) and brown bears (Corbett and Harris 1991).

Changes from 0 AD – 1800 AD
Since the first century AD the climate has remained predominately cool and wet, though a warm period occurred in the Medieval followed by the Little Ice Age of 1600-1850 AD. Woodland cover declined further. Initially it is estimated at 40%, but by around 1000 AD it had been reduced to 15% and by 1800 was probably half this (Figure 2). Woodland destruction was halted by famine and plague, which in the 1300s devastated the human population. Most woods survived the next 500 years, particularly because by the time the population had recovered the industrial demand for wood was high. Many woods survived as small, isolated fragments, though concentrations occurred in parts of southern Britain.

During this period lime woodland declined further, whilst oak, hazel, ash, and sweet chestnut were promoted, especially in lowland woods treated as coppice (-with-standards) (Rackham 1980). Beech and hornbeam increased in southern Britain, partly due to natural colonisation of abandoned farmland or woodland disturbed by human activity (Godwin 1975a, 1975b, Birks *et al.* 1975, Birks 1989). At Epping Forest, lime woodland declined dramatically at around 600 AD, probably due to selective clearance and increased pastoral use of the landscape: later from about 1000 AD when farmed land was abandoned, beech increased greatly and hornbeam became a component of the woodland (Baker *et al.* 1978). In the New Forest, beech-dominated woodland expanded from about 1500 AD onto ground that had originally been mixed woodland of mainly oak, lime, alder and hazel that had long been treated as wood-pasture (Barber 1975, Flower 1980a). The Romans introduced sweet chestnut and around 1800 AD many coppices in south-east England were replanted with this. Sycamore was planted widely in the 1600s and 1700s and consequently naturalised in many areas. Widespread woodland destruction and inhabitation of much of the countryside led to the decline and/or loss of many native woodland animals, notably beavers, wild boar, wolves, red deer, roe deer, and red squirrels. Fallow deer, rabbits and pheasants were imported as food sources around 1100 AD: later all escaped, naturalised widely, and fallow deer and rabbits became forestry pests (Rackham 1986, Corbett and Harris 1991).

2.2.2 Management of Woodland

General Management of Woodland
Rackham (1976, 1980, 1986) and Peterken (1993) provide details of the history of woodland management in Britain. This originated in the Neolithic (4000 BC) and for several thousand years after there was a demand for an abundant and regular supply of fast-grown underwood (so as to be pliable), small, uniform-diameter timber in straight lengths, and the occasional large timber. This was grown in coppice or coppice-with-standards systems, the excess woodland being treated less intensively as wood-pasture. The earliest evidence of coppicing is from 3174 BC (early Neolithic), where it was used in the Somerset Levels, west England, to produce material for raised track ways over marshland, winter leaf-fodder and house-building (Rackham 1977). Plantation forestry originated around 1600 but did not reach ascendancy until the late 1700s.

Coppice and coppice-with-standards
In these systems, underwood and standard trees shared the same site. The underwood was mostly coppiced, with a portion being cut each year. The site was being divided into roughly equal sized coupes, which were sometimes subdivided and spread around the site. Pollards, other trees, banks and/or ditches were often used to mark compartments. Rotation lengths were short, mostly within 5-30 years. The underwood was valuable for fuel, fencing, wattle in buildings, charcoal, tools, furniture, utensils, crates, and industrial usage: even the smallest material was in demand and little material was left. The iron and glass industries were prominent

users of fuel wood and charcoal during Roman times and again between 1550 and 1700, when large areas of woodland deliberately preserved for the purpose and managed regularly (e.g. Hammersley 1973). In fact, the output of the Roman ironworks was probably supported by a stable coppice system covering 9,300 hectares of the Weald (Cleere 1974, 1976). Most underwood grew from sprouts on low-cut stumps, though occasionally these stools were left up to about 1 m height. The stands were often of mixed native species, but some were improved from the 1600s by planting (e.g. beech, sweet chestnut, sycamore, ash, oak and willow) and weeding (e.g. hawthorn).

Standard trees were grown for up to about 100 years and occupied only a small portion of the ground. Most were oak and were replaced by seedlings (records of planting trees in existing woods are rare before 1750 AD). Many were cut when small, because of the constraints and practises of pre-industrial carpentry, larger and longer trees being used only in grand buildings and ships. Medieval woodlands contained trees of all sizes, but with a preponderance of young trees, very few mature ones, and a high turnover. After 1543 AD, however, standards were grown to larger size before felling and many were then sawn into pieces before use. Densities and sizes tended to increase into the 1700s, and it was then the practice to fell a certain proportion annually according to a predetermined plan.

In some coppices, permanent fences, hedges and/or ditches strictly excluded livestock. However, elsewhere deer, cattle, horses or sheep were commonly allowed to graze, though these had to be controlled to protect the underwood. Grazers were generally excluded for 4-7 years after coppicing by either a permanent live hedge or a temporary dead-hedge. Occasionally grazing became uncontrolled and threatened the existence of the wood.

Wood-pasture

Wood-pasture was the alternative to coppice and probably the dominant form of land-use during most of the pre-industrial period (Rackham 1980, 1986, Peterken 1993). This combined trees and grazing animals either *uncompartmented* (where trees, coppice, scrub, grassland, heath and livestock were combined in the same place such that trees were frequently pollarded 2-3m above the ground), or *compartmented* (where certain areas were treated separately as fenced coppice and others as grassland, with or without trees). Products included large timber trees, underwood and livestock. In areas with both trees and livestock, grazing did not entirely prevent the regeneration of trees, though long periods may have occurred between regeneration waves. For example, in the largest extant wood-pasture in Britain, the New Forest, it is possible to discern three age-classes of the trees that are correlated with times of reduced grazing (Peterken and Tubbs 1965). Pollarding was often regular and organised, as were grazing and other rights.

Wood-pasture occurred in the form of wooded commons, forests, and deer parks. Wooded commons belonged usually the local lord, but had certain communal rights for local people, often livestock grazing, fattening of pigs on acorns or beech mast (pannage), and collection of fuelwood from coppice or pollards. Many commoners had rights for pannage during Anglo-Saxon and Norman times, but the practice had declined by the 1400s. In 1100 AD wooded commons accounted for up to 24% of the land-use in some parts of England. However, by 1300 AD they had declined greatly due to excessive grazing, and conversion to coppice, Forests or parks.

The Norman Kings introduced the concept of Forests around 1100 AD. These were large, unfenced tracts of open habitats and woodland. They occurred either as royal Forest or equivalent private Chases, governed by special laws concerned with protecting deer for hunting, though with common rights maintained. At their height, in the 1200s, they amounted to perhaps 160,000 hectares. Afterwards they gradually declined. Much of associated woodland became very ineffectively managed (Hammersley 1957), and, for example, over 700ha in the New Forest was made into coppices in the Middle Ages (Tubbs 1964, Flower 1980b). From about 1650 AD modern plantation forestry encroached upon the remaining Royal Forests.

Deer parks originated before 1100 AD, were widespread in the medieval, but declined greatly in the 1500s and 1600s. They were mainly private and derived from the church lands of the local lord. Typically they were stocked with red, fallow or roe deer, contained at least some ground under wood-pasture, and were enclosed by a substantial earth bank with a hedge, fence or wall.

2.2.3 Management of Beech Woodland

Coppice
Beech was included in the underwood of coppices (Rackham 1980, 1986). Although often regarded as responding poorly to such treatment, it nevertheless increased in coppices where it was highly valued for fuel and the production of charcoal. It was used in small quantities in wooden track ways across the Somerset Levels at 2500 BC (Godwin 1960). Later it became an important component of coppice woods in the Weald, Chilterns, Cotswolds, and south part of the English-Welsh borders, where it was used mainly as fuel and charcoal. In the 1500s and 1600s it had a specific use for the glass industry, especially in the West Sussex Weald. At the same time, it was part of the mixed coppices that supplied fuel for the iron furnaces and forges around Monmouth, on the south Wales borderlands (Peterken and Jones 1987).

Beech was scarce as a standard tree and there are few medieval references to it as timber (Rackham 1980, 1986). It casts a heavy shade and as timber was useful only for miscellaneous purposes, such as wheel rim maskings, planking for houses, wedges for ships and turnery (Mansfield 1952, Edlin 1973). It was never important for building, even in the heart of the Chiltern beechwoods. In the early 1600s it formed a minor component of the timber trees and fetched a low price in woods on the English-Welsh borders (Peterken and Jones 1987).

Beech was especially abundant in the Medieval coppice woods of the south-west and central parts of the Chilterns (Mansfield 1952, Roden 1968, Preece 1987). It probably occupied every scarp and was recorded as the dominant in woods up to 120ha. Although it was the most important species, it often grew in mixture with oak, ash, and sometimes field maple, alder, aspen and whitebeam. Apart from supplying local demands, it was sold in large quantities and transported along navigable waterways to satisfy the fuelwood needs of London from the medieval and until coal became available in the mid-1700s. Coppice produce was used for firewood and fuel in tile, brick and baking kilns into the 1900s. Beech was valued especially as firewood and was considered superior for glass making in the 1700s. On occasion it was been planted to form coppice, and sometimes grown into standard trees. Even beech roots were sold, presumably from windblown or trees deliberately pulled over. The coppice rotation was 7-15 years and on larger estates at least some coupes were taken every year. Beech appears to have been treated slightly differently than other coppice species. In an example lease where beech was to be coppiced for poles and firewood, it specified that no beech less than 9 years were to be cut.

Although many Medieval Chiltern beechwoods were treated as coppice and cut regularly, others were cut less frequently and formed high forest, with some beechwoods being so dense that the underwood was largely shaded out. These were sometimes selectively and rarely clear-cut, with beech being sought after. An example from 1353 AD states that 'all beeches are to be cut in different parts of the wood, as shall be most profitable'. After about 1550 AD the demand for firewood and charcoal increased. Some large fellings occurred (e.g. 1000 of the biggest and best beeches in Kingswood were sold in 1541), and much beech woodland was turned into coppice cut on an 8-10 cycle. Standard trees of oak and ash were cut heavily for construction timber, leaving the beech coppice ever more prominent. This lasted until the early 1800s when, with the appearance of coal and the development of the beech furniture industry at nearby High Wycombe, most beech woods were allowed to grow into high forest.

Wood-pasture
Many areas with beech were traditionally managed as wood-pasture, with beech often treated as a pollard (Rackham 1980). Examples include the New Forest in Hampshire (Flower 1980a, Tubbs 1968, 1986), The Mens in Sussex (Tittensor 1978), Burnham Beeches west of London (Frater and Read 1993), and Epping Forest northeast of London (Dagley and Burman 1996). In the latter, pollards were cut for firewood on a 10-15 year rotation, the felling taking place in winter at about 3-3.5m height. Not all beeches in wood-pastures were treated as pollards, some having only branches removed from the main trunk (Flower 1980a), whilst others were probably not cut regularly so that crops of nuts could be produced for autumn pannage.

Beech wood-pastures were frequent in medieval times in much of the Chilterns (Mansfield 1952, Roden

1968). Most were common woods with controlled rights for firewood, building wood, pannage, grazing, and hay cutting. Occasionally private woodland was also used for livestock pasture, including pannage. The common woods were generally more open, had less underwood, and some were so heavily grazed that eventually they changed into open scrub and heath or grassland.

2.3 Industrial Period (1800 AD – 1980 AD)

2.3.1 General Changes in Woodland

Causes

With the coming of the industrial revolution, large social and other changes occurred that resulted in major changes in woodland cover, composition and management (Rackham 1980, 1986, Peterken and Allison 1989, Peterken 1996, Aldhous 1997, Selmes and Peterken 1997). From 1801 to 1901 the population rose almost fourfold from 8.9 to 32.5 million and shifted from rural to urban locations. This combined with industrialisation to create a massive initial demand for fuel wood, small wood products, and constructional timber.

However, small wood then became replaced by coal (and later electricity) and manufactured metal (and later plastic) goods. Canals and (later) improvements to the rail and road network allowed for quick and cheap transport. New agricultural practices and mechanisation made farming more profitable, such that land previously unsuited for cropping was brought into use, including cleared woodland. In the remaining woods the demand shifted to large, constructional timber, with mechanisation increasingly allowing ready extraction and transportation. Management though was largely unsystematic and much exploitative felling of timber occurred. The 1800s saw a change in attitudes associated with increasing wealth and the rise to Britain as a global power. The desire to 'enrich' the landscape became fashionable, including the planting of exotic trees, introduction of exotic animals, and spread of professional game-keeping.

In the early 1900s the Forestry Commission was formed to deal with the depletion of the national timber resource, noticeably during the First World War. The interest now was in growing exotic conifers, which offered the prospect of quick-grown, profitable, large timber. Thereafter, forestry became organised by the state service under a national forestry policy, though later it became subject to much regulation.

Changes in Woodland Cover, Composition and Management

The industrial revolution started a new period of woodland clearance. In the Chilterns, as elsewhere, woodland and especially coppice was extensively converted to farmland (Mansfield 1952). By 1895 woodland cover in Britain was reduced to just 4%, when perhaps 25% was coniferous (including native pinewoods in Scotland) (Figure 2). However, in 1919 the Forestry Commission was formed and set about a national programme of afforestation to establish a strategic reserve of timber (Aldhous 1997). Two million hectares of productive forests were established in Britain by the end to 1900s (Figure 3). This increased the total area of woodland to 11% overall: in England it is 7%. However, 70% of the total is coniferous plantation, mainly Scots, Corsican and Lodgepole pine, Sitka and Norway spruce, European, Japanese and hybrid larch, and Douglas fir (Forestry Commission 1983). Overall, recently established plantations now account for 81% of the woodland in Britain. Only 11% remains as ancient semi-natural woodland, whilst 8% is recently established semi-natural woodland derived from the colonisation of former heath, grassland or wetland (Spencer and Kirby 1992).

Much of the conifer afforestation was in Scotland, and in England about 60% of woodland remained broadleaved (Forestry Commission 1983). Much of this was oak and beech established pre-1911, less broadleaved than conifer planting having occurred in 1920-1980. Beech was planted widely for both timber and ornament (Brown 1953, Jones 1961), and now accounts for about 14% of the high forest area in England (Forestry Commission 1983). Although it remains most abundant within southern England, elsewhere it has naturalised, especially in acid oakwoods and valley ash-wych elm woods in northern and western Britain (Peterken 1996, Selmes and Peterken 1997).

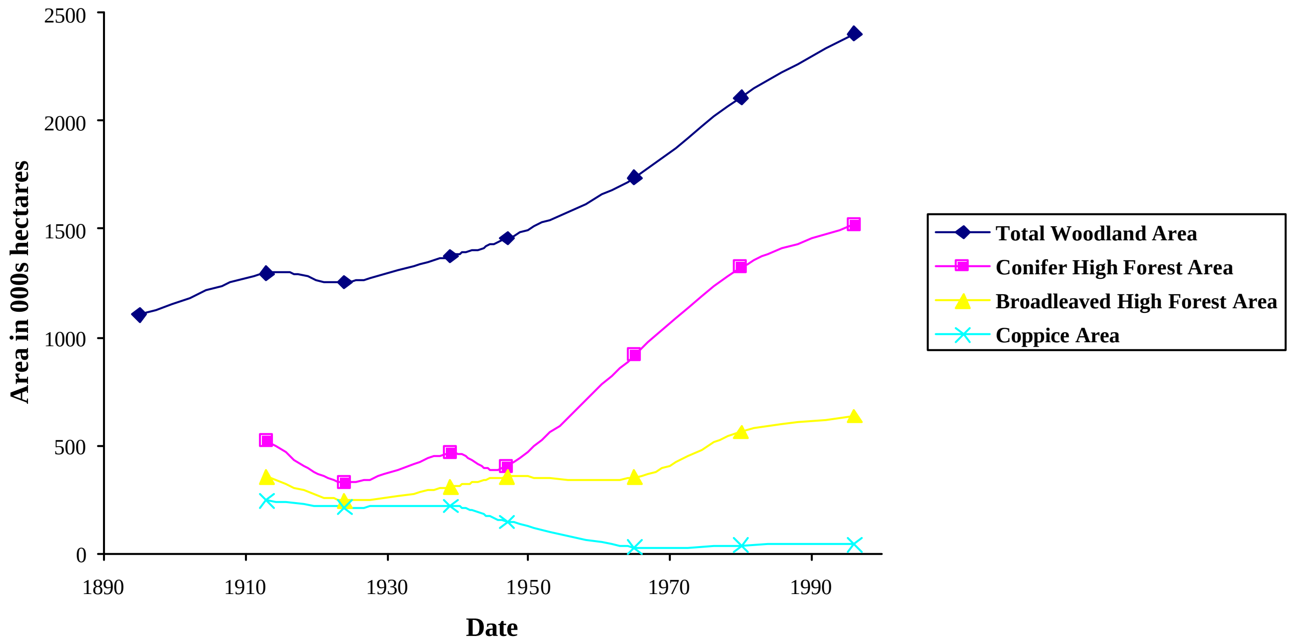

Figure 3. Changes in woodland area in Britain from 1895 to 1996 derived from various national woodland censuses (see Peterken and Allison 1989, Peterken 1996, Aldhous 1997).

Decline in Coppice Woods

Coppice woods and management therein declined from the early 1800s (Rackham 1980, Peterken 1993). Despite remaining widespread around 1900, coppicing had declined substantially in northern Britain, and by 1940 most former coppices were neglected. In the Chilterns only 332ha of coppice remained in 1947, with only 5ha being beech (Mansfield 1952). In the east Midlands the area of coppice woodland had fallen by about 60% from 1825 to 1946: by 1972 only a very small area was still being cut (Peterken and Harding 1975, Peterken 1976). Much of the 20,000ha coppice or so that remained worked in England in 1965 was sweet chestnut in south-east England (Locke 1970), which had retained a market for paling fences and hop poles.

By the mid-1980s very few traditional mixed coppices survived intact (Spencer and Kirby 1992). Of the ancient mixed broadleaved woodland present in England and Wales in 1930s, most of which had formerly been treated as coppice, 7% had been cleared and 37% converted to plantation. Converted sites were predominately to conifers or mixtures with conifers and had the original coppice removed and the regrowth sprayed with herbicides. The remaining 55% had been left uncut to develop into high forest.

Decline in Wood-pasture

Enclosure Acts, agricultural reclamation or the decline in common grazing led to the loss of most remaining wooded commons and forests (Roden 1968, Tittensor 1978, Rackham 1986, Peterken and Allison 1989). Some had already degenerated into heath or grassland because of excessive grazing, whilst in others grazing waned and high forest developed. Elsewhere, common rights were extinguished and the land converted for agriculture or into plantation. In some cases attempts at farming failed because the land was so infertile.

The loss of large commons produced much concern amongst locals and the general public, who often opposed enclosure. The destruction of most of Hainault Forest in the mid-1800s motivated a conservation movement, which culminated in the preservation of large wood-pastures such as at Epping Forest, Burnham Beeches, and, most notably, the New Forest where almost 4,000ha of mainly beech-oak wood-pasture survives (Tubbs 1986). Recreational use of these increased, but traditional management declined as common rights for grazing, wood and pannage were not exercised. Pollarding was neglected generally from the 1800s, though earlier declines occurred at Writtle Forest (around 1650) and the New Forest (outlawed from 1698). Few common wood-pastures have sustained traditional grazing. Declines in grazing allowed many former areas of pasture to regenerate to woodland, even in the New Forest where pony and cattle grazing has continued more-or-less uninterrupted (Peterken and Tubbs 1965).

Rise of Plantation Forestry

High forest became the main form of woodland management through storing or planting of coppices and afforestation (Rackham 1980, 1986, Peterken 1993, Selmes and Peterken 1997). Plantations became widespread from the late 1700s (Jones 1961). Initially it was small-scale and mainly of Scots pine, oak, ash, larch beech, Norway spruce, sweet chestnut and sycamore. These were often established in mixture. Beech and oak were already being planted with conifer nurses, usually Scots pine, larch or Norway spruce. Planting was often at 1x1 m spacing and thinning began early because markets existed for small poles. Natural regeneration of high forest was rare.

During the 1800s demand for larger sizes of timber accelerated, but after 1850 the price for hardwoods fell by up to 50% as metal was increasingly used in ship-building and construction. Conifer planting therefore gained favour. During the First World War many woods were harvested and the dependence of Britain on imported timber was highlighted. Shortly after the war ended the Forestry Commission set about implementing a national forestry policy. This involved a massive programme of afforestation and conversion of most woodland to plantation through clear-cutting and tree planting. Even-aged, clear-cut systems became dominant, and conifer planting predominated. Despite broadleaved plantations being favoured less, some markets for hardwood timber remained and about 60% of woodland in England remained broadleaved (Forestry Commission 1983). Much of this was oak and beech established pre-1911, with less broadleaved than conifer planting occurring during 1920-1980. Many ancient broadleaved sites that were originally coppiced, were left to develop into high forest without tending. They suffered also from exploitative felling, especially during the Second World War. In general, broadleaved silviculture was neglected, and many sites were left with little valuable timber or recent regeneration.

The change to plantation occurred also in the Chilterns, with beech high forest becoming the norm in the 1800s (Mansfield 1952, Roden 1968, Tilney-Bassett 1988). Initially, the main market was the local furniture-making industry (Dallimore 1911). Most oak trees were extracted in the early 1800s, leaving beech the dominant tree. There was considerable planting of beech, though many owners included some oak, ash, sycamore, European larch and Norway spruce, especially after 1860. Management was by a small-scale selection system that utilised all sizes of timber. However, at the end of the 1800s the situation changed. Competition from imported timber increased, the market for small dimension material became severely restricted, and demand for high-quality large timbers rose. Exploitative felling of top quality trees occurred, leaving woods stocked with mature but low-quality trees and neglected younger stands. After 1945, some mature beech stands were clear felled, sometimes on a large-scale, and often were replanted with conifers. This caused much outcry, mainly on landscape and nature conservation grounds. From about 1970 the aim of management changed to perpetuating the remaining broadleaved forest areas, predominately with beech (Chilterns Conference 1971). Felling coupes were limited to 3ha maximum and regeneration of woods was to take place over 30-40 years. Conifers were limited to use only as nurse crops.

2.3.2 Management of Beech Woodland

Beech has remained an important broadleaved timber species, second only to oak. It has been used for furniture, joinery, flooring, plywood, turnery, charcoal, pulpwood, and firewood. Management of beech woodland during the period is detailed below, much of which remains applicable (Bourne 1931, Brown 1953, 1955, Penistan 1974, Aldhous 1981, Evans 1984, Pryor and Savill 1986, Mathews 1989).

Site Selection

Beech is capable of growing and regenerating in most of Britain. The mean yield class is $6m^3\ ha^{-1}\ yr^{-1}$. In Scotland it is lower at $4m^3\ ha^{-1}\ yr^{-1}$. A few stands on fertile sites achieve $10m^3\ ha^{-1}\ yr^{-1}$. Growth is a little slower and stature somewhat less in northern Britain. It is more tolerant of exposure than oak and ash and can often be found at altitudes above 300m, though rarely above 500m. Moisture supply is critical. In low rainfall areas and on shallow soils it grows better on the damper north to east aspects. Good growth often occurs on well-watered dip and scarp slopes. Young beech is sensitive to frost and is mostly absent from frost-prone valley bottoms and depressions.

Beech is grown on a wide range of soils and site conditions. Best growth is associated with deep, moderate acidity to slightly alkaline, well-drained loams, clay loams, and sandy loams. It is poorest on very acid and very alkaline soils. On acidic podsol soils beech rarely attains great stature and yield averages $4m^3$ ha^{-1} yr^{-1} or less. On strongly calcareous, shallow, rendzina soils beech rarely does well, often developing lime-induced chlorosis after canopy closure (Day 1946, 1948). Poorly drained sites with clay or silty clay textured soils are unsuitable (waterlogging is lethal to small beech plants), and very shallow soils over clay (which are liable to excessive drying in summer droughts).

2.3.3 Silvicultural Systems

Clear-Felling
Clear-felling has been the main treatment for beech high forest during the past century. The basis is to create large even-aged blocks, undertake regular thinning until the final crop is clear felled, and then restock by planting bare-root transplants and controlling weeds with herbicides. It is particularly appropriate for the beech/conifer mixtures, where orderly lines and blocks can be created. The main disadvantage is lack of protection when establishing beech, particularly from frost and drought. It has also been criticised for landscape and nature conservation reasons, mainly because of the sudden and scale of changes, use of planting and lack of habitat diversity. These can be reduced by the use of small coupe fellings, as recommended the Chilterns.

Shelterwood System
A limited number of beech stands in Britain have been managed by shelterwood systems. Here, some retained overstorey trees are used to naturally regenerate and protect the new crop. Such treatment requires careful control in Britain. Beech mast years are infrequent and late spring frosts common. Beech regeneration may take time to come and be patchy. Sometimes, ash, sycamore or birch are more plentiful in the new crop. Recently, an abundant mast year in 1990 was used to regenerate 40 hectares of a beech forest in the Chilterns (Pakenham 1996). This involved making use of a mast year, ploughing and rolling in the autumn to bury and protect seed, and undertaking mechanical and chemical weed control of bramble and grasses. At the end of 1995 the area was well stocked with beech seedlings of 15-80cm height. Elsewhere in the Chilterns, a form of shelterwood has been used where the new crop is established by under-planting rather than natural regeneration, and the overstorey is retained to sustain forest conditions and reduce bramble growth.

The shelterwood system shares some of the disadvantages of clear-felling. Regeneration fellings can cause severe landscape changes, and the end product is essentially even-aged stands of uniform density. Protection for young beech is only moderate. It becomes more desirable if smaller areas are used, when the system becomes Group Shelterwood.

Group Selection Systems
Group systems involve felling small groups of trees sometimes as a shelterwood. They have been used more in Britain than uniform shelterwood or single-tree selection systems, all of which are consistent with "continuous cover forestry" (Garfitt 1994). An impressive example is at the Ebworth Estate in the Cotswolds (Workman 1986). The basis is to establish advance natural regeneration of beech and release this by felling the overstorey, though sometimes ash or sycamore may develop instead. Groups are usually less than 0.3ha. Typically, it takes around 30 years to naturally regenerate a stand, and sometimes infilling with beech transplants may be necessary. Ground vegetation is controlled by manipulation of the overstorey. Respacing is generally completed by the 15th year.

A recent example of group felling here comes from Queen Wood in the Chilterns (Hart 1995). Initially, 27-36m diameter (0.05–0.1ha) gaps were cut. Beech regenerated naturally on the margins, but did not disperse in the centres. More recently, 0.5-1.0 hectare coupes were created and restocked by planting beech and cherry. Although the Chiltern beechwoods are often cited as being managed by selection forestry, many sites have suffered exploitative felling. Group shelterwood has been used to regenerate 1200ha of mixed broadleaves with mainly beech and oak in the Forest of Dean (Joslin 1982). Here, regeneration felling removed 60% of the volume to create groups, followed 5-7 years later by one or more secondary felling. After 11 years, 12% of the area was successfully regenerated, and 48% stocked with advance regeneration. However, in places the regeneration is sparse and birch predominant. The size of regeneration unit is 1-5 hectares.

Group systems are often most desirable when combining timber production with landscape and nature conservation. Landscape changes are small and structural diversity of the stand high. Young beeches are both well protected and illuminated, and natural regeneration can be more readily achieved. They are generally recommended for managed ancient semi-natural woodland (Kirby 1984, Peterken 1993, 1996).

Single-tree Selection System
Single-tree selection involve the removal of individual trees from within a stand. There are no extensive examples of its application in Britain, even with beech. It is difficult to apply to because it requires sustained long-term application, stable markets, and skilled, highly regulated forestry working. However, it has been suggested as appropriate to for beech woods where intensive management is not possible or desirable.

Economics
Three economic analyses have been published comparing different systems of beech forestry (Lorrain-Smith 1982, Crockford *et al.* 1987, Hubert *et al.* 2000). These suggest an order of profitability as plant and clear-fell mixtures > plant and clear-fell pure beech > other systems involving natural regeneration and restrictive management practices or group felling. However, the group systems could easily be as profitable if they produce higher quality timber, as is claimed by supporters.

Forestry also produces a variety of non-market financial benefits (e.g. public recreation, carbon fixation, nature conservation). A cost-benefit analysis was performed for a replanting in east England, comparing the cost of timber production with the approximate financial benefit of indirect values (Whiteman 1991). Although timber production made a loss of £180 ha^{-1} yr^{-1}, the non-market benefits were £348 ha^{-1} yr^{-1}. Thus, with private grants available to forestry currently estimated at £153-£340 ha^{-1} yr^{-1}, this suggests that most private forestry should be profitable.

2.3.4 Establishment and Aftercare

Natural Regeneration
Natural regeneration of beech has many advantages. Notably, it uses local provenance and maintains genetic variability; it can establish a dense crop, which gives greater protection to young plants and allows greater selection thereafter; and it maintains vegetation cover and is sympathetic with landscape, amenity and nature conservation aspirations. Moreover, because beech is a shade tolerant species that generally establishes better with shelter, natural regeneration using shelterwood or group selection systems seem desirable.

Despite these advantages, natural regeneration has rarely been used for restocking beech woodland in Britain because of problems in ensuring success (Bourne 1942, 1945, Jones 1952, Harmer 1994). Beech masts infrequently and patchily, and both seeds and established seedlings suffer much from predation and browsing. In addition, beechwoods are often small and privately owned, meaning that sustained long-term treatment is problematic. Restocking in private woods has been led by grant-aid from the Forestry Commission that has focused on planting. Although planting requires considerable labour input, it is not necessarily more expensive because of the need for careful tending of natural regeneration (Hubert *et al.* 2000).

Recently, natural regeneration has become fashionable and its use is being advocated in ancient semi-natural woodland and through grant schemes. The following guidelines are given for natural regeneration of beech in Britain (Bourne 1942, 1945, Penistan 1974, Aldhous 1981, Workman 1986, Evans 1988, Harmer and Kerr 1995, Pakenham 1996). Seed production should be maximised by thinning mature stands to leave well-formed trees with large healthy crowns. Beech seedlings can establish in moderate-deep shade, and it is advisable to wait for a bank of these to develop before opening the overstorey. Following a mast and once seed has fallen, stands can be opened moderately. Fallen seed needs protecting from seed-eating mammals and birds by burial. This can be achieved by light soil scarification or opening of trenches before seedfall and covering after. Extraction of thinned trees provides a good opportunity to scarify the soil. Seedlings are sensitive to frost, so a balance is achieved between opening the stand and maintaining a protective overstorey. Weed growth and browsing are discussed below.

Planting

Planting has been preferred over natural regeneration because it is faster, more reliable, more easily managed, and allows greater control (Penistan 1974, Aldhous 1981, Evans 1988, Tilney-Bassett 1988). Direct sowing of seed is not used because it is unreliable, although cheaper. Seedlings are grown in nurseries before planting out over winter as bare-rooted transplants. The seed does not store well, and is usually sown immediately. The optimum size for planting is 25-50cm height with the root collar diameter at least 5mm. Larger plants confer no extra advantage; spindly plants and those with little root should be avoided. Plants will remain suitable for transplanting for several years.

In recent years, transplants have been spaced out mostly at 1.8-2m. This is less than traditional close spacing (1-1.4m) and requires the use of appropriate stock to ensure adequate selection of well-grown stems in later thinning. Wider spacing can be used if side shelter is available and is cheaper, though it may encourage crown forking and impair height growth. In the Chilterns, 3m spacing is used for planting pure beech, while mixtures are planted at about 2-2.2m.

Seed Provenance

During 1920-50, much of the seed collected for the Forestry Commission came from within Britain (Figure 4). This was collected without regard to the quality of the parent stand. Later, seed provenance became more important and seed stands were identified on the basis of parent tree vigour and stem form, especially lack of forking. A list of fourteen registered seed sources were identified within Britain, which meet with the European Commission regulations to control the sale of seed or plants intended for forest use. Since 1995 it has been possible to use this has meant that beech seed can now be collected from many more sources in Britain. Although seed from the best British stands appear to be at least as good as most European sources, most seed has been imported since 1950 (Figure 4).

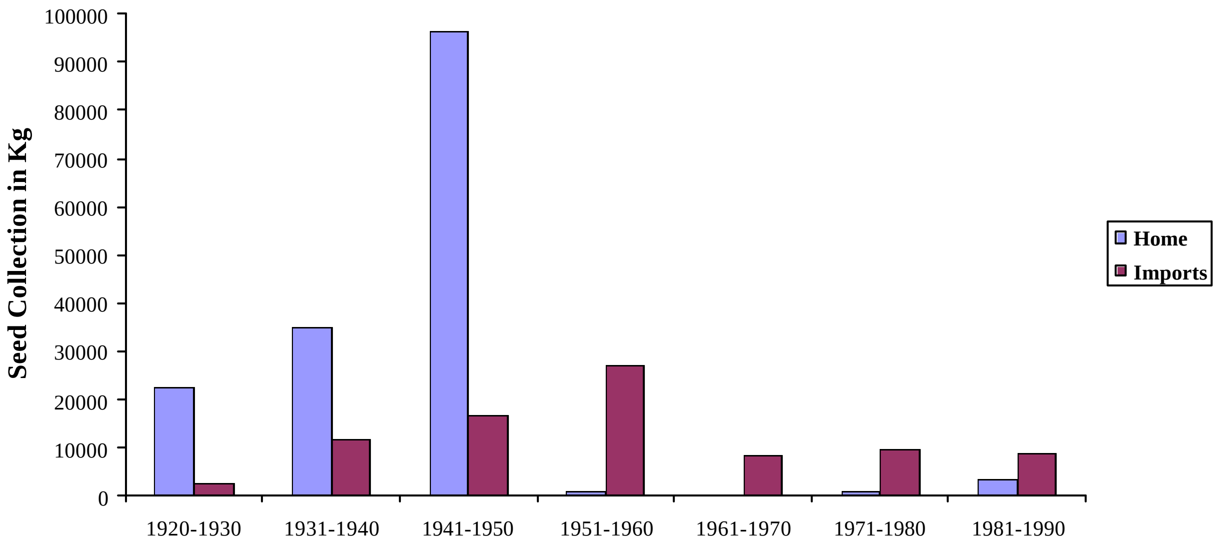

Figure 4. Origin of beech seed used by the Forestry Commission from 1920 to 1989 (Lines 1999)

Nurses
Beech has sometimes been established in mixtures with other faster-growing species (Aldhous 1981, Evans 1984). This can increase yields, bring early financial returns, and provide shelter (nurse) for beech. Nurses have been especially useful on exposed, frost-prone sites and in the uplands. On open grassland underlain by chalk, initial growth of beech is faster and stem form better when planted amongst pine stands or gorse (Brown 1953, Wood and Nimmo 1962). Suitable conifer species include Lawsons cypress, western red cedar, Scots or Corsican pine, and occasionally European larch and Norway spruce. Species suitability depends on site conditions. Planting in three rows beech followed by three rows conifer has been successful. Broadleaved nurses include cherry, ash, birch, and sycamore, which are sometimes developed from natural regeneration.

However, mixtures have been problematic. The nurse species needs to grow about the same rate as beech in early years, or intervention is needed. The anticipated conifer yield should never be more than double that of beech, except for larch that should not be more than 50% better (Evans 1984). Conifer mixtures can look unsightly, especially if planting is done in a regular pattern. Beech is sometimes planted as an ornamental screen or belt around conifer plantations, as has often been done in the Chilterns. Broadleaved nurses are often more compatible and the planting design less important.

Weeding and Cleaning
Dense weed growth can suppress young beech by competing for moisture, nutrients and light. Unless controlled, losses can be considerable. Brambles, grasses and bracken cause most problems, and can be encouraged by excessive scarification. Weed control is always necessary for several years where beech is planted in large openings and on ex-farmland. In group and shelterwood systems, weed growth needs to be limited before and may need controlling after stand opening. Both mechanical weeding and herbicides have been used.

Cleaning – control or removal of woody weed growth and the removal of unwanted planted species in mixtures – has been an essential treatment for beech, though it is expensive (Tilney-Bassett 1988). In naturally regenerated stands, it usually occurs once the regeneration gets to 2m height. Stems are selected for vigour and stem form, and the canopy is then opened gradually over the next 15-20 years.

Browsing
In recent decades, fallow deer (mainly in lowland England), roe deer (mainly in south England and upland northern Britain), and Chinese muntjac deer (mainly in lowland England) have spread and generally become forestry pests (Corbett and Harris 1991). Beech can suffer from browsing by these and rabbits, though generally less so than ash, oak and sycamore. Where numbers are high, protection is usually by tree shelters or fencing. Shelters are generally more economical for smaller areas, while larger areas and natural regeneration tend to be fenced.

Thinning
Thinning during the course of a rotation is important for beech to ensure trees with good stem form and vigour are promoted and that other species are not crowded out (Brown 1953, Aldhous 1981, Evans 1984). Where thinning appears safe, it should be light, selective, and aim to removing poor-formed, non-vigorous and diseased trees. Beech is responsive to thinning up to about 80 years of age, and responds well even after neglect. Heavy thinning in neglected stands over 100 years can be damaging, because exposed trees are liable to get sun scorched bark. This has occurred in the Chilterns where older beech stands have been opened up. Markets for thinned out trees are poor, mostly firewood or pulp, and pay for only the cost of marking and part of the cost of the thinning operation.

Grey Squirrels
American grey squirrels have replaced the native red squirrels in most of England. The red squirrel was re-introduced to Britain after becoming extinct in 1840. It spread strongly and became a pest, only to decline catastrophically in 1900-1920. Later it recovered, but by this time grey squirrels had started to spread rapidly from introductions around 1900 AD, and now it is the grey squirrel that is abundant and a pest through much of Britain (Rackham 1986).

Stands of young beech up to about 40 years of age are vulnerable to debarking by American grey squirrels (Shorten 1954, 1957, Rowe 1984, Rowe and Gill 1985). In severe cases, the trunk or crown branches can be completely ringed and killed. Old debarked patches are vulnerable to staining and decay though healing may occur from callus growth (Mercer 1984). Large trees are frequently debarked at the base and along crown branches, but the most vulnerable stems are pole-sized (10-30cm d.b.h.), sappy and growing rapidly, and within stands that have a high density of squirrels, a major component of beech, a diversity of seeding tree species, and a history of debarking: recently thinned stands are especially vulnerable (Kenward 1982, Kenward *et al.* 1988a, 1988b, 1992, 1996, Mountford 1997, Mountford and Peterken 1999).

Shooting, nest destruction, cage-trapping and/or grain hoppers baited with warfarin poison can control squirrel numbers (Rowe 1980, Gurnell and Pepper 1998). Rewards for shooting were once offered, but now grants are now available for the cost of poisoning. Squirrel control presents several problems: shooting and nest destruction are labour intensive and difficult to carry out effectively; squirrels do not always take grain from hoppers; hoppers are sometimes destroyed by the public; unless control is widespread squirrels will readily migrate in from adjoining areas. Squirrel damage has become so widespread and abundant in lowland Britain that the long-term status and silviculture of beech has been questioned (Tilney-Bassett 1988, Mountford 1997). Systems that grow beech slowly (continuous cover treatments) or as a minority component of mixtures until final thinning appear to offer the best alternative to uniform thinning (Kenward *et al.* 1988b, Kenward and Dutton, 1996, Mountford and Peterken 1999).

Beech Bark Disease

Beech bark disease is considered the most serious disease complex affecting beech in Britain (Lonsdale and Wainhouse 1987). It is associated with the beech scale or felted beech coccus *Cryptococcus fagisugi*, a sap-sucking insect that infests trunk crevices and exudes a characteristic white woolly secretion. Heavy infestations can be debilitating, but more critically they often render bark tissues susceptible to normally weakly pathogenic cankering-forming *Nectria* fungi. Bark necrosis, weeping, decay and death can ensue on dominant and subdominant trees. Other fungi may secondarily invade trees killed by *Nectria*, such as the polypore decay-fungus *Bjerkandrea adusta*, which often results in trees snapping a few metres above the ground (known as beech snap disease). Development into the bark disease involves a complex series of predisposing factors including drought, lime-induced chlorosis on chalk scarps, competition in dense pole-stage stands, proximity to coccus-infected trees, host-resistance, and prior bark-damage. Severe outbreaks of the disease have recently affected 15-40 beech year-old stands in southern England, though trees of all ages can be infested by the coccus or canker. However, losses are generally not catastrophic.

Drought

Beech is vulnerable to drought. In 1976 a severe drought caused widespread crown damage to beech across southern Britain, exacerbated by its shallow-rooting and the mature character of many beechwoods (Lonsdale *et al.* 1989, Power 1994, Peterken and Mountford 1996, Mountford *et al.* 1999). Trees on shallow, free-draining or stagno-gley soils suffered most, and some mature beech were killed immediately or sent into a slow terminal decline. Many survivors grew little for several years afterwards.

Windthrow

Beech is vulnerable to windthrow. Many mature beechwoods in south-east England suffered damage during The Great Strom of October 1987, including a few that were nearly levelled (Grayson 1989, Whitbread 1991, Mountford and Peterken 2000, 2001) Although beech proved vulnerable because it is shallow-rooted, it was also prominent on shallow soils, exposed slopes and plateaus, and many beechwoods were mature and had been part-opened and weakened by drought. Although this was a rare event (perhaps occurring every 200 years), lesser but damaging gales are a regular occurrence in Britain.

Atmospheric pollution

Atmospheric ozone pollution has been shown to reduce beech sapling growth, albeit that the impact is confounded by drought (Davidson *et al.* 1992, Pearson and Mansfield 1994), and is partly blamed for the poor crown condition of beech trees in southern England (Ling and Ashmore 1987, Stribley and Ashmore 2000).

2.4 Modern Changes

Recently, values other than timber production have gained importance. In particular, nature, landscape and archaeological conservation, and public recreation have been written into national forest policy and regulatory measures.

2.4.1 Changes in Objectives, Policies and Regulations

Broadleaved and Ancient Semi-Natural Woodland
Since 1919 the Forestry Commission has implemented national forestry policy by managing woodland it owns or leases and by controlling operations in private woodland through the approval of felling licences, forestry plans or grant-aid schemes (Aldhous 1997). Initially, it focused on afforestation and conifer plantations, whilst broadleaved forestry took second place and nature conservation was largely ignored. Outside the Forestry Commission, nature conservation had gained importance through the National Parks and Access to the Countryside Act in 1949. This created the Nature Conservancy and allowed them to designate the most important broadleaved woodland sites as SSSIs (Sites of Special Scientific Importance) or NNRs (National Nature Reserves). Although the attitude of the Forestry Commission towards broadleaved woodland changed from about 1960, greater priority being given towards their planting and silviculture, much ancient semi-natural woodland remained neglected or was cleared or converted to conifer plantations. Much of the later was grant-aided by the Ministry of Agriculture or Forestry Commission, and many woodland SSSIs were destroyed or badly damaged.

Matters changed radically in the 1980s. Most significant was the 1981 Wildlife and Countryside Act and its amendment in 1985. The first gave the Nature Conservancy Council increased powers to designate and regulate important woods for nature conservation, whilst the second required the Forestry Commission to seek a balance between timber production and the conservation of wildlife and landscape. The Forestry Commission combined with the Institute of Chartered Foresters in the early 1980s to discuss the future of broadleaves in Britain (Malcolm *et al.* 1982). During the 1980s the Nature Conservancy Council identified those woods that were of highest importance for nature conservation by complied an inventory of all ancient semi-natural woodland sites attaining 2ha (Spencer and Kirby 1992, Peterken 1993). These were sites that had been present in about 1600 AD and had remained semi-natural in composition (i.e. still composed mainly of trees and shrubs native to the site). In 1985 the Forestry Commission issued new policies, guidelines and a grant scheme for their management (Forestry Commission 1985a, 1985b, 1985c). These intended to:

1) prevent clearance of broadleaved woodland for agricultural purposes
2) retain all existing broadleaved woodland as such
3) increase the total area and area of managed broadleaved woodland
4) give special attention to the conservation of ancient semi-natural broadleaved woodland.

Since, there have been several changes to grant schemes offered by the Forestry Commission and Ministry of Agriculture, and projects and other activities aimed at the management of broadleaved and ancient semi-natural woodland. These have provided considerable resources and focused attention on: (i) planting and/or natural regeneration of broadleaved and new native woodland on farmland and in restocking felled woodland; (iii) treatments that improves the conservation value of ancient semi-natural woodland (e.g. including protective fencing, deer management, grey squirrel control, livestock removal, coppice restoration, removal of invasive non-native species unwanted species (e.g. rhododendron, sycamore), in particular measures in accordance with the UK Biodiversity Action Plan (see below); (iv) undertaking uneconomic treatments that bring small (<10ha), neglected broadleaved woods back into management; and (v) management planning based on professional ecological and silvicultural surveys.

General guidelines for forest nature conservation (Forestry Commission 1990) and specialist Forest Practice Guides for the management of ancient semi-natural woodland were produced (Forestry Commission 1994). Specific projects, part funded by the EU, have also been developed to focus on the restoration of broadleaved and especially ancient woodland. Plans have been made to restore a portion of the ancient woodland sites that have been converted to conifer plantations. Despite these efforts, only a portion of the ancient semi-natural woodland has been brought into favourable condition through management, and much broadleaved woodland still needs attention to improve its silvicultural potential.

Sites of Special Scientific Interest and National Nature Reserves

Protection of woodland by the Nature Conservancy Council increased greatly after 1981, mainly through the designation of important woodlands for nature conservation as Sites of Special Scientific Interest (SSSIs). In England, about 1800 woods (about 49,000ha) are now within SSSIs (Thomas *et al.* 1997). Much of this is ancient semi-natural woodland, but a proportion is recent semi-natural woodland or plantation on ancient woodland sites. Overall, about 14% of all ancient woodland is within SSSIs. The management of SSSIs is regulated because the owner must consult with the Nature Conservancy Council and gain their agreement to proposed operations. Nevertheless, there has been only limited success in getting such sites under appropriate management: nearly a quarter of the woodland SSSIs in England remain in unfavourable condition and 10% are the same and declining (Solly *et al.* 1999).

Appropriate management is more assured in the 3300ha of woodland SSSIs that are designated National Nature Reserves (NNRs) (Marren 1994). The Nature Conservancy Council or an approved body manages these. They represent some of the most important woodland for nature conservation, and include a range of woodland types treated variously to maximise their nature conservation interest.

Biodiversity, Species and Habitat Action Plans

In 1992 the UK became a signatory of the UN Conference on Environment and Development, including the Forest Principles and Biodiversity Convention. In response, the government developed an action plan on biodiversity in the UK (Department of the Environment 1994). Consequently, over 400 species action plans and 40 priority habitat action plans have been formulated, including four semi-natural broadleaved woodland types and lowland wood-pastures and parklands (available at http://www.jncc.gov.uk/). The Forestry Commission and Nature Conservancy Council are the main agencies responsible for the promoting the targets identified in the plans associated with woodland species and habitats.

***Natura* 2000 Series**

The UK is involved with the development of the *Natura* 2000 site series, as part of the EU effort to promote the conservation of important areas across the continent. Under the 1992 Habitat and Species Directive, member states are obliged to designate and protect a set of Special Areas of Conservation that host habitats and species considered to be important/threatened at a European level. Ten of the listed woodland habitats are represented in the UK. A provisional list of representative sites has been drawn up by the national nature conservation agencies and submitted to the EU.

UK Forestry Standard

In 1998 the UK Forestry Standard was published ‘to set out the criteria and standards for the sustainable management of forests and woodlands in the UK’ (Forestry Commission 1998). It was informed by international commitments under the 1992 UN Conference on Environment and Development and the 1993 EU Ministerial Conference on the Protection of Forests in Europe (Helsinki Guidelines), and incorporates all existing relevant policies and regulations applicable to forestry. There are Standard Notes that identify acceptable options in general forestry practice, creating new woodland, creating new native woodland, felling and restocking planted woodland, managing semi-natural woodland, and planting and managing small woods.

Areas of Landscape Importance

Landscape conservation is an important objective for many broadleaved woods, and due consideration must be given for all operations grant-aided by the Forestry Commission following their landscape design guidelines (Forestry Commission 1992, 1994).

Some woods fall within National Parks or Areas of Outstanding Natural Beauty (AONBs) that are protected for their landscape beauty. Specific regulations apply here that limit the scale of operations within woodland and the extent and location of new plantings. Committees that include representatives of local authorities and local interest groups administer these areas. The ten National Parks in England are mostly in upland areas, but the New Forest in south England is essentially the equivalent of a National Park. About a third of southern England falls within an AONB.

Archaeological Sites
A large number of archaeological features occur within ancient and recently established woodland. These include ancient burial monuments, stone circles, hillforts, field system remains, industrial furnaces, quarries, saw pits and lime kilns, medieval boundary banks and charcoal burning platforms. Some are statutorily protected as Ancient Monuments, but the majority are not. Forestry Commission policy is that sites of archaeological importance in woodland should be conserved following their published guidelines (Forestry Commission 1995).

Public Recreation
Public access and recreation have increasingly been recognised as important objectives for woodland. They are included in the Forestry Commission broadleaved woodland policy and advisory guidelines have been prepared (Forestry Commission 1992). Many public rights of way exist in woodland and these must be kept open. Most sites under the control of the Forestry Commission and other bodies facilitate public access. The Forestry Commission provides some targeted grant-aid and other assistance to facilitate appropriate access in woods.

Game-keeping
Keeping of pheasants for game continues as an important activity some estates and farms. Young birds are protected in rearing pens and then allowed to roam through the woodland before being culled in organised shoots. Shrubby cover is encouraged as shelter, especially rhododendron and other exotic plants, and many small woods are planted and managed with game rearing as an objective.

2.4.2 Management of Beech Woodland

The modern management of beech woodland needs to be considered within the framework outlined above. Treatment varies according to the woodland type, and particularly if they are recent or ancient in origin (i.e. pre- or post-1600 AD), semi-natural or plantation in composition, fall within the remit of the beech biodiversity habitat action plans, or lie within an area designated as a Site of Special Scientific Interest (SSSI), National Nature Reserve (NNR), Special Area of Conservation (SAC), National Park (NP), or Area of Outstanding Natural Beauty (AONB).

Recent Beech Plantation
Recent beech plantation comprises 5-10,000ha in the lowlands and perhaps 20,000ha in northern England and Scotland. Felling and other management must comply with the Forestry Commission broadleaved woodland policy, guidelines, and grant scheme, and the UK Forestry Standard (see section 4.1). Objectives are multi-purpose but timber production is normally given high but not exclusive priority.

Woods in this category can be managed by any silvicultural system. The UK Forestry Standard specifically notes that conifer mixtures can offer improved cash flow and timber yield, and that environmental benefits can be gained from using shelterwood, group felling and sequential coppicing as alternatives to clear felling. Otherwise:

?? landscape design principles must be followed, fitting felling areas to the local landform and including appropriate open space
?? existing and potential access and recreational opportunities should be considered
?? felled areas must be regenerated with broadleaved woodland, though conifers can be included as nurses
?? restocking should be with tree species and local provenances suited to the site
?? clear felling should avoid complete clearance of a site and the felled area must have to got the to thicket stage before adjoining stands can be felled
?? several age classes should be developed in large woods, whilst in even-aged woods up to 20ha at least two, widely different age classes should be developed

- some selected areas and trees must be retained to the increase structural and ecological diversity through dead wood and large old trees and pollards.

2.4.3 Ancient Beech Woodland

Aims, Extent and Regulation
The aims for lowland beech and yew woodland are covered by a specific habitat action plan (see section 4.1). This applies to an estimated 30,000ha (i.e. about half the UK beech woodland). This is largely (15-25,000ha) ancient semi-natural beech and yew sites within their native range (southern England and southern Wales, see Figure 1), but also includes long-established planted beech woods outside the native range where they have acquired a high nature conservation value. The main targets are to:

- maintain the total current extent and distribution of this habitat type, including all areas that are ancient and semi-natural
- initiate measures that intend to achieve favourable condition in all SSSIs, Special Areas of Conservation, and 80% of the total area of this habitat type, and by 2010 achieve favourable condition in 70% of designated sites and 50% of the total area
- initiate restoration of at least 1,500ha of this habitat type and complete restoration in over half of this area by 2010 and all by 2015
- initiate colonisation or planting of 3,000ha of this habitat type on unwooded or ex-plantation sites, completing establishment by 2010
- develop monitoring and research based on national inventories, site condition assessments, and a small series of minimum intervention reserves
- achieve the above by developing the national forestry framework, specific forestry/landscape/habitat/species/pest strategies and long-term management plans, grant schemes and other funding mechanisms, designation of protected sites, identification of priority areas for restoration, demonstration sites to show good practice, training courses, advisory services, European links and funding from the European Union.

The aims for lowland beech wood-pasture are covered by the lowland wood-pasture and parkland habitat action plan. This applies to an estimated 5-10,000 ha beech wood-pasture in southern Britain. The main targets are to:

- protect and maintain the current extent and distribution of this habitat type
- initiate a programme to restore 2,500ha of this habitat type by 2010
- initiate the expansion of 500ha of this habitat type by 2002
- develop monitoring and research based on targeted surveys and site condition assessments
- achieve the above by developing the protection of veteran/dead trees and old pasture and parklands under EU and national regulations and incentive schemes, specific strategies and long-term management plans, identification, designation and purchase of important sites and priority areas for restoration and expansion, advisory services, training courses, and promotional literature and events

Management in ancient semi-natural woodland/wood-pastures must follow the UK Forestry Standard and the Forestry Commission broadleaved woodland policy, forest practice guides and grant scheme rules in order to qualify for grant aid or a felling licence (see section 4.1). These aim to: maintain, restore or increase (as appropriate) the semi-natural woodland types present and the diversity of structure, species and habitat; include a mature habitat; minimise rates of change; and use low-key establishment techniques. Ideal management options include high forest, coppice and/or wood-pasture, depending on the previous history of the stand and its present condition. Although most examples of ancient beech woodland and wood-pasture should be actively managed, a few, selected larger sites should be left untreated for scientific purposes.

Approximately 20% of lowland beechwood is within SSSIs, NNRs or candidate SACs, most of which is ancient and semi-natural. In all these sites, the Nature Conservancy Council must additionally agree on management and nature conservation is given priority. SACs must also be maintained in favourable conservation status as agreed on by the European Union. Most ancient beech wood-pastures are protected as

SSSIs, NNRs and/or SACs, and many are owned and managed by conservation concerned primarily with nature conservation, landscape and public recreation. These include Burnham Beeches, Ebernoe Common, Epping Forest, The Mens, and the New Forest (about 3,000ha of mature beech-oak and the largest remaining ancient wood-pasture in north-west Europe). Beechwood NNRs include a small area but are some of the best sites for nature conservation. An individual site management exists for each, which is agreed, funded and implemented by the Nature Conservancy Council or an approved body. Management is aimed primarily at nature conservation, though to vary degrees, timber production, scientific research, landscape/archaeological/ geological conservation, game/hunting, and public recreation are included. Beech NNRs include Ashford Hill, Aston Rowant, Beacon Hill, Cotswolds Commons and Beechwoods, Cwm Clydach, Highbury Wood, Lady Park Wood, and the New Forest (which is effectively managed as an NNR). Nine beech woodland areas have been included as candidate SACs. Sites with *Ilex* and *Taxus* and rich in epiphytes (*Illici-Fagion*) are Burnham Beeches, Ebernoe Common, Epping Forest, The Mens, and the New Forest, whilst *Asperulo-Fagetum* sites are the Chiltern Beechwoods, the Cotswold Beechwoods, the East Hampshire Hangers, and the Wye Valley Woodlands. Many are wholly or partly within NNRs or similar nature reserves.

High Forest Management

Beech stands are particularly well suited to high forest systems, and this is the emphasis in the future management of ancient semi-natural woodland. Ideal management should be (Forestry Commission 1994):

?? based on a management plan that contains an evaluation of the site and its features, and sets out the site objectives and a long-term strategy for silviculture, operations, and monitoring
?? uneven-aged with a pattern of small groups, normally varying in size between 0.2-0.5ha and with a width of around 1.5-2 times the top height of the stand, though smaller groups occupying the area of one or two large trees and modifications determined by the species mixture are acceptable – large woods should have a range of age classes, ideally five, spanning the rotation – in small woods periodic, small-scale felling is desirable – the rotation for beech should be about 100-120 years, and for ash and cherry 60-80 years
?? tended and thinned to develop the stand structure, timber potential and natural regeneration – in naturally-regenerated stands respacing should be done after about 15 years – beech-dominated groups should be thinned first after about 30-40 years and last at about 80-90 years, stems being selected for vigour, form, timber potential, retention of dead wood, and to retain all species in the stand for as long as possible – exotic trees should be removed where practicable - final thinning should promote natural regeneration – harvesting should avoid damaging soils, watercourses, vegetation and archaeological features
?? regenerated naturally rather than planted, though planting may be carried out to enrich natural regeneration, fill blanks, and maximise timber-potential - local provenances should be used where possible and nurse species should mainly be native broadleaves - limited soil disturbance and weed control (for 3-4 years using spot herbicide applications and hand-cutting) may be useful in achieving natural regeneration – fertilisers are unnecessary except for spot applications on the most degraded soils
?? managed to leave some large, old trees and dead wood, notably in inaccessible areas, at the wood edge, and in other areas dedicated to minimum intervention
?? managed to limit grazing (seedlings and saplings can be protected by fencing, tree guards or shelters where necessary), grey squirrels debarking (numbers can be control using poison-baited hoppers, cage-trapping and shooting where necessary), and retain some open areas, such as rides and glades.

An example of agreed management on a beechwood SSSI comes from Kingston and Crowell beechwoods. These are part of the Aston Rowant SSSI in the Chilterns AONB. They are managed mainly for timber production, pheasant shooting, and nature conservation. A group selection system is used: felling coupes are about 0.5ha and at least 25m apart; thinning occurs only in areas were canopy cover is 80% or more; natural regeneration is preferred to planting and encouraged by light soil scarification; planting is only with native species and contains at least 50% beech; ten trees/hectare are left to mature and die *in situ*, including a small number of old beech pollards.

Broader and more specific measures occur on NNRs. For example, in the Cotswolds Commons and Beechwoods NNR, the aims are to combine nature, timber, landscape, recreation, archaeology, and scientific research interests. This is achieved by managing most of the woodland by a combination of group selection and shelterwood systems, which create uneven aged, beech-ash stands that are mainly regenerated naturally and retain a scatter of old senescent trees and fallen logs. In these, non-native sycamore/conifers/poplars are removed. Otherwise: patches of coppice, pollard trees and rides/glades are cut rotationally; specific management is carried out for rare species; a former lake is under restoration; small stands of minimum intervention are retained; various research, survey and monitoring projects are carried out; and information is provided for visiting groups.

Coppice Management
Coppicing is recommended only in a small proportion of ancient semi-natural beechwood sites (Forestry Commission 1994), mostly in western areas of southern Britain. It is especially appropriate in smaller woods and in mixed stands that have been treated as such within the last 50 years. In larger woods, it is suitable along rides and glades. The guidelines are the same as for high forest, except rotations should be shorter and matched against target wildlife species and possible timber markets. A range of different-aged coupes linked by coppiced rides is ideal. Tending and thinning should aim only to remove exotic trees and promote a selection of scattered, standard trees (beech not recommended as a standard). Beech stools may be left with a single stem after coppicing to promote their regrowth. Old coppice stools should be conserved as dead wood habitat.

Wood-pasture Management
Surviving beech wood-pasture sites should continue to be managed by grazing to develop a mixture of open habitats, scrub, pollard trees and woodland (Forestry Commission 1994). A management plan should be developed to evaluate the site, set out objectives and a long-term strategy for silviculture, operations, and monitoring. Specialist advice will usually be necessary.

In general, an adequate amount and distribution of open space should be maintained at all times by grazing. This must be periodically reduced to allow news trees to naturally regenerate, though only in particular areas, possibly using temporary fencing. Thinning should be used to conserve old trees, relieving them from excessive competition from younger trees, and to remove exotic trees. Some young trees should be pollarded, and consideration given to cutting old pollards, though with specialist advice. Old beech pollards respond poorly to excessive pollarding, with partial and gradual removal of branches from old trees and cutting young trees giving best results (Mitchell 1989, Read *et al.* 1991, 1996, Dagley and Burman 1996). In addition, management should avoid damaging the site, opportunities should be taken to maximise dead wood habitat, grassland and other open areas should receive minimal fertiliser and herbicide inputs, and the landscape design should be considered.

Minimum Intervention Reserves
Minimum intervention beechwood reserves are distinct from small minimum intervention areas within managed woods: they are principally for scientific research and monitoring and selection is based on specific criteria (Peterken 2000). A small number of such reserves already exist (Hall *et al.* 1999, Morecroft *et al.* 1999), including Lady Park Wood NNR (Peterken and Mountford 1995) and Denny Wood in the New Forest (Mountford *et al* 1999) where long-term research into natural dynamics has been carried out. Recently, a series of representative minimum intervention reserves was proposed for England, including examples of beech woodland or wood-pasture (Mountford 2000, Peterken 2000).

Beechwoods in Areas of Landscape Importance
Many beechwoods occur in areas designated for their scenic importance, and in some they are a major element of the scenic interest. A large area of beech wood-pasture occurs in the New Forest, which is almost equivalent to a National Park, and small areas of beech woodland fall with the Brecon Beacon National Park in south Wales. Areas of Outstanding Natural Beauty (AONBs) with important tracts of beech woodland include the High Weald, Kent Downs, Sussex Downs, East Hampshire, Chilterns, Cotswolds, and Wye Valley.

Special guidelines affect woodland management in these, aimed mainly at perpetuating the wooded landscape, keeping the forest cover near-continuous, and encouraging multi-purpose objectives including timber production and local usage, nature/landscape/archaeological conservation, and public recreation.

Local woodland initiatives that support appropriate woodland management occur in some of these, for example the Chilterns Woodland Project.

An example comes from the Wye Valley AONB Joint Advisory Committee (1996). The wooded gorge has impressive limestone cliffs and extensive ancient beech woodland along its course. The AONB guidelines are concerned mainly with landscape issues and in particular state that:

?? felling coupes should be in scale with the landscape – small coupes should be used in small woods and along the gorge slopes – coupe shapes should follow the land form, rather than being regular – coupes should stop before the skyline, leaving a substantial depth of woodland on the hill top
?? wooded skylines are frequent and require careful, sensitive management – when mature skyline trees have to be felled, a fringe of trees with sky showing between should not be left – coupes should be carried down the slope to a level determined by the appearance as seen from viewpoints on the other side of the valley
?? the Wye Gorge, of the five landscape zones within the area, is the most sensitive and critical because landscape is of prime importance – nature conservation value is high also, and usually timber production takes third priority – management has to be particularly sensitive to skylines and possible felling operations should consider the impact on these from both low and high viewpoints.

2.5 Summary

2.5.1 Pre-Industrial Period (5,000 BC – 1800 AD)

?? The original-natural woodland of Britain at 3,000 BC probably covered most of the landscape. Old-growth, mixed-species, high forest stands were probably dominant. Lime, oak, hazel, ash, alder and elm were the main tree species. Some large trees, dead wood accumulations, and open spaces were present. Structural and spatial complexity was high. Some areas were probably kept open permanently by large mammalian herbivores. Human impact was limited, though hunting had probably led to the extinction of several large mammals.

?? From about 3,000 BC, Neolithic and later cultures transformed the landscape. Large tracts of woodland were cleared. By 500 BC perhaps half the original woodland of lowland England had gone. By around 1000 AD only 15% remained and by 1800 AD probably half of this had gone. Most woodland survived as small, isolated, managed blocks, though several regions remained relatively well-wooded. Most woods were managed either as coppice or wood-pasture, though not all woodland was immediately brought under regular management. For example, in the medieval Chilterns, some beechwoods were still cut infrequently and formed dense, high forest.

?? Coppice systems often included both underwood and standard trees. The underwood was often of mixed native species. It was cut regularly, mostly on a rotation of 5-30 years, and mostly regenerated naturally. Demand for underwood was high: even the smallest material was removed. Standards were grown as scattered, single trees, and most were oak. Many were cut after only a few decades growth, but after about 1500 AD they were grown larger. Some coppices excluded livestock permanently, but in some temporary grazing by deer, cattle, horses or sheep was allowed. Beech became an important part of the underwood in coppices in the Weald, Chilterns, Cotswolds, and south part of the English-Welsh borders. In the medieval Chilterns, beech coppice was valued highly for fuelwood, cut every 7-15 years, and occasionally was planted to form coppice. After about 1500 AD, it became widespread and increasingly dominated by beech, the standard oak and ash trees being cut heavily.

?? Wood-pasture was the dominant form of land-use before the industrial revolution. It combined trees and grazing animals, sometimes together (where many trees were pollarded regularly 2-3m above ground) and sometimes in separate compartments of (fenced) coppice or grassland/heath (with or without trees). Long periods might have occurred there was little or no tree regeneration. Three main systems of wood-pasture existed. *Wooded Commons:* these that often had rights for livestock grazing, fattening of pigs on acorns or beech mast, and collection of fuelwood, and were widespread before 1300 AD. *Forests and Chases*: these were large, unfenced tracts governed by special laws that protected deer for hunting but with other rights as for wooded commons maintained, and in 1200 AD were abundant. *Deer Parks*: these were typically stocked with deer, self-contained, contained some wooded ground, and were widespread in medieval times. Beech wood-pastures were commonplace. Often the beech trees were pollarded every 10-15 years, but some were only part-lopped and others were retained to produce mast. In the medieval Chilterns, wooded beech commons typically had rights for firewood, building wood, pannage, grazing, and hay cutting. Some private beech woodland was similarly used, though the common woods were generally more open, had less underwood, and some were heavily grazed.

?? The composition of surviving woodland changed, though the broad distribution of most native trees was altered little. Elm declined early and abruptly, probably because of disease. Lime declined gradually and irregularly, probably reflecting clearance of woodland from fertile soils, increased use of surviving woodland for fodder and pasture, and possibly confounded by climate change. In general, oak, hazel, ash, beech, hornbeam, sweet chestnut and sycamore have become more important. Initially, beech and hornbeam expanded in southern Britain but remained minor species until about 1000 AD. Thereafter they expanded, partly due to natural colonisation of abandoned farmland and woodland that had been disturbed by selective cutting and treatment as wood-pasture. Sweet chestnut was introduced around 0 AD and was strongly promoted in coppices around 1800 AD, whilst sycamore naturalised from plantings after about 1700 AD.

?? Woodland destruction, hunting and persecution resulted in the early loss of aurochs (wild cattle) and brown bears, and later declines or losses of beavers, wild boar, wolves, red deer, roe deer and red squirrels. Fallow deer and rabbits were imported as food sources around 1100 AD, but later escaped, naturalised and became forestry pests.

2.5.2 Industrial Period (1800 AD – 1980 AD)

?? A new wave of clearance reduced woodland cover to 4% by 1895, about 25% of which was coniferous. During the 1900s, woodland cover increased to 11%: 70% of this was coniferous plantation (mainly pine, spruce and larch), 11% remained as ancient semi-natural woodland, and 8% was recently established semi-natural woodland.

?? Coppice woods throughout England and Wales declined. By 1940 most were neglected, save for sweet chestnut coppices in south-east England. By 1980 about 7% had been cleared for agriculture, 37% had been converted to plantation (mainly conifers), and the remainder were left uncut.

?? Wood-pasture commons and forests were largely destroyed. Some had already degenerated into heath or grassland; some were enclosed for agriculture; and some were made into conifer plantations. Several large commons survived due to public concern, though traditional management declined and most were not grazed or pollarded. The main exception was the New Forest where pony and cattle grazing continued more-or-less uninterrupted.

?? High forest became widespread. Even-aged, clear-cut systems became dominant, and conifer planting predominated. Although about 60% of woodland in England remained broadleaved, including much oak and beech, though these suffered from exploitative felling and broadleaved silviculture was generally neglected. In the Chilterns, beech high forest became the norm, but felling of only the best timber trees left most woods stocked with low-quality trees and neglected young stands. After 1945 some stands were clear felled and often replanted with conifers. This met with much opposition, and from about 1970 policy changed: broadleaved woods could no longer be converted to conifers, beech had to be favoured, felling coupes were limited to 3ha, and woods had to be restocked over 30-40 years.

- Beech remained an important broadleaved timber species, second only to oak. It has been grown on a wide range of sites in most of Britain. The mean yield class is $6m^3\ ha^{-1}\ yr^{-1}$. Best growth is associated with deep, circum-neutral, well-drained loamy soils, moisture supply and frost being critical. Clear-felling of large, even-aged, regularly-thinned, planted blocks has been the main treatment, with only a few sites treated by shelterwood or group systems. Natural regeneration has rarely been used for restocking because of problems in ensuring success, mainly due to infrequent mast years, high seed predation and browsing damage, and logistical problems. During 1920-50 most beech transplants came from seed collected within Britain, but most seed since has been imported. Conifer nurses have been popular, especially in exposed and frost-prone sites. Establishment has usually involved mechanical weeding and/or herbicide use and removal of woody weed growth. In recent decades measures have been taken to limit deer browsing and control grey squirrels damage, whilst in southern England many beech trees have suffered from drought, windstorms, bark disease and/or atmospheric ozone pollution.

2.5.3 Modern Changes

- After 1981 protection of woodland by the Nature Conservancy Council increased mainly through the designation of Sites of Special Scientific Interest (SSSIs). In England, about 1800 woods (49,000ha) are now within SSSIs, including about 14% of all ancient woodland. Although owners must consult and get agreement off the Nature Conservancy Council over proposed management operations therein, nearly a quarter remain in unfavourable condition and 10% are the same and declining. Appropriate management is more assured in the 3300ha of woodland SSSIs that are in National Nature Reserves (NNRs), which are managed by the Nature Conservancy Council or an approved body.

- In 1985 the Forestry Commission was charged to seek a balance between timber production and the conservation of wildlife and landscape. They (and the Ministry of Agriculture) issued new policies, guidelines and grant schemes to prevent any further clearance of broadleaved woodland for agriculture or to conifer plantation, to increase the total area and area of managed broadleaved woodland, and to give special attention to the conservation of ancient semi-natural woodland. An inventory of sites and several specific projects, grant schemes and other activities have been aimed at the latter, though only a portion has been brought into favourable condition.

- Landscape conservation became an important consideration for many broadleaved woods, especially those within areas protected for their landscape beauty (mainly National Parks or Areas of Outstanding Natural Beauty). Similarly, archaeological features, public access and recreation, and game-keeping became recognised as important consideration in woodland management.

- In response to the UN Conference on Environment and Development, a UK Biodiversity Action Plan was developed, which included habitat action plans for various semi-natural woodland types. A provisional list of woodland Special Areas of Conservation (SACs) has been drawn up as part of the *Natura* 2000 site series, under the European Union 1992 Habitat and Species Directive. In 1998 a UK Forestry Standard was published that identifies acceptable options in general forestry practice, creating new woodland, creating new native woodland, felling and restocking planted woodland, managing semi-natural woodland, and planting and managing small woods.

- Felling and other management in recent beech plantation, which covers about 5-10,000ha in the lowlands and 20,000ha in northern England and Scotland, must comply with the Forestry Commission broadleaved woodland policy, guidelines, and grant scheme, and the UK Forestry Standard. Objectives are multi-purpose but timber production is normally given high but not exclusive priority. Any silvicultural system can be used, including conifer mixtures. Landscape design principles must be followed, and access and recreational opportunities should be considered.

Felled areas must be regenerated with broadleaves (though conifers can be included as nurses), and restocking should be with suitable tree species. Clear felling should avoid complete site clearance and adjoining stands cannot be felled until the felled area has regenerated. Several age classes should be developed in large woods, and in woods up to 20ha at least two age classes should be developed. Some selected areas and trees must be retained to the increase structural and ecological diversity through dead wood and large old trees and pollards.

?? Management of ancient semi-natural woodland/wood-pasture must follow the UK Forestry Standard and the Forestry Commission broadleaved woodland policy, forest practice guides and grant scheme rules. In addition, the biodiversity habitat action plans for lowland beech and yew woodland and lowland wood-pasture and parkland apply, and about 20% is covered by SSSIs/NNRs/SACs. These encompass an estimated 30,000ha of woodland (mostly ancient semi-natural beech and yew woodland in southern England and Wales) and 5-10,000ha of wood-pasture. Management must aim to maintain, restore or increase (as appropriate) the semi-natural woodland types present, the diversity of structure, species and habitats, include a mature habitat, minimise rates of change, and use low-key establishment techniques. Ideal management options include high forest, coppice and/or wood-pasture, depending on the previous history of the stand and its present condition. Although most examples should be actively managed, a few, selected larger sites should be left untreated for scientific purposes.

?? High forest management is emphasised for ancient semi-natural beech woodland. This should be based on an evaluation of the site and a long-term strategy. Stands should be uneven-aged, with a pattern of small groups usually 0.2-0.5ha in size. Large woods should ideally have five age classes spanning the rotation. Periodic, small-scale felling is desirable in small woods. The rotation for beech should be about 100-120 years. Periodic thinning should develop the stand structure, timber potential, natural regeneration, dead wood, and mixed species stands, removing exotic trees where practicable. Harvesting should avoid damaging soils, watercourses, vegetation and archaeological features. Regeneration should be natural, though planting may be used to enrich natural regeneration, fill blanks, and maximise timber-potential. Transplants should of local provenances where possible. Nurse species should mainly be native broadleaves. Limited soil disturbance, weed control, and protective measures against browsing and grey squirrels may be used. Some old trees, dead wood, and open areas should be maintained.

?? Coppicing is recommended only in a small proportion of ancient semi-natural beechwood sites, mostly in western areas of southern Britain. It is especially appropriate in small woods, in mixed stands that have been coppiced in the last 50 years, and along rides and glades in larger woods. General management aspects are similar to high forest, except rotations should be shorter and matched against target species and markets. A range of different-aged coupes linked by coppiced rides is ideal. Tending and thinning are necessary mainly to remove exotic trees.

?? Surviving ancient semi-natural beech wood-pastures should continue to be managed by grazing and mixture of open habitats, scrub, pollard trees and woodland developed. Site evaluation and specialist advice will usually be necessary. Grazing should keep an adequate amount and distribution of open space. Periodically new trees should be allowed to regenerate naturally in particular areas. Thinning should be used to release old trees and remove undesirable species. Some young trees should be pollarded. Old pollards should be cut following specialist advice. Management should avoid damaging the site, conserve dead wood, protect old grassland and features, and consider impacts on the landscape.

?? Many beechwoods occur in areas designated for their scenic importance. Special guidelines affect woodland management in these, aimed mainly at perpetuating the wooded landscape, keeping the forest cover near-continuous, and encouraging multi-purpose objectives including timber production and local usage, nature/landscape/archaeological conservation, and public recreation.

?? A small number of minimum intervention beechwood reserves exist. Proposals to extend this into a representative series in England have been developed.

2.6 Impacts on Biodiversity

2.6.1 Pre-industrial impacts

No truly natural woodland survives in Britain. Although early human impact was limited, hunting contributed to the extinction of several large mammals (Corbett and Harris 1991), which might have lead to a loss of original-natural open space (Vera 2000). From about 5,000 BP, clearance of woodland for agriculture had a severe impact, directly destroying a large part of the original-natural woodland. The loss was disproportionately higher on level, moderate-sloping, and fertile ground, in regions and lowland areas where farming has expanded most, where later conversion of semi-natural woodland to conifers and other non-native trees has been substantial, and where pseudo-wooded habitats outside of woods have been destroyed thoroughly (mainly in the modern era). Fortunately, a small proportion of the original-woodland survived on ground that has remained continuously wooded and in a semi-natural state, albeit modified by long-term management. Such ancient semi-natural woodland, including a sizeable are dominated by beech, retains a wide-range of the original woodland plants, animals, and habitat types, though some species, habitats and processes have been largely eliminated (Peterken 1993, 1996).

Increasingly, semi-natural woodland has survived in relatively small, isolated fragments. These would have been unsuitable for carnivorous mammals, ungulates and birds that require large territories, and species that preferentially inhabit forest interiors or are sensitive to edge effects (Peterken 1993, 1996). The combination of clearance and hunting/persecution resulted in the loss of many of the original-natural large carnivores, ungulates and other mammals. In individual woods and in areas where most woods were reduced to very small and isolated fragments, the loss of biodiversity would have been even greater (Peterken 1991, 1992). More localised species and habitat types would have been lost, and a long-term relaxation in species would occur because some populations had been reduced below the minimum critical size (such small populations are prone to extinction from localised or temporary changes in habitat conditions, and a proportion of such species would be unable to re-colonise from nearby woods and other habitats). To some extent the effects of fragmentation and isolation were reduced by the concentration of woods in some regions (which occurred in many places where beech woodland was predominant) and the presence of hedges, wooded streams, wood-pasture, field edges and unimproved pastures and heaths in the agricultural landscape. The latter provided migration routes between woods and also a refuge for some of the species found in surviving woodland.

Woodland management has had a major impacted on biodiversity (Peterken 1991, 1992, 1993, 1996, Buckland and Dinnin 1993). Coppice systems (including those with beech) converted most habitat to temporary open space and young-growth, and many of the features, processes and species associated with the natural old-growth woodland were destroyed. In particular, most old trees, snags and fallen dead wood, and specialised microhabitats (e.g. the pit-and-mound topography associated with natural windthrow, stream debris dams) were lost. This resulted in a general loss of saproxylic species dependent on dead wood and mature structures, including many types of fungi, epiphytic lichens, beetles, flies, other timber-utilising invertebrates, and various cavity-nesting birds and bats. Virtually all species that relied on conditions found in forest interiors and those sensitive to edge effects would have been lost, and correspondingly many types of mosses, ferns, and invertebrates associated with wet and humid conditions would have declined. In most coppices some permanent grassland or heath was retained, and in some this was grazed (albeit in a modified form and by domesticated livestock). Along with the underwood, the open rides and glades of coppice woods served as important semi-natural refuges for many organisms associated with the former natural forests, including a wide-range of trees and shrubs, ground vegetation plants, small mammals, birds, and invertebrates (Marren 1990, Peterken 1993).

Wood-pasture retained a greater range of woodland habitats than coppice and the natural combination of trees and grazing animals (Peterken 1993, Kirby *et al.* 1995). Nevertheless, open grassland and heath, scrub, and edge habitat generally increased, whilst large trees, standing and fallen dead wood, specialised microhabitats, and forest interior habitat generally decreased. In addition, grazing animals were mainly domesticated livestock, and were more abundant and in different combinations and proportions than in most natural situations. Despite losses and changes in the associated biodiversity, many wood-pastures probably retained a wide-range of original-woodland species and habitat types, and unlike coppice retained more species dependent on dead wood, mature structures, and forest interiors. However, grazing-sensitive plants and associated organisms suffered more than in most coppice woods, and many wood-pastures ended up very open and with little forest interior habitat. In both coppices and wood-pastures, new species associated with agricultural landscapes outside of woods invaded (e.g. arable weeds), and some of the original-natural species undoubtedly evolved in response to the new conditions (e.g. some invertebrates within isolated woods became more sedentary). New semi-natural assemblages and habitats arose (e.g. semi-improved grassland and pollard trees).

Changes to the tree and shrub composition also impacted on biodiversity (Peterken 1996, REFS). Although many types of semi-natural woodland survived and the broad distribution of many native trees altered little, the original-natural composition shifted. Lime declined substantially and beech become increasingly more dominant. In coppices, light-demanding species capable of vigorous stump growth (notably hazel, ash, oak), and those valued for fuelwood (notably beech) or the production of straight, fast-grown stems (notably sweet chestnut) were favoured. Often, the only large trees in coppices were oak. In wood-pastures, trees that pollarded well were favoured (notably beech, oak and hornbeam), whereas those that were palatable declined (notably lime, hazel, ash and elm). Consequently, some associated species thrived whilst others must have declined. The monophagous (reliant on a particular tree) bark-beetle *Ernoporus caucasicus*, for example, was originally common and widespread but survived only in a few ancient woods in the Midlands where native lime persisted (Marren 1990). On a more general level, more plant-eating insect species are likely to have survived where native willows, oaks and birches predominated, rather than where hazel, ash, beech, lime or hornbeam did (Southwood 1961), and similarly mature oak, ash, beech and elm trees support the greatest numbers of lichens (Harding and Rose 1986).

2.6.2 Industrial impacts

Substantial changes occurred in the industrial period and this had major impacts on biodiversity. Woodland cover increased (probably including that of beech), potentially reducing the long-term impact of fragmentation and creating opportunities for wildlife to expand. However, much of the new woodland was coniferous plantation, and only in a limited number of places was there a substantial increase in broadleaved woodland where native wildlife had a realistic chance of expanding. Even then, colonisation by plants of ancient woodland was slow and after two hundred years incomplete (Peterken and Game 1984).

Many ancient semi-natural coppices and wood-pastures were destroyed or converted to conifer or broadleaved plantations. The latter disrupted several thousand years of relatively stable conditions where prolonged heavy shading was rare, and often led to the forcible destruction of important habitat features such as large coppice stools and ancient pollard trees. Conifer plantations had the greatest impact: typically the original native trees and shrubs were replaced; heavy shading (eventually including much of the original open space) greatly reduced the ground flora and most dependant species (e.g. invertebrates) were lost; and the soil fauna changed substantially as the soil became acidified and a thick mat of surface litter accumulated (Mitchell and Kirby 1989). The effects were less severe where broadleaved high forest was established, though this depended to what extent the original trees and semi-natural mixture were retained, and if non-native sweet chestnut or sycamore became predominant, these having fewer associated plant-eating insect species than most native species (Southwood 1961). Nevertheless, most light-demanding species in the ground layer and understorey were lost because of increased shading, and the canopy was reduced to just one or two species. This was especially true for beech high forest, which became predominately simple in composition (often either beech or a beech-conifer mix), and because beech casts a heavy shade, produces slow-decaying litter and causing soil podsolisation (Piggott 1989). In addition, in beech wood-pastures there was a decline in the special lichen flora associated with ancient trees because this survives only where it is light-shaded (Rose 1992).

Management of beech and other broadleaved plantations also affected biodiversity. Although there was some selection and shelterwood management of high forest (notably beech woodland in the Chilterns in the 1800s and a few sites since), increasingly stands consisted of large, even-aged, one- or two-species blocks, many of which were felled exploitatively, clear-cut and/or neglected. The latter often exacerbated the effects of heavy shading and minimised the diversity of the stand structure, but it did produce small amounts of standing and fallen, dead wood and retained some diversity to the vertical structure. Where exploitative felling was moderate, this at least created some opportunities for light-demanding species, but extensive clear-cutting was usually decidedly damaging to biodiversity, producing a rapid shift in structure and loss of habitat. In addition, extraction increasingly involved the use of large, heavy machines that caused (often carelessly) damage to the soils, vegetation and other features. The switch to the use of planted imported stock rather than natural regeneration, which was typical for beech, destroyed the genetic integrity of many stands. In addition, restocking increasingly involved heavy ground treatment and applications of herbicides aimed specially at reducing the ground flora and coppice/shrub element.

The industrial period has also seen widespread atmospheric pollution and recently the spread deer. The first caused a major loss of lichens across most of central and eastern Britain due mainly to sulphur dioxide and air-borne soot, with lichens on exposed trees suffering most (Marren 1990). Roe, fallow and muntjac deer have increased in much of lowland England and in places caused damage by selectively eating particular ground vegetation species and destroying natural regeneration (e.g. Kirby and Thomas 1999).

2.6.3 Modern changes

Opportunities for biodiversity conservation have increased greatly in the last two decades. Most of the important woodland for nature conservation (including all ancient semi-natural woodland) has been identified and nearly all broadleaved woodland is secure against further clearance or conversion to conifers. Active management necessary to conserve biodiversity interests has improved through purchase and management of key sites, and targeted grant schemes, special projects and other measures (though much remains to be done). The development of the biodiversity habitat and species action plans, the guidelines on the management of semi-natural woodland, and the UK Forestry Standard have clearly identified future objectives, targets and acceptable practices.

Biodiversity should be conserved and enhanced in all woodland (including beech) because general and particular management measures and now required. These are most demanding and precise in ancient semi-natural woodland and wood-pasture, and less so in recent plantations. They affect the need for site assessment, management planning and specialist advice, the possible stand composition and structure, the scale and type of felling and thinning, the disturbance caused by harvesting and extraction, the method, composition and practices associated with regeneration, and the retention of open space, dead wood, old trees, pollards, and grazed habitats. Most woods are to be actively managed, but a few sites will be retained untreated for scientific purposes.

2.6.4 Distinctive features of beech and beechwoods in Britain

There are several distinctive features associated with beech woodland in Britain that have important consequences for its conservation:

?? Beech was a late entrant to Britain, though there were some early concentrations (e.g. around the New Forest, Bristol Channel).
?? Beech only became dominant after people had modified the landscape and its expansion seems to be associated with people more so than most other native tree species.
?? Having arrived, or expanded, late, beech is still mainly confined to the south, its spread having possibly been curtailed by fragmentation of woodland unlike other native species.
?? Beech has been planted well beyond its native range, and is probably the most widely planted broadleaf except oak. Some planting may have been into areas that it would have colonised naturally if it had been able to expand through a non-fragmented landscape.
?? This confusion of original-, inherited- and future-natural ranges is greater in beech than other native trees.
?? Beech is weak as coppice (unlike many other native species) and would have been unwelcome as standards in a coppice: it would thus have been restricted in the dominant traditional woodland type,

which might have influenced its spread.

?? Beech is better at withstanding browsing, and its early spread seems to have been associated with areas that had much wood-pasture. Currently it is favoured in woods where deer are spreading, or which have some pasturage.

?? Beech is a better shade-bearer than most other British trees. Thus, it has and is spreading in neglected woods.

?? Beechwoods have a long tradition as high forest, especially in the Chilterns and Downs, and this conversion was probably more extensive than simultaneous conversions of oakwoods.

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2.8 Management of beech in Britain: a case-study on the Chiltern Hills

2.8.1 Introduction

The Chilterns is a hilly area approximately 50 kilometres north west of London. It has been designated an Area of Outstanding Natural Beauty (AONB) because of its national value for landscape and wildlife, and covers an area of approximately 800 km^2 (Fig.1). Together with the North and South Downs, Lower Wye Valley, Cotswolds and New Forest, it is one of the main areas of Beech forest in England. 16,000ha (20%) of the 81,000ha AONB is covered by woodland (Fig.2) of which approximately 33% is overmature and predominantly beech (Appendix 1), much of which is ancient, i.e. at least four centuries old (Inventory of Ancient Woodlands, 1988).

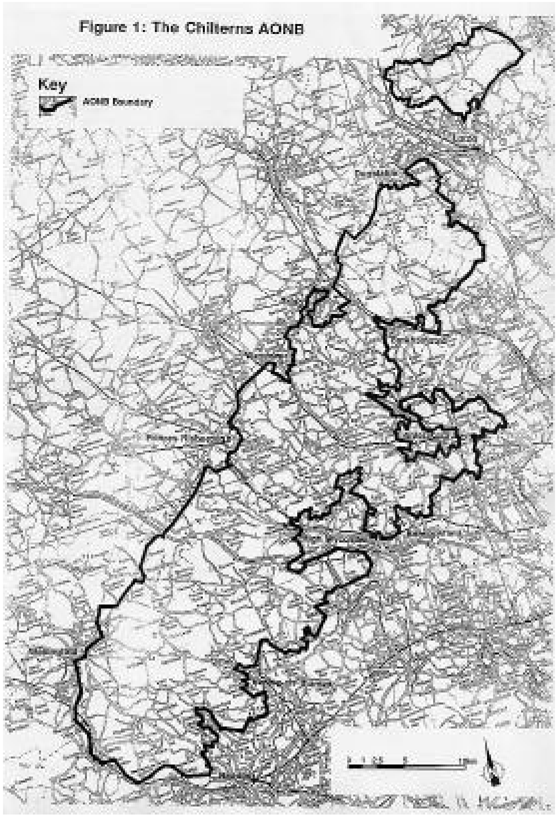


Figure 1. The Chilterns AONB.

Figure 2. Forestry and woodlands in the Chilterns.

Historically Chiltern woodland has always had a ready market for buying and selling at least since the 13th century (Roden 1968). At this time owners ranged from large manorial estates, Oxford University Colleges, the Church, farms and there were also common woods for local communities. Some of these woods are still in the same ownership today, for example Stonor Estate and Merton College. Economic growth, some local but much from London, led to the development of country houses and estates. These peaked at 1820 and it is estimated (Prince 1959) that 600 parks over 4 hectares covering 15,300 hectares were in existence, many with large farms and woodlands attached. Some still exist today such as West Wycombe and Ashridge. The Enclosure Acts since 1845 led to many of the commons and associated woodlands/wood pasture being enclosed and commoners rights being extinguished. As fortunes and agriculture waxed and waned many large estates were broken up and sold off. Farms expanded and contracted, and as wealth became more widely distributed the pattern of ownership at the present time is more fragmented. Current ownership varies from government bodies such as the Forestry Commission (state forest service), English Nature (the statutory body for nature conservation) and Ministry of Defence. Non-governmental organisations (NGO) and charities, for instance The National Trust, Woodland Trust, and local Wildlife Trusts are also included as well as private individuals who own woods for recreation, sport, nature conservation and long-term investment. Until the 1988 budget, syndicates, trusts and individuals invested to benefit from tax relief.

2.8.2 Chiltern site characteristics

The National Vegetation Classification (Rodwell 1991) recognises three distinct woodland communities in which Beech is the dominant tree species.

?? W12 Fagus sylvatica	Mercurialis perennis (Peterken 1981 Stand Type 8C)		
	- Subcommunities	Mercurialis perennis (calcicolum)	
		Sanicula europaea	
		Taxus baccata	
?? W14 Fagus sylvatica	Rubus fruticosus (Peterken 1981 Stand Type 8E)		
?? W15 Fagus sylvatica	Deschampsia flexuosa (Peterken 1981 Stand Type 6C)		
	- Subcommunities	Deschampsia flexuosa (ruscofagetum)	

A mild maritime climate prevails with the following features (Soil Survey of England and Wales 1984)

Altitude	42-260 metres
Rainfall	675-750mm
Aspect	Northeast-Southwest, Scarp slope faces Northwest, Dip slope faces Southeast
Average temperature range	0ºC to +20ºC
Sunshine hours	1400 hours annual average
Predominant geology	Chalk
	Plateau Drift and clay with flints
	Plateau and glaciofluvial drift
	Chalk and gravel river alluvium

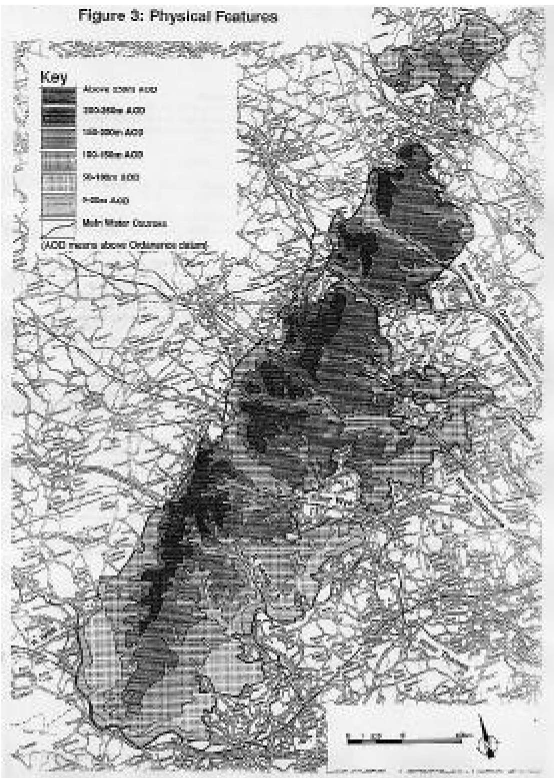


Figure 3. Physical features of the Chilterns.

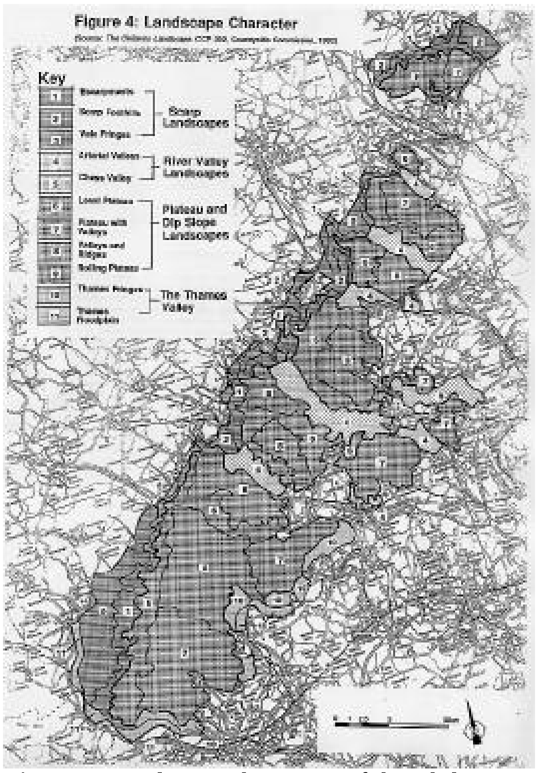


Figure 4. Landscape characters of the Chilterns.

2.8.3 History

Pre-industrial history

The history of woodland development started in the British Isles approximately 12,000BC after the last ice age ended (Godwin 1975), when colonisation started from the south of what is now mainland Europe. Beech pollen remains have been dated from 6,000BC, 500 years before the English Channel was formed (Mabey 1996). Therefore Beech can claim to be a native of Britain. Its natural spread advanced north and west in a line from the Bristol Channel to the Wash (latitude 53º N), but it has been planted up to the north of Scotland. Beech was a small component of the original wildwood, which was dominated by ash and lime. 99% has been destroyed and the remaining 1% is no longer wildwood, but a heavily human-influenced woodland structure (Rackham 1986).

Human impact on the wooded landscape started during the Neolithic period (3500-4000BC) with the development of permanent settlements and the advent of farming where woodland was cleared for cultivation and the grazing of livestock. However the Chilterns suffered far less clearance of woodland to agriculture than the rest of lowland England prior to the permanent Roman colonisation in AD43. This was probably due to the heavy soils, steep topography and the lack of permanent water supplies, the spring line being lower down the hills. Thus most colonisation was on the periphery of the Chilterns where the soils were easier to cultivate, of better quality and where water supplies were available.

The first major human incursions started in the 5th century AD and accelerated through to the 10th century. Initially the woodland was used for seasonal grazing with wood pasture developing for cattle and pigs and the more open downland along the western edges for sheep. Temporary summer shelters developed into farms and hamlets, with fields being cleared and enclosed. This process accelerated during the 11th and 12th centuries as the population increased, but by the mid 13th century the clearance had virtually ceased. The woodlands were then recognised as a valuable resource to be utilised for firewood, charcoal and construction timber, and not destroyed. These conditions prevailed until the beginning of the 16th century when the growing demand for food led to the expansion of agriculture and the reduction of woodland.

The 17th and 18th centuries saw the area of woodland sometimes increased depending on the value and profitability of agricultural land, so much so that about one third of the present woodland area survives on what was farmland 300-400 years ago. However the trend was a general decline. At the beginning of this period the woods are thought to have consisted of 1/3 oak, some ash and the rest beech, mostly managed as coppice with or without standards. The beech would have been used for fuelwood and the oak for construction and shipbuilding.

By the mid 18th century most of the oak had been felled. Coal delivered by the fast developing canal network was cheaper than wood, and the rapid increase in agricultural land values led to an equally fast decline in the wooded areas as large tracts were converted to farmland. This led to the remaining woodlands developing into a high forest of principally beech timber. This progression to high forest coincided with the development of the chair manufacturing and furniture industry from the mid 18th century, which expanded into a major consumer of beech timber.

Post Industrial History

Due to cheaper food imports, agricultural land values began to fall during the later part of the 19th century, while the expanding furniture industry demanded ever-increasing volumes of beech timber. Consequently there was little change in the area of woodland into the 20th century. The chair legs and spindles were initially turned by 'bodgers' working in the woodlands, using the same diameter beech timber that was used to supply the fuelwood trade. This small dimension timber was thinned as well as the large trees, which went direct to the sawmills. The woodlands were more intensively managed under the 'Chilterns Selection System', which allowed trees of different age and diameter class to develop. By the end of the 19th century most of the woodlands had been converted to high forest. Oak was no longer required for shipbuilding since the advent of iron and later steel. Beech was favoured over other deciduous species either by natural regeneration or planting with many areas being planted in mixtures, principally with European larch.
By the beginning of the 20th century mechanisation of the turnery industry meant the demise of the bodger and timber became cheaper to import from abroad than produce locally. Although some demand from brush manufacturers for smaller trees continued, these changes meant that thinning of younger trees was neglected and only the larger, best quality trees were marketable. Therefore the structure of the woods deteriorated and became more even-aged. Management changed to produce the larger timber now in demand, as well as the introduction of more species variety by planting of ash, oak, sycamore and faster growing conifers of larch,

Norway spruce and pine. This change to conifers was particularly relevant on sporting estates where, since the invention of the breech-loading shotgun, pheasant shooting has been increasingly popular, and conifers were planted for shelter and roosting cover. This continued deterioration of woodlands nationally was causing increasing concern to the government. A series of reports and advisory committees were set up to ascertain the current position and advise on its improvement. These acquired a greater urgency on the outbreak of the First World War in 1914. During the war it became increasingly apparent that timber was essential for the economic survival of the country. Soon after the end of hostilities, in 1919 the Forestry Commission was formed to promote afforestation and timber production, to build up a reserve in case of further wars, and to repair the devastation caused by clear felling, thought nationally to be in excess of 180,000 hectares.

While the government through the Forestry Commission was purchasing and planting large areas of land, this was not replicated in the private sector, and although grants had been available to encourage planting since 1919, these were on a rather *ad hoc* basis, it was not until 1927 that these became species specific rather than based on the type of ownership (£5 per hectare for conifers, £10 per hectare for broadleaves). By the end of 1939 Britain was at war again and from this date until 1947 it is estimated that 208,000 hectares of woodland were cleared of all useable timber of which 10,300 hectares were in England, and much within the Chilterns. In 1943 a consultative report titled ‘Post War Forest Policy’ was published. Within this document a section on the future of privately owned woodlands was concerned with dedication of those woodlands to long-term management. The criteria being:

To use the land in such a way that timber production is the main object.
To work to a plan, to be approved by the Forest Authority, which would lay down the main operations to be undertaken.
To employ skilled supervision.
To keep adequate accounts.

In return for agreeing to these criteria, grants and loans were available. This became known as Dedication Scheme Basis 1 and was eventually confirmed in the Forestry Act 1947. Since this date incentives in various manifestations have formed the basis of all management agreements between government and the private landowner, right up to the present time (Appendix I).

This exploitation and then post-war neglect combined with the previous demise of the Chiltern Selection System meant that the woods were over-mature, even aged, with a closed canopy. This prevented natural regeneration as well as creating an impoverished ground flora. The decline was recognised by the government and the Forestry Commission made the Chiltern woods the subject of a special project in 1951. This combined with other controls, namely The Town and Country Planning Act (1947), the introduction of Tree Preservation Orders (1949) and the Forestry Act (1951) probably saved large areas of woodlands from being removed to accommodate the rapid expansion of towns, roads and the boom in agriculture (Appendix 3).

A special project known as the Chiltern Project led to the revitalisation of many woodlands but had a dramatic, and many would say negative impact on the landscape and ecology of the area (see Silviculture and Management Overview). Up to the beginning of the 20th century the forests had been intensively managed but with relatively low impact. Landscape and ecology underwent major changes during the devastation of the two world wars. Factors influencing these included the ensuing neglect caused by lack of management plus the advent of modern machinery, which allowed the fast removal of trees from the forest. This was compounded by the 'coniferisation' policy of the post war years. During virtually all of the 20th century up to 1970 the major objective of most actively managed woodland ownership was timber production, with little if any thought for the effect this was having on the landscape and ecology of the area. It was not until the early 1970s that people became aware, through the work of Oliver Rackham (Rackham 1976) and George Peterken (Peterken 1974), of the history of ancient woodland and the negative impacts modern forest management systems were having on it. In 1971 the Chilterns Standing Conference produced *'A Plan for the Chilterns'*. This was designed to resolve the many conflicting problems within the AONB, and particularly the future of the ageing beech woodlands. It proposed a programme of felling and replanting in small blocks, with the largest size permissible being 2.8 hectares, with the aim of full replacement over 30 years, with the emphasis on replacement with beech and other broadleaved species. The woodland section of this plan was revised in 1985 to coincide with the Forestry Commission's Broadleaved Policy Review and the introduction of the Broadleaved Woodland Grant Scheme. It was designed to meet the following aims:

1. More of the unmanaged woodland should be brought into management.
2. The replacement of managed woodland should be speeded up.
3. In woodland identified as particularly sensitive for nature conservation, the biological diversity should be protected.
4. Continued and increased efforts to control pests (mainly grey squirrels, deer, rabbits and edible dormice) are required.

And to adopt these four principles:

1. All woodlands should be actively managed with the objective of perpetuating a landscape, which is broadleaved in character, with an emphasis on beech where appropriate.
2. Heritage Woodlands should be managed in such a way as to support a rich variety of wildlife.
3. The woods should be managed to increase timber production.
4. The total area of woodland should be retained and, if possible increased.

The aim of the conference was to secure the active management of all woodlands in the Chilterns by 1996, but this is still a long way from being achieved. Approximately 60% of woodlands have an approved management scheme (A Plan for the Chilterns 1988). The mid 1970s to mid 1980s saw gradual, but dramatic changes in management thinking. These included a decline in conifer planting and an increase in broadleaved planting, partially led by increased grants for broadleaves over conifer, but also with an awareness of the many other benefits apart from timber production. These included landscape, environment, conservation and recreation. This process accelerated in 1988 when the government's March budget removed commercial woodlands, subject to some transitional arrangements, from income and corporation tax benefits (Hart 1991). This coincided with a rationalisation of the grant schemes and a further increase in planting grants, and the publication in 1988 of the Inventory of Ancient Woodlands (Nature Conservancy Council 1988). This identified all woodlands over two hectares that existed in 1600, prior to the advent of forestry, and therefore had probably always been woodland, and therefore had a high ecological value. Guidelines were developed to improve and diversify these values such as ride edge, open ground, riparian zones and wetland management (Appendix 4).

Areas of special conservation interest had been protected for many years (Fig. 5) with three National Nature Reserves (NNR), four Local Nature Reserves (LNR) and 73 Sites of Special Scientific Interest (SSSI) within the AONB. In 1994 the European Habitats and Species Directive of 1992 was adopted into Law, and the Chiltern Beechwoods were proposed to be designated as a Special Area of Conservation (SAC). Increasing pressure for access and public recreation from the neighbouring suburban connobations and London led to the development, particularly in state owned forests, of provision for walking, cycling, horse riding, running and other facilities such as car parks and interpretative material.

The late 1990s have seen a decline in regenerating beech forests. The policies designed to improve the management and rehabilitation of the Chiltern beech woods have generally failed. This is mainly due to the constantly changing political guidelines, considerably reduced restocking grants with the emphasis being put on new woodland establishment on farmland, thus attempting to reduce agricultural surpluses. The very poor prices received for Beech timber due to the high pound, cheap imports and the decline of the sawmilling industry. Forty percent of all the woodlands are still unmanaged, with large areas of overmature and declining beech dominating the landscape. A continual and rapid rise in the numbers of predators principally deer, rabbits, and grey squirrels restrict natural regeneration or make its establishment very expensive. There are also reductions in skilled labour resources with both the experience and financial ability to be able to purchase the modern equipment required to harvest large timber.

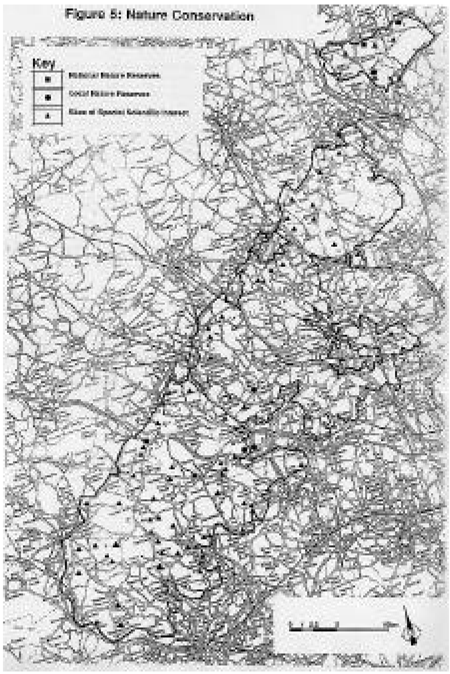


Figure 5. Nature conservation in the Chilterns.

2.8.4 Silviculture overview

The main silvicultural systems used in the Chilterns (Matthews 1989) are:

- Coppice with or without standards and pollards in a wood pasture situation (pre-industrial).
- Clear cutting.
- Shelterwood - group, irregular and strip.
- Group and single tree selection.

Many of the shelterwood systems we see today were opportunist or occurred by accident. Nature filled the void left by felling/thinning operations. The biggest impact this century and particularly since World War 2 was the move to clear cutting and replanting with non-native species, particularly conifers. This had major implications on the landscape, ecology, stability and management of the Chilterns. At this time much of the forest was unmanaged but of the areas that were managed many moved to this system. Large areas, one up to 20 hectares, were clear cut and replanted. A proportion was pure conifer, usually of one species, but sometimes mixtures of species with compatible growth rates. More often they were conifer/broadleaved mixes. The mixtures were initially in rows generally 3 conifer (50%), 3 broadleaves (50%) usually one species of each. The theory was that the conifers act as a 'nurse' crop for the broadleaves, produce early returns from sales of thinnings and are removed once the age of maximum mean annual increment had been achieved, approximately at age 60 or 70, leaving the broadleaves to grow on up to year 120, in the case of beech. Thus two crops of timber were grown on the same area and produced fast grown, knot free quality sawlogs. This practice relied on thinnings being carried out at the right time silviculturally, but often they were delayed to meet market conditions or not carried out at all. The consequence was that the conifers overtopped the broadleaves and shaded them out, or produced very drawn up, unstable, valueless stems.

From a landscape perspective these mixtures looked very artificial, particularly on hillsides. A variation on this theme became more widely adopted in the 1970s and 1980s where broadleaves were planted in groups rather than rows within a conifer matrix. Blocks of nine (25%) or twelve (33%) trees were sited at what would be their final spacing, of which one tree would be selected. The advantage of this over line mixtures was a less artificial landscape impact, if the conifers were not of marketable dimensions or the market price was not viable before they started to shade out the broadleaves, a few trees could be cut to waste to free the broadleaves, unlike the row mixes, where complete lines would need to be removed to benefit them. The number of trees per hectare was generally between 2250-3100 (2.1-1.8 metres). The major species used were:

Conifers	**Deciduous**
European larch *(Larix decidua)*	Oak *(Quercus robur)*
Japanese larch *(Larix leptolepsis)*	Ash *(Fraxinus excelsior)*
Norway spruce *(Picea abies)*	Beech *(Fagus sylvatica)*
Corsican pine *(Pinus nigra)*	Cherry *(Prunus avium)*
Scots pine *(Pinus sylvestris)*	
Douglas fir *(Pseudotsuga menziesii)*	
Western red cedar *(Thuya plicata)*	
Western hemlock *(Tsuga heterophylla)*	

The government led this coniferisation when the Forestry Commission acquired Queen Wood near Watlington in 1947 and started the Chiltern Project in 1951. Although beech and mixed broadleaved forest was the ultimate aim, this system led to a landscape dominated in many areas by conifers up to the present day. Since the early 1980s a move away from conifers has led to replanting with mixed broadleaves, particularly where broadleaves have been felled. The areas are generally between 0.25 and 2 hectares, the majority of species are timber producing with a minority of minor species and shrubs. Therefore a typical mix would be 70-80% timber species, 10-20% minor species and 10% shrubs. The shrubs would be concentrated on the edges with the others either randomly planted or in random species groups at between 1100-2500 (2-3 metres) per hectare. The species choice is:

Timber Species	**Minor species**	**Shrubs**
Oak *(Quercus robur)*	Hornbeam *(Carpinus betulus)*	Hazel *(Corylus avellana)*
Ash *(Fraxinus excelsior)*	Rowan *(Sorbus aucuparia)*	Hawthorn *(Crataegus monogyna)*
Beech *(Fagus sylvatica)*	Whitebeam *(Sorbus aria)*	Guelder rose *(Viburnum opulus)*
Cherry *(Prunus avium)*	Wild service tree *(Sorbus torminalis)*	Dogwood *(Cornus alba)*
Lime *(Tilia cordata)*	Alder *(Alnus glutinosa)*	Holly *(Ilex aquifolium)*
	Field maple *(Acer campestre)*	Dog rose *(Rosa canina)*
	Crab apple *(Malus sylvestris)*	Blackthorn *(Prunus spinosa)*
	Silver birch *(Betula pendula)*	
	Yew *(Taxus baccata)*	

More recently the wider adoption of Continuous Cover Forestry systems (Yorke 2001) is slowly increasing in usage, where the maximum area of clearcut is limited to 0.25ha in any one block. The major limitations on establishing young trees apart from occasional extreme weather conditions are browsing, seed predation and weed competition.

The principal browsers are rabbits, hares and deer, most of which are non-native. Control of these species is essential but not implemented enough to reduce numbers significantly. Therefore protection of young trees is generally carried out by fencing or tree shelters.

A wide range of competing plants from grasses through to woody shrubs is controlled either mechanically by powered cutting machinery or chemically by approved herbicides. Disease and insects are generally not a problem but specific localised attacks on various species can cause losses of vigour or occasionally death (Butin 1995). The major ones affecting beech are: beech seedling blight *(Phytophera cactorum)*, felted beech coccus *(Cryptococcus fagisuga)* and beech bark disease *(Nectria coccinea)*. However once the tree is established the major limitation for the future development of beech is the grey squirrel *(Sciurus carolinensis)* introduced from North America in the mid 19th century. It is estimated that over 90% of all beech under 40 years old have some bark stripping damage, where the squirrels remove the bark in patches or in severe attacks peel large areas down to the cambian layer. This causes reduced vigour, loss of timber value or death with many plantations being completely destroyed (FC Practice note 1998).

2.8.5 Case study Rumerhedge Wood

Site Description

Situation:	Near Checkendon, Oxfordshire, England
OS Map Ref:	SU 677814
Area of wood:	43.2 hectares
Altitude:	120-150 metres
Aspect:	NW-SE
Rainfall:	700mm per annum
Designations:	Ancient semi-natural woodland (ASNW) (Nature Conservancy Council 1988) Ancient replanted woodland (AWS)
Soils:	Hornbeam 1 Association – Plateau and glaciofluvial drift (Soil Survey of England and Wales 1984) (Clay with flints overlying cretaceous chalk) Fine and coarse loamy over clayey stagnogleyic paleo-argillic brown earths with red-mottled subsoils. Slightly acid with slight seasonal waterlogging.
VegetationClassification:	W14. Fagus sylvatica – *Rubus fruticosus* (Rodwell 1991)(Peterken 1981 Stand Type 8D)
Prevailing wind:	South-west
Archaeology:	Ancient earth boundary banks Saw pits
Public rights of way:	One footpath through wood One bridleway (horseriding-path) on northern boundary

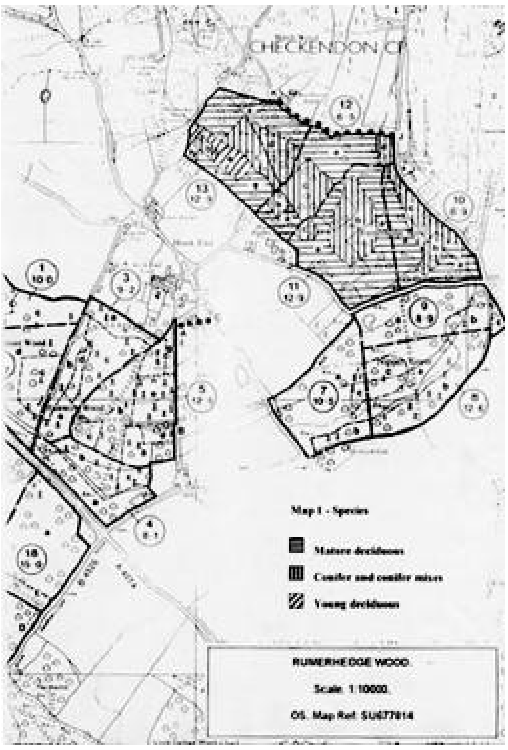
Ownership since 1945

Rumerhedge Wood was originally part of the Hook End Estate, a traditional agricultural and forestry holding. This was broken up and sold in the late 1950s and the woodland element of it was bought by a forestry investment syndicate and managed for the tax and fiscal advantages on offer at that time. It remained in this ownership until the late 1980s when it was sold to a family trust who purchased it for long-term investment and inheritance tax planning. It was then sold again in 1999 to the owner of an adjoining property, who also bought it for a long-term investment and inheritance tax planning, and for personal enjoyment.

Visual Assessment

A visual assessment (Map 1) of the site shows 59% of the woodland as deciduous high forest principally dominated by beech *(Fagus sylvatica)*, with approximately 5% of other canopy species namely oak *(Quercus robur)*, cherry *(Prunus avium)* and ash *(Fraxinus excelsior)*. In Cpts.13a and g the oak percentage is nearer to 30%. Occasionally where light levels permit a scattered weak understorey of hazel *(Corylus avellana)*, holly *(Ilex aquifolium)* and goat willow *(Salix caprea)* exists with opportunist groups of beech and occasional ash natural regeneration of varying ages, but all less than 25 years old. Very occasional other tree and shrub species are silver birch *(Betula pendula)*, hornbeam *(Carpinus betulus)*, small leaved lime *(Tilia cordata)*, hawthorn *(Crataegus monogyna)*, whitebeam *(Sorbus aria)* and elder *(Sambucus nigra)*. There are also large groups and scattered plants of *Rhododendron ponticum*, amounting to approximately 8 hectares in total. This is a non-native species, which is rapidly spreading from original ornamental plantings and was first introduced to England in 1763 (Hillier 1973).

The shrub layer is dominated by bramble *(Rubus fruticosus)* with other more common ground flora species of bracken *(Pteridium aquilinam)*, bluebell *(Hyacinthoides non-scripta)*, foxglove *(Digitalis purpurea)*, male fern *(Dryopteris filix-mas)*, tufted hair-grass *(Deschampsia cespitosa)* and creeping soft-grass *(Holcus mollis)*.



Map 1. Rumerhedge Wood

Four percent is plantation of mixed deciduous trees, and the remaining 37% is conifer and conifer/ broadleaved mixtures, most of which have been planted since 1960 in a mosaic of clear fells within the deciduous high forest (Appendix 5). The ground flora is almost non-existent due to the dense shade, but in some of the older plantations *Rhododendron*, holly, birch and some natural regeneration of conifers as well as deciduous trees is beginning. Throughout the wood some standing and ground deadwood is present but in limited quantities.

A series of rides, principally designed for access and timber extraction exist, with an average width of between 4-6 metres. Two permissive rights of way, one pedestrian and one for horse riders, have been granted to allow zoned public access linking in with existing public rights of way.

Silviculture and Management

The devastation of the wartime fellings does not appear to have been so severe in this woodland. Tree felling obviously took place, but this seems to have been carried out as a thinning and not the total removal of everything utilisable. So by the late 1950s the whole wood was high forest principally dominated by beech, with very little if any felling carried out after the war.

In the 1960s and early 1970s a series of groups were clear cut in the mature beech and replanted with faster growing conifer and conifer/broadleaved mixtures. The conifers are generally of one species but some are mixed in lines. A line thinning of these plantations has been carried out where one row in every six was removed as well as a light selective thin in the areas between. The spaces left by the rows removed were used for extraction of the produce.

The remainder of the mature beech has also been lightly thinned during the mid-1980s and currently stands at an average stocking density of 145 trees per hectare with a volume of 200 cubic metres per hectare. Since the 1980s minimal, if any silvicultural operations have taken place. The current management plan proposes a 'catch up' of the delayed conifer thinnings and a move in all areas to a nature-based silviculture using group, single tree selection and shelterwood systems. Operations are planned to improve the biodiversity of the site, such as ride widening and management, an increase in both standing and ground deadwood, the removal of invasive exotic species such as *Rhododendron*, plus an area of minimum intervention.

2.9 Interview

2.9.1 General description

Time and place of interview:	15th November 2000, Little Dean, Cinderford, Glos.
Interviewer:	Rik Pakenham
Interviewee:	Keith Wallis
Organisation:	Forestry Commission (State Forest Service)
Position:	Chiltern Forest District Manager (Dec. 1985 – Dec. 1997)
Area:	Responsible for 3238ha of which 1532ha are in the Chilterns AONB and 30% is beech of varying age class.

The Forestry Commission Chiltern Forest District covered all the AONB as well as areas outside. The office was based in Wendover Forest near Aston Clinton, Bucks. The District Manager is responsible for all management within this area, with the chain of command going to the Region (based in Cambridge) responsible for the instructions and guidelines, and then Headquarters (in Edinburgh) who decide policy. Keith had a wide range of people reporting to him - foresters, harvesting managers, ecologists and wildlife and recreation rangers. He also had access through the organisation to draw on other expertise when required, such as engineers for roadbuilding, researchers, public relations and education officers, and health and safety experts. Much of his time was not directed exclusively towards silviculture. He represented the Forestry Commission on various committees and steering groups, and other disciplines related to government policy. By the time he retired in 1997 his time was apportioned approximately as 20% Recreation, 30% Conservation and 50% Forest Management.

After World War II most of the management had been aimed at timber production and predominantly at conifers. These were thinned, clear felled and then replanted with conifers as recommended in Yield Class Management Tables (Forestry Commission 1971) with little consideration for landscape or conservation. However by the early 1970s landscape and landscape design became a major consideration particularly on hillsides and within designated areas. Premature contour felling to break up large conifer blocks was introduced, and by 1985 replanting was with mixed broadleaves usually 45% beech, 45% oak and 10% cherry.

Informal public recreation started in the mid 1970s with access for walking. This developed with way-marked trails for hiking and horse riding, and information guides highlighting points of interest. Rangers were employed to manage and develop an educational resource for the public and school parties. 1992 saw the construction of a Sculpture Trail where artists design and construct sculptures using natural materials within the forest. 1995 a fitness trail and 1997 a mountain bike course. Improved car parking facilities and a forest drive were also built. Most of these activities were developed in the larger woodland blocks, principally Wendover and Cowleaze Woods.

Conservation management started to develop in the late 1970s initially on designated sites such as SSSIs. By the early 1990's all woods had conservation plans drawn up in conjunction with English Nature. These plans resulted in great improvements to the general biodiversity by ride and glade management, and retaining a deadwood resource where health and safety was not an issue. Some specific projects included clear felling to restore old heathland and chalk downland sites, to the specific retention and management of conifer plantations which had become a major nesting site for the firecrest *(Regulus ignicapillus)*. Timber production from the management of conifers is still a management prescription but tends to be concentrated in the areas away from major public access. Many of these areas are small, scattered woods that are thinned on a five to seven year cycle with no work implemented in between except for some pest control. The volume of mature hardwood is very low (Appendix 1). These areas are thinned or clear felled in small half hectare plots to meet opportunist or niche timber markets. Natural regeneration was hoped for but not very successful, due probably to the lack of management input to control weeds and pests. Replanting of conifer areas now tends to be with conifer/hardwood mixes of which beech is a major component. This is planned for the end of the commercial conifer rotation, generally between 60 and 80 years old. However, in some areas where soils are thin over the chalk conifers, principally pine die at approximately 40 years old due to lime induced chlorosis.

These are therefore managed on short rotations or replaced with a lime tolerant species. Timber values declined in the 1990s. The shortfall in returns was initially made up by selling property and small outlying woods. However, this was stopped by the government in the mid 1990s as being politically unacceptable. Other sources of income were from sporting rents, sale of Christmas trees, renting sites to film companies and charging for car parking and educational visits.

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2.11 Appendices

2.11.1 Overview of broadleaved forest (Appendix 1)

This shows the amount and proportion of private and Forestry Commission woodland, which were mature broadleaved at the time of the Census of Woodlands in 1980 - 3% of the stock. By 1990, the next age class, containing a further 10% 1500ha of mainly broadleaved woodland, had been recruited to the mature class.

Table A. Chilterns Area of Outstanding Natural Beauty. Forestry Commission Census of Woodlands 1980

Area of AONB:	80992 ha
Area of Woodland over 0.25ha:	15016 ha

Summary of Woodland Areas by Forestry Type and "Ownership" Hectares.

	Private Hectares	%	Forestry Commission Hectares	%	Total	%
Mature Broadleaved High Forest	4813	32	97	1	4910	33
Other: Immature Broadleaved High Forest	5123		487		5610	
Mature Conifer High Forest	88		9		97	
Immature Conifer High Forest	2483		690		3173	
Coppice with standard, coppice, scrub, cleared	1223		3		1226	
Total Other	8917	59	1189	8	10167	67
Total Woodland	13730	91	1286	9	15016	100

Notes: Mature broadleaved High Forest taken to be planted in 1900 and earlier
Mature conifer High Forest taken to be planted in 1910 and earlier
Percentage of Total Woods shown in brackets

2.11.2 Forestry Commission Grant schemes in operation since 1947 (Appendix 2)

Grant Scheme	Date Started	Date Ended
Dedication Basis I	1947	1972
Dedication Basis II	1947	1972
Dedication Basis III	1974	1981
Small Woods Scheme	1977	1981
Forestry Grant Scheme	Oct.1981	Mar.1988
Broadleaved Woodland Grant Scheme	Oct.1985	Mar.1988
Farm Woodland Scheme*	Sept.1988	Sept.1991
Woodland Grant Scheme I	Jun.1988	Jun.1991
Woodland Grant Scheme II	Jun.1991	Jul.1994
Woodland Grant III	Sept.1994	Current
Farm Woodland Premium Scheme*	Oct.1991	Current

* New planting on agricultural land

2.11.3 Key Legislation since 1914 (Appendix 3)

1916	Forestry sub-committee of the Reconstruction Committee (The Acland Committee)
1919	Forestry Act (Forestry Commission established)
1928	Report on Census of Woodlands
1943	Report on Post-war Forest Policy
1945	Forestry Act
1947	Forestry Act
1951	Forestry Act
1952	Report on Census of Woodlands
1957	Report of the Natural Resources Technical Committee (The Zuckerman Committee)
1968	Countryside Acts
1967	Forestry Act
1970	Census of Woodlands 1965/67 Report
1971	The Wild Creatures and Forest Laws Act
1980	Census of Woodlands Report
1981	Wildlife and Countryside Act
1985	A Policy for Broadleaved Woodlands
1985	Amendment to Wildlife and Countryside Act
1986	National Audit Office report on the Forestry Commission
1987	Guidelines on Water, Nature Conservation, Archaeology, Landscape, Recreation
1989	Guidelines on the Management of Semi-natural Woodlands
1991	Forestry Policy for Great Britain
1992	Indicative Forestry Strategies for England
1994	Sustainable Forestry: The UK Programme
1996	Rural White Paper for England
1998	The UK Forestry Standard
1999	England. Forestry Strategy

2.11.4 Forestry Guidelines and Standards (Appendix 4)

Since 1988 the Forestry Commission has published a series of Guidelines, which detail the means of achieving national forestry policy. They describe the concepts and processes of woodland design and operation planning which allow forestry to be conducted in a way that protects and enhances the environment. To date these are:

Forests and Nature Conservation	1990
Community Woodland design	1991
Lowland Landscape Design	1992
Forest Recreation	1992
Forests and Water	1993
Forest Landscape Design	1994
Forests and Archaeology	1995
Forest Soil Conservation	1998
Forestry Practice Guides to theManagement of Semi-Natural Woodlands	1994

3. History and management of beech in North European Lowland Denmark, south Sweden[1], north Poland and north Germany[2]

K. Hahn, The Royal Veterinary and Agricultural University, Denmark

3.1 Introduction to beech forests in North European Lowland

Beech forests are an important component of the north European lowland landscape, an area also known as the southern Baltic region. Within this region both optimal beech forest sites and the northern and northeastern growth limit of beech occur (figure 1). The further north in the region, the less is the importance of deciduous beech forests. Beech is limited to the nemoral zone of the region, only extending further north along the Norwegian coastline, where the climate is milder. The border between the boreal and boreo-nemoral zone is defined as an E-W line through the southern part of Sweden, app. following the hatched area on figure 1.

The composition and extend of the present beech forest area in the region is significantly influenced by human activity. A classification of beech forests into PNV-types (present natural vegetation) can therefore be problematic (Zerbe 1997).

Figure 1. The northern distribution limit for beech in Scandinavia (Naturhistoriska riksmuseum 1996)

The Baltic region is characterised by lowlands with moderate elevations. Most soils with beech forest are classified as nutrient rich brown earth soils developed on hilly moraine, sometimes moderately waterlogged, but well drained in the upper layer. At most sites the litter decomposes rather rapidly, forming mesotrophic mull although light mor is common, too. The majority of the beech forests in the region occur on young

[1] South Sweden is here defined ad the southern Swedeish provinces Skåne, Halland, Blekinge and Småland.
[2] North Germany is here defined as the northern lowland bundesländer Schleswig-Holstein, Mecklenburg-Vorpommern, Niedersachsen and Brandenburg.

moraine deposits from the last glaciation, but beech forests are found on a variety of sites, and has been planted well outside its natural range, hereby extending the classification of beech forests.

In Denmark, beech forests are unevenly distributed, with 60% in the eastern island region and 40% in Jutland (Brøndum & Bisgaard 1998). In Sweden, about 85% of the beech forest areas are found in the southernmost province, Skåne, with a distinct concentration at the elevated ridges (Söderåsen, Hallandsåsen, Linderödåsen and Ryssberget) (Lindgren 1970). In Northern Germany, beech occurs in the coastal regions as well as on inland fertile, lowland sites. In Poland, beech grows naturally in two distinct regions - the northwestern coastal lowland and the southern mountainous region. In this chapter only the northern lowland beech forests of Poland are described.

3.1.1. Beech forest vegetation

In general, beech types in the Baltic region can be divided into three main types, although not all types are equally represented, 1) beech forests on calcareous substrates, 2) beech forests on circum-neutral substrates and 3) beech forests on acid substrates.

Calcareous beech forests

Scandinavian beech forests on basic and fertile soils have been classified to the *Fagus sylvatica-Fraxinus excelsior-Stachys sylvatica* community (Diekmann et al. 1998) and in Germany the type has been named *Lathyro verni-Fagion* (Mayer 1984). Here, the dominant trees species is beech (*Fagus sylvatica*), with possible occurrence of ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*) (recent invasion), wild cherry (*Prunus avium*), and elm (*Ulmus glabra*) in the canopy and sub-canopy. As the canopy usually is rather dense most shrubs occur in large gaps or on the lighter edges of these forests. Typical shrubs are *Crataegus* sp., *Euonymus europaeus*, and *Coryllus avellana*.

Circum-neutral beech forests

Those beech forests occur commonly in all countries in the Baltic region, where young moraine deposits are present. In Scandinavia the forest type has been classified as the *Fagus sylvatica-Corylus avellana-Galium odoratum* community, typically occurring on moderately fertile and acid soils (Diekmann et al. 1998). In Germany the equivalent name for this forest type is *Melico uniflora-fagetum* (Mayer 1984). The dominant tree species is beech (*Fagus sylvatica*), typically in monoculture or in mixture with individuals of sycamore (*Acer pseudoplatanus*) (recent introduction) or oak (*Quercus robur* and *Q. petrea*) (e.g. remnants of previous oak stands). Individuals of ash (*Fraxinus excelsior*), wild cherry (*Prunus avium*) and *Acer platanoides* (subcontinental species) may occur in limited amounts. In the eastern part of the region hornbeam (*Carpinus betulus*) may occur in mixtures with beech (e.g. southern Skåne and Bornholm), as a transition into the eastern sub-continental oak-hornbeam woods (Mayer 1984). The Atlantic shrub, holly (*Ilex aquifolium*) is found, but not abundantly, as an understory shrub in eastern-central Jutland, but not further eastwards in the region.

Acid beech forests

In Denmark this forest type mainly occurs in central and northern Jutland and northeastern Zealand. In Sweden this forest type is restricted to the northern part of the region as well as the ridges in Skåne (Lindgren 1970), in Norway this species-poor forest type occur in the northernmost beech forest in the western part of the country. In northeastern Germany and Poland the forest type is the least common of the three. For Scandinavia this forest type has been classified as the *Fagus sylvatica-Sorbus aucuparia-Deschampsia flexuosa* community, typically occurring on very acid and oligotrophic soils (Diekmann et al. 1998). This is equivalent to the *Luzulo luzuloides Fagion* in German literature (Mayer 1984). Beech (*Fagus sylvatica*) typically form closed stands, as more nutrient-demanding tree species are absent from those soils. Oak (*Quercus robur* and *Q. petrea*) may be present in the canopy as well. In larger openings birch (*Betula pendula* and *B. pubescens*), rowan (*Sorbus aucuparia*), and alder buckthorn (*Frangula alnus*) may occur. At the most nutrient poor soils, bordering to heath-land, the dwarf shrubs *Calluna vulgaris*, *Vaccinium myrtillus* and *Vaccinium vitis idaea* occur.

3.1.2 Climate

Climatically, the Baltic region is characterised by a gradual transition from the oceanic climate of NW Europe to the continental climate of NE Europe, with four distinct seasons. Winters are generally colder than in Atlantic Europe, with average January temperatures between 0? C and -2? C and average July temperature of 15-16? C (Wallén 1970). Beech is not found in places where the mean temperature is colder than –3 ? C (Huntley et al. 1989).

The annual rainfall averages 500-750 mm with highest precipitation in fall and winter. Summer droughts occur regularly, as there is an average precipitation deficit of 50-100 mm during June through August (Jahn 1991). The length of the growing season is 140-210 days (Wallén 1970, Dygasiewicz et al. 1984, Peters 1997). Snowfall, occurring in winter is highly varied, but generally the number of days with snow is higher in the Baltic region than in the Atlantic region. In winter, snow may occasionally cause breakage of branches and other damage to trees, typically in periods with rapid temperature changes. The prevailing wind direction is western (Cappelen & Jørgensen 1999).

Windstorms occur in the region and are occasionally severe enough to cause substantial damage. Main windstorms (wind speed >17,5 m/s), are most common in autumn and early winter, when the temperature difference between the still warm southern Europe and the rapidly cooling Scandinavia is greatest (Dygasiewicz et al. 1984, Cappelen & Jørgensen 1999). These gales primarily affect the coastal region around the Baltic Sea with a frequency of 2-6 days a year, but rarely reach hurricane force with wind speeds over 33 m/s (Wallén 1970, Peters 1997). Fires caused by extremely dry seasons are not considered an important disturbance factor in this region.

3.2 Pre-industrial period (12,000 BC – 1800 AD)

Through time, all woodland and therefore also all beech forests in the Baltic region have been altered significantly by man, with no completely untouched natural forests existing at present. It is documented that man had already influenced the forests in certain ways by the time the beech trees arrived to the region.

3.2.1 Changes in woodland cover and species composition

The arrival of beech

Following the retreat of the Weichsel glaciers, open birch forests replaced the early tundra vegetation, supplemented by juniper (*Juniperus communis*) and aspen (*Populus tremula*). Pine (*Pinus sylvestris*) arrived around 8.700 BC. After a period with open forests containing a number of large grazing and browsing mammals a period of more dense forest followed. This forest contained hazel (*Corylus avellana*) (8.500 BC), elm (*Ulmus* sp.) (7.500 BC), alder (*Alnus glutinosa*) (7.200 BC), lime (*Tilia cordata*, *Tilia platyphyllos*) (6.200 BC) and ash (*Fraxinus excelsior*) (6.500 BC) (Aaby 1994). The landscape changed dramatically between 6.500 BC and 5.500 BC, as the sea level increased. The coastline of the Baltic rose up to 25 m vertically within 500 years, changing the landscape from continental to coastal, now characterized by islands and fiords. Within the following 3.000 years the species composition within the forests did not change much (Aaby 1994).

Pollen analyses show that beach reached the coastal area of the Baltic Sea from south and established in Poland and Germany around 1.500 BC, and Denmark and southern Sweden by 0-500 AD (Huntley & Birks 1983, Küster 1997, Pott 2000). By 500 BC, beech occurred at nearly all its potential sites, becoming the dominant forest tree around 500 AD (Aaby 1994). At AD 1000 very high pollen values occurred in Denmark, although elsewhere in Europe those values were decreasing (Huntley & Birks 1983).

The late establishment of high values for beech in northern Europe, especially Denmark and Sweden, is possible related to the colonization of beech on areas of cleared and abandoned woodland sites, which developed due to anthropogenic activities (Björkman 1996, Küster 1997, Pott 2000). Although some research, comparing the pollen distribution of *Fagus* sp. in Europe and North America, suggest that climatic change has been the primary factor controlling Holocene migrations and abundance changes of beech (Huntley et al. 1989) others suggest that anthropogenic activity has replaced climate change as the major driving force for vegetation change during the last 2000 years (Lindhblad et al. 2000), at least at the local scale (Björkman & Bradshaw 1996, Karlsson 1996, Björkman 1999). Others again state that it is difficult to distinguish the impact of climatic changes from anthropogenic influences with regard to the spread of beech (Pott 2000).

In one area of Småland, Sweden, beech was present from year 0, with significant presence from AD 1200 and onwards, primarily in forests close to villages (Lindbladh & Bradshaw 1998). In other examples from southern Sweden beech did not become locally established until fire-disturbances ca. AD 800 and 1050 (Björkman & Bradshaw 1996, Karlsson 1996, Björkman 1998). Research at the northern limits of beech in southern Sweden shows that beech probably would had continued to expand if it had not been prevented by human activities (Björkman 1996). In Norway, beech probably established later than in Sweden, between 0 and 1000 AD (Fægri 1954). In Poland, where approximately 75% of the beech forests are located at the Baltic Coast and in the Carpathian Mountains with almost no natural stands in the central and northeastern regions (Tarasiuk 1992) it has been suggested that the natural extend of beech forests has possible not yet reached their NE-limit, as beech grows and reproduces well outside the present range (Tarasiuk 1992).

Changes in species composition

Local pollen analyses from Denmark support the idea of beech being facilitated by anthropogenic activity. In 'Suserup Skov', the rich deciduous forest almost disappeared by 600 BC, as a result of human clearance activities, and by AD 900 a beech-dominated forest with oak and ash had established (Hannon et al. 2000). In 'Draved Skov', the original mixed deciduous forest with lime (*Tilia*) has survived, although beech has become a semi-dominant tree species (Iversen 1958). Similarly, beech gained foothold on Bornholm, Denmark, AD 100 following anthropogenic clearances and forest destruction (Mikkelsen 1963).

In western Jutland, beech was present at least between AD 800 and 1500 but became extinct at many sites in historical time and only few, very small, local populations survived up till the 20th Century (Odgaard 1994). The growth and expansion of beech in this region was mainly limited by strong and continuous human impact rather than by climatic or edaphic mechanisms (Odgaard 1994, Worsøe 2001). Similar to the findings from western Denmark, research from northern Germany, Lüneburger Heide, conclude that before man started to extensively destroy the forests in the middle ages, beech must have been more widespread in the region, not only on rich sites but also on poor sandy soil (Leuschner et al. 1993).

Changes in landscape pattern

The landscape pattern changed significantly during the period due to human activity, and in comparison with more mountaneous regions north and south of the Baltic region, the relative flat landscape of the region has provided easy access to the forest resource (Lorenzen-Schmidt 1994).

Around 4000 BC the first, light traces of agriculture in Scania occur (Emanuelsson 1987). Based on interpretations of pollen diagrams, larger and permanent forest clearances began around 500 BC with the purpose of agricultural production. The next wave of forest clearance did not take place until 1100-1200 AD where a new agricultural expansion took place, mainly in regions rich on woodland (Aaby 1994, Lorenzen-Schmidt 1994). Because the potential sites for beech were identical with sites useful as arable land beech was a good indicator for the intensity of farming in prehistoric time, as the frequence of beech pollen is negatively correlated with the presence of open farmland (Aaby 1994).

In the centuries from 1400 AD up until the agricultural reforms of 1800 AD the forests experience a large reduction in density as well as area. Increased clearances of forests for farmland, timber harvests, which were larger than the increment, and high grazing pressures within the forests, were the three main factors responsible for this (Fritzbøger 1994b, Lorenzen-Schmidt 1994). However, the massive clearings of forests did not leave the medieval landscape completely bare. There were many, scattered woods interchanging land cleared for agriculture and the medieval landscape is often described as an intimate mixture of farmland and woodland (Fritzbøger 1994b). Until the agricultural reforms around 1800 AD, trees occurred on many fields, with beech, ash and oak on the drier parts and alder in the low-lying ditches (Fritzbøger 1994). The fallow fields furthest away from the villages often turned into forest again, if the rotation period was too long. This was sometimes a problem for the general land registration in the 1680's, as the registrants could not access those fields, as they were too dense (Fritzbøger 1994b).

The first settlement of what land belonged to what village or estate was established between 1400 and 1500. The change from village farming to individual farming did not occur until later. During 1600, the division of the forest into individual lots began (Fritzbøger 1994b). However, there was great variation between regions, and in some few areas the forests are still today managed as common ownership of a village. In Denmark, many forested areas were cleared between 1500 and 1650 due to an expanding population (Fritzbøger 1994). Timber demand was high, but also the land that the forests occupied had high value for other purposes, primarily agriculture (Borggreen 1994). Similarly, national and regional war affairs also resulted in destruction of the wood sources, and all together, the gradual removal and degradation of forested land caused wood shortage.

A general depression in society, which began around 1650, was initiated by epidemics and war. Although timber was needed for rebuilding of the warships, the forests experienced a relatively quiet period, because the grazing pressure was greatly reduced. In 1770, after 100 years of almost no reduction, the forest in Denmark covered only 7%. Due to great need for new arable land, increased demands for timber and fuel, and series of destructive military campaigns caused additional destruction of the forests. Other reasons for the increased wood demand were the consumption of large amounts of timber for building of manors and castles and the rearming of the Danish Navy. In northern Germany, the wood consumption for fortifications and new towns was enormous too (Lorenzen-Schmidt 1994). Compared with the large wood consumption for civil life, destruction of forests during wars was insignificant (Lorenzen-Schmidt 1994).

Much forest was felled from 1770 to 1800 reducing the forest area with 1/3 within this 30-year period (Fritzbøger 1994b). Owing to the increased livestock in most regions, the large cuttings never succeeded in growing into forest again, but became brushwood or treeless commons (Fritzbøger 1992).

Another important factor affecting the national forests was the – from a Danish perspective – sad loss of the southern Swedish provinces (Scania, Halland and Belkinge) in 1654-60. This severely affected the Danish wood supply (Fritzbøger 1994b). Until the disintegration of the Danish kingdom in 1600, Denmark had a colony-like supply of wood from its outer areas, such as southern Sweden, Norway, Slesvig-Holstein in northern Germany, Iceland and some Baltic Islands, from which natural resources were imported in large quantities (Borggreen 1994, Lorenzen-Schmidt 1994), often with little care about the local consequences. About 40% of the timber supply came from Denmnark (in its present form), 20% came from Gotland, 25% came from southern Sweden and 10% came from Norway and 5% from other places. Similar, 50% of the firewood supply to the royal household in 1660's was covered by import from Sweden (Borggreen 1994).

In Sweden, over-exploitation was not as severe as in Denmark, due to the much large forested areas. However, local shortage of wood was reported in the 17th and 18th century (Weislander 1936), and especially southern Sweden was affected due to the short distance to Copenhagen, which was capital at that time. In Germany, an example of the destruction of woods is given from Brandenburg, where the long-term trend until the eighteenth century was woodland clearance, although there were periods when land that had been cleared became wooded again as in other European regions (Wulf 1998).

In general, regions, which were poor on forestland around 1800 AD, have had a continual and significant exploitation of the land for the last 2-3000 years with very little forest cover for just as long. Opposite, regions, which were characterized by still having remnants of original woodlands left around 1800 AD, had probably escaped clearance until the Middleages (Aaby 1994). Remnant forests in those areas are therefore characterized by a long continuity, although structure and species composition may have been altered.

3.2.2 Social changes

Population changes
From the early arrival of early Neolithic, normadic perople to the steady increase of the more and more permanent population, the inhabitants have influenced the surrounding environment. Similar there has been a change in social attitudes from the simple need for survival to town-like settlements together with the development of sophisticated skills in agriculture, social structures, trade, etc.

Ownership patterns
As long as the forests were plenty, no-one wieved wood as a scarce resource, which should be cared for. Although local wood crisis had been known for a longer time, the first clear signs of regional wood crisis only date back to 1450 (Fritzbøger 1994b). The crisis lead to a division of ownership between the peasants and and the larger estates. The peasants, who traditionally had the communal rights for the brushwood, used the forests as coppice and grassland, while the manorial lords and crown foresters had the right to the high forest. This division, with two groups using the same forests for different purposes caused many problems and especially the forest owners complained about the loss of potential timber trees due to the heavy grazing and removal of regeneration (Fritzbøger 1992, 1994). Large, fruitbearing trees of beech and oak were considered high forest, whereas other species and young seedlings of beech and oak belonged to the brushwood (Fritzbøger 1994b). This naturally led to degradation of the forests, as regeneration was prevented from growing up into the overstory. The common ownership to the resource did in many places not only lead to opposite interests between the two groups, but also to a gradual degradation caused by interests within each group due to unsustainable harvesting. Even after the sectionizing of the woodland into individual lots, common forest grazing continued until the agricultural reforms of 1800-1850.

In Denmark, the rural need for wood was primarily fulfilled by local production, while the demands of the State and larger towns for large dimension wood for construction, and firewood for tile production, glass works, and chemical industry such as the potash production, was accomplished by imports from Norway and the Baltic states (Borggreen 1994, Fritzbøger 1994b).

Regulations and legislation
During the first significant wood supply crisis 1550-1650 AD a number of regulations and laws were issued, in the form of 1) wood saving initiatives, 2) forest protection and 3) steps for harvest control. Wood saving initiatives included an early ban on construction of bolehouses, changing the building practice to half-timbering houses, thereby saving a lot of wood (Borggreen 1994, Fritzbøger 1994b, Lorenzen-Schmidt 1994) and substitute of wood with other resources, such as peat for firewood (Borggreen 1994). Forest protection included a ban on goats grazing in the forests and an order to use earth or stones for permanent fencing rather than using of coppicewood, which often had to be replaced (Borggreen 1994). Harvest control included an order to only remove dead wood from the forest, establishment of permanent forest officer positions, and export bans for large dimension timber (Borggreen 1994, Lorenzen-Schmidt 1994). That theft from forests was a common problem was often reflected in the regional laws. The Scania Law, for example, states that cutting of leaf fodder from other mans fenced forest was forbidden (Fritzbøger 1994b).

The first independent forest legislation was issued in 1665 and 1670, and after an unsuccessful attempt to re-conquer the southern Swedish provinces more laws were issued (1680-1733). Those laws were effective for royal forests as well as private forests. Theft from forests was viewed as serious crime and did in 1710 AD obtain its own court (Borggreen 1994).

3.2.3 Management of woodland

General management of woodland

The pre-industrial forests served a wide range of purposes, with the intensity of use depending on the regional traditions, the ownership situation and the population pressure. Typical use of the forests and their products included firewood, construction timber, ship timber, cattle grazing, feeding of mast pigs, cutting of leaf hay, coppicing and pollarding, collection of edible forest products and hunting. Simultaneously, the forests experienced a large decrease in area due to clearings for arable land (Fritzbøger 1994).

The first signs of directed forest activities occur in Neolithic time around 3.000 BC in the form of 1) leaf cutting for fodder and 2) coppicing of hazelwoods for production of fence pickets for shallow-water fishing (Aaby 1994). Thus, forest management activities took place and altered the forest structure and species composition long before beech arrived in the region.

Between 500 BC and 500 AD, where beech became a dominant tree species, forest clearance was common and both shifting cultivation and semi-permanent fields were found in the forests. At the same time pannage in beech forests began (Aaby 1994). Sporadic cuttings as well as periodically more widespread events occurred. The multiple use of the forest resource continued for several centuries. Thus, it was characteristic for the middelages that the forests were not homogenoeus, but contained a variety of forest types and structures, because they were used for getting multiple resources. This is illustrated by an example from 1650 AD, where Danish cartographers classified forests as “all land at which trees were growing”, no matter of the purpose of the land (Fritzbøger 1994b).

Firewood was the most important forest product at least up until the 18th century, not only for private households but also for various kinds of production (tileworks, glassworks, potash, etc.). In regions with little forest left, wood was typically substituted by heather or peat (Fritzbøger 1994b). For agriculture, coppice management was of special importance, as all fields were fenced, typically with a combination of earth banks, ditches and wattles made by cuttings from coppice forests (Fritzbøger 1994b).

Grazing

Grazing cattle in the forests was common and could reduce the regeneration significantly. As oak is more resistant to grazing than beech, remnants of grazed forests are typically dominated by oak. However, there are some examples of grazed beech forests. In northern Jutland, Denmark, beech trees, which were grazed as young trees by either sheep or cattle in historic time have formed distinct, circular, even-aged beech clusters, sometimes with more than 100 stems (Bülow-Olsen & Carey 1996, Worsøe 2001). The clusters have likely been maintained by a combination of grazing and coppicing, mainly in the north-central part of Jutland from Vendsyssel in north to Mossø in central Jutland (Worsøe 2001). During the Middleages it became clear that grazing had a significant impact on the forest vegetation. Gradually, forest grazing became more and more regulated. One of the first regulations came in 1557, where goats were banned from nearly all forests in Denmark by order from the king (Fritzbøger 1994b). Other types of grazing, wood pastures and forest meadows were rather common in other types of decisuous forests, but rather uncommon in beech forests, probably due to the dense foilage of beech, providing little light to the desired ground vegetation.

Pannage

Pannage, which is the practice of fattening pigs with acorns and beechnuts, was much used in Denmark, southern Sweden (Skåne) and northern Germany (Schleswig-Holstein) (Fritzbøger 1992, Lorenzen-Schmidt 1994). The method was so common that the taxation of beech forests was assessed on the basis on the number of pigs they could support (Fritzbøger 1994, Kardell & Kardell 1996). Mast feeding had its grand period during 1500-1700 (Kardell & Kardell 1996, Lorenzen-Schmidt 1994), but even in the 17th century large numbers of pigs was sent to the forests in the fall and winter. Densities as high as 10 pigs/ha were reported and in good mast years the state forests alone supported feeding of 100.000 pigs. By the 1750's the number was markedly reduced, but as late as 1819 the use of mast-pigs was still reported from private forest districts (Fritzbøger 1994). It is likely that the presence of mast-feeding pigs have contributed to the displacement from mixed deciduous forests to pure beech forests (Fritzbøger 1994b). Modern time experiments have revealed different results on the effect of mast pigs on regeneration. An early trial by Bjerke (1959) found that the presence of pigs in a beech stand resulted in a favorable germination habitat for beech, with seedling densities up to 160 times as dense within the treated area as outside, due to removal of herbaceous vegetation and uprooting of the soil in a depth of 20-60 cm. Other experiments by Kardell & Kardell (1996) found little effect of pigs, other than partial severe soil disturbance.

Coppicing and pollarding

Pollarding of deciduous trees has been known as a common practice for collecting fodder for domestic animals in all of Europe, presumable as early as the Neolithic (Rasmussen 1990). In historic time pollarding has been carried out in a systematic fashion either as top-pollarding or as shredding of side branches for leaf-fodder (Christensen & Rasmussen 1991). Beech was not a preferred species for pollarding, and beech pollarding has not been a common practic e in the Baltic region. Worsøe (1979, 2001) only describes few cases of pollarding of beech from Denmark, whereas it has been reported a frequent practice for elm, ash and *Salix*. Remnants of the pollarding practice in beech forests typically occur in the fringes of the forests, where the pollarded trees still have characteristic low forks and wide bases. Similar to pollarding, the tradition of coppicing is more characteristic for other species as hazel and oak than for beech. Coppicing of beech is thought to be more difficult than oak coppice. It is for instance characteristic for coppiced and grazed forests, that oak is more likely to dominate the area due to its high potential for vegetative regeneration (epicormic sprouting). In Denmark, high coppice or pollards of beech was formerly common in central-north Jutland and northern Zealand, whereas it has been a virtually unknown practice elsewhere in the country. One source in Denmark describes coppice of beech every second year as a source for firewood production (Fritzbøger 1994). The same was found in Sweden, where beech has been a rather rare species in coppice woods due to its low ability of re-sprouting, the sense shade and the acid litter. Instead, birch, hornbeam, alder, ash and oak were the preferred species (Bergendorff & Emanuelsson 1990).

It is characteristic that although beech itself did not perform well in regularly coppiced forests, it had the ability to establish in coppiced forest of other species. Typically, coppiced woods, which have been left unmanaged or where the cutting interval has exceeded 40 years, have developed into beech-dominated forests (Emanuelsson & Bergendorff 1995). Similarly, as the practice of combined hay meadows and wood production, which formerly took up as much as 30% of the total land use in southern Sweden, decreased by year 1800, the land was converted, either to agriculture or to beech forests by seeding or planting (Emanuelsson & Bergendorff 1995).

Charcoal production

The forests have always been a source of wood for energy supplies and beech was a preferred species, especially for firewood and charcoal production. In Denmark, northern Germany and southern Sweden, production of charcoal has been known since prehistoric time (Fritzbøger 1992, Lorenzen-Schmidt 1994). In Denmark, the production was concentrated to central Jutland, where the wood supply was stable and large beech woods occurred (Fritzbøger 1994). The charcoal production was not only for national consumption (Serup 1999) as there was a significant export to large, urbanized areas in the Netherlands and England (Lorenzen-Schmidt 1994). However, the rate of regrowth was unable to keep up with the demand created by the early modern economy.

High forest management

Management of the high forest, which often consisted of beech and oak, was a task of the estate owners, as the peasants did not have the right to the high forest. The high forest was important for mast production, but especially as a source of timber for building material. By 1750 larger estates and state forest districts in northern German started planting new forest, with the purpose of creating high forest on former heathland as well as on old forest land. Pine, spruce, larch, oak and beech were the preferred species, thereby introducing conifers to the region (Lorenzen-Schmidt 1994).

Forests managed for hunting

Hunting has been an activity closely tied to the forests for as long as man has been present. The early, unregulated hunting became regulated and formalized when forest ownership was defined. In Medieval time, the hunting rights were strictly divided between owners. The royal forests, which were often used for huntig sports and often had character of game reserves became common 1300-1800 AD (Fritzbøger 1992). Those forests were not managed for wood production (Borggreen 1994). As the deer parks were private, owned by the local manorial lord or the king, they were protected and marked by stones, ditches or earthbanks and were stocked with red deer, fallow deer and roe deer. Later, between 1500 and 1800 AD the exotic pheasant was introduced as free ranging game (Fritzbøger 1992). Due to the high density of browsing animals in the deer parks, they often have a characteristic look with solitude beech and oak trees, pruned from beneath by the animals. Another characteristic of the royal forests was the construction of special forest road systems, for the French-inspirated parforce-hunts in 1600-1800 AD. The star-shaped network of roads is especially typical in the large beech-dominated forests on northern Zealand in Denmark (Fritzbøger 1992).

Unaffected forests

By the end of the pre-industrial period humans in one way or another had affected nearly all forests in the Baltic region. Forests close to densely inhabited areas probably were the most affected, whereas woodlands in inaccessible areas were less influenced.

3.3 Industrial period with organized forestry (1800 AD – 1980 AD)

The change from unorganized to organized beech forest management was a natural reaction to the shortage of wood supply that northern Europe experienced. In the industrial period, the primary function of the forests changed from multipurpose forest towards mono-production of wood. Starting in 1800 AD forestry became professional and market oriented, separating it from the agricultural sector, with regards to social and economic, as well as landscape factors (Fritzbøger 1994b).

3.3.1 Land reforms and forest regulations

By 1800 the forest areas were historically low, especially in Denmark, covering few percents of the country (Fritzbøger 1992). Wood clearly was in short supply and the traditional agricultural systems were inefficient. A number of land reforms during the period 1769-1805 altered the traditional land use system. These reforms included abolition of the adscription, relocation of the farms from dense villages out into the open fields, and the "Woodland Preservation Act" of 1805 (Fritzbøger 1992, 1994). The reforms resulted in a sharp division between forests and open, agricultural land. Grazing domestic animals were banned from the forests, and the agricultural system was changing towards larger fields owned by independent farmers. As a consequence of this strict division of functionality at the landscape scale, wood production became the primary aim of forests. The agricultural reforms reduced the forest area with about 1/3 to only 2-3%, because parts of the old forests were converted to grazing areas as a trade-of for the complete grazing ban within the remaining forest area (Fritzbøger 1994b).

These events are considered the point of return in Danish forestry, The production of wood was so important that even in the royal forests were hunting was a rather important function, a resolution of 1848 states that red deer and fallow deer, outside restricted game parks, should be exterminated in order to promote regeneration and growth in the forests as well as in the fields (Fritzbøger 1994). Although the grazing ban seems strict, there is no doubt it continued in several years after the ban in many areas.

3.3.2 Forest functions

Wood production

In the industrial period, the primary function of beech forests became wood production. The change towards wood production was reflected in the use of beech forest products. Although it is not possible to list the total wood consumption during historical time, there are indications of a change in the main use of beech wood products (Table 1). As the demand changes from firewood to construction wood and veneer logs, the need for straight boles and larger homogenous quantities increased. This change in demand is reflected in the change towards more intensively managed forests.

Table 1. National trends in the beech wood consumption in Denmark 1600-2000. Based on Fritzbøger (1994) and Brøndum & Bisgaard (1998)

Time scale	Primary use of beech wood
Until1600	**Firewood** and **charcoal production**
Until 1800	90% of the beech wood was used for **firewood**, hereafter gradually replaced by imported coal
1880	The production of **wooden clogs** consumed 17,000 m^3 beech wood annually (by 1938 the consumption has decreased to only 10% of the total wood consumption)
1930	**Cask production** (cooperage) consumed 40% of the beech wood for an annual production of 4 million butter casks. By 1960 the production was reduced to 1/5 of the 1930 level
1936	The production of **railway sleepers** has increased to 203,000 beech sleepers from a 1914 level of 18,000.
1939-1950	Increased cutting of beech and other species for **firewood** during World War II
1960	1/3 of the beech wood is used as **firewood**, 2/3 is sold as **logs** for national industry
Present	1/3 of the wood is used as **firewood**, 1/3 is sold as industrial logs and 1/3 is sold as veneer and sawnwood **logs**, the best quality for export to the Asian market

Secundary functions

In the 18th century, where sand drifts became a large problem in certain regions in Denmark, probably due to earlier deforestation, sand masses were moving uncontrolled along the west coast of Jutland as well as on the north coast of Zealand. Although forests generally have multiple functions, including protective functions against soil erosion, sand drifts etc. this had until then not been a major issue for beech forests in either the pre-industrial or industrial period. In 1726, however, the first attempt to stop sand drift was initiated and plantations, primarily consisting of conifers were established. Beech never became a popular tree in plantations on sandy soils (Fritzbøger 1994). Similar problems have been reported from the coastal areas towards the Baltic Sea coastline of Sweden and Poland, where large conifer plantations also have been established (Malmström 1939, Szafer 1966).

A rather different 'function' of the beech forests arose with the Golden Age around year 1800, with its preference for harmony between man and nature, as illustrated in romantic paintings and literature. Here, artists expressed the forest as an open park landscape, creating the lasting image of open forest landscapes with free ranging deer and solitary beech and oak trees (Fritzbøger 1994). By 1800, beech was the most popular tree, judged by the frequent occurrence in Danish poetry and even the national song regarded the beech the national tree (Kjærgaard 1996), - a status it still has.

3.3.3 Changes in woodland area and species composition

Reduction of forest area and conversion to coniferous forests
All the countries in the Baltic region experienced a decline in the beech forest area in favour of agricultural land as well as a conversion to plantations with fast-growing coniferous species. Only within the last few decades, the trend has changed back, towards a preference for native, deciduous species.

In Denmark, the forest area was historically low (2-3%) at the time of the forest preservation act of 1805, due to intensive felling, grazing and clearance for agricultural land. Since then, it has increased almost 160%, rising from 155.000 ha to 417.000 ha at present (Fritzbøger 1994). On the contrary, the beech forest area has been reduced markedly during the last century in relative as well as absolute terms. During the last hundred years (1878-1990) the beech forest area decreased from 50% to 30% of the total forest area in eastern Denmark and from 28% to 10% in western Denmark (Fritzbøger 1994). This was caused by a combination of planting of coniferous plantations (*Picea abies*) on sandy soils, primarily in Jutland, and increased conversions to spruce in the old forest regions. As an example, beech forests covered 104,000 ha in 1931, but were down to 76,000 ha in 1976 (Møller 1965, Jensen & Jensen 1985, Brøndum & Bisgaard 1998). The forestry debate in Denmark 1950-1980 was dominated by intense discussions regarding the choice between Norway spruce and beech (Petersen 1967), facilitated by short-term (unrealistic) economic calculations showing favourable net results of even-aged monoculture spruce plantations (Jensen & Jensen 1985). The arguments for continuation of deciduous forestry stressed the instability of spruce plantations (Juncker 1966, Petersen 1967), and later economic revisions by forest district officers also showed that natural regeneration of beech is far superior to spruce, at least on the fertile soils (Petersen 1981). In a more recent comparison of the profitability of natural regeneration of beech with planting of Norway spruce Holten-Andersen (1987) found that with interest rates up to 3-4% beech management with natural regeneration is superior to planting of spruce. The results emphasized the importance of maintaining beech on sites where natural regeneration is possible. At present the forest area is again on an increase, due to massive afforestation projects, favouring deciduous species.

In northern, lowland Germany, the forest cover was and is generally lower than in the southern mountaneous regions. The average forest cover was reduced significantly from the estimated natural level of 90%. The forest area increased due to new plantations and afforestation projects and reached 30% by the end of the industrial period. In Schleswig, northern Germany, the forest cover increased with 32% between 1870 and 1913, primarily due to fastgrowing coiferous species. In 1883, 69% of the forest consisted of deciduous trees, being reduced to 51% in 1927 and down to 44% in 1981 (Lorenzen 1994). Another case study has shown a similar shift in geographical position of north-German forests, so that coniferous plantations on sandy soils, by large, have replaced the former deciduous forests, which grew on the fertile soil. Ancient woodland mainly survived on soils, which were not suitable as arable land. As a consequence, this shift has altered the species composition significantly, with many red-list species now depending on ancient semi-natural deciduous woodland (Wulf 1998).

In the past, forests occupied as much as 90% of the total area of Poland, an estimate similar to Germany. The deforestation process was initiated in the 14th century, continuing until 1939, with the most intensive deforestation taking part at the turn of the 19th/20th century (Zielony 1999). The overall pattern has been clear-felling of the original species rich mixed deciduous forest with subsequent introduction of single-species stands, most frequently spruce and pine. The proportion of coniferous trees has become particular high and comprised ca. 88%, whilst deciduous trees covered a total of 12% in the 1960's (Szafer 1966), but has since then decreased systematically in favour of broadleaved forests. In 1993, 75% of the forest was coniferous and 25% was deciduous (Rykowski 1995). Szafer (1966) states that it is clear that the percentage of deciduous trees is considerable lower in Poland than one would expect from the habitat potentials of the country.

In southern Sweden the beech forest area was reduced significantly within the 18th and 19th century by felling and degradation to heathland. Typically, both heathland and remaining beech forests were then converted to spruce plantations in the 20th century (Malmström 1939, Karlsson 1996). A further reduction of the beech forest areas was hindered with the beech forest law (1974), the deciduous forest law (1984) and the forest protection law (1993), which caused great discussion in public and in forestry circles (Helles 1985). The basic idea was that the deciduous forests area should be kept as deciduous forest and preferentially expanded. This was accomplished with a restriction on the transference of deciduous forest to coniferous forest supplemented with economic support to deciduous forest management (Kardell 1998).

3.3.4 Organized beech forest management

The foundation of a forestry school in Kiel, northern Germany, in 1785, was the starting point for a more formal education and professionalization of forestry. In 1833-34 the school was transferred to Copenhagen (Lorenzen-Schmidt 1994) being the official education of foresters. The school was strongly influenced by Germany forest management. In 1863 the school was relocated and joined with other academic disciplines to its present location, the Royal Veterinary and Agricultural University (Henriksen 1969). In Sweden, Norway and Poland forestry as an academic discipline was also linked to the agricultural universities.

The early transition to organized forestry

The development of organized, rationale forestry skills in northern Europe and the Baltic region were somewhat delayed compared with south-central Europe. As an example, the transition from unorganized exploitation to organized forestry in central Germany, took place early. At the forest district Langula, Thüringen, which by year 860 was a deciduous forest managed by unorganized selection cutting, the change towards an organized management regime already took place in 1569, when the forest was converted to coppice with standards and again in 1872 converted towards an organized selection cutting forest (*Plenterwald*) dominated by beech in mixture with several other deciduous species in 1872 (Morsing et al. 1999). This concept of plenterwald became common in southeastern Europe and in Alpine regions with mixed silver fir forests (Schütz 1993), but never established as a common silvicultural practice in northern Europe (Jacobsen 1995). Another example is the concept of thinning of forest stands, thereby improving stand growth. This took hold in Germany as early as in the 16th century, although it was not until the mid-19th century the question of thinning was only systematically researched (Brandl 1991).

High forest management

As a reaction to the general over-utilization of the forests, two general types of high forest management emerged in Germany around year 1800, where the primary aim was to secure a sustained production of wood products. Those two types are 1) **continuous forest cover systems** (*Dauerwald*) and 2) **clear cutting systems** (*Kahlschlag*). Within the continuous forest cover systems two types have emerged; the homogeneous, shelterwood systems (*Grossschirmschlag*) and the inhomogeneous group selection systems (*Femelschlag*), which was described and applied as early as 1878 in Bavaria (Møller 1965). Also, more sophisticated systems as the strip systems (*Saumschlag*) developed on the basis of the two main types.

In northern Poland, man has influenced the beech forests for many years. The organized rationale management of forest resources started at the turn of the 18th/19th century (Zielony 1999). During the German occupancy of 'Ostpreussen' in Poland, the normal forest model was typically applied for beech forest management. Although many forests were regenerated naturally, several plantings also took place. This concept reached as far as Kaliningrad and Kiev (Tarasiuk, pers. comm.). The intensive management regime combined with a high population density means that almost no forests are left in natural conditions (Tarasiuk, pers. comm.).

In Denmark, organized forestry was initiated with the 'Gram-Langenske forest statutory' (1764), which was developed primarily by the German forester J.G. von Langen (1699-1776) (Fritzbøger 1994, Jørgensen 1999). Until then, regular forest management had not been an issue. The shelterwood system was brought to Denmark from Germany by professional foresters as Sarauw, Brüel, Ulrich and Oppermann in 1800-1900 (Møller 1965) and became a popular management system. The group selection system, which was also practiced in Denmark (Muus 1921) experienced less success than the shelterwood system. The preference for the homogeneous shelterwood system in northern Europe has been explained by the infrequent mast years due to a colder climate (Henriksen 1988). As there are many examples of gap regenerations it is more likely that the preference is linked to the need for efficiency, administrative advantages and easy economic calculations. Strip systems and selections systems have not been applied in any significant extend in Danish beech forest management. An example of typical, traditional beech forest management is given in the case study of 'Sorø Akademi Forest District'. The case study illustrates the organized, even-aged shelterwood system as it has been practiced at several Danish and Swedish forest district.

3.3.5 Silvicultural aspects of beech forestry

Natural regeneration

Beech is one of the most common species used for natural regeneration (Henriksen 1988) with shelterwood regeneration being the most typical method of regeneration. This method involves partially felling of the near-homogeneous parent stand in four tempi; 1) preparation (thinning of canopy), 2) thinning after seeding, 3) later thinning to increase light for the understory and 4) final removal of the old canopy. Often, only the last two types of thinning are carried out, whereas the first two types are considered undesired, especially where the canopy cover is light, as there is a risk of a dense grass or herb vegetation developing (Henriksen 1988). Traditionally, all harvesting has been carried out in wintertime, as the process of selection and cutting is easier when the trees are leafless. In modern times, activities with heavy machinery on frozen soil are preferred.

Following the technical development and availability of tractors for forestry purpose within the last 50 years, disc ploughs have been the typical machinery used for the preparation of a seedbed (scarification) in shelterwood regeneration. Following seed fall, the seeds are covered with a thin layer of soil by a roller in order to reduce the seed predation (birds). A general guideline for shelterwood regeneration has been that a minimum of 50-100 beechnuts/m^2 should be present, with a density of 20 well developed seedlings per m^2 the following year and up to 1000 seeds/m^2 in heavy mast years (Henriksen 1988). The intense testing and discussion of various types of scarification reflects the traditional intense use of soil scarification before regeneration. The methods include light soil scarification with harrow as well as radical methods with complete removal of the vegetation and upper organic layer by bulldozer (Madsen 1987). In order to reduce the competing vegetation, herbicides have often been used during the last 50 years, primarily to control grass vegetation. The use of pesticides for vegetation control is expected to stop in near future as pesticides are banned from year 2003 in all Danish state forests districts, and eventually also in private forests.

Parallel to the wide use of shelterwood regeneration, continuous forest cover practice with slow development of natural regeneration was applied at beech dominated forest district in eastern Jutland in the first half of the 20th century (Bornebusch 1950, Krarup 1956). Here, the old beech canopy was removed over a period of 20-25 years, preferable in an irregular pattern with no experience of decreasing value increment on the remaining canopy trees. The regeneration consisted of beech, mixed with some ash and sycamore. The reported advantages of the slow removal of the overstory included prevention of the competing grasses, creation of favorable microclimate as well as protection of the neighboring stands. Only in cases where a second mast year did not occur within 4-5 years of the first mast, supplementary plantings were required to fill in gaps (Krarup 1956). Although the practice was recognized as en economic sound method producing rich forest stands with good regeneration climate and soil development as well as aesthetically appealing stands (Bornebusch 1950) the method never gained wider popularity due to the lack of spontaneous regeneration at sites with less fertile soil.

Planting

Planting has been a much-used method of regeneration in both Denmark and southern Sweden since 1900, especially at sites where a change of species was desired. The former tradition of digging up excess natural regeneration and planting it at bare sites or in other stands has diminished due to high labor consumption and ban of sale of non-certified plant-material in the 1970's (Plantedirektoratet 1995, Søgaard 1997). Afterwards, planting of nursery plants from certified seed sources increased in popularity. During the 1950's the technique and economy of natural regeneration versus plantings were discussed intensively in Denmark (Henriksen 1986). Typically, planted beech stands required large initial investment due to the dense plantings, whereas the initial investment in natural regeneration was much lower. As late as in the 1960's the density of plantings was 20,000 plants/ha (1.5 x 0.6 m), but this decreased to a plant maximum of 5,000-10,000 plants/ha with a spacing of 1.5 x 1 m in the 1980's (Henriksen 1988). Typically 2/0, 2/1 or 3/0 bare-root nursery plants have been used (Henriksen 1988), but 1-2 year old container-plants are becoming increasingly popular because of the lower price.

Seed sources

As early as 1880, import of foreign seed material (exotic provenances) was practiced in Denmark. An overall trend has been that Denmark imported seed from southern countries and that Sweden imported seed from Denmark. The most important seed import regions were the Carphatian Mountains, Switzerland (Sihlwald), The Netherlands, Belgium (Forêt des Soignes), and several places in southern and central Germany (Henriksen 1988). Of less importance were seed sources in Romania, Bulgaria, Czech Republic, Slovakia and Slovenia. In the period 1960-80 the average annual import of beechnuts was 4,8 tons/year. This equals 86% of the total seed consumption in the period. In the period 1980-1995 the average annual import was 10,3 tons, equaling 74% of the total consumption (Larsen et al. 1997). The high import reflects the low production of beech seeds in Denmark and the long interval between mast years.

Thinning regimes in beech

Thinning in beech is generally divided into the early pre-commercial thinning and the later marketable thinning. Traditionally, the labour intensive pre-commercial thinning is thought to play an important role in the formation of high quality timber (Ekö et al. 1995). The costs of pre-commercial thinning vary with the difficulties of maneuver in the stands and with the opportunities to find a market for small dimensions, typically as firewood.

In Denmark, two general thinning regimes emerged between 1800 and 1900. One system ("suppressed/restrained thinning") was based on very light thinning until year 50-60 with the aim of producing long boles clean of side-branches. When the bole height reached a desired height of ca. 8 m, a more intensive thinning regime was applied as to increase the increment (Møller 1965, Henriksen 1988). The other thinning system ("active thinning") aimed a strong thinning from the beginning, with removal of wolf trees and the aim of increasing the diameter growth early. Over time, most management regimes have gradually moved towards the intensive, early thinning in order to force the diameter increment and lower the rotation age. At most forest districts, the rotation age typically has been and still is app. 100-120 years (Henriksen 1988), which is considerable lower than just 100 years earlier. A trend towards even lower rotation ages of 100 years is significant, primarily due to the risk of red heart in older trees and the economic advantages of earlier return. Economic evaluations show that a cyclic beech regime in which regeneration is initiated at age 90 of the stand, and the canopy trees are cleared at age 110 is a superior model at interest rates up to 3-4% (Holten-Andersen 1987).

In natural regenerations in southern Sweden the first, pre-commercial thinning of beech takes place when the saplings are 2-3 m tall. Here, only the most dominating badly shaped trees are removed, as a high density (>5,000 stems per ha) is desired. A second thinning at 4-6 m height should reduce the stem density to 3,000-4,000 stems per ha. At the age of 25 years (height ca. 9 m) 500-600 future trees per ha are selected. From age 25 to 50 selective thinning is carried out every 5 years, while the interval is increased to 10 years after year 50. At age 100-110 the stand is ready for final cutting, ideally with 150-200 stems per ha, dbh 50-60 and a clear bole of 6-8 m on good soils (Rytter 1998). As in Denmark, there is a desire to lower the rotation age in beech in Sweden (Rytter 1998).

In Germany, the thinning tradition has been less intensive with a larger inclination to leave the dense, young stands to self-thinning until at late stage (Ahbe et al. 1996, Astrup & Ohff 1998). As the thinning regime is naturally reflected in the rotation age, the recommended thinning rates and rotation ages in Denmark, Sweden and Germany are listed for comparison in table 2. It is clear that there seems to some dissimilarity in opinion of stem reduction and rotation age between Scandinavia and Germany.

Table 2. Comparison of stem density and rotation age in mature beech stands of good production (9 m^3/year) in Denmark, Sweden and Germany (after Rytter 1998).

Country and source	Production class	Rotation age	Stem density/ ha	
			by year 100	by the end of rotation
Denmark, Møller 1933	Bonitet III	120	237	149
Denmark, Løvengreen, 1951	Bonitet II	120	242	178
Sweden, Petrini 1938	Bonitet II	120	271	202
Sweden, Carbonnier 1971	Bok32, program A	120	169	137
Sweden, Carbonnier 1971	Bok32, program B	120	143	143
Sweden, Persson 1996	Bok32	100-110	150-200	150-200
Germany, Schober 1967	Bonitet II, normal thinning	150	448	188
Germany, Schober 1967	Bonitet II, strong thinning	150	319	119

Production
As a result of the combination of organized forest management, stabilization of the forests and the ban of grazing in the forests, the standing volume as well as the productivity per ha increased significantly in the industrial period. For beech, the annual production increased from 3-4 m^3/ha at the turn of the 19^{th} century, till now, 100 years later the production averages ca. 9 m^3/ha (Fritzbøger 1994). In this period, the first yield tables were also developed (Møller 1933).

3.3.6 Damaging agents

Browsing
Deer browsing, especially by roe deer has been a serious problem in deciduous forrestry, especially with regard to natural regeneration. The problem was already recognised in the early days of organized forestry (around 1800 AD), where district officers state that a reduction in the deer density alone would be sufficient to make successful natural regeneration of beech (Fritzbøger 1992). Fencing of the regeneration stands has been a traditionally rather effective, but also expensive way of solving the problem. Mice can be a problem in young beech plantings where they eat the bark, typically under the snow cover in wintertime or where weeds and grass provides protection against predators.

Damage to older trees
Bark damage can be caused by either abiotic or biotic agents or in combination. Sudden exposure to direct sunlight, typically following intense thinnings, may cause bark damage where the cambium is killed (Henriksen 1988). Heavy infestations by the felted beech coccus (*Cryptococcus fagisuga*) may be a predisposing factor for the fungus *Nectria coccinea* and the development of slime flow and necroses (Butin 1995). Secondary infestation by the 'tinder fungus' *Fomes fomentarius* rapidly causes snap or breakage of the stem or branch at the site of infection. The problems are primarily related to individual unhealthy trees, as the fungus is too weak a parasite to attack healthy trees (Butin 1995).

Older beech trees and trees, which have been injured by branch breakage or bark damage, may develop red heart. Red heart is false heartwood, which occur in various shapes in the central part of the stem. The presence of red heart lowers the price significantly. It is known tha the risk increases with the age of the trees

and it has also been suggested that the risk of red heart is linked root damage due to soil compaction from heavy machinery and fluctuating local ground water table (Henriksen 1988, Butin 1995).
Drought and wind are the two most important abiotic factors damaging beech trees. Drought damages are common on sites with fluctuating ground water tables, preventing the roots from developing a deep root system. Drought may cause lowered production and local die-back in the crown. Windthrow occur at irregular intervals, either as individual tree falling in storms or large-scale disturbances in infrequent strong gales, the last major storms being 1967, 1981 and 1999.

3.4 The contemporary situation – modern changes (1980 -)

The change from industrial to contemporary forestry is characterized by an increased demand for multi-functionality. Today, forestry is not just wood production. The importance of wood production has decreased, whereas the purposes of nature protection, species conservation, public recreation, and ground water protection all have increased. Thus, the aims of forestry are questioned, the functions have widened, and the silvicultural systems are changing. The normal-forest, that secured a sustainable wood production, is no longer an adequate model and the application of nature-based forestry as a successor of the traditional silvicultural methods is the clearest example of radical changes within forestry.

3.4.1 Present beech forest conditions

Forest ownership

In Denmark, approximately half of the forests are privately owned, 1/3 is owned by the state and 1/6 is owned by companies, cooperatives etc. (Brøndum & Bisgaard 1998). In Sweden, approximately half of the forests are privately owned, 1/3 is owned as company forests and less than 5% is state forest (Skogsstyrelsen 2000). It is characteristic that private, large estates own most of the beech forests in southern Sweden, whereas the large beech forest areas in Denmark are almost nearly evenly distributed between private and public ownership. In northern Germany many forests are state (bundesländer) or municipally owned. The average ownership distribution in Germany is 54% public and 46% private, but it varies much between regions. In Mecklenburg-Vorpommern for example, 62% of the forests are public owned and 38% are privately owned (www.wald-mv.de). In Poland, the ownership structure changed following World War II. The state forests area grew and now constitute over 82% of the total forest area, whereas the role of private forests decreased (Dygasiewicz et al. 1984, Tarasiuk 1992).

Beech forest area

In most areas of the Baltic region, the forest area has increased significantly since the low values of 1800. In Denmark app. 12% of the total area is covered by forest, which is equal to 501.000 ha (Brøndum & Bisgaard 1998) and in Sweden 55% of the total land area is forested, which is equal to 22,613,000 ha of forest (Skogsstyrelsen 2000). In northern Germany the forest cover is much lower than in the country as average. Schlesvig-Holstein, bordering Denmark only has 8.7% forest cover, compared to an average of the former WestGermany of 27% (Lorenzen-Schmidt 1994). In Poland, forests cover app. 28% of the land area, which equals 8,755,000 ha (Dygasiewicz et al. 1984, Zielony 1999). The forest covers of the countries and provinces in the Baltic region are shown in table 3.

Beech is the most important deciduous tree species (Henriksen 1988). In Denmnark, beech covers 17% of the total forest area (72,000 ha) (Skov- og Naturstyrelsen 2000a) and in Sweden it covers a total of about 50,000 ha, which is equivalent to 45% of the total area of southern deciduous forest, but less than 0.5% of the total Swedish forest area (Skogsvårdstyrelsen 2000). In Germany, beech forests covers 17% of the total forest area (figure 2). In Poland, pure and mixed beech forests cover 8% of the total forested area (533,100 ha) (Tarasiuk 1992), but beech alone only covers 4% of the forest area (Dygasiewicz et al. 1984).

Table 3. The forest cover of the Baltic region.

Country/province	Forest area in ha	Forest area in %	Beech forest area	Beech forest area in % of total forest area
Denmark	501.000	12	42.000	17
Sweden	22.613.000	55	50.000	0,5
Poland	8.755.000	28	250.000	4-8
Brandenburg, Germany	993.000	37		
Hamburg, Germany	3.400	5		
Mecklenburg-Vorpommern	532.000	23		
Niedersachsen, Germany	1.068.000	23		
Schleswig-Holstein, Germany	155.000	10		
Germany, total	10.740.100	30	1.825.800	17

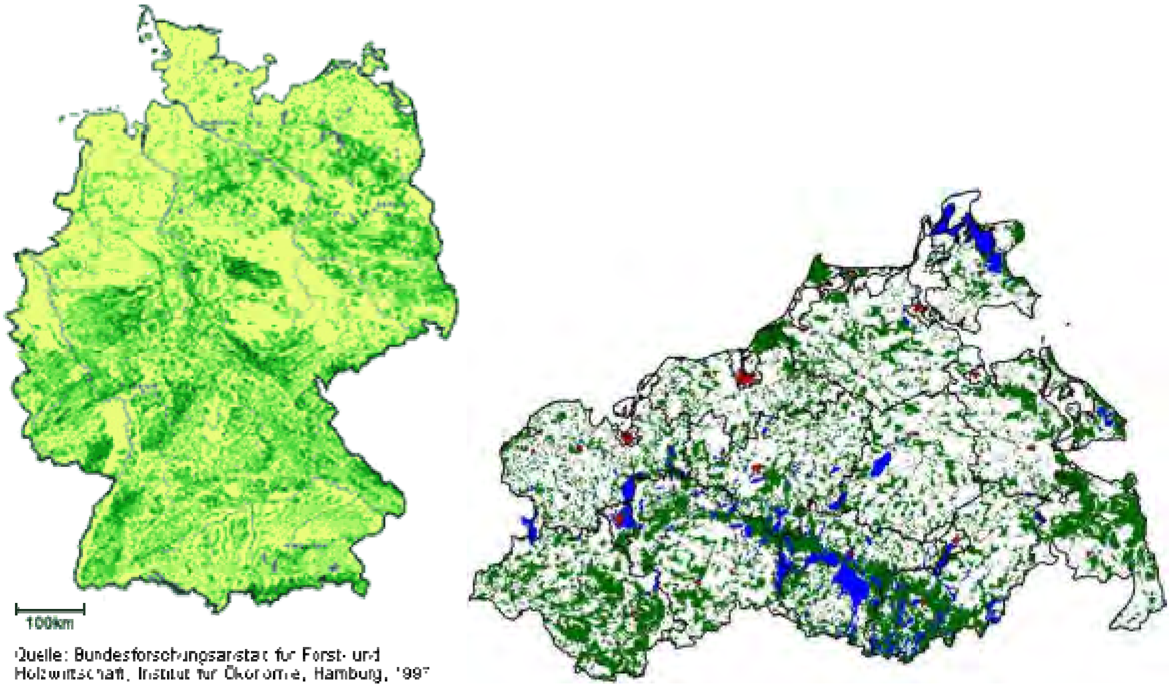

Figure 2. Left: The forest areas in Germany are concentrated in the central and southern regions. In the easily accessible, fertile lowland areas, there is less forest cover. Right: The forest distribution in Mecklenburg-Vorpommern shows that forests are concentrated in certain areas with steeper terrain.

Afforestation projects

The identification of the need for new forests with a multiple range of functions has constituted to the political goal of increasing the forest area from 12% to 25% in Denmark within one tree generation (80-100 years) has initiated a process of afforestation projects (Skov- og Naturstyrelsen 2000c). This means that 400,000 ha of agricultural land should be converted into forests at a speed of 4-5,000 ha / year as either private of state forest. Afforestation projects are often linked to the establishment of urban forests, establishment of larger natural areas, regional interests in protecting ground water resources, and private landowner interests. In contrast to previous waves of forest plantation in Denmark (the 'coniferization' of the vast heathland during 1800-1900), this afforestation project is characterized by the use of deciduous species. More than ¾ of the afforestation projects are planted as deciduous forests (Skov- og Naturstyrelsen 2000c). Despite its generally high popularity in Danish forestry, beech plays a rather small role in the afforestation projects, in comparison with oak, due to the lack of forest climate on the large, open afforestation areas. Instead oak is the preferred species.

Productivity characteristics
Beech wood is the most productive commercial hardwood of the region. In Danish forests and plantations it constitutes 25% of the total felling (Brøndum & Bisgaard 1998) and the average annual production on fertile soils is 10 m^3/ha with trees reaching heights of 30-40 m. On infertile soils, the average annual productivity can be as low as 3.7 m^3/ha with heights reaching only 17 m in 120 years (Møller 1965, Henriksen 1988). On extremely wind-exposed sites, beech is only a shrub of 1-2 m height (Ostenfeld 1932). In Sweden, the growing stock for beech is 15,4 million m^3, but this averages only 0,5% of the total growing stock due to the large quantities of coniferous stocks (Skogsstyrelsen 2000). With regard to performance, beech from southern Sweden and Denmark are described as being rather similar (Larsen et al. 1997), although beech in southern Sweden may have a lower and more variable mean annual increment of 5-10 m^3 (Rytter 1998). In northern Germany the production is similar or higher than the average Danish production, averaging 11,5 m3/ha/year at good sites (Bechsgaard & Nord-Larsen 2000). It has not been possible to obtain information on the productivity of lowland beech forests in northern Poland, but although the average annual productivity of all forest types in Poland is 3-4 m^3 (Zielony 1999), it is estimated that the productivity of beech forests is close to the Swedish data.

Protective status of beech forests
With regard to managed beech forests, there are no specific privileges protecting beech forests in Denmark, as the forests are only protected as forest land by the Forest Act §3.1: "Areas preserved as forest reserves must permanently be used for forestry purposes". It is estimated that more than 90% of the Danish forest area falls into the category of forest reserves. With regard to non-intervention forest reserves, beech forests are protected only to some degree. In Denmark, the presence of genetically original, natural forests has been surveyed, showing that app. 60% of the natural forests in state owned forests are beech forests, whereas only 20% of the privately owned natural forests were beech forests (Møller 1988, 1990). Some of those forests are protected as strictly untouched forests, a protective status, which has increased from 500 ha in the early 1990's to 5,000 ha in year 2000, with most of the strict forest reserves being state forests (NORD 1994, Skov- og Naturstyrelsen 2001). Among the few privately owned beech forest reserves 'Suserup Skov' and 'Strødam reservatet' are the most well-known. Beech forests are not included or protected in the EU-habitat directive (Pihl et al. 2000). In Poland beech forests are mainly protected in national parks.

In Sweden, beech forests are more strictly protected as they cannot be converted into other either coniferous forest or arable land. The basic idea behind the deciduous forest law (1984) and the forest protection law (1993) was that beech forests and other deciduous forests are protected to the degree that they should be managed as deciduous forest in all future and preferentially expanded (Helles 1985, Kardell 1998). In Sweden, approximately 5,000 ha beech forest is strictly protected in forest reserves (NORD 1994:7). A few southern national parks contain beech forests, the most well-known being Dalby Söderskog, Skåne, which was set aside as a national park in 1918, and strictly unmanaged since 1938 (Lindquist 1938).

3.4.2 Changes in forest functions

Looking back at the previous 200 years of afforestation and organized forestry in Denmark, the period has resulted in 1) plantations established large-scale since 1800, which are 2) dominant by exotic conifers species, and are 3) located in areas with low population density, and where the primary aim was wood production (Bach 2000). This is however far from the needs of modern society and the contemporary needs have been defined as forests,

which provide recreational facilities near urban areas
which protect/provide space for authentic biological diversity
which are planned in a landscape ecologic perspective
which have environmental purposes e.g. protection of ground water and CO2-storage
which have flexibility
and in which production of wood is one among many other goals (Bach 2000).

Thus, forests should contain a full range of other products and functions. This demand is typically defined in national forest acts, but is also reflected in the views expressed by forest owners and managers provided in the interviews conducted for this study. The emergence of the multi-functional forestry is described below with examples from Danish and Polish forest acts. During the last 20 years it has become clearer that forests host a range of functions, ranging further than the traditional major objective of wood production, typically functions regarding recreation, biodiversity protection, and environmental protection. Those multifunctional aspects of forestry are now being incorporated in national forest acts.

Forest Acts

The Forest Act in Denmark, which has had wood production as its main objective since 1805 was revised in 1989 and 1996, where wood production, nature protection and other goods and services obtained from the forest were ranked equal. The Forest Act states that '*forest reserves shall be used for good and multi-use forestry and shall be managed in accordance with a comprehensive view*' (The Danish Forest Act 1997, §15.1) and further '*good and multi-use forestry implies that the forests are managed in order to increase and improve wood production and to protect landscape amenity, nature conservation, cultural heritage and environmental protection interests, as well as recreational activity interests*' (The Danish Forest Act 1997, §15.2).

Similar expressions are found in the Forest Act in Poland where *"Forest management is run according to the plan of forest management, with particular attention to the following objectives:*
1) the maintenance of forests and their positive influence on climate, air, water, soil, living conditions and human health as well as on the balance in nature,
2) protection of forest, with a special emphasis on those forests that are natural fragments of our domestic environment or forests particularly valuable due to:
a) the preservation of forest genetic resources
b) landscape values
c) the needs of science
3) protection of soils and terrains subjected to pollution or damage, or terrains of special social importance
4) production of wood and minor forest products following the principle of maximum remunerativeness" (Forest Act chapter 2, art. 7).

Management attitudes

Changes in functions, products and management aims are reflected in several of the interviews conducted for this paper. At the forest district level, the management regime is now adjusted to those specific functions, sites and management aims each owner defines with regard to timber production, nature conservation, and restoration management. A range of new functions of beech forests, commercial products as well as externalities, have been mentioned in the interviews, with a few listed here:

"There is a change coming up these years. Before, the forest provided a simple production of wood for firewood or as logs, but now there are new products and some of the old products are less profitable. It is obvious that things like ground water and recreational values are some of the new products we are looking at." (Jens Kristian Poulsen, Sorø Akademi forest district)

"We know that the forests in this area have a recreational value, they provide the town with a lot of good-will. It is also reflected in the prices of houses. This is a high-price area." (Jens Kristian Poulsen, Sorø Akademi forest district)

"Planting of forests with the aim of securing pure ground water is a new, interesting product, which we have started a cooperation about". (Jens Kristian Poulsen, Sorø Akademi forest district).

"This (cooperatively owned) forest is considered a little bit like a public forest… we permit activities that are not allowed at the neighbouring private forest district. This is for instance horse riding, and we have many

tourists who come to the forest to use the beech for swimming etc. in summer time." (Bjarne Jensen, Fanefjord forest district)

"The main aim of this forest (166 local owners) is not a large economic surplus, but to have a nice forest and some good hunting parties." (Bjarne Jensen, Fanefjord forest district)

"The wishes for how the forest should look from an aesthetical point of view certainly have influence on how the forest is managed". (Niels Peter Dalsgaard Jensen, Salten Langsø forest district).

"The beech forest is the essence of what a forests is, in eastern Denmark. They are of significant recreational, cultural, and natural importance." (Michael Krüger Jacobsen, Randbøl State forest district).

3.4.3 Changes towards nature-based forestry

A number of problems related to the traditional, normal forest system have been addressed within the last two decades. What was the influence of organized forestry on the biodiversity in the forests? What were the consequences of having homogeneous forests with a simple structure? What were the risks of even-aged, single species stands? There were reports of regeneration problems in the open forests with no understorey, and there was criticism of the forests for being rather far from the original, natural forests characterized by high structural diversity, mixed species. Finally, there were problems with red heart, typically in stands where the standing volume had changed considerable and where heavy machinery had compressed the forest floor. As late as the 1980's, shelterwood regeneration was still considered the only possible type of natural regeneration for beech in Denmark. However, at the same time, a move away from the traditional, labour intensive, shelterwood regeneration with dense regeneration and subsequent expensive thinning programmes was initiated, e.g. Heding & Jakobsen (1980) who advocated for a silvicultural system based on the growth of single trees rather than management based on average stand data and clear-cutting systems. The authors were inspired by two German management principles, namely 'zieldurchmessern' (target diameter cutting) (Holm 1974) and 'gruppendurchforstung' (irregular dispersion of trees in the stand due to selection for quality rather than selection for even dispersal in the stand) (Kato 1979).

Not only the silviculture of existing beech stands, but also the re-conversion of spruce stands to deciduous stands have become part of contemporary forestry in northern Europe (Emborg & Larsen 1999). In Denmark, existing grant schemes support the establishment and management of stable and diverse stands. This is specifically linked to broadleaved forest of indigenous species, preferable of uneven-aged structure with several tree species and some of the largest grants have been used for the conversion of coniferous forests back into deciduous stands (Emborg & Larsen 1999).

Nature-based forest management in private forests

This has resulted in a larger interest for other forest management systems, with the most important being nature-based silviculture. The growing interest for nature-based silviculture in Denmark is illustrated by the initiation of a Danish counterpart of the European Pro-Silva federation in 1995 (Einfeldt 1995), just six years after the European Pro Silva organization was founded in Slovenia (Otto 1995). More than 140 people entered within the first year (Einfeldt 1995), and at present there are 275 members in Denmark. The emerging interest for nature-based forestry is reflected in the interviews conducted with Danish forest owners and managers, as expressed in the quotations below:

"We view ourselves as district based on the principles of nature-based forestry, which is aiming to become completely nature-based. But we know that it will take us about 150 years to get there…" (private forest owner, Denmark)

“We are aiming for a nature-based forest management…. It is only very few of the owners who are not interested in the idea of nature-based forest management”. (Niels Peter Dalsgaard Jensen, Salten Langsø forest district)

I think the management here can be defined as nature-based forest management – as close as we can get…. In many other places they remove the sub-canopy or shrub layer to give room for a large tractor and a harrow. I think that is a ‘deadly sin’ ”. (Bjarne Jensen, Fanefjord forest district).

Thus, at present, the inspiration for contemporary Danish beech forest management often comes from northern Germany, where beech also has increased popularity. Similarly, projects in beech in southern Sweden have tested the possibility of postponing thinning in beech stands until commercial thinning as to avoid the large costs of pre-commercial thinning. This idea is also clearly inspired by positive German results with low-intensity thinning (Ekö et al. 1995).

Nature-based forest management in state forests

Nature-based forest management has been known and practiced at private forest districts for many years in Germany (Jakobsen 1995). The recently incresed interest is followed up by plans for new guidelines by relevant ministries to be implemented at state forests districts. Eventually, this conversion from traditional to nature-based forest management, may serve as an example for private forests districts to follow. Implementation of nature-based forest management has been carried out in all state forest districts of Niedersachsen and Mecklenburg-Vorpommern, Germany.

The actions undertaken by the state forest administration in Niedersachsen, Germany are reflected in the LÔWE-programme (Langfristige Ökologische Waldentwicklung ~ long term ecological forest development), which is a remarkable example of how nature-based forestry can be carried out. There are 13 statements in the program of both Niedersachsen and Mecklenburg-Vorpommern, which serve as the major guidelines for how the conversion and the future management should be carried out. The two approaches are rather similar as they are based on the pan-European guidelines for sustainable forest management, see table 4.

Table 4. Guidelines for nature-based forest management in Germany. Source: Niedesachsisches Ministerium für Ernährung, Landwirtschaft und Forsten 1992, der Minister für Ernährung, Landwirtschaft, Forsten un Fischerei des Landes Meckelenburg-Vorpommern.

Niedersachsen	**Mecklenburg-Vorpommern**
1. Use of locally adapted tree species and secure soil protection	1. Increase the use of native tree species
2. Increase of the area with deciduous and mixed deciduous forest	2. Increase the area with mixed stands
3. Ecologically based health	3. Decrease the area with exotic tree species
4. Promote the use of natural regeneration	4. Increase the use of natural regeneration
5. Improvement of the forest structure (forest level)	5. Improvement of the forest structure
6. Target-diameter harvest	6. Increase the amount of dead wood in the forests
7. Protection of old trees and rare species	7. Protect flora and fauna
8. Establishment of a network of protected forests	8. Establishment of forest reserves
9. Incorporation of other forest functions	9. Ensure protection and recreation
10. Management of forest edges	10. Better management of forest edges
11. Ecological forest protection	11. Adaptive game management
12. Game management in cooperation with forest management	12. Mechanically and biologically protection of forests
13. Forest operations with ecological considerations	13. Careful use of machinery in forests

In Denmark, the ideas of nature-based forest management is present at many private and state forest districts, and is also an important issues in the Ministry of Environment, which is the head of the state forest districts.

The chief forester of the forest planning office, who are working for the conversion towards nature-based forestry at all Danish state forest districts says: *"We are working with plans for the initiation of nature-based forest management at all the state forest districts within this year – being aware that it will take more than 100 years to fulfill this vision"* (Bent Egede Andersen). The practical experiences, the results from research and the future possibilities for nature-based forest management in Denmark are evaluated by Larsen & Madsen (2001).

3.4.4 Beech forest reserves and research programmes

Beech forest reserves

Beech forests have been subject of nature conservation programmes in most countries. In Denmark, beech forests among other forest habitats have been subject to conservation in the 'Strategy of natural forests', where semi-natural old woodlands have been protected as non-intervention forests. In Sweden, some few beech forests are protected as national parks (larger areas), but also as small key habitats ('nyckelbiotoper'), typically characterized by presence of very old trees, swamp areas, ravines and large dead wood. In Germany dry, calcareous beech woodland is protected as a biotope of special importance, containing rare plants such as orchids. In northern Germany those forests are most common at south and southwest exposed calcareous slopes, e.g. at Rügen (Landesamt für Forsten und Grossschutzgebiete 2000). In Poland the area with protected forest in the form of national parks has increased significantly within the last 20 years, from 40,000 ha to 100,000 ha (Rykowski 1995). Of those however, only one national park is of importance for lowland beech forest, with 10,000 ha forested landscape of which app. 20% is natural beech forest) (Polish National Parks 2000).

Research projects

In Denmark, a number of research projects regarding the management of beech forests were initiated. Experiences with nature-based forestry and conversion from traditional even-aged forestry to nature-based forestry appeared as research objects (Madsen et al. 1999a, 1999b). A larger research programme studying the patterns and processes in natural beech-dominated forest was initiated in 1999 (the Spy-Nat-Force project) (Emborg et al 1998), and the general sustainability of nature-based forest management has been evaluated in "Project sustainable forest" ('Projekt bæredygtig skov'). In Sweden, a conference on biodiversity in managed forests attracted more than 400 biologists, forest ecologists etc., indicating the large interest in research on maintaining biodiversity in the temperate zone (Gustafson et al. 1998). At the same time, a national research programme, SuFOR (Sustainable FORestry in southern Sweden) (1997-2004) was initiated. The project has the objective of giving research-based recommendations for sustainable forestry in Southern Sweden, not only with regard to wood production, but also for biodiversity management and multi-purpose use (Nihlgård et al. 2000).

3.4.5 Public participation in forestry

The issue of public participation has come up on the European forest agenda following the Lisbon Resolution 'People, Forests and Forestry' (1998) as a new issue in forest management in Europe. On the basis of this, user councils were introduced at the Danish State forest districts in 1995 with the objective of enhancing the influence of local users on forest management in the state forests. At present there are 29 user councils with a total of more than 350 members all with a locally defined interest in the management of the local state forest district. Most are designated members from municipalities, counties and a few major interest organizations (NGO's) (Skov- og Naturstyrelsen 2000b). An evaluation of the user councils and their perceived influence in 1998, three years after initiation, revealed that the main objective of improving the local involvement and influence was only partly achieved (Boon & Meilby 2000).

3.5 Case study: Traditional beech forest management, 'Sorø Akademi Forest District' 1800-2000

Interviewer:	Katrine Hahn
Interviewed person:	Forest officer Jens Kristian Poulsen Sorø Akademi Forest District
Date and place of the interview:	February 2000, Sorø

The case study is based on an interview with the present forest officer and a review paper by the former district forester (Bruun 1999).

3.5.1 Description of the area

'Sorø Akademi forest district', which is owned by an independent foundation, is situated in central Zealand on well-drained calcareous till and below-average precipitation (600 mm annually). It is regarded a classic beech forest district with a long tradition of beech management. The forest district manages 4245 ha forest of which 1510 ha is beech.

Figure 3. The area of Sorø Akademi forest district is situated in a mixed landscape with agricultural land (white), forests (grey) and lakes (dark grey). The near-natural forest 'Suserup Skov' is situated at the lake-side south of Sorø town (marked with a circle).

Before 1800 AD, the forest was managed as a multiple-use forest characterized by degradation and non-sustainable use. Typical for the time, the low forest was regarded a common good for the local peasants, whereas the high forest belonged to the forest owner. The present management regime was initiated in 1805 by a German forester, Brüel, who organized the forest as a high forest with compartments, where the primary aim was wood production. In order to secure the regeneration, grazing was banned in the forests. In 1815, another German forester, G.C. Ulrich, refined the management concept by development of reliable methods for natural regeneration of beech. By the early 20th century (1907-1937) the Danish district forester Mundt experimented with continuous forest cover (Dauerwald). This was, however, not regarded successful and was not continued. In the 1960's the district officer, Bruun, changed the beech forest management towards selection cutting (Plenterwald). The result was, however, closer to a group regeneration system (Femelschlag) and was only regarded a success in the forests close to the local town, where forest continuity and diversity had high priority. Despite of the management experiments, the most common forest practices for beech management at the district has been the classical shelterwood system, which is continued today.

Figure 4. Beech grown as high forest in central Zealand, rejuvenated by shelterwood regeneration and with little or no understory.

When a mast year is expected, the practice is to prepare large areas for regeneration at a time. In order to secure an optimal, dense regeneration, the shrubby understory is removed, pesticides are applied to reduce the competition from grasses, and the seedbed is prepared mechanically. A strong thinning of the overstory trees before the emergence of the seedlings is usually done. This radical practice includes the risk of uncontrolled growth of herbs and grasses under the light canopy in case the regeneration fails. The district officer is aware of the risk: *"If it goes wrong - fortunately that is rare- the chance is missed. I think you should be willing to accept the risk… one should not believe that there is a second chance"*. Generally, the district has a success rate of 80-90% with the described regeneration system.

The cyclic management of shelterwood regeneration in beech at Sorø Akademi forest district is described below:

YEAR 0	Initiation of the regeneration phase when the old stand reaches an age of 90-100 years. By waiting longer, there is an increased risk of red heart development. Characteristics of the old stand: dbh=50 cm, standing volume=400 m^3/ha The canopy trees are not subject to thinning before seeding, as the canopy is light enough to initiate seedling development. In addition, a dense canopy can help preventing dominance of ground flora, especially *Deschampsia caespitosa* on the more fertile soils. The summer before expected mast fall soil preparation with harrow takes place. In autumn, after mast fall, the beechnuts are covered lightly by harrowing
YEAR 2-3	First thinning of canopy trees, where app. 15-20% of the standing volume is removed
YEAR 3-15	Gradual removal of old canopy trees, so that all the old canopy trees are felled by year 15

YEAR 18-20 The first, systematic pre-commercial thinning of the by now 4-5 m high regeneration. The stem density is reduced with 50-60%. The thinning procedure is repeated 3 times within 10 years.

YEAR 28-30 The first selective, profitable cutting

YEAR 30-50 Selective cuttings are carried out every 3-4 years

YEAR 50-80 Selective cuttings are carried out every 4-5 years

YEAR 80+ Selective cuttings are carried out every 6-7 years, where the light but frequent thinning should prevent the development of dominant grasses at the forest floor. The ultimate production goal is the development of clear bole of 12 m height.

YEAR 100 Initiation of next generation of natural regeneration

YEAR 120 Felling of remaining old canopy trees

The district is reluctant to changes from their traditional shelterwood system into a more 'sophisticated' group selection system, primarily because the economy in the traditional system is good and the technique is well known. The traditional system with strong and frequent thinning making a short rotation age is also preferred for its economic advantages: *"To us, it is more important to have white wood (no red heart) than to produce large dimension wood. This preference is directly based on the present market relationship between quality and market price"*. Although the district expresses hesitation to changes in the traditional shelterwood system, they are open for inspiration, especially from German beech forest districts: *"It is obvious that if we want to develop our silvicultural methods in Denmark, we should go to Germany or perhaps to France. We can learn a lot about nature-based forestry!"*

3.6 Summary

?? **PRE-INDUSTRIAL PERIOD**

?? The Baltic region, characterized by lowland with moderate elevations, contains optimal beech forest sites. The majority of the beech forests are found on young moraine deposits from the last glaciation. The northern limit for beech forests is found within this region.

?? The general development the landscape from the retreat of the glaciers until the beginning of modern time can be described by the following stages (Rune 2001):

1) Tundra
2) Birch/Pine forest
3) Hazel forest
4) Lime-dominated forest
5) Open landscape mixed with forests influenced by agriculture
6) Open landscape and forests dominated by beech and oak
7) Open landscape and coniferous-dominated plantations

?? Pollen analyses show that beech reached the coastal areas of the Baltic Sea from south and established in Poland and Germany around 1500 BC. In Denmark and Sweden beech established between 0 and 500 AD.

?? Around 4000 AD the first light traces of agriculture in Scandinavia occur. Larger, permanent forest clearances began around 500 BC. The relatively flat landscape of the region has provided easy access to the forest resource. The strong colonization of beech was possible related to human activity, where clearance and later abandonment of farming provided sites for establishment. It has been suggested that anthropogenic activities have replaced climatic change as the major driving force during the last 2000 years.

?? Beech would probably have continued to expand in Sweden and Poland if it had not been prevented by later human activities.

?? From 1400 AD up until the agricultural reforms of 1800 AD, the forests experienced a large reduction in density as well as area. Increased clearing of forests for farmland, timber harvests that were larger than the increment, and high grazing pressures within the forests were the three main factors responsible for the forest reduction. The quality of the forests also decreased, as the forests were open and had no understory, were subject to illegal cuttings and little care was taken for the regeneration.

?? The common ownership to the forest resources did not only lead to conflicts between the owners of the high forest and the peasants who had the right to the brushwood. It also led to a gradual degradation due to unsustainable harvesting.

?? Firewood was the most important forest product at least until 1900 AD, but beech was also a preferred species for charcoal production. During the first significant wood supply crisis 1550-1650 AD a number of regulations and laws were issued in the form of 1) wood saving initiatives, 2) forest protection and 3) harvest control. The first independent forest legislation were issued in 1665 and 1670.

?? Grazing cattle in the forests were common, but reduced the regeneration significantly. One of the first regulations for grazing was given in 1557, where goats were banned from the forests as they ate everything.

?? Pannage, which is the practice of fattening pigs with acorns and beechnuts, was much used in Denmark, south Sweden and north Germany until 1800. It is likely that the presence of mast feeding pigs has contributed to the shift from mixed deciduous forests to pure beech forests.

?? Beech was not a preferred species for coppicing or pollarding due to the poor ability for resprouting. However, coppic ed woods, which were abandoned often developed into beech-dominated forests.

?? By the end of the pre-industrial period humans had – in one way or another – affected nearly all forests in the region. Forests close to inhabited areas were probably the most affected, whereas woodlands in inaccessible areas were less affected. In Denmark, the forest area was historically by by 1800 AD, being only 2-3% of the land area.

?? **INDUSTRIAL PERIOD**

?? Around 1800 AD forestry became professional and market oriented and a number of land reforms altered the traditional land use system. Forests were separated from the agricultural sector with regards to social, economic and landscape factors.

?? In the industrial period wood production became the primary function of forests. As the demand changed from firewood to construction wood, the need for straight boles and large, homogeneous quantities increased.

?? All the countries in the Baltic region experienced a decline in beech forest area in favour of agricultural land as well as a conversion to plantations with fast-growing conifers.

?? The foundation of a forestry school in northern Germany 1785 was the starting point of a more formal education and a professionalisation of forestry, although the development of organized, rational forestry skills were late compared with south-central Europe.

?? There were two general types of high forest management, where the primary aim was to secure a sustained production of wood. Those types were: continuous forest cover systems and clear-cutting systems. Shelterwood regeneration became the most common type of natural regeneration.

?? Planted beech stands required large initial investments due to the dense plantings. Between 74% and 86% of the total seed source was imported, reflecting the low seed production and the long intervals between mast years.

?? The rotation age of beech in Sweden and Denmark was/is typically 120 years, whereas it is up to 150 years in Germany. This is related to the preferred thinning regimes.

?? Deer browsing (roe deer) is a serious problem in deciduous forestry, especially with regard to natural regeneration.

?? Red heart development is a big problem at many sites. It is thought to be related to age, but is also linked to soil compaction and damage by heavy machinery as well as fluctuating, high, ground water tables.

?? **MODERN PERIOD**

?? The importance of wood production has decreased, whereas the purpose of nature protection, species conservation, public recreation and ground water protection all have increased. The normal-forest that secured a sustainable wood production is no longer an adequate model.

?? In most areas the forest area has increased significantly since the low values of 1800, and beech is not only the most important deciduous tree species, it is also the most productive hardwood.

?? There are no specific privileges protecting beech forests in Denmark, as the forests are only protected as permanent forest. Some few beech forests are protected as strictly untouched forests. In Sweden, beech forests are more strictly protected, as they must not be converted into either coniferous forest or arable land.

?? The modern beech forests contain a full range of products and functions. It is the emergence of sustained multi-purpose forestry. Re-conversion of spruce stands into deciduous stands has become part of contemporary forestry in northern Europe.

?? Implementation of nature-based forest management is carried out at the state forest districts of Niedersachsen and Mecklenburg-Vorpommern, Germany, the criterias based on the pan-European guidelines for sustainable forest management. In Denmark the ideas of nature-based forest management are being evaluated at present.

3.7 Impacts on biodiversity

3.7.1 Pre-industrial impacts

?? Agriculture was an early impact factor on the original biodiversity. The occurrence of grain pollen indicates that forests were cleared for farming around 3.000 BC. Larger areas with grazing animals occur 3.900 – 2.800 BC. During this period farming was characterized by normadic slash-and-burn technique (Aaby 1994). The impact of those early management activities on biodiversity is not known, but it is evident that the impact has been highly variable from region to region, spatial as well as temporal. The human activities have probably been so small, that the forest ecosystems were able to regenerate themselves (Aaby 1994).

?? Larger forest clearances, which began in the middle ages, have created forest remnants, which were isolated islands in an open landscape. Considering the island-biogeographic theory, this may have had large influence on the species diversity and frequency due to local extinction (Aaby 1994).

?? With the change from the early, open birch-pine forests to the denser hazel-dominated forests, elk, aurox and wildhorse disappeared and forest-adapted animals such as wildboar, red deer, roe deer, fox, wild cat, pine marten and polecat increased in numbers. Around 7000 BC most mammals typical for the mixed forest landscape had established (Aaby 1994, Rune 2001). Already in Atlantic time (7.000-4.000 BC) elk, bear, lynx aurox were extinct from Denmark (Aaris-Sørensen 1988) and the beaver disappeared from Denmark in Neolithic time. In Denmark, the last wolf was exterminated around 1800 AD (Fritzbøger 1992), but wolf as well as bear, lynx and elk have all survived in Sweden, Germany and Poland.

?? In the first half of the period, forests were generally not managed. The increasing population density and permanent agricultural settlements had larger impact on the forests than any of the former activities. Unorganised forest management began. Forest grazing and coppice forestry were two important types of management.

?? The long continuity of coppice management has been important for the preservation of certain species, which did not survive the later conversion to high forest management. The species diversity in coppice forests strongly depends on the rotation period, as many species need the light environment 1-3 years after the last coppice (Rune 2001). Where coppiced oak forests have been left unmanaged for longer periods of time, beech has typically invaded the sites.

?? Forest grazing and deer parks often created light and open habitats, desireable for several plants, insects and fungi. Where grazing stopped or declined the forests developed into darker, closed forest habitats, changing the species composition. Of special importance for the species diversity is the presence of a mixture of browsers/grazers to avoid an undesired species composition due to the food preference of the grazers. A large component of the species from the original forests has survived in old grazed forest remnants (Rune 2001).

?? By the end of the period, the increasing population, the demand for wood and cleared land for agriculture had destroyed most forests, the remnants being inaccesible forests on steep slopes and ridges. The forests were species poor compared to the original forests and dead wood was presumable scarce, as it had often been collected for firewood.

?? New game species were imported established successfully in nature in this period. Fallow deer was introduced in Medieval time as game for royal hunting, and pheasants were imported during 1500 AD, but pheasants did not become free ranging until around 1840. Neither of the two species has increased to uncontrolled numbers.

3.7.2 Industrial impacts

?? Large parts of the decidious forest areas and heathland/degraded sites were converted to plantations with exotic coniferous species. This had a large impact on biodiversity, primarily that many important habitats were lost. Although new species associated with (boreal) coniferous forests showed up too, the total was a net loss of species.

?? The first species protections (flora and fauna) took place around 1860 (in Denmark), recognizing that some species had become rare (Fritzbøger 1992).

?? With the introduction of modern forestry, new methods were applied in forest management, such as soil preparation, weeding, large machinery and large-scale clearcuttings, thereby changing the disturbance regime from small-scale to large-scale.

?? Many forests have been drained systematically by ditching since 1800 in order to optimize the wood production. As the biodiversity in forests is closely linked to the hydrological conditions, those drainage projects have decreased the diversity of habitats. Good hydrological conditions in forests provide:

- specific biotopes
- habitats for specific species
- small moist sites of importance for fouraging animals
- a general species dispersion
- variation, gradients, light and open microsites
- a desireable forest micro climate (Møller 2000)

?? However, the attempts to increase the hydrological diversity in forests have been a limited succes, and at present the strategy has only been applied at 1% of the Danish State forest areas (Paulsen 2000). Beech forests are only a limited proportion of those areas.

?? The use of pesticides in forestry began around 1950 but has mainly been applied in Christmas tree plantations, and new plantings, primarily to control undesired competition from grass and other weeds. A smaller proportion has been used to control insect attacs on young planted conifers. The amount of pesticides is reduced in the 1990's and it is a political goal to phase out pesticides in forestry. From a biodiversity perspective, the effects of pesticides are often combined with significant soil disturbance (soil preparation for plantings), which alters the species composition (Rune 2001). The use of pesticides in beech forests is minor.

?? The use of fertilizers in forestry is low compared to agriculture (less than 2% of the state forest area in Denmark is fertilized). With regard to beech forests, the use of fertilizers only has relevance for new plantings on nutrient poor soils (Rune 2001). In general, research has shown that the authentic species composition for fungi as well as flora changes markedly when fertilizers are applied, but that the total species number not necessarily decreases (Rune 2001).

?? Atmospheric deposition of nitrogen has increased significantly within the 1980's and 1990's reaching 20-35 kg N/ha/year in Danish forests. Ellenberg indicator values have shown an increased N-indicator score in e.g. southern Sweden, documenting that the floristic composition has changed (Rune 2001).

3.7.3 Modern changes

?? In the industrial period and continuing at present, species become extinct. It has been estimated that about half of the wild plant and animal species, which are present in Denmark at present, are linked to forests or trees (Rune 2000), where the relict stands of original forests play a large role. However, the reduction in specie s diversity has been dramatically reduced due to historical and modern forest management. This is specifically true for flora and fauna linked to deciduous forests with a long continuity, a low degree of disturbance, dead wood, large old trees, high humidity and moist locations (Møller 1997, Rune 2000).

?? The loss of species is also reflected in the official Redlist where half of the threathened and vulnerable species are related to forests and of those, one third are specifically linked to unmanaged, near-natural forests (Stoltze & Pihl 1998).

?? Modern reintroduction of regionally extinct species, which once were part of the forest landscape, has been debated. The reintroduction of beaver has been successful in Sweden and Denmark (Asbirk 1998, Berthelsen et al. 2001).

?? There have been several attempts to secure endangered species and their habitats in recent years, but it is difficult as many habitats are isolated and small and under significant unfluence of the surrounding environment.

?? Nature-based forest management may be one solution for securing structure, continuity, species and habitats in forests. The positive impact on biodiversity in single-tree selection systems, which have been suggested as an important tool in modern forest management is primarily linked to the continity of the forest cover and the absence (or low degree) of soil disturbance (Rune 2001). However, the areas with single-tree selection and naturebased forest management are still limited.

?? Other types of forest-management, such as coppice and grazed forests, are subsidiced in order to secure or restore the continuity in the remaining few areas.

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Sveriges meteorologiska och hydrologiska institut, 2000: www.smhi.se

Interviews:

The interviews were conducted in February-March 2001 by Katrine Hahn

12/2 2001
Mr. Michael Krüger Jacobsen, assistant forest officer
Randbøl state forest district
State forest district, 4670 ha of which 720 ha is beech

12/2 2001
Mr. NN (anonymous), private forest owner
Eastern Jutland
Private forest district, 1 owner, 375 ha of which 120 ha is beech

13/2 2001
Mr. Niels Peter Dalsgaard Jensen, forest officer
Salten Langsø forest district
Private forest district, 42 owners, 3700 ha of which 375 ha is beech

19/2 2001
Mr. Bjarne Jensen, forest manager
Fanefjord forest district
Private forest district, 166 owners, 225 ha dominated by beech

19/2 2001
Mr. Jens Kristian Poulsen, forest officer
Sorø Akademi forest district
Independent foundation, 4245 ha of which 1510 ha is beech

1/3 2001
Mr. Bent Egede Andersen, head of office
Office of Planning, Department of Forest and Nature
Ministry of Environment and Energy

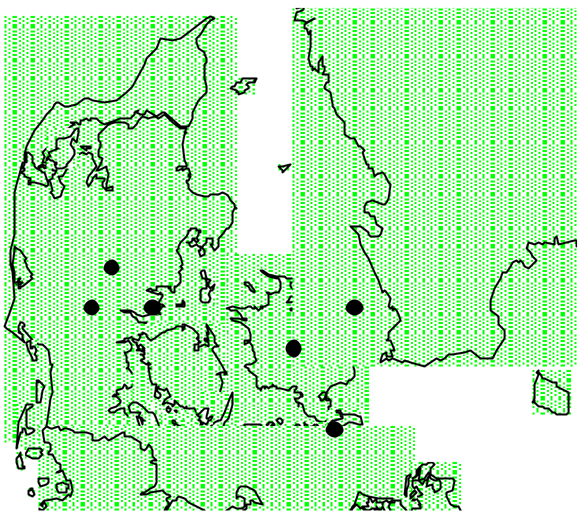

Figure 1. Each dot represents a forest district or organization where an interview has been conducted, 2001.

4. History and management of beech in Central European Uplands Southern Germany, Czech Republic, Slovakia

J. Fanta, Alterra, The Netherlands

4.1 Introduction

Central Europe is an area with very divergent forestry conditions. The area knows a long forestry tradition; in the European forestry history (last 300 years), the Central European forestry concepts, methods and practices often played a prominent role.

Throughout the long and turbulent history of Central European forests and forestry common beech (*Fagus sylvatica* L) has had varying status and beech forests have had locally varying functions. Ones the most widespread tree species in original forests, beech was broadly exploited for various purposes, degraded to a commercially not interesting species in the last two centuries and re-discovered by the ecologically oriented nature conservation and forestry of the last decades.

This report describes the development of beech forests and forestry in Central Europe on the basis of three examples: Land Baden-Wuerttemberg (Federal Republic of Germany), the Czech Republic and Slovakia. These three countries have, on the one hand, rather similar natural conditions and postglacial forest history. But on the other hand, they went through very divergent political, economic and forestry development since the 1700s and especially in the second half of the 1900s. As a result, beech forests and forestry have had a very different status and position in the forestry policy in the above countries.

The report is based on national literature reviews and interviews on conceptual level with leading foresters in each country. As a supplement, four case studies are attached (one for Baden-Wuerttemberg, two for the Czech Republic and one for Slovakia). These interviews on operational level give insight into practical aspects of the contemporary beech forestry in the concerned countries. All interviews took place in the second half of 2000.

4.2 Pre-industrial period (From the Neolithic period to 1700)

Beech (*Fagus sylvatica* L.) survived the Quarternary cold periods in the Balkans and in the Apenine peninsula. Its post-glacial migration to the North from the latter area had been blocked by the geographical barrier of the Alps. As a consequence, the whole present European area of beech had been colonized from the refugia in the Balkans (Demesure et al., 1996; Taberlet et al., 1998).

During its post-glacial migration, beech colonized a broad area of Europe in both lowlands, colline-submontane, montane-altimontane and subalpine zones and became the most widespead tree species of Central Europe (Huntley & Birks, 1983; Lang, 1994; Ellenberg, 1996; Pott, 2000). From the Neolithic times onwards (in Central Europe from ca. 7500 BP) the colonization of Central Europe by Man had changed landscape patterns – first in fertile and warm lowlands; but it extended gradually to beech-dominated submontane and montane zones. Deforestation and fragmantation of forest cover continued with varying intensity in parts of Central Europe until the Middleages, depending on regional population growth, warship, famine and disease events. Beech forests had been broadly used for various purposes (wood extraction, forest pasture, pannage, litter raking, etc.) by both Celtic, German and Slavic populations which, in succession, colonized parts of Central Europe and laid down the basis for the present demographic structure of this part of Europe. Between 7000 BP and early Middeleages all fertile grounds (esp. loess soils) in Rhineland, Bavaria, Hesse, Saxony, Bohemia, Moravia, Slovakia and Austria were deforested and cultivated. Shifting cultivation in early times and local abandonment of agricultural land in early Middleages probably supported the expansion of beech at the costs of oak, hornbeam, hazel and other broadleaved tree species (Kuester, 1998). Only the lime tree in the lowlands, European fir in the lower montane zone and Norway spruce in high altitudes were able to withstand its competitive power. The palynological and archeological evidence witness for the fact that already at the end of the Roman period not only the forested area of Cenral Europe was strongly reduced, but also the composition of the remaining fragmented forests was changed (Kuester, 1998; Pott, 2000).

The first centuries of the new era was the turbulent period of the Great Migrations in Central Europe. During this period the intensity of land use diminished and earlier deforested areas recovered. But some areas with stabilized settlements remained more or less intact (e.g. Rhineland; Kuester, 1998) or the land use even extended and intensified such as in central and north-east Bohemia (Waldhauser & Kosnar, 1997).

The sedentary way of life, population growth, change in social structure of population and technical progress in the early Middleages enabled further and more intensive use of landscape with, as a result, ongoing deforestation and forest fragmentation. In 795 AD the Emperor Karl der Grosse issued the decree *Capitulare de villis*, which ordered further exploitation of forests and, simultaneously, prevention of natural forest restoration on abandonned agricultural land. Forest pasture, copicing, pollarding and shreding, pannage and woodcutting were the most widespread use of forest. Repeated cutting of vegetatively resprouting tree species (oaks, hornbeam, ash, lime tree and others) enabled these trees to survive, while the representation of the not resprouting beech in forests was suppressed. Particular tree species of mixed Central European forests had specific use: oak for pannage and construction, ash, elm and lime tree for shredding, beech for fuelwood and pannage, etc. Simple methods of repeated cutting in resprouting trees gave rise, already in the early Middleages, to the coppice culture, which developed into the first form of an organized forest exploitation.

In the 1200s organized land colonisation became a general trend in Central Europe, supported by both profane and church authorities. Also distant and until now hardly accessible mountain areas were colonized to exploit their natural resources, esp. ores. Increasing demands on timber and wood had devastating effects on forests. First decrees were issued by enlighted rulers to protect forests – e.g. *Majestas Carolina* by the Czech king and Roman Emperor Karel IV (1355). Nevertheless, the over-exploitation of forests continued. In 1500s and 1600s, accessible slopes in Central European mountain ranges (Harz, Black Forest, Ore Mts., Krkonose Mts., some parts of West Carpathians) were largely deforested. Both fuelwood and construction timber were shipped, floated, and transported over land over large distances to supply mining areas, docks and cities. At the end of the Middleages the forested land in Central Europe was reduced to its minimum extent.

During the Middleages forest ownership structure in Central European countries developed its typical form with kings, gentry, church and cities as the principal owners. Common use of forests (esp. wood pasture and pannage), free in earlier times, started to be regulated by general or local decrees and edicts.

Rational forestation activities aiming at restoration of degraded and over-used forests started in Central Europe already in the 1300s. First sowings of Scots pine seeds were carried out in Nuernberg, Bavaria, in 1386. In 1516 first forest mensurations were performed in the Harz Mts. to estimate timber and wood reserves in support of the local mine activities (Mathe, 2001).

4.3 Beech forests in the industrial period (from 1700 to 1980)

These first attempts and efforts to get the acute shortage on timber and wood under control marked the way to the inception of an organized forestry as a rational commercial activity aiming at production of this scarce resource. Basic ideas were put down by H.C. von Carlowitz in his work *Sylvicultura Oeconomica* from 1713. Based on its own and Franch experience, Von Carlowitz defined, for the first time, the term "Nachhaltigkeit

– sustainability" as the basic principle of the arising forestry. Von Carlowitz' concept of sustainability represented the unity of the sustainable existence of the forest and sustainable yield of timber and wood, to be achieved in a continual process of planning and management.

Further steps in the development of the Central European forestry vere made during the second half of the 1700s and in the beginning of the 1800s (Hartig, 1791, 1808; Hundeshagen, 1828; and others). These foresters, however, did not follow exactly Von Carlowitz' concept. Instead of keeping balance between sustainability of forest existence and sustainable yield, they emphasized more and more the latter. Forestry academies of Tharandt and Eberswalde, Germany (H. Cotta, M.R. Pressler), represented this development, which, since the end of the 1800s, became known as the German forestry school based on the soil rent theory. Its main goal was maximum production of timber, sustainable yield and financial profit for the forest owner, realized in man-made forests. During this "forest restoration period" from 1700 to 1980 (Waldaufbauphase – Von Teuffel & Krebs, 1999), hundreds thousends of hectars of overexploited and degraded forests were restored, new forests planted on derelict agricultural land and brought into culture to produce timber and wood. In these efforts fast growing and commercially interesting coniferous tree species had often been preferred, while other (esp. broadleaved) tree species had been neglected. Clearcut was a usual and economically effective method of harvesting timber.

In this system, for common beech only a modest role was reserved locally. Probably the first attempt to organize the beech forest management in Central Europe was the Hanau-Muenzenbergische Forstordnung by Moser from 1737 (Moser, 1757). With his approach Moser laid down the principles of the 3-phases shelterwood management system, which has been applied in beech forests until the present.

Under the influence of the soil rent theory the representation of beech in some Central European countries diminished drastically. This development dominated during the 1800 and in the first half of the 1900s. It has especially affected countries with a long forestry tradition – Saxony, Bavaria, Bohemia, Moravia, Austria. It was continued despite of serious setbacks (storm and snow calamities, insect plagues) and warnings of prominent foresters, e.g. K. Gayer (1886). In the present Czech Republic, e.g., the representation of beech has been reduced from more than 40 % of the (reconstructed) natural representation to 5 % today, while the share of Norway spruce increased from some 11 to 55 % (Vasicek, 1997 – see the country report).

The paradigm of the Central European forestry of the 19th and the first half of the 20th century was based on very intensive treatment of forest stands organized in the age-classes system (thinnings, artificial regeneration), a very strict and prescriptive planning and sophisticated management technics. To keep this timber production system under control in a closed management system, natural processes in forests have been largely ruled out. The Normalwald-system based on the age-classes model has governed the Central European forestry until recently and has been anchored in national and countries' forest laws and sectoral prescriptions. The attempts to develop another model of forestry, e.g. the Dauerwald (Moeller, 1922) and Naturgemaesse Waldwirtschaft – close-to-nature forestry (Krutsch & Weck, 1935) have had some influence locally but had not been broadly accepted in that time.

In the beginning of the 1800s the last remnants of fully natural forests were cleared in the western part of Central Europe (e.g. the Hollanderhiebe – Holland cuttings in the Black Forest; Bartsch, 1940). The very last remnants of these primaeval forests have been spared in South Bohemia and became the first European nature reserves. In the eastern part of Central Europe (esp. Slovakia), due to inaccessibility of high mountains and distant areas (West Carpathians) the pressure on commercial exploitation of natural forests was lower. Here, more remnants of primaeval forests have survived and have been proclaimed nature reserves in the 1900s.

During the 1800s cattle grazing in forests, pannage and litter raking were recognized as serious devastating factors and were forbidden by national and country forest laws (e.g. 1852 for the whole Austrian monarchy). Various political circumstances in particular countries led to agrarian reforms with, as a result, deep changes in ownership structure of forests.

Until 1950 the main function of forests, including beech woodlands, was timber and wood production. Devastating effects on forests of the World War II gave rise to revival of nature protection movements in particular countries and attempts to development of a different forest management model based on increasing ecological insight (e.g. the Czech ecological school; Konias, 1951; Fanta, 1999). In the following decades most nature reserves in forests were established to protect valuable remnants of more or less natural (broadleaved) forests, among others beech. Nevertheless, the conservative forestry approach (Normalwald model, production function) was not able to accept the arising ecological and social functions and services as fully qualified orientation of forests and forestry.

In the last decades of the industrial period the Central European forestry has been confronted with various ecological misachievements and setbacks coming from the environmental deterioration on the one hand and in the inflexible orientation on timber production on the other. Since the 1960s Central European forests have been heavily affected by acid deposition originated in industrial agglomerations in particular countries. Only in the so called "Black Triangle", the core area of Central Europe along the German-Czech-Polish border, some 80,000 ha of coniferous forests died off, while the vitality of all other forests decreased considerably in all Central European countries. Instability of coniferous plantations reached disastreus dimensions. Forests have repeatedly suffered from storms, snow and insect plagues with following unacceptably high financial losses and ecological setbacks. In the Czech Republic, e.g., the casual fellings amounted more then 60 % in the period 1980-1990, with a maximum 85 % in 1984 (Moldan, 1990; Vasicek, 1997). Under these circumstances a regular forestry is hardly possible. Next to new developments in European forestry, these misachievements marked the necessity of change in the further orientation of the Central European forestry.

4.4 Beech forests in the modern period (since 1980); trends towards future

The political, economic, sociological and ecological changes in Europe and in the world in the last two decades form the background of the change the Central European forestry is facing at the beginning of the new millenium. The situation brings new environmental, ecological and societal demands on forests and forestry, an other market orientation and professional tasks, all together forming a new challenge to the Central European forestry. Forests and forestry are expected to fulfil a much broader function, by combination of and integrating the ecological, societal, economic and environmental aspects within a multifunctional management system, which will be fully anchored in the principle of sustainability. This orientation follows the resolutions of the UN Conference in Rio de Janeiro 1992 and following forestry conferences in Helsinki, Montreal and Lisbon.

Due to very divergent political and socio-economic situation of the last five decades of the 1900s the present development in forestry in particular Central European countries differs for a goed deal. As a result, the principles of the new approach as described above have been generally accepted in all countries but interpreted in a different way. While the German forestry is seriously busy with elaborating a new forestry paradigm fitting to the new economic, ecological and environmental situation (Waldumbauphase – forest reorganisation; Von Teuffel & Krebs, 1999) and the Slovak forestry relies strongly on its comfortable situation of more than 7o % of forests with the natural tree species composition, the forestry sector in the Czech Republic performs a very conservative approach. Contrary, the nature conservation and management in this country is much more innovative and follows principally the same way as German countries. Due to these distinguished differences the approach to beech forest management has been described separately in the following country reports. Specific topics of the beech forestry have been highligted in the attached case studies.

4.5 Country report: Baden-Württemberg

4.5.1 General description

Land Baden-Wurttemberg lays in the SW part of the Central-European mixed oak-beech forest district (Rubner & Reinhold, 1953; Polunin & Walters, 1983) characterized by a rather mild climate. The area has a variety of sites and growing conditions reaching from the Upper Rhine Lowland (with altitudes around 120 m asl) up to subalpine conditions in the highest elevations of the Black Forest (Feldberg 1.493 m asl).

Public forests of the Land B-W (state and communal property) cover 1,380.000 ha, what represents 37 % of the country area. Beech takes 21 % of this area, some 290.000 ha. With the exception of the lowest (Upper Rhine Lowland) and highest areas (High Black Forest) the original forests of the Land B-W were beech and mixed beech-silver fir forests (Dieterich, 1981). The present share and area of the beech is a result of a long historical development of the B-W forests and forestry, wherein the last 300 years of the organized forestry and its commercial orientation have played an important role.

4.5.2 Historical background

Due to the geographical position of the country – bordering France to the West and Switzerland to the South – the influence of the classic German forestry school based on the soil-rent theory (Hartig, 1808; Hundeshagen, 1828) was not as strong as in other parts of Germany. That's why the rationale of the age-classes planning system ("Normalwald") has been well adopted in the country, but the general conversion of broadleved tree species to conifers was not. Nevertheless, in the past, beech lost some 1/3 of its natural grounds: its original (reconstructed) site-related representation was some 31 %. This figure is the target the B-W forestry is aiming at in its planning to achieve a more natural composition of the B-W forests.

Another aspect of serious importance was the function of beech forests in the past. Throughout centuries, beech forests were mostly grown to produce fuelwood for local residents, communities and industry. Until 1960 the main target of the beech forestry was the quantity of the produced wood; timber quality was of inferior importance. Beech forests were grown in closed canopy at maximum standing volume and basal area to achieve maximum volume increment (at least 200 trees/ha; basal area minimum 30 m^2; cf. Assmann, 1961). The forests were mostly managed in a 3-4 phases large-scale shelterwood system.

In the 1960s the perils of the WW II were over, the industrial development of the country enhanced and the economic situation of the whole country changed completely. New criteria of quality production started playing a role also in forestry. In the 1960s and 1970s three aspects became important:

Due to the new economic situation the fuelwood production had to be abandonned as a not paying use of beech forests. Instead, quality timber production came in the picture, enabling more income and a beter economic position of forestry suffering of increasing costs. To cover this new funtion of beech forests, the whole concept of beech forestry had to be changed. Various tending methods and silvicultural system were subjected to analyses and evaluation (e.g. Assmann, 1961, 1965; Freist, 1962; Altherr, 1971; Schober, 1972) to develop a new approach.

In the same period, the revitalisation of the "close-to-nature forestry" concept (Naturgemasse Waldwirtschaft), based on the Dauerwald-idea (Moller, 1922; Krutsch & Weck, 1935; Wobst, 1954) started playing a role in German forestry. The concept gradually achieved more attention and gained more space in the forestry practice due to its ecological features, especially when related to the increasing environmental pollution and its negative impact on forest ecosystems.

The necessity arose to pay attention to natural regeneration of beech forests, neglected in previous decades. Both ecological and economic reasons played herein a role. In the 1960s the necessary information in this field was supplied by a concentrated research programme (e.g. Burschel, Huss & Kalbhenn, 1964; Burschel & Schmalz, 1965a, b; and others).

The close-to-nature forestry concept and management methods working with natural regeneration appeared to become easily adopted to the B-W forestry practice. However, the first abovementioned aspect of change, i.e. the production of high quality timber, was an extremely difficult issue especially due to its economic consequences for the whole forestry sector.

The most important contribution to the new concept of beech forestry planning and management was delivered by Altherr (1971). Building on the previous knowledge about the growth rhythm of beech, but contrary to the former practice of continuous tending and maintaining close canopy in beech stands throughout the whole rotation period (with a high basal area), Altherr proposed the following alternative approach:

- ?? Restricted thinnings in young stands until 40 years (high costs – no financial return; can be compensated by natural selection in thickets; when intervention necessary due to high number of "forrunners" of bad quality, to apply ringing)
- ?? Strong intervention in the age of 40-50 years, combined with the choise of 100-120 future trees of the best stem quality (basal area to be set back, e.g. from 24 to 20 m^2 - see Fig. 1; the understorey remains untouched to prevent early natural regeneration; removing thick trees of bad qualitity competitive to the selected individuals delivers first return)
- ?? Strong release cuttings in the age of 55-65 years (2-3 interventions to keep basal area at some 20 m^2; thinnings 50-80 m^3 per intervention; branch-free stem of the selected future trees 9-10 m)
- ?? Continued release cuttings in the age of 65-85 years (the ongoing volume increment to be removed; total fellings some 140 m^3/decade)
- ?? Stage of volume growth in the age of 85-100 years (2/3 of the volume increment to be removed; increase basal area to 24-25 m^2; total fellings around 90 m^3/decade; introduction of natural regeneration in canopy openings)
- ?? Period of cutting stop in 100-120 years (basal area increase to 31 m^2; maximum DBH increment to achieve final dimensions of at least 60 cm DBH in stems of the highest quality; prolongation of the rotation period to 130-140 years possible when no red heart occurs).

Combining and integrating the above elements of beech management the B-W foresters were able to meet the most important problems of the contemporary forestry:

- the production of high quality timber (concentration of increment on future trees of the best quality)
- strong reduction of costs related to tending young stands in the first 1/3 of the rotation period
- profitable thinnings (removing thick trees competitive to the future trees throughout the second 1/3 of the rotation period)
- strong reduction of costs of forest regeneration through regulation of the onset and full use of the natural regeneration (both beech and admixed species to assure natural forest composition; but also possibility for introduction of commercially attractive species – e.g. Douglas fir – by planting, to increase the future commercial effect)
- implementation of ecological insight and working methods in the forestry practice.

4.5.3 Beech forest communities, forest typology

In the Land B-W, beech grows in the planar, colline, submontane, montane and subalpine zones, on very different sites, except of gley and very dry soils. Soil pH may vary broadly, with optimum on soils well supplied with calcium. In submontane zone the admixed tree species may be oaks, ash, elms and the lime tree. Under optimum conditions beech can form pure stands of very high vitality. But typical of the B-W situation (and especially that of the Black Forest) is the mixture of beech and European silver fir. Together they form valuable stands of high diversity and productivity. Norway spruce and sycamore accompany beech in the higher altitudes. On its highest foreposts in the subalpine zone beech changes its growth form from a monocormonal tree to a polycormonal shrubby growth.

Within this broad area with variable site conditions beech forests form a range of forest communities more or less (due to the impact of management) corresponding today with the types of the potential natural vegetation. Summarized, they can be divided into four groups (Ellenberg, 1978):

- acidic beech forests with moder humus form (Luzulo-Fagion)
- mesic beech forests with moder/mull humus form (Galio-odorati-Fagion/Asperulo-Fagion)
- rather dry beech forests on mesic to rich sites, mostly steep slopes (Cephalantero-Fagion; rich in sedges)
- subalpine beech forests (Aceri-Fagion; rich in ferns, Cicerbita alpina, Adenostyles alliariae and other nitrophilous species).

The forest site mapping system of B-W distinguishes, within the regional division, the following main beech and mixed beech forest types (Forstliche Standortskartierung, 1997):

- planar oak-beech forests
- colline beech and beech-oak forests
- submontane beech-oak forests, evt. with admixed silver fir
- submontane beech forests with oak and/or (locally) silver fir, Norway spruce and Scots pine
- paenemontane beech-silver fir forests in the lower montane zone
- montane beech forests with oak
- montane silver fir-Norway spruce-Scots pine forests with admixed beech.

The site classification and forest typology system provide the basis for the differentiation of beech forest management throughout the whole Land B-W.

4.5.4 Beech forest functions; management concepts and aims

With the exception of specific sites, public forests in B-W have been managed as multifunctiional forests fulfilling simultaneously, economic, ecological and social functions. This concept has been realized in the framework of the close-to-nature forestry (Naturgemasse Waldwirtschaft) as fixed in the Forest Act of the Land B-W (Landeswaldgesetz B-W, 1995) and applied in the planning procedure and forest inventories.

Since the 1960s to 1990s the leading principle of the forestry planning was the management target type – a specified objective expressed in tenths of the tree species representation in forest composition at the end of the rotation period, derived from forest site conditions, related type of the potential natural vegetation and economic considerations (Von Teuffel & Krebs, 1999). This rather inflexible planning system appeared to form a serious obstacle in the last time, when radical changes started, putting their stamp upon the B-W forestry. The change in beech forest management – emphasis on high timber quality, decrease of costs and implementation of ecological working methods into forestry practice – contributed strongly to developing new methods of forestry planning in the 1980s and 1990s. Recently, the new planning method acquires its more or less definitive shape, supported by developments in the whole country (Arbeitskreis Zustanderfassung und Planung, 1997). The main feature of the new planning approach is the introduction of the term "Waldentwicklungstyp – forest development type," which has replaced the former management target type (Palmer, 1995;Von Teuffel, 1999; Von Teuffel & Krebs, 1999; Bundesministerium 1999; Landesforstverwaltung B-W, 1999).

The term “forest development type” goes back to the 1950s; it was introduced by Aichinger (1952a, b) in his plant sociological studies in man-made forests in Austria. In its contemporary context as elaborated in B-W, the term attains a practical importance as a central instrument in the forestry planning.

Forest development types (FDT) involve forest stands of a similar present state and similar future target to be aimed at, and to be realized by similar management measures. Particular FDTs describe the most appropriate management methods and techniques to be applied to achieve the target forest type with regard to the multifunctionality of the forest (production, nature conservation and recreation function). With this term a dynamic principle has been introduced in the forestry planning and management. The method fits fully to the earlier developed concept and aims of forest beech management. Nowadays, the concept attaines its definitive content and form (Wilhelm, Letter & Eder, 1999; Von Teuffel, 1999; Landesforstverwaltung B-W, 1999) and becomes operational not only in the Land B-W but in whole Germany (Bundesministerium, 1999; Perpeet, 2000).

4.5.5 Forest reserves programmes

Land B-W is one of the leading countries in the European Forest Reserves Programme. The idea goes here back to 1911 when the first “Bannwald” – forest reserve was established. In 1970 the State Forest Service took this issue over in its own working programme. A new concept of the forest reserves programme has been set out (Bucking, Aldinger & Muhlhauser, 1930). In the new concept protection of rare forest communities, biotope and species protection, and conservation of historical forest management forms have been integrated. A research and monitoring programme has been set up. According to the planning, 2 % of the forest area of the Land B-W (some 26,000 ha) should be set aside from the regular management and left to natural development without any management intervention. The reserves are spread over the whole country and represent the most important forest types. Research and monitoring reveal valuable reference to the ongoing forest management methods and information on natural forest dynamics under various conditions.

4.5.6 Summary

The concept of FDT-forest development type meets different demands on and complies with requirements of modern forestry: it is an adaptive, site and state of the forest respecting approach; close-to-nature, working with minimum intervention and giving maximum room to natural processes; it avoids extensive clearings and works on small scale in support of both species, spatial and temporal diversity; it attains high quality timber production at low costs.

The beech forest management as introduced by Altherr (1971) has been adapted and fully incorporated into the FDT planning and management system (Landesforstverwaltung B-W, 1999). For particular FDTs (including those of beech) the management systematics and operational rules have been described in the abovementioned document. Further application in the field goes on via the directives for forest inventory and planning (Bundesministerium, 1999).

The alternative method of beech management by Altherr (1971) has been an issue of continuous research and monitoring, resulting in new growth models (e.g. Kladtke, 1997; 2000a, b). The research reveals, that a decrease of some 5-10 % of the total volume production has to be reckoned with due to strong interventions in standing stock in the second third of the rotation period. However, this decrease in volume has been fully compensated by the high financial return from the high quality timber production.

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4.6 Case study: Karlsbad

Interviewer:	J. Fanta
Interviewed persons:	Mr. Schafer, Director, Forstamt Karlsbad Mr. Hauck, Director, LFV Baden-Wurttemberg, Dienst Forsteinrichtung, Karlsruhe/Freiburg
Date and place of the interview:	September 15, 2000, Karlsbad

4.6.1 Description of the area

Forest district Karlsbad is situated in the contact zone of the Upper Rhine Lowland (to the W), the hilly landscape of the Neckarland (E) and the northern foothills of the Northern Black Forest (S). The latter part of the district – the headlands of the Northern Black Forest – has been chosen as the case study area.

The geological parent materials are varied sandstones covered with loess deposits, rather rich in nutrients. The hilly landscape has a general N and NW exposition, with altitudes between 350 and 500 m asl. The climate is mild, with atlantic/subatlantic features, influenced by the warm Upper Rhine Lowland. The average yearly temperatures fluctuate around 8^{o} C and yearly precipitation is between 800 and 1,000 mm (Bartsch, 1940). The soils of the area vary greatly, among others due to the thickness of the loess cover. Most of them can be arranged to the group of brown and/or podzolized brown soils with pH varying between 4,0 and 5,5. The most forthcoming forest communities belong to:

- the alliance Luzulo-Fagetum on dryer and more acid sites
- the alliance Galio-odorati-Fagetum on mesic and moist sites

Characteristic of the area are mixed forests of beech and silver fir. Naturally admixed species in beech forests are also the sycamore and ash. In the long course of forest culture Norway spruce and Scots pine were introduced in both monocultures and admixed, and larch, oak and Douglas fir as admixed species to beech to enhance the economic profit. In most cases, these species have replaced the native silver fir which, in the last century, strongly suffered from insect plagues (*Dreyfusia*) and deer browsing in the stage of natural regeneration.

4.6.2 History of the mixed beech forest management in the area

In the southern part of the Black Forest, in the past beech was the most important commercial species. Contrary, in the Northern Black Forest forestry focused on the admixed and especially coniferous species. The reason was a well-established timber trade with Holland, using the Rhine as the transport route (floating). For centuries, the best silver fir timber in the form of whole stem logs was used as masts in the Dutch ship-building industry (Hollandertannen, Hollanderhiebe – cf. Jagerschmid, 1800, in Bartsch, 1940). Forestry activities concerning beech were limited until 1970: beech was grown to produce fuelwood for local use in a rotation of 80 years.

In the last decades, under the influence of the new economic situation, the approach to beech and beech forestry in the area has changed. The main reasons were economic in the first place: the change in focus from fuelwood to high quality timber production appeared to be feasible and promised an attractive income to the forest entreprise. This was necessary due to a rather precarious financial situation in the forestry sector. More over, it appeared that the whole beech management system in the district can be extensified, adapted to the idea “low costs – high return” which, since the 1980s, has been developed by the B-W State Forest Service. A very favourable feature of the new approach has been the fact that it has fit very well into and has accomodated rather easily the ecological aspects of the modern forestry: enhancing the ecological stability of the forests, their biodiversity (species, age, structure), restoration of the natural species composition and forest development processes (cf. Altherr, 1971). The contemporary manaagement in mixed forests of beech and coniferous tree species (silver fir, Norway spruce, Douglas fir, but also larch and Scots pine) has been fully adopted to the new approach as developed by the B-W State Forest Service (cf. Von Teuffel & Krebs, 1999; Von Teuffel, 1999; Wilhelm, Letter & Eder, 1999; BMF, 1999). The leading idea of the new approach is the forest development type.

4.6.3 Contemporary management of mixed forests of beech and conifers

Following the FDT scheme, the main FDT in the district is the mixed forest of beech and coniferous species (silver fir, Norway spruce, Douglas fir, Scots pine, larch). The share of both beech and conifers in the tree species composition may vary in broad limits (beech 40-80 %; conifers 20-50 %; remaining broadleaves 0-20 %. Assuming the state and composition of the present forest stands, the focus of the management has been set up on three goals:

2) optimal use of quality increment in both beech and conifers to achieve the final BHD dimension at least 60 cm
3) maintaining forest communities in their natural or close-to-natural state with their site-typical flora and fauna
4) making sure the presentation of mixed and especially shade-intolerant tree species.

The development of the tree species composition in the area and its long-term target are shown in Table 1. In the management unit the main FDT mixed forest of beech and conifers has been divided into three local subtypes (Table 2).

Table 1. Tree species composition development (%) in Forest district Karlsbad (Exkursionsfuhrer, 1999)

Year	Norway spruce	Silver fir	Douglas fir	Scots pine	Larch	Total conifers	Beech	Oaks	Other broadl.	Total broadl.
1987	20	18	7	19	6	70	27	2	1	30
1997	16	16	9	14	7	62	30	4	4	38
long-term	18	17	15	3	5	58	35	3	4	42

Table 2. FDT subtypes, development their share (Exkursionsfuhrer, 1999)

FDT mixed beech-conifers forest	Type of forest stands	% 1987	% 1997	% long-term target
A	Conifers-rich mixed forests (silver fir, Douglas fir, Norway spruce, Scots pine, beech); submontane zone; maintaining via nat. regeneration	53	53	57
B	Beech-rich mixed forests (with Scots pine, Norway spruce, larch, silver fir, Douglas fir, sycamore, oak); colline and submontane zone; maintaining via nat. regeneration	20	37	38

C	Man-made mixed forests (Scots pine, broadleaves); to be reduced and conversed into mixed forests ad A and/or B via thinning and/or natural regeneration	27	10	5

4.6.3 The tending scheme

Tending young stands, mostly forthcoming from natural regeneration, has been strongly reduced and extensified. Huge numbers of sapplings and young trees always offer the opportunity to utilize natural selection to achiev quality growth. Only "forerunners" of bad quality must be removed and the desirable share of admixed species secured by thinning. In both cases ringing the trees proved to be better than removing – the latter intervention creates gaps with following crooked growth of neighbouring individuals. The canopy of young stands must remain closed. In the B-W management system the first third of the anticipated rotation period (until ca. 40 years age) is called "the phase of qualification." In this phase, the focus is on natural selection of young trees of the highest quality and admixed species. With this approach the costs of tending young stands has been reduced by 50 %.

Regular thinnings start at the time when the quality trees develop branch-free stems the length of which would be at least 25 % (-30 %) of the anticipated final length of the future trees.The following second third of the anticipated rotation is called "the phase of developing dimension." At the beginning of this phase the future trees would be chosen. In the Karlsbad area beech and valuable admixed species have the highest vitality and growth expectations. That's why only 60 future trees/ha can be seen as optimum number to achieve maximum quality timber production. The interventions are concentrated to the surroundings of the future trees, the area in between remains untouched and in full canopy to prevent early regeneration. The interval between interventions would be 4-10 years. The maximum volume allowed to be removed in one intervention is 80 m^3. Admixed species are preferred and released within this procedure; only thick trees of lesser quality would be removed with, as a result, positive effects for the income and the genetic quality of the stands.

The last third of the rotation period is devoted to maximum *volume development and natural regeneration* ("the phase of ripening"). *The volume building* in particular future trees of all tree species has a concentrated attention because of its economic importance:

- a too late felling can lead to a loss of value (esp. red heart)
- a too early felling would mean that the growth potential of the selected trees would not be used.

In beech, these two aspects play a very important role. The differences in price of particular assortments are very high and can be strongly influenced by the applied management measures. In the Karlsbad area the following criteria of quality must be takem into consideration (Exkursionsfuhrer, 1999):

- branch-free length of the stem
- DBH dimension
- red heart
- splitting the stem
- felling damage

The length of the branch-free stem: depends on the closed canopy in young stands ("Qualification") and selection of the future trees. Prunning in beech has not been applied until now; its effects are not known.

DBH dimension: achieving maximum DBH increment on future trees is the target in "the phases of dimension and volume building". In the Karlsbad area DBH of 70-75 cm in beech can be achieved. Hence, during the last ten years of the rotation period a shift in value of timber production can be realized representing 300 % of the regular price.

Red heart: comes in "the phase of ripening and volume building." It can stride along both bottom-up and top-down. Recently the latter case is more frequent than the first. The main cause undoubtedly are forks and dead thick branches. Trees with these features must be removed first to avoid devaluation of quality.

Splitting the stem when cutting trees: is another source of devaluation. In most cases a fork is the cause of splitting of the upper part of the log.

Damage on stem of cut trees: comes on slopes and stony sites. Experienced woodcutters are a "conditio sine qua non". Another remedy is adaptation of the planning to the specific local conditions.

4.6.4 Natural regeneration

Due to good soils and high precipitation the natural regeneration of most trees in the Karlsbad area can be taken for granted. Especially the (semi)shade-tolerant species profit strongly from the above described small-scale shelterwood system (Femelschlag). Nowadays, after 20 years of the application of the above management system, natural regeneration covers 80 % of forest regeneration and represents a good deal of the biological automation, with substancially decreased costs. Nevertheless, several conflicts are hidden in this rather favourable situation:

- the longer the shelterwood period, the more favourable conditions for the shade-tolerant species; shade intolerant species become rare in the natural regeneration; Norway spruce, too, cannot stand shading for a long time and losses the ground against beech, silver fir and Douglas fir
- beech profits most; the small-scale shelterwood system creates the most favourable conditions for natural regeneration of beech; another beech supporting phenomenon is the low brosing damage by deer
- due to deer browsing, silver fir loses its share compared to beech (local browsing monitoring: beech 2 %; silver fir 35 %)
- prolonged sheltering, evt. with fully released individuals can bring a considerable financial effects, but results sometimes in a felling damage on the understorey; laying-out a network of extraction paths (distance of 40 m) is applied to diminish the damage; on the other hand, the local experience confirms that the felling damage can be repaired by planting conifers, esp. the Douglas fir, even in beech thickets of 3-4 m high; in pure beech thickets this is a welcome opportunity to modify the tree species composition.

4.6.5 Conclusion

The introduction of the small-scale shelterwood system (Femelschlag) in the Karlsbad area 20 years ago proved to be a successful step. The management system has been further adapted to modern ideas, applying contemporary research results, esp. the concept of the forest development type. The economic demands of forest production are not in contradiction to the ecological conditions. The former large-scale shelterwood system produced uniform forests with a low diversity. Contrary, the small-scale shelterwood system has introduced more biodiversity at both forest and landscape level, with strongly structured forests. Due to the fact that Karlsbad is a recreation resort, forest aesthetics is a welcome supplementary feature of the forest management system.

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4.7 Country report: Czech Republic

4.7.1 General description

The total forest area of the Czech Republic is 2,632.000 ha (1997). This represents 33,4 % of the area of the country. The whole country makes part of the Central-European beech-oak forest district (Rubner & Reinhold, 1953; Polunin & Walters, 1985), characteristic of a rich variety of growing conditions and mixed, mostly broadleaved forests. During the medieval forest exploitation and following 300 years of commercial forestry activities the original tree species composition of forests has been fully changed in favour of conifers, esp. Norway spruce and/or Scots pine on less favourable sites (Table 1).

Table 1. Tree species composition of Czech forests: reconstructed “natural”, current and recommended (Vašícek, 1997)

Forest composition	Norway spruce	Silver fir	Scots pine	Other conifers	Total conifers	Oaks	Beech	Other broadl.	Total broadl.
Reconstructed natural	11,4	18,0	5,4	-	34,4	17,2	37,9	10,5	65,6
Current	55,2	0,9	18,0	3,9	78,0	6,3	5,8	9,9	22,0
Recommended*)	36,5	4,4	16,8	6,7	64,4	9,0	18,0	8,6	35,6

*) species composition as recommended by Ministry of Agriculture; time horizon not given

Apart from the reliability of the “reconstructed natural” forest composition (cf. Neuhauslová et al., 1998), the figures clearly show the distorted relation among the species which, evidently, will not be fully corrected in the near future.

4.7.2 Historical background

Already before the organized forestry came to its existence, beech was strongly reduced in Czech forests. This was caused by an extensive Medieval exploitation of forests in behalf of ore mining, metal processing, glass furnaces and local fuelwood supply. Since its very beginning the forestry was not concerned in beech at all; under the strong influence of the German forestry school (e. g. Hartig, 1791) beech forests had been managed in a regular large-scale shelterwood system applying 3, 4 or 5 phases procedure. An acute shortage on wood for arising industry and timber as construction material in the 1800s was the main reason to introduce, on large scale, growing monocultures of coniferous tree species. In this period the Czech forestry fully accepted the economic principles of the German forestry school based on the soil-rent theory and the Normalwald model (Hartig, 1791, 1808; Hundeshagen 1828). During the 1800s beech had further lost the ground; remaining beech forests had been mostly converted into Norway spruce monocultures. The situation changed somewhat at the end of the 1800s and in the beginning of the 1900s under the influence of Gayers school, putting accent on mixed forests (Gayer, 1886).

In the 1930s Czech forestry achieved several important impulses. Arising ecological ideas and their application to forestry were introduced by Konšel (1931). Also Cajanders ideas on forest typology (Cajander, 1926) made their introduction. Further on, disastreus impact of an extensive nun-moth plague (*Lymantria monacha*) in man-made Norway spruce forests in the 1930s draw attention to the necessity of change in the forestry approach. After the WW II this need was strengthened: during the whole 1950s the man-made Norway spruce forests suffered heavilly under a barkbeetle plague (*Ips typographus*).

As a reaction to the above situation, in the 1950s the Czech forestry sector developed a strategy of conversion of coniferous monocultures into mixed forests principally based on a small-scale shelterwood system (the Czech forest ecological school - Konias, 1951; Polanský, 1956; Fanta, 1999). In this strategy beech played a prominent role as an ecologically stabilizing element. Unfortunately, in the 1960s, this school was broken down by the totalitarian regime, which turned the Czech forestry back to coniferous monocultures and large-scale clearcuts. Through an unlimited environmental pollution during the 1960s until 1990s this system turned into a real disaster: it resulted in full destabilisation of forests, extremely high casual fellings and in an extensive forest dieback of mountain forests in the northern part of the country (Moldan, 1990; Kubíková, 1991; Cerný & Paces, 1995). Nowadays, steps are taken to revitalize the approach developed in the 1950s, to adapt it to the new situation and to orient it fully towards rehabilitation of the degraded forests into self-sustaining ecosystems (Míchal et al., 1992; Fanta, 1997). In this process, again, beech will play the most prominent role.

4.7.3 Beech forest communities; forest typology

In the Czech Republic, beech occurred originally in the submontane, montane and subalpine zones in elevations between 300-1300 m asl. (figure 1 and 2).

Figure 1. Distribution of herb-rich beech and silver fir woodlands and calcareous beech woodlands, based on the map of potential natural vegetation of the Czech Republic (Nauhauslová et al. 1998).

Figure 2. Distribution of acidophilus beech and silver fir woodlands, based on the map of potential natural vegetation of the Czech Republic (Nauhauslová et al. 1998).

On a broad range of sites a great number of forest communities has been identified which, according to the map of the potential natural vegetation, can be embodied in three greater groups (Neuhauslová et al., 1998):

- Eu-Fagenion: rich beech woodlands on mesotrophic sites in submontane and montane zones (the most important community Dentario-eneaphylli-Fagetum)
- Cephalantero-Fagenion: calcicole beech woodlands on eutrophic, bases-rich sites, esp. in the submontane zone
- Luzulo-Fagion: acidophilous beech and silver fir woodlands on acid, mineral poore soils in the submontane and montane zones (most often occuring community Luzulo-Fagetum).

The Czech system of forest typology (Plíva, 1991) distinguishes a range of forest types with beech:

- forests with beech as dominant species on optimal sites in the lower montane zone
- beech forests with admixed oaks on submontane sites
- mixed beech-Norway spruce forests in the higher montane zone.

Mixed beech-silver fir forests have been distinguished as a forest type unit but have a very small representation in the reality. On its highest foreposts in the subalpine zone beech, growing as a polycormon, comes in contact with the shrubby growth of the mountain dwarf pine (*Pinus mugo*; Fanta, 1981).

4.7.4 Beech forest functions; management concepts and aims

With the exception of protected forests, most beech forests have a production function or have been managed as multifunctional forests with preference for timber production (Lesprojekt, 1983). Beech forests on extreme sites (e. g. dry calcareous, steep slopes; high mountainous) have been proclaimed nature reserves with nature and/or soil protection function, or make part of national parks and/or protected landscape areas. From the total area of 153.000 ha of beech forests in the country more than 115.000 ha fall under one or another category of conservation or protection. In the case of protected landscape areas, management of beech forests has been regulated by the Nature and Landscape Protection Act (1992) and the ecological and protective functions of beech forests prevail above timber production. Due to a rather unsatisfying level of conceptual co-ordination this situation often forms an issue of dispute among the forestry and nature conservation bodies (e. g. Míchal, 2000).

Within the "forestry approach" beech has not attained specific attention in the last decades. Increasing its share to some extent, together with other broadleaves, is anticipated in the framework of the Czech forestry policy (Anonymus, 1996). Details, however, have not been given.

The practice of forest management follows in general the directives and recommendations linked up with forest typology (Ministerstvo zemedelství, 1997). Within this approach, clearcuttings until 1 ha, large and small-scale shelterwood and selection practic es are allowed to achieve the management target types expressed in % of the tree species representation in particular situations. Intensive tending of young stands aims at achieving quality, by removing "forerunners" and trees with a fork or broom stem form. Also the desired admixed tree species can be best supported in this development stage (Polanský, 1956; Indruch, 1985). The target of thinnings is to achieve the highest possible stem quality of all trees in the upper level of stands, both beech and admixed species. On mesic sites in the age of 60-70 years the number of trees in the upper level can be as high as 400 pcs/ha, grown in closed canopy and with understory without openings. Further tending in matured stands aims at regular development of the crowns of the very best trees and stimulation of the DBH increment to achieve the desired dimensions. Within this approach, natural regeneration can be taken for granted, especially when the large-scale shelterwood system has been applied (Indruch, 1985). By applying a small-scale approach, however, the desired representation of valuable admixed broadleaves (oaks, ash, lime tree, elms, sycamore, wild cherry) can be better assured during the natural regeneration. Also the risk of failure of natural regeneration is limited and controle over development can be beter realized in a small-scale shelterwood system (Polanský, 1956).

The Czech forestry policy has formally accepted the biodiversity concept; its implementation in forest management, however, stagnates in the technical sphere, limited to terms of the target tree species composition. The implementation of the other aspects of the concept (i. e. age, pattern and structure) remains rather vague (cf. Zezula, 2000; Morávek, 2000). In these forestry programmes beech did not get specific attention yet. Planning and management follow the recommendations issued by the Ministry of Agriculture (Ministerstvo zemedelství, 1997).

4.7.5 Nature conservation and nature reserves programme

Czech Republic is the country where the European nature conservation made its first steps. In South Bohemia the first nature reserves in Europe were proclaimed: the Žofín and Boubín primaeval forests, established in 1838 and 1858, respectively. Both reserves, examples of the natural Herzynic mixed forests, exist until now. Since the very beginning, tree species composition, structure and regeneration of these forests have been investigated. In the Boubín primaeval forests first research the leading forester J. John established plots in 1847 to monitor this primaeval forest development (Fig. 3 - John, 1847 in Rehák, 1958, 1959; Pruša, 1985, 1990; and others). Later, this iniciative has given impulses to establish a broader network of nature reserves in old (semi)natural forests and to monitor their natural development. These research activities are going on until the present (Zlatník, 1959, 1968; Pruša, 1990; Vrška et al., 2001).

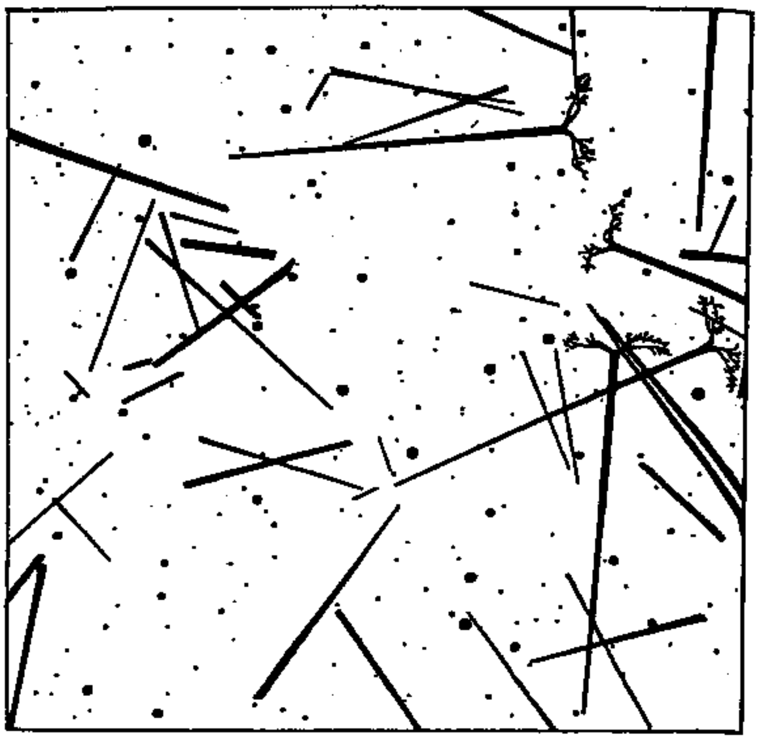

Figure 3. Boubín primaeval forest, plot nr. V established by J. John in 1847. Johns plots in Boubín represent the first attempt in Europe to monitor the development of a primaeval forest. Plot area 0,5754 ha (Prusa 1990).

Today, forests in nature reserves, national parks and protected landscape areas involve approximately 25 % of forest cover of the country. Due to the fact that these protected areas are situated mostly in hilly and mountainous areas, beech forests play there an extraordinary important role, supported by the Nature and

Landscape Protection Act (1992). As mentioned earlier, 75 % of all beech forests lay in these protected areas.

While the "forestry approach" puts emphasis on the technical execution of forest management, the "nature conservation approach" to beech and beech forests focusses on conceptual aspects in the first place. The concept of biodiversity – both species, age, pattern and structure – plays herein the most important role (Míchal & Petrícek, 1999). Within this concept, the technical approach is seen as an instrument to achieve the target, not as a target itself. In the multifunctional conception, the ecological, protective and social (recreation) functions of beech forests and forestry in protected areas attain then more emphasis than timber production of the forests. As a result, restoration of a more or less natural species composition of beech forests in protected areas and their natural dynamics and structure come in the focus. The figures in Table 2 show the current and desired/expected representation of beech in protected forests; they come very close to figures concerning beech representation (current, reconstructed natural) in Table 1. Thus, the differences in approach to beech are clearly anchored in difference between the forestry and nature conservation policy. Management principles of protected beech forests based on the biodiversity concept, natural ecosystem dynamics and maximum use of natural processes have been formulated by Moravec & Míchal (1999). Their concept is a valuable contribution to the nature based beech forest management.

Table 2. Current and planned representation of beech in protected landscape areas and national parks according to conservation management plans (Machatová, 1997)

Category of protected areas	Total forest area – ha	Current representation of beech	Desired representation of beech acc. to conservation management plans
Protected landscape areas – 24 in total	550.930	8,5 %	34,2 %
National parks - 4 in total	98.060	4,7 %	24,5 %

Since the 1970s the remnants of natural (beech) forests in nature reserves have been subjected to research and monitoring to reveal scientific information about the natural dynamics of these forests (Míchal, 1983; Pruša, 1985; Vrška et al., 2001). Within this research programme, valuable information has been gathered which, among others, can be applied in both regular and restoration forest management. The Czech State Forest Service makes use of some nature reserves as demonstration objects for excursions (e. g. Lesy Ceské republiky, s. a.; Máša & Brezina, 1997).

4.7.6 Summary

Contrary to the situation today, beech will have an important position in the future Czech forestry and nature management. The most important aspects of its role are:

- enhancing forest stability (wind, storm, insect plagues, environmental stresses)
- increasing biological diversity of forests (species, age, pattern, structure, ecosystem processes)
- water and soil protection (esp. unstable soils in flysh areas)
- production of high quality timber
- sustainability of forests
- forest aesthetics and amenity

Due to its broad ecological amplitude and management flexibility, beech is a suitable tree species to be used to solve some very topical contemporary problems of the Czech forestry and nature conservation. It is the most important tree species whereupon the conversion of coniferous plantations into mixed forests will be buit up. Both biodiversity and quality timber production as well as sustainability of forests will benefit of its substantially higher representation in forests. Implementation of ecological management principles and methods, as elaborated by and applied in the nature management and conservation, into the regular forestry practice is a task of utmost importance.

4.7.7 References

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4.8 Case study Masarykuv Les

Interviewer:	J. Fanta
Interviewed person:	Ing. J. Truhlár, Manager Training Forest Enterprise Masarykuv Les, MUAF-Forestry Faculty, Brno
Date and place of the interview:	July 19, 2000, Krtiny

4.8.1 Description of the area

The Training Forest Enterprise Masarykuv Les (TFE) is situated in South Moravia, to the North of the city of Brno. It is a hilly area intersected by deep valleys of two rivers. Altitudes vary between 210 and 574 m asl. Mean annual temperatures in the area lay between 7,5-8,1^{o} C; mean annual precipitations vary between 528 and 685 mm. Prevailing parent materials are granodiorites (W part), limestones (C part – the Moravian Karst) and clayey slates and grawacks (E part of the area). Loess deposits are spread locally throughout the area.

Due to different parent materials and hydrological conditions, soil types vary greatly. Brown forest soils (cambisols) prevail (63 %); oligotrophic cambisols, luvisols and rendzinas cover the rest of the area. The area can be divided in four vegetation zones with different types of the potential natural vegetation:

- oak forests (5,4 %)
- beech-oak forests (27,1 %)
- oak-beech forests (51,5 %)
- beech forests (16,0 %)

The TFE covers 10,441 ha, of which some 2,600 ha are occupied by beech (Truhlár, 1997).

4.8.2 History of beech forest management in the area

Already in the Middleages beech had been cut in forests to produce charcoal, which was used in small iron furnaces established in the area. This simple exploitation went on through centuries. Still during the 1700s and 1800s beech forests were broadly used as source of fuelwood for ironworks and glas furnaces in the surroundings (charcoal and potassium production). Also the nearby city of Brno was a great fuelwood consumer. Already in the first half of the 1700s, however, problems arose due to overexploitation of forests. This situation led to working out the first forest management plan in 1841. A systematic withdrawal of beech from forests resulted in its underrepresentation; the grounds were gradually taken over by conifers: Norway spruce, Scots pine and European larch. Towards the end of the 1800s the economic situation in broader area changed considerably. The unprofitable small ironworks were closed, the great ones switched to hard coal as source of energy. At the end of the 1800s management of forests was converted into normal commercial business, fortunately not in the form of coniferous monocultures, but in the form of mixed forests of Norway spruce (50 %), beech (25 %), and Scots pine and larch (25 %). These forests had been managed in a large-scale shelterwood system. Natural regeneration and intensive thinnings had been applied and gave rise to stands dominated by Norway spruce with admixed tree species – both broadleaves (mostly beech) and conifers (Scots pine and larch). The change in the tree species composition in the course of the 1900s is given in Table 1 (Truhlár, 1997).

Since 1923 the area is in ownership of the Forestry Faculty, Mendel University of Agriculture and Forestry, Brno. It has been put in service as a training centre for education of forestry students and managed under suprvision of teachers of the Forestry Faculty. Due to this arrangement, the TFE has a long tradition of a consistent, decades-long forest management based on a small-scale shelterwood system as formulated at the moment of its establishment by J. Konšel, the first professor of silviculture (Konšel, 1929, 1931).

Table 1. Development of tree species composition in the 1900s (% representation)

Year	Norway spruce	Silver fir	Scots pine	Larch	Other conifers	Total conifers	Oaks	Beech+ hornbeam	Other broadl.	Total broadl.
1898	13,8	33,0	11,5	0,5	--	58,8	3,2	38,0	--	41,2
1927	26,9	14,5	14,2	3,4	--	59,0	9,5	28,2	3,2	41,0
1999	25,9	1,3	11,3	8,7	1,2	48,4	13,9	33,2	4,5	51,6
Target	23,9	0,2	9,9	10,0	1,7	46,3	19,9	27,8	6,2	53,7

With its share of some 25 % in the tree species composition, beech is one of the main species in the area. It can be expected that its importance will grow in the future with regard to the ecological instability of conifers during the ongoing climatic change. More over, beech is the core species of the natural forest composition in the Protected Landscape Area Blanský Les, which a considerable part of the TFE belongs to.

4.8.3 Principles and methods of beech forest management; management techniques

In the area two specific types of beech forest management have been applied for a long time:

A: Management of forests with beech as a dominant tree species

The management aims at maximum natural regeneration, stand quality and high volume increment during the release phase in the last part of the rotation period. All these aspects are related to and make use of the capacity of beech to react to conditions created by management interventions – even in a high age of trees and stands.

Intensive tending of young growth has been adopted to form the basis for a high stem quality of beech stands. Forerunners and overtoped trees, forks and broomy stem forms must be removed – i. e. mainly negative selection is applied during the first thinnings. In the following stage the tending method shifts to a combination of the negative and positive selection to support trees of high quality by removing competing trees of lesser quality. During the tending of middle-age stands heavy canopy disturbance and release is not allowed; the canopy must remain closed. According to Indruch (1985) this approach has the following positive features:

- it improves the stand microclimate and facilitates higher increment
- it is a condition for a long, branchless stem
- the subdominant trees can replace depreciated promising dominant trees
- the subdominant trees protect the soil from weeds during thinnings and stand maturation
- the subdominant trees protect the promising trees from barking loss
- the understorey generates an aesthetic impresion

The above-described thinning method is used until the stemwood stage. A systematic removing of trees of bad quality improves the overall quality of the stand and gradually leads to opening the canopy. Tending operations successively pass into release thinnings in the form of a full-area shelterwood felling and creating favourable conditions for natural regeneration.. To regulate the light access to soil surface, heavy and moderate interventions can alternate.

The rotation period in beech in the TFE is 130 years; the length of the regeneration period may be as long as 60 years. Seed mast years come in rather irregular intervals; during a long regeneration period all seed years, even the meagre ones, can be utilized for natural regeneration. Groups of the advanced growth are released by applying group shelterwood cuttings, when they reach the height of some 50 cm. A sudden release of the young growth must be avoided due to the danger of dryness, especially on dry calcareous sites.

To avoid later damage on young growth, a spatial organisation of stands must be applied by means of skidding lines. The regeneration proceeds from inside the stands to the margins. In difficult accessible terrains a cable system would be used to skid the logs; the cutting – regeneration procedure would then be arranged in strips (Saumschlag) down the slope.

Achieving quality increment on best trees is given specific attention. The precondition hereto is a deep, regular crown and a branchless, spindly stem developed during the stand tending period of some 70-80 years. A specific number of selected future trees are not given. Also the final DBH dimensions to aim at are not specified – will be different on particular sites in any case.

B: Management of mixed beech - larch stands

European larch is not a native tree species to the area. It has been introduced at the end of the 1700s; the introduction has been fully documented (Nožicka, 1962; Novotný, 1973). Nevertheless, due to its vigorous growth and excelent timber quality (the highest tree measured 48,5 m; standing stock in mixture with beech more than 800 m^3/ha) it is a very important commercial species. The timber is of excelent quality with old wood dark red in colour, with a narrow yellow sapwood. According to historical documentation the first imports originated partly from Jeseníky Mountains (a native, endemic provenance), partly from the Alps (Innsbruck, Austria). By merging of both provenances a valuable local ecotype has developed ("Adamov larch").

A small-scale shelterwood system offers good possibilities to combine the differing ecological properties of both species and unify them in a sound and sophisticated management system, which is very flexible in application.

In the "larch rotation" the management focusses on the commercially attractive larch in the upperstorey. In this period, the function of beech in the understorey is threefold:

- soil protection and amelioration
- supporting development of the highest stem quality in larch
- supressing development of weeds

In the prolonged “beech rotation” the focus shifts on beech crown development and stem quality, high increment on released trees and quality timber production.

Both species regenerate naturally and sufficiently in gaps and on stand margins. In most cases larch, as a shade intolerant species, may appear later than beech, but, due to its rapid growth, it quickly acquires the necessary leading position in the mixture, which it maintains during the whole rotation period. The share of both species in the mixture can vary broadly and can also be easily manipulated by tending the stands. Shading of the beech understorey by larch has a positive effect on beech stem quality, so that the shift in focus from larch to beech in the second part of the rotation can be realized smoothly and without breaks and/or specific measures.

4.8.4 Conclusion

The small-scale shelterwood management system in beech has been adopted at the Masarykuv Les at Krtiny continuously for 70 years. The management scheme is anchored in the age-classes forest structure and adapted to various site conditions. It follows the principle of multifunctionality, with emphasis on economic results. The management is very intensive, involving high investments in labour for tending (esp. young stands) to support future quality timber production. Red heart in old trees remains an issue of sorrow.

Aspects of nature conservation in the area have been highly respected. For a good deal the TFE makes part of the Protected Landscape Area Blanský Les. Nature reserves cover 820 ha, 7,7 % of the TFE area. These reserves remain intact as gene pool resource. Specific measures to support biodiversity have not been incorporated in the management scheme, except of valuable admixed tree species. Coarse wood debris, both standing and laying, remains in nature reserves, but not in managed stands. No specific research and/or monitoring has been performed in nature reserves to develop information on natural dynamics in protected semi-natural forests which, eventually, would be applied in local forest management.

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4.9 Case study Jizerskohorské buciny

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Administration of the Protected Landscape Area Jizerské hory Liberec
Date and place of the interview: July 27, 2000, Liberec

4.9.1 Description of the area

Jizerskohorské buciny is the largest complex of beech forests in the Czech Uplands. It is situated in the northernmost part of Bohemia, on the northern slopes of the Jizerské hory Mountains, facing the borderline between N-Bohemia and SW Poland. The complex (some 2,700 ha) makes part of the Protected Landscape Area Jizerské hory Mts. (366 km^2, altitudes 360-1,124 m asl., forest cover 73 %). The area is built from granite, with typical boulder outcomes on slopes and ridges (tors). The steep northern slope is cut by numerous ravines into locally hardly accessible parts. The climate is subcontinental, rather harsh, humide and cold. Average annual temperatures vary, with regard to the elevation, between 7,1-4,0^o C, annual precipitations between 900 and 1.705 mm. Soils are light, rather acid (pH less than 4,5), prone to erosion. The following main soil types, more or less related to the altitude, can be distinguished (Vonicka, 2000):

- brown forest soils
- podzolized brown forest soils
- podzols in the highest elevations
- peaty soils on flat ridges.

Since the 1970s the area, which makes part of the Black Triangle, has been cracked by heavy acid deposition caused by industrial emissions produced in power plants in the nearby Upper Lusatia, along the borderline of E-Germany and SW-Poland. As a result, some 11,000 ha of Norway spruce forests died off in the Czech part of the area and some 14,000 ha in Poland (Pelc, 1994; Paschalis & Zajaczkowski, 1994; Cerný & Paces, 1995). The elevations above 900 ma asl. were nearly fully deforested. In the last 20 years afforestation have been carried out on the extensive clearcuts, with various success, to restore declined forests in broader area. Next to the Norway spruce also exotic species as *Picea engelmanii* and *Pinus contorta* were used as planting stock by the State Forest Service. The situation has stabilized in the last decade when industrial pollution has decreased; conversion of exotic forest stands is on the way.

The complex of beech forests has been hit by the above ecological catastrophe as well, but contrary to Norway spruce forests, it has survived. With descreased emission of pollutants since the 1990s (today some 25-30 % of the top in the 1980s) the situation has stabilized and a revitalization programme could be started (Pelc, 1992, 1999; Pelc et al., 1994).

Three main types of beech forest communities can be distinguished in the area (Neuhauslová et al., 1998):

- Dentario-eneaphylli-Fagetum: mostly in lower altitudes and on richer sites
- Luzulo-Fagetum: on acid soils
- Calamagrostio-villosae-Fagetum: in higher altitudes and on very acid soils, heavilly affected by acid deposition.

4.9.2 History of beech forest management in the area

Parts of the area had been exploited since the 1300s (ironworks, glass furnaces, construction and fuelwood). In the 1700s and 1800s organized forestry introduced large-scale conversion of original mixed forests into

Norway spruce monocultures, mostly of non-indigenous provenances, managed in a large-scale clearcutting system. The northern slope of the mountains with its beech forests remained outside of this exploitation due to its relative inaccessibility. In the course of the first half of the 20th century these beech forests were managed in a rather traditional shelterwood system combined with clearcutting. Due to extremely difficult terrain conditions, all operations had to be carried out in handwork. Even the skidding of logs and fuelwood was a matter of man-power and sledge.

Silver fir and other admixed species did not get any attention in the past management; contrary, these species had often been removed from stands due to negative selection applied in thinnings. The result of this management are the present-day extensive homogenous, one-storey beech stands. Silver fir has eventually been proclaimed a red-list species in the broader area.

In 1960s two important events took place. First, the most inaccessible areas have been proclaimed nature reserves with a total acreage of 666 ha, to be left to natural processes. Second, a cabel system for skidding was introduced by the State Forest Service, enabling strip clearcutting of mature stands and regeneration by planting. This management was applied throughout the 1960s until 1980s. Last clearcuts date from 1992 and 1993.

Since the beginning of 1990s a new situation arose. Both foresters and nature conservationists became aware of the need of a close co-operation necessary to restore the heavilly destructed forests in broader area. In this framework the surviving beech forests form an invaluable source of potential information which, once revealed, can be used in the rehabilitation of declined forests. And it also is a valuable gene pool of indigenous material to produce planting stock for re-afforestation. In 1999 the whole complex of beech forests was proclaimed a protected area containing 950 ha strict reserves surrounded by a buffer zone of 1,750 ha.

4.9.3 Principles and methods of beech forest management; management techniques

For the whole beech forest complex a management plan has been worked out (Anonymus, 1994, 1996) and the main principles of the management have been formulated (Vacek, Podrázský & Pelc, 1996; Vacek, Soucek & Podrázský, 1999).

The main management target is enhancing ecological stability of beech forest ecosystems and supporting natural processes. Due to the impact of unproper forest management in the past and heavy acid depisition in the last decades, the development of forest ecosystems has been deregulated. Nowadays, various steps must be taken simultaneously and in due time to suppress the negative effects of the past and to support natural ecosystem functioning:

- stabilization and extension of the upper limit of the beech complex
- restoration of the natural species composition, especially in the higher elevations, where silver fir and Norway spruce have been eliminated by acid deposition
- stimulation of natural regeneration; some parts of the beech forest are already 250 years old and have no understorey due to lack of seed years, acid soils and a heavy grass encroachment
- by all means a sudden large-scale decay of old beech stands without regeneration must be prevented; where necessary, underplantings must take place using indigenous planting stock
- introduced exotic tree species (*Picea engelmanii*, *Pinus contorta*) and stands of native trees but of non-indigenous ecotypes (*Picea abies*) must be reduced and eventually converted
- to speed up the rehabilitation of the beech forest deer population must be curbed to reduce browsing damage to young growth and to speed up beech regeneration.

The forest and site conditions in the beech complex vary greatly. To specify management measures, forest stands in both the reserves and the buffer zone have been divided into four groups (Table 1). Within these groups management measures are adapted to local site conditions and potential risk factors.

Table 1. Groups of stands – forest management types (Anonymus, 1994, 1996)

Group	Nature reserves	Buffer zone
A - stands of natural composition, able to develop naturally, without intervention	13 %	4 %
B – stands with a close-to nature composition, limited intervention	71 %	38 %
C – stands which need intervention to achieve specific targets	11 %	33 %
D – stands with unappropriate species composition intended for conversion	5 %	25 %

4.9.4 Conclusion

The outlined policy and management procedures are the result of a good co-operation between the nature management and forestry bodies. On this basis maintaining and enlargement of this unique object has been made possible. This and a decrease of industrial emissions achieved in the last ten years enabled to start an effective forest restoration programme for the broader area. Within this programme, the beech forest complex has a threefold function:

- an example of how to approach the difficult issue of restoration and rehabilitation of an extensive area of degraded forests
- the beech complex is a regional centre of biological diversity
- the beech complex is a gene pool of indigenous species to be used in conversion and restoration of man-made forests in the whole Protected Landscape Area

The concept of biodiversity in all its aspects (i.e. species, age, pattern and structure) has been applied as the leading principle in forest management. Management interventions in the reserves are limited to inevitable cases to remove obstacles hindering natural processes. In the buffer zone the management has the character of a small-scale shelterwood system combined with selection and irregular small-strip interventions; the accents here lay more on natural regeneration, soil protection, species composition (both trees, flora and fauna), less on timber production. All dead wood remains in the reserves, both standing and laying on the ground. Outside the reserves and spread over the whole area standing old trees of all species have been left to die, to form a natural habitat for animals, birds, insects and fungi. This measure is not valid for declining Norway spruce stands and trees infected by the barkbeetle (*Ips typographus*). Experiments with ringing old beech trees, e. g. on behalf of the release of young growth, are on the way. Experimental plots have been established to monitor the effects of management measures and natural processes on stand development and regeneration.

Although the emission of industrial pollutants has substantially decreased in the past ten years, the acid deposition remains the highest risk to the beech forest management for future decades. Especially unexpected accidents in power plants combined with climatic fluctuations form a serious source of sorrows.

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4.10 Slovakia

4.10.1 General description

Among Central-European countries, Slovakia has the largest area of beech forests. Beech takes full 30 % in the tree species composition (Anonymus, 1997), what represents some 650.000 ha from the total forested area of 1,990.000 ha of the country. From these 650.000 ha some 430.000 ha are covered with pure beech stands. In the original (reconstructed) tree species composition of forests the share of beech was around 45 %. During its historical development in the last 100-150 years Slovak forestry fully accepted the principles of the age-classes forestry (the German forestry school and its soil-rent theory; Hartig, 1808; Hundeshagen, 1827), but has only moderately been affected by conversion of its native forests into coniferous monocultures (Tab. 1).

Table 1. Tree species composition of Slovak forests (% forested area – Anonymus, 1997)

Tree species	Original (reconstructed) tree species composition	1950	1980	1997
Conifers	23,6	42,8	42,5	42,5
of which Norway spruce	7,7	27,3	26,4	27,1
Broadleaves	76,4	57,2	57,5	57,5
of which beech	45,2	28,4	29,5	30,0

As a result today, 70-75 % of Slovak forests have a tree species composition corresponding with the original forests. Hierwith Slovakia has a very exceptional position among Central-European countries wherein, during the last 250 years of organized commercial forestry, the tree species composition of forests has largely been changed in favour of conifers.

4.10.2 Historical background

In the surroundings of mining sites forests had been exploited since the Middleages, especially for charcoal production. The usual form of exploitation was clearfelling. Thereafter, the cleared areas had been left to nature. Distant areas and steep mountain slopes remained unexploited and unmanaged until the end of the 1800s.

Since the beginning of the 1900s a systematical forest management has been introduced, based on forest management plans. Large-scale clearcuttings have been abandonned and replaced by a shelterwood management system, both large and small-scale (Schirmschlag, Femelschlag, Saumschlag) between 1920s – 1960s, making use of natural regeneration. Large scale conversions into coniferous monocultures were applied only exceptionally. A short period of applying heavy Scandinavian machinery for increased forest exploitation between 1980 and 1990 finished without success due to extensive damage to natural regeneration. Since the 1990s the prevailing method of beech forest management is a small-scale shelterwood system (Femelschlag), applied on approximately 60 % of the forested area. Application of the selection system (Plenterung) is planned to be applied on some 17 % of the forested area, while the clearcutting, today adopted on 39 % of the area will be dimished to some 23 %. According to the forest law, maximum clearcut allowed is 1 ha.

Due to the application of small-scale management methods, natural regeneration (today 70-80 %) can be taken for granted. Herewith, principles of the close-to-nature forestry are being introduced. Also main aspects of biodiversity are assured due to the more or less natural tree species composition of beech forests. With regard to the above management approach the share of beech in the tree species composition of Slovak forests remains stable (see Table 1).

4.10.3 Beech forest communities; system of forest typology

In a hilly and montainous country (the highest elevation 2.666 m) with a high variety of site conditions, beech occupies an extensive area in elevations between 300 and (more than) 1.300 m, on various geological substrates with different hydrological regimes and soil chemical properties. The West Carpathians are an area of natural climax beech forests (Klika, 1938). Beech grows in both mixture with other tree species (oaks, Scots pine, lime tree, ash in lower altitudes; silver fir in the lower montane zone; Norway spruce and sycamore in higher montane zone) and in pure beech forests in its optimum in middle elevations between (400)-500 – 900-(1.000) m asl.. In this extensive area beech forms and takes part in a broad range of forest communities. The following beech dominated forest communities as the major types of the potential natural vegetation have been distinguished (Michalko et al., 1986):

- Beech forests on calcareous bedrocks (Cephalantero-Fagenion Tx. 1955)
- Submontane beech, and montane beech and silver fir species rich forests (Eu-Fagenion Oberd. 1957)
- Acidic submontane and montane beech forests (Luzulo-Fagenion Lohm. et Tx. 1954)
- Sycamore-beech mountain forests (Aceri-Fagetum Ellenberg 1963)

The Slovak system of forest typology (Zlatník, 1959) is based on altitudinal vegetation zonation and divided in a large number of types united in forest types groups (Zlatník, 1959; Hancinský, 1977). Table 2 shows the most important groups of forest types which cover more than 5 % of the forested area of the country.

Table 2. Main groups of beech forest types and their representation in the total forested area (Voško, Bublinec & Kubica, 1988)

Forest type group	% forested area
Fagetum pauper (Fp)	18,25
Fageto-Quercetum (Fq+ac+de)	15,93
Abieto-Fagetum (AF)	11,50
Fageto-Abietum (FA)	9,20
Querceto-Fagetum QF+til+de)	8,40
Fagetum abietiono-piceosum (Fap)	5,50

4.10.4 Beech forest functions; management concepts and aims

With the exception of the extreme high mountains or dry calcareous sites, nature reserves and other protected areas, Slovak beech forests have fulfilled, in the first place, the timber production function or have been managed as multifunctional forests whereby timber production played the most important role. Within the scheme of the age-classes forestry various aspects of sylvicultural technics – thinnings, growth, regeneration, etc. have got attention in both forest research and practice in the last decades (e.g. Štefancík, 1976, 1994; Šebík, 1983; Saniga, 1983, 1985, 1994; Ronay, 1985; Kamenský, 1994). This approach was also stressed by organizing the 3rd IUFRO Beech Symposium in Slovakia in 1988 (Korpel & Paule, 1988). The general scheme of beech stands tending is as follows:

- intensive thinnings until 40 years: negative selection in the highest layer; intervention in the lower layer of trees in this age to be omitted; intensity of first thinnings irregular (thinnings in strokes alternating with strokes without intervention); valuable admixed tree species to be supported
- selection of the best future trees in the age of 40 years (200 pcs/ha)
- less intensive thinnings between 40 – 90 years
- the length of the regeneration period 20-30 years: average final stand age 110 years; regeneration between 90 – 110 – 120 years
- three phases shelterwood system: preparation cutting – regeneration cutting – release cutting (1-2x); clearing remaining trees
- target DBH: 45 cm.

The main reason for the rather short rotation period of 110 years is the development of red heart in beech in the age of around 100 years, and its strong increase in higher age with, as a result, a considerable financial drawback. There are two possibilities how to counteract this phenomenon (Saniga, 1998):

- shortening the rotation period from 110 to 100 years (main disadvantage: disturbing balance in the age classes structure with serious management consequences)
- intensification of thinnings in the age of 70-90 years (main advantages: removing potentially affected thick trees of lesser quality; supporting regular crown development in potentially not affected future trees of the highest quality).

Next to the red heart the beech forest management knows only few specific risks. In the course of climatic change the ecological and economic risks merge. The “T-disease” (trachaeomycosis) manifested as drying up of the upper part of crowns in old trees can be expected to become a serious problem in later stages of development. A lower risk can be expected in smale-scale forms of the shelterwood system than in the large-scale ones. A pending natural risk form wind and storm damage in forest types Fagetum typicum and Fagetum pauper. These types develop on sites characteristic of a shallow root system in beech. Especially in long rainy periods the storm damage can be a serious problem in both beech and admixed tree species. The function of beech and beech forests within the Slovak forestry sector is twofold:

- ecological: beech is ecpected to be a stable element with regard to the climatic change; with its broad ecological amplitude and flexible adaptation to various site conditions, beech forests are supposed to form a stable framework to the national forestry sector
- economic: the timber processing industry is fully adapted to the primary production wherein the beech plays the most important role (e.g. the pulp production depends in 60-70 % on beech; it is expected that this share will grow in the future).

4.10.5 Nature conservation and nature reserves programme

The tradition of nature conservation in Slovakia goes back to the beginning of the 1900s. It was especially the existence of extensive primaeval forests which took attention of the nature conservation bodies. First nature reserves involving examples and remnants of primaeval forests have been established already before the WW1 – e.g. the National Nature Reserves Badín and Dobroc, both established in 1913. In the 1960s and 1970s, according to the proposal of Zlatník (1968), the number of nature reserves involving remnants of primaeval and examples of the most important native forests was enlarged and completed to form an extensive nature reserves network. Beech and mixed beech forests form an important part of it. The surface of particular reserves varies between several tens to several hundreds of hectares. In the same time the scientific significance of these reserves for studies on forest development was recognized and systematic inventories were started (Zlatník, 1970). This task has been further developed by the Forestry Faculty, Zvolen (Korpel and fellow workers of his school) into a specific scientific programme (e.g. Korpel, 1958,1971,1989,1995). The results of this programme have been continuously applied in forestry education and practice (Korpel et al., 1991). Nowadays, this programme is continued by Saniga (e.g. Saniga, 1999a, 1999b).

This programme is a good example of a usefull co-operation among forestry and nature conservation bodies. The present policy of fully separated forestry (Ministry of Agriculture) and nature conservation activities (Ministry of Environment) with a low level of co-operation and/or even opposition in matters concerning forest management outside nature reserves cannot by far be seen as a favourable situation. Harmonisation of concepts and close co-operation of both sectors also in forests outside nature reserves is an option for future development, esp. with regard to the expected negative effects of the climatic change and ongoing application of the concept of the close-to-nature forestry.

4.10.6 Summary

Introduction of the small-scale shelterwood management system (Femelschlag) opens the possibility for a broader application of the close-to-nature forestry principles in the Slovak forestry. Tree species composition of Slovak forests has not been deeply disturbed in the past and corresponds with the potential natural vegetation to a great deal. Structural diversity of forests has been diminished in the long period of applying management methods of the commercial forestry. Nevertheless, recent developments in the forestry sector ensure that the share of beech in the tree species composition of Slovak forests will not diminish.

Co-operation with nature conservation bodies yields good results in case of research and monitoring of nature reserves involving remnants of primaeval forests, but a further co-operation of both sectors in forest management outside the nature reserves is at a low level. The above research on Slovak primaeval forests with its long observation series is unique in Europe. It can be seen as a valuable source of information and an important contribution to the nature-based management of beech forests in Europe.

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4.11. Case study: Bohunice

Interviewer: Josef Fanta
Interviewed person: Ing. J. Farkaš, Assistant Director, Forest Entreprise Levice, Slovakia
Date and place of the interview: November 24, 2000, LS Bohunice, Slovakia

4.11.1 Description of the area

Forest District Bohunice is situated in Central SW Slovakia, on the south slopes of the Štiavnické vrchy/ Štiavnica Hills. The area is of volcanic origin and has a very miscellaneous geological parent material. With the highest altitude Sitno (1010 m asl.) the Štiavnica Hills can be seen as a representative part of the West-Carpathian hills to the south of the main Carpathian ridge. As to geomorphology, the area is not build up in steep ridges and deep valleys, but forms a rather extensive middle-mountain massif. The main part of the FD Bohunice lies in altitudes varying between 300-650-800 m asl. The climate is subcontinental/continental and rather mild; the main ridge of the West-Carpathians protects the area from the north, while it is open to the influence of the warm Pannonian lowlands from the south. Brown forest soils originated from andesite bedrock are rich in nutrients. This is positive as to production capacities of forest stands, but it involves risks in the form of wind and storm damage due to shallow rooting of trees.

Forests in FD Bohunice cover 7,741 ha (47 % of the area). In lower altitudes beech and oaks are the main tree species; ash, hornbeam, wild cherry and other broadleaves are admixed. Pure beech stands dominate on medium sites in higher altitudes. Locally, on suitable sites, the sessile oak and silver fir make a valuable admixture in beech forests. A broad range of forest communities is present, closely related to and/or representing the local types of the potential natural vegetation. In most cases, the species diversity of both tree, shrub and herbal layers is high and principally corresponding with the composition of the natural forest communities (Michalkoet al., 1986). Forest management in the past has turned down the diversity in pattern and vertical structure of forests: firstly by applying large-scale clearcutting, later through large-scale and uniform shelterwood management system, and by the introduction of the age-classes structure to forest manaagement and planning.

The representative groups of the local forest types are:

- mesotrophic oak-beech forests
- moist beech forests
- mesotrophic beech forests
- mesotrophic silver fir-beech forests

4.11.2 History of beech forest management in the area

The primaeval beech forests in the area were cleared during past centuries mostly for charcoal production in behalf of mining sites in Central Slovakia and for local purposes. Since 1920s clearcuttings were abandonned and replaced by a large-scale shelterwood management system. Planning and management based on the the age-classes structure was introduced, extensive forests divided into compartments; a network of forest roads was estaablished to improve access and to make exploitation and management of compartments possible. The shelterwood system was based on a 3-phases procedure (preparation, regeneration and release cutting) followed by clearing up the remaining trees. On mountain slopes this scheme and its maintaining was realized in downhill strokes enabling skidding of logs without great damage to natural regeneration. The compartment structure of the forest enabled cuttings to be realized simultaneously on many sites. With this organization of forest management both local site conditons and timber market demands could be served. A weak point of this rather stiff and spatially inflexible procedure is the wind and storm damage, which often disturbs the planning in both space and time. Extensive stands of the same age can rather easily be blown down due to their instability, especially on moist sites. Under such circumstances, when casual fellings exceed planned cuttings even several times, the management system can be fully disrupted. (E.g. in 1999 FD Bohunice was struck by a heavy storm with, as a result, 100.000 m^3 blown up timber. This volume represents nearly six years timber volume cut in regular planning – on average 16.800 m^3/year). High costs of clearing of the affected area and situation on the timber market play a role; also the whole sylvicultural planning has distorted and its goals cannot be achieved.

4.11.3 Principles and methods of beech forest management; management techniques

To diminish the above disadvantages and constraints, the management system has been adapted by 1992. The large-scale shelterwood system has gradually been abandonned and replaced by a small-scale one (Femelschlag, Saumschlag). With this important change in approach to the planning and field organisation, forest management aims at enhancing stability of forests in the first place, going out of the knowledge that spatially structured forests are more stable than extensive stands of the same age with a one-layer canopy structure.

To a large extent, the above management method can be realized, maintained and developed due to favourable conditions in natural regeneration. Recently, natural regeneration of beech covers 80 % of the whole regeneration need and planning. Remaining 20 % go to the costs of management deregulations caused by storm damage, mostly followed by development of grassy (e.g. *Luzula* ssp.) or herbal vegetation (*Senecio, Rubus, Chamaenerion angustifolium* and others). Under normal conditions natural regeneration in beech is exuberant and in mixed stands accompanied by seedlings of admixed species. Tending of stands during their development usually follows the following procedure (Korpel et al., 1991):

- first thinnings within 10 years age: not over the whole regenerated area, but mostly only in strokes covering some 40-50 % of the area to reduce costs; negative selection in support of sapplings of good stem quality and valuable admixed tree species
- repeated thinnings (2x a decade) until 40 years age: mostly in strokes covering 40-50 % of the young stand surface; removing fast growing trees of bad quality (forerunners) in support of trees of good stem quality and admixed tree species
- choise of future trees: some 200 trees/ha of the best stem quality spread more or less regularly over the stand
- thinnings until 80-90 years age: repeated removing of trees competing future trees to support development of a regular and deep crown in future trees (1/3 of the total stem length)
- non-competitive trees remain untouched as wel as trees of the second level, to counteract development of weeds
- natural regeneration: the length of the regeneration period as a rule 20, maximum 30 years; use of a longer regeneration period is thwarted by development of red heart in matured trees
- during the regeneration period the following steps are taken: preparation cutting in the age of 80-90 years: a strong thinning to release future trees, to support their crown development and fructification in the mast year to come
- regeneration cutting: a strong intervention before, in or immediately after the mast year to support natural regeneration; critical degree of canopy opening 30 %
- soil disturbance due to felling and skidding before or in the mast year is a positive phenomenon; cutting to start uphill and/or inside the stands, continuing downhill and/or to the margins
- release cutting: once or two times within the decade following the mast year and establishing natural regeneration to support the growth of seedlings (light, soil moisture) and to diminish root competition (especially important on dry sites – Fagetum pauper, Fagetum nudum)
- simultaneously a strong DBH increase on best trees must be realized to achieve the best timber quality

- clearing up the last trees: in the period when sapplings achieve the height of some 1 m, to restrict damage to natural regeneration; prolonged felling only in trees along roads.

Within this management procedure natural regeneration of beech and admixed species can be taken for granted. Places without or with an unsatisfactory natural regeneration (mostly only a few % of the stand surface) are planted – usually with conifers (Norway spruce, silver fir) to increase future economic value of timber production. For this purpose a good quality planting stock is used to counteract a negative impact of weeds. Some 5 % of timber volume remains in stands (uprooted and broken trees, logs of inferior quality) to form the pool of dead wood debris.

4.11.4 Conclusion

By applying the above management procedure the species diversity does not decline. It is lower in young stands with closed canopy but developes fully during the last third of the rotation period. The small-scale shelterwood system (Femelschlag) is supposed to support the pattern and structural diversity of forests and, simultaneously, to increase the stability of beech forests. In economic respect the management system is feasible and profitable, needs no subsidies under present conditions. Some reserves must be developed for the future with regard to the expected growth of labour costs.

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4.12 Impact on biodiversity

Pre-industrial period

?? Common beech was the most widespread tree species of Central Europe. During its post-glacial migration, it occupied various sites in the colline, submontane and montane zones and reached even the alpine timberline on its highest foreposts. It grew in mixed stands with broadleaved tree species (ash, lime tree, oaks, hornbeam, wild cherry, etc.) in lower altitudes. On optimum sites in the higher submontane and montane zones, beech formed extensive single-species forests; on many sites beech was accompanied by silver fir. High altitudes had mixed forests of Norway spruce and beech, and sycamore and rowan accompanied beech at the timberline.

?? From the Neolithic times (in Central Europe since ca. 7,500 BP), impact of Man can be traced in Central European landscapes, first in warm and fertile lowlands, later in higher altitudes. Both shifting cultivation and later the sedentary agriculture had used the beech forests as an irreplaceable natural resource, supplementary to the primitive agricultural production. All forms of forest use by Man affected the diversity of forests.

?? Early Medieval beech forests had been used for various purposes: fuelwood, timber, forest pasture,, pannage, litter raking, etc. Under the Central European conditions, beech does not regenerate by re-sprouting. As a result, it was not suitable for the primitive early Medieval coppice culture and was often replaced by other well re-sprouting broadleaves, e.g. oaks, hornbeam, lime tree or hazel. Browsing by cattle had a similar effect. Due to this impact, already in the early Middleages not only the forested area of Central Europe was reduced, but also the composition of accessible forests was changed for the worse of beech.

?? Since the 1200s land colonisation intensified and reached mountain areas of Central Europe, aiming at exploitation of their natural resources, esp. ores. In this connection, mountain beech forests had been exploited above all as source of fuelwood (charcoal production) for metal processing, glass furnaces and similar pre-industrial activities. Deforestation and deterioration of forests, and resulting acute shortage of wood and timber became a general fact in the Middelages.

?? In 1355 the first decree to protect forests was issued by the Roman Emperor and Czech King Karel IV (*Maiestas Carolina*). In 1386 first forestation activities were undertaken in Nurnberg, Bavaria, to restore devastated forests. By 1500s and 1600s, accessible slopes of Central European mountains – mostly beech forests – were largely deforested. At the end of the 1600s the forested area of Central European countries reached its minimum, with large forests limited to the inaccessible slopes and distant highlands.

Period from 1700 to 1980

?? The acute shortage of wood and timber and the desolate situation of forests gave rise to attempts to improve the situation. Basic ideas were put down by H.C. von Carlowitz (1713). Von Carlowitz defined the term "sustainability" as the basic principle of dealing with forests: the sustainable existence of forest is the basic condition for sustainable yield of timber and wood. Von Carlowitz' successors declined from this basic principle and developed forestry as a commercial activity aiming at sustainable yield and financial profit. In Central Europe this approach has been known as the German forestry school based on the soil rent theory. In some Central European countries, application of this approach resulted into a wholesale conversion of mixed and broadleaved forests in fast growing coniferous plantations during the next centuries. The share of beech in e.g. Saxony, Bohemia and Moravia has been reduced to a minimum. Contrary, in some other countries, the theory did not attain enough support (e.g. Baden-Wurttemberg). As a result, the representation of beech in forests remained at a rather high level until the present.

?? The first attempt to organize the beech forest management as a sylvicultural system was undertaken by Moser (1736; 1757). His approach laid down the principles of the 3-phases shelterwood system, which has been applied in the Central European beech forest management until the present.

?? Due to their devastating effects, pannage, forest grazing, litter raking and similar free use of forests have been prohibited in all Central European countries in the course of 1800s. Increasing populations of deer (elimination of large predators, increased concern in hunting, shrinking area of broadleaves), however, replaced the impact of domestic animals in Central European forests. In some areas, deer browsing has reached an extent, which makes natural regeneration in beech forests impossible.

?? During the 1800s and 1900s, Central European forestry developed as a close and fully controled production system with its own specific paradigm (set of rules, measures and criteria used in planning and management) aiming at maximum timber and wood production. In this system in some countries hardly any room was left for beech. Natural processes (selection, regeneration) have been mostly and often fully excluded and replaced by various methods of thinning, artificial regeneration and sophisticated felling systems. Irrespective of high costs this intensive technical approach to forest management resulted in an ecological and physical destabilisation of forests, extremely high casual fellings, economically unacceptable losses and ecological setbacks. In coniferous monocultures the biodiversity loss has reached its maximum extent.

?? In the period between 1960s and 1980s Central European forests had been subjected to a heavy impact of environmental deterioration. In the "Black Triangle" along the German-Czech-Polish border line, some 80,000 ha of coniferous forests died off and the vitality of forests on thousands hectars decreased considerably. Contrary to Norway spruce monocultures, beech forests in affected areas have survived this disastrous situation and proved to be an important stabilizing element of Central European mountain forests and landscapes.

Modern period; trends towards future

?? The contemporary political, socio-economic, ecological and environmental situation in Central Europe brings a new challenge to forests and forestry. The new concept of the contemporary Central European forestry is based on the principles of sustainability and multifunctionality – to be realized within a management system working with low costs and low risks, maximum ecological stability, preservation of biodiversity and maximum use of natural processes. The concept of the close-to-nature forestry elaborated in Germany already in the 1930s offers an adaptive approach, which meets the above demands and enables an integration of ecological, economic, social and environmental functions of forests, as well as a possibility to comply with the arising threat of the climatic change. This concept strongly adheres to a (more) natural composition of forests. In this respect, rehabilitation of beech and its stabilizing role in Central European forests is a *conditio sine qua non*.

?? Due to different political and economic development in the past decades, the forestry situation in particular Central European countries differs considerably. Although the necessity of a new concept of forestry has been generally recognized, the interpretation of the basic principles is different as well as the measures and steps taken until now to apply the concept in the forestry practice.

?? Slovakia takes an advantage from the semi-natural character of its forests. More than 70 % of forests have a natural tree species composition; representation of beech is 30 %, compared to some 45 % of the original (reconstructed) representation. Beech forests have been predominantly managed in a both large and small-scale shelterwood system, with maximum use of natural regeneration of both beech and admixed species. Treatment of young stands is rather intensive, aiming at support of desired admixed species and quality in beech. Thinnings in older stands aim at supporting future trees to achieve maximum quality and economic result. The management approach to beech forests can be characterized as rather traditional and reserved. A strong feature of the Slovak forestry is its long tradition in research of primaeval beech forests (Korpel, 1995). Results of this research (esp. forest dynamics and succession) deserve to get more attention in the forestry practice.

?? In the Land Baden-Wurttemberg beech had lost some 1/3 of its natural representation in the past. To restore its 31 % original representation in the tree species composition (site-related recontructed representation) is one of the main targets of the Baden-Wurttemberg forestry. Since the 1950s the B-W forestry goes through a very complicated structural change which is of utmost importance for beech and beech forest management:

- a shift from fuelwood to quality timber production
- a shift from the Normalwald to the close-to-nature forestry concept (Dauerwald)
- a shift from financially supported to a economically sound forestry model.

Since 1980 this change has been given content and form and resulted ultimately in the formulation of a new forestry paradigm. In this process, beech and beech forests played a very important role and specific procedures have been developed and measures applied to realize the above goals in beech forests. In the management systematics maximum room is given to natural processes (regeneration, selection). Herewith a considerable decrease of costs can be realized. Thinning systematics in beech forests has been simplified and thinnings limited to support admixed species and trees of the highest quality. With the term “forest development type” a dynamic principle has been introduced in the forestry planning, enabling an adaptive instead of the formerly usual prescriptive planning approach. With this innovative changes steps have been taken to depart from the Normalwald model and switch to the close-to-nature forestry system, which fully meets the emands of sustainability and multifunctionality.

The contemporary forestry situation in the Czech Republic can be characterized as rather contradictory. Concerning beech, the country belongs among those with its lowest representation (some 5 %) while the natural (reconstructed) representation should be at least 40 %. In the 1950s Czech forestry developed a fully operational system of conversion of Norway spruce monocultures in mixed forests relying upon integration of ecological and economic criteria and on information about forest dynamics revealed by studies in natural forests and forest reserves (Czech forest ecological school). In that management system restoration of beech representation in the tree species composition of forests played a central role. This school and approach were fully ismantled by the totalitarian regime and replaced by an industrial explotation of forests. Today, most (75 %) of the remaining beech forests have a protective status and fall under various regulations of nature conservation executed by various management bodies (national parks, State Forest Service, private owners). The management systematics of these forests varies greatly – from no intervention to management based on the sustainability and multifunctionality principles. Rehabilitation of beech forests by conversion of coniferous monocultures is the basic target of forestry in national parks and protected landscape areas. In both planning and management the nature protection bodies and their management follow the way leading to introduction of the close-to-nature forestry model, with a strong accent on biodiversity (both species, age, pattern and vertical structure).

The remaining not protected beech forests have been managed in a rather traditional way oriented towards timber production under a vague presumption of an automatic fulfilling of other services and functions. Aspects of biodiversity in these beech forests are neither emphesized nor actively pursued.

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5. History and management of beech in Southeast European Mountains Slovenia, Austria, Croatia, Romania

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5.1 Introduction

The following text is the result of literature review, case studies and interviews with beech forest silviculture experts in three different countries: Croatia, Austria and Slovenia. Basic information is given about site conditions and the present beech forests status in those countries. Past and present beech forest management is described with some information about possible impacts on biodiversity.

5.2 Slovenia

Slovenia falls within the temperate climate zone, in which temperatures and precipitation are in the main favourable to the development of forests. This region with varied relief and diverse geological conditions, in which Mediterranean, Alpine and the continental climates converge, is characterised by a wide diversity of forest sites (Beguš 1999). Forests in Slovenia cover the area of 1,077,000 ha, which represent 53 % of the total country area. Different types of beech forest cover 70 % of forest area of the country (figure 1).

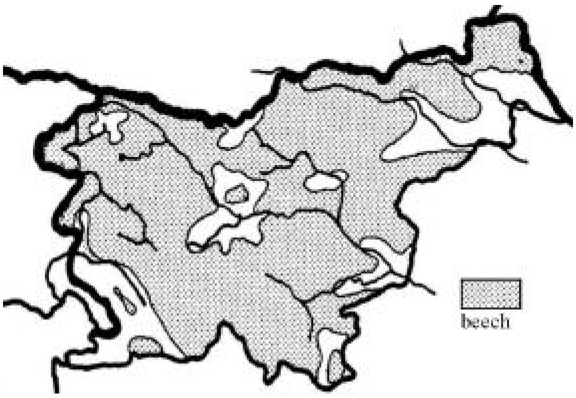

Figure 1. Beech distribution in Slovenia (Remic 1975).

The forests are in a relatively good condition, especially in terms of the diversity of composition of natural tree species and (vertical and horizontal) stand structure. The composition of tree species has been changed (due to the dominance of the Norway spruce) in only about 15 % of the forest.

Table 1. The proportion of the most important tree species in the growing stock of Slovenia's forest (Beguš 1999).

	Potential vegetation (%)	Current vegetation (%)
European beech	58	29
Norway spruce	8	35
Silver fir	10	11
Oak	8	8
Valuable broadl.	6	3
Other broadl.	8	7
Pine	2	7

There is a considerable difference between the current tree species composition of Slovenia forests and the natural composition (table 1). The main reason is planting of Norway spruce in the past (following the German school of forest management) (Gašperšic 1995) and planting of Austrian pine and its further dissemination in the karst (Jurhar, Miklavžic et al. 1963).

5.2.1 Soils

Slovenia is very diverse geologically with diverse climate and relief. On relatively small area all the major forest soils types are present.

Rankers and rendzinas represent the lowest soil development stage. Rankers are rare in Slovenia. They develop on silicate substrate, are very shallow with low productivity. Rendzinas are shallow too, but they develop mostly on dolomite. Sometimes rendzinas can be found on limestone. Their productivity differs according to their depth and precipitation. They cover relatively big areas in Gorenjska, Dolenjska, Notranjska and Primorska region. Slopes covered with rendzinas on limestone are steep and rocky, while those on dolomite are smooth with no surface rocks. Carbonate brown soils are common in Slovenia. Their depth varies because of typical karst phenomenon as dolinas and pockets in limestone substrate. They are more productive than rendzinas. Typical for Slovenian karst is soil type terra rossa. This type is deeper in dolinas and sinkholes, but usually shallow. Areas where terra rossa prevails are usually densely covered by smaller rocks. Brown soils are deep and loamy. They originate from softer substrate like marl and flysch. They cover the lower parts of slopes and flatlands on eastern and north-eastern parts of Slovenia. Acid brown soils are spread on the whole area of Slovenia on silicate substrate like slate and sandstone. On limestone and dolomite covered with clay, well-drained podzol like soils developed. They occur in Dolenjska and Bela krajina region. Podzol is rare in Slovenia and can be found only in small areas with silicic sand. Pseudoglei is spread all over the country. It covers moderately steep slopes and flatlands with alluvium base. Those areas forests have been heavily cut in the past and are today mostly covered by fields and pastures.

Other soil types that occur in Slovenia are young soils on river banks, heavy soils on swamp ground and moor soils developing in high underground water areas. Soil types described are only general view through the diversity of forest soils in Slovenia (Remic 1975).

5.2.1 Phytogeographic areas in Slovenia and their climate

Great diversity of vegetation of Slovenia is in close connection to geological, orographic, ground and climate conditions. According to vegetation types and climate, Slovenia is divided into six phytogeographic areas: Alpine, Dinaric, Submediterranean, Sub-Panonic, Pre-Dinaric and Praealpine (figure 2).

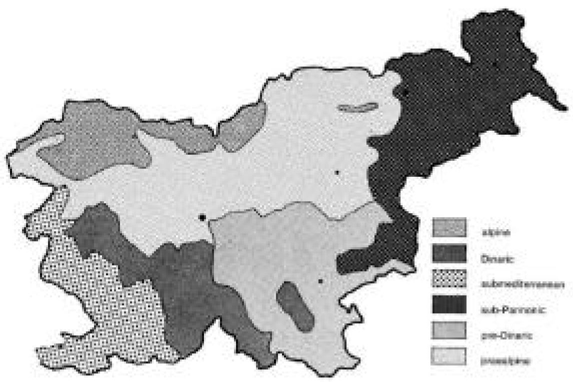

Figure 2. Phytogeographic areas in Slovenia (Marincek 1987)

Besides phytogeographic area with its growing conditions, altitude belt is important factor that influences the development of different vegetation types (figure 3).

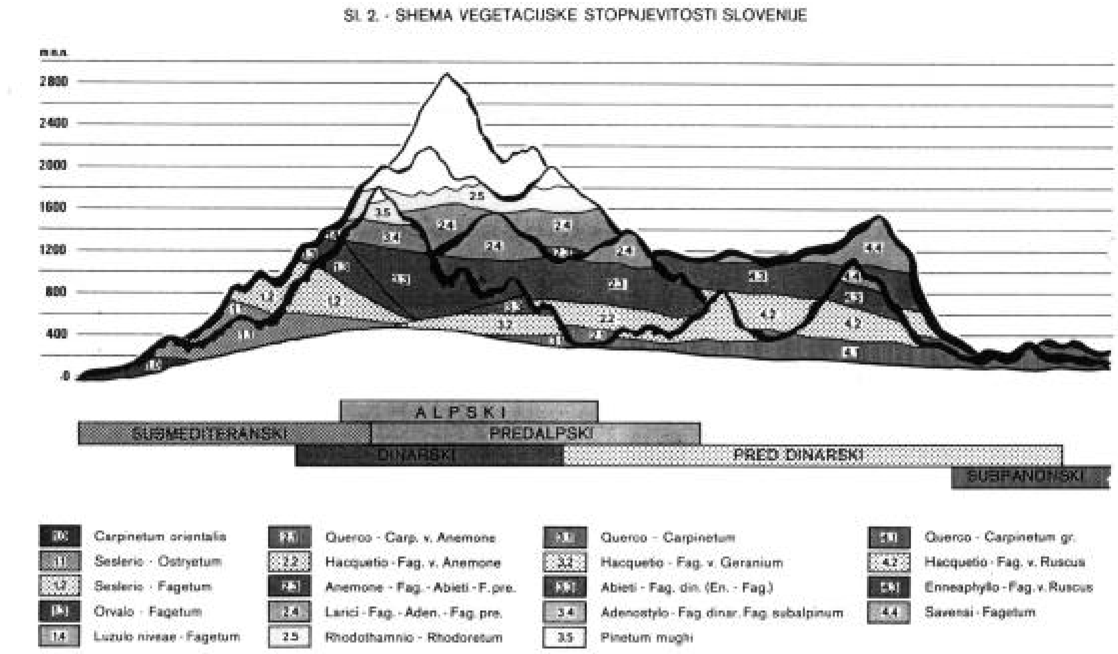

Figure 3. Vegetation stratification according to phytogeographic area and altitude belt (Remic 1975)

Alpine area stretches on the slopes of Southern Alps. The relief is extremely diverse. The alpine beech forest (*Anemone trifoliae - Fagetum* TREG.57) is prevalent forest in that area. Larch (*Larix decidua*) is very frequently associated tree species and alpine beech forest with larch usually forms the upper timberline. The climate is cold and moist with abundant precipitation and snow cover during the winter. Although winters are cold, summer temperature, at least at lower altitudes, is high. Precipitation generally decreases towards the east, with up to 2500 mm falling in west Alpine valleys. The area has suffered intensive human usage, and only a few near-natural forest remnants and some larger areas of semi-natural forests occur. Beech is present throughout, missing only at high elevations.

Dinaric area comprises the high plateau of the Dinaric mountain chains. The central Dinaric Mountains are aligned NW-SE along the Adriatic Sea. Winter and summer temperatures are both relatively moderate, but precipitation is high, generally reaching 2000-2500 mm. It is evenly distributed over the year, which means are permanently moist growing conditions. The Dinarics consist mainly of limestone with some dolomite on the borders. The well-developed karst landscape provides varied topography with deep and shallow calcareous brown soils. The area has not been intensively populated or utilised and retains large areas of semi-natural and some of the best examples of near-virgin beech and beech-fir forests in Europe. Fir-beech forests (*Omphalodo-Fagetum* (TREG.57) MAR. et al. 93) are the most important and abundant forest type here, covering large areas at 700-1350 m altitude. Pure beech stands occur in some places in this montane zone, but are dominant in the altimontane and subalpine zones above where beech forms the timberline at altitudes up to 1800 m.

Submediterranean area covers littoral part of Slovenia and West-South edge of Dinaric area. Coppice forests of hop hornbeam prevail in the lower altitudes and beech forests (*Seslerio automnalis-Fagetum* M.WRAB. ex BORHIDI 63) are more common in higher altitudes. Here the winters are mild, the summers hot, and, despite moderate rainfall, substantial droughts occur that limit tree growth. Slopes descending to the coastal area are mainly composed of limestone with brown calcareous soils. This area has been heavily exploited and beech forests are scarce.

Sub-Panonic area covers the north-eastern and eastern part of Slovenia, with flat land to the east and hills up to 400 m altitude to the west. Here the climate is more continental with higher summer temperatures and less rainfall. The two main soil types are gleys on low ground and acid brown soils on hills, with alluvium close to rivers. Forests have been used intensively and in places only *Pinus sylvestris* survives, though broad-leaved trees are now increasing. Acid beech forests are dominant in hilly areas at 200-400 m altitude, preferring moist north slopes and growing only on southerly aspects if some calcareous substrate is present. Oak-hornbeam forests replace beech forests at lower elevations.

Pre-Dinaric area is area between Alpine and Dinaric part and has more Dinaric then Alpine characteristics. Its gravity is Dinaric submontane area down to the Sava river. Carbonate rocks are predominant and the area is reach with Illyrian plant species. Beech forms mostly pure beech forests.

Praealpinum area stretches out along alpine territory, down from to the littoral part up to all over the central Slovenia and Pre-Panonic area in the East. The area is diverse in terms of bedrock, soil, climate and vegetation. Beech forests interchange with fir forests and artificially introduced spruce forests. Forest have very often human induced tree composition. The area is under hard pressure of agriculture and other human activities.

5.2.2 Beech forests

Beech is dominant tree species in Slovenia. It covers altitude belt from 300 to 1800 m. Beech covers subalpine altitude belt only on calcareous substrate. Acid substrates allow beech only to grow up to 1200 m above sea level. Its lower altitude border was raised due to intense use of the land in past 300 years (Brinar 1957). Beech is missing in eastern subpanonian and south western Mediterranean parts of Slovenia mainly because of low precipitation, high summer temperatures and regular occurrence of spring frost.

Although site and climate conditions are diverse in Slovenia, three main and general groups of beech forest communities can be recognised (Acceto and Robic 2001):

?? *Aremonio-Fagion* – beech forests on calcareous substrate (limestone, dolomite), which include *Epimedio-Fagenion* – beech forests in submontane altitude belt (most common community *Hacquetio-Fagetum), Lamio orvalae-fagenion* – beech forests in montane altitude belt (most common community *Lamio orvalae-fagetum,* includes also fir-beech forests *Omphalodo-Fagetum), Saxifrago rotundifoliae-Fagenion* – beech forests in altimontane altitude belt and *Ostryo-Fagenion* – thermophylus beech forests on southern slopes (most common community *Ostryo-Fagetum*)
?? *Fagion sylvaticae* – beech forests on moderately acid substrates (perm parent rock, mixed substrate), which include *Luzulo-Fagenion*
?? *Quercion roboris-petraeae* – forests on very acid substrates (sandstone, slate), with most common *Blechno-Fagetum*

Main beech forest types that are used for management and planning purposes on national level are (Beguš 1999):

?? beech-oak forests
?? beech forests on carbonate substrate
?? acidophilic beech forests
?? Dinaric fir-beech forests

Other more precise types of beech forests are used in lover levels of management and planning.

5.3 Croatia

Forests and forestland in Croatia cover 2.485,300 ha, which is 43.5% of the total area. Forests in their various silvicultural forms take up 83.6%, or 2.078,00 ha, and productive and unproductive forest land accounts for 16.4% or 406,000 ha. On average, there is 0.51 ha of forests per capita.

In Croatia, forests have mostly developed with natural regeneration. Of the total forest area, only about 5%, or 100,000 ha, are covered with broadleaves and conifer cultures and plantations. The rest of the forests are natural. About 1.200,000 ha, or 58%, are high silvicultural forms, about 500,000 ha, or 24%, are low silvicultural forms or coppices, and about 300,000 ha, or 13%, are various degraded stages (maquis, garrigues, brushwood, thickets).

Of the total growing stock, beech takes up 36%, or 89.140,490 m^3, pedunculate oak 16%, or 40.541,780 m^3, European fir 12%, or 30.975,420 m^3, sessile oak takes up 9%, or 22.976,488 m^3, other hard broadleaves 18%, or 45.076,990 m^3, other soft broadleaves 4%, or 10.245,387 m^3, and other conifers 5%, or 11.869,893 m^3 (Matic, J. Diaci 1998).

5.3.1 Climate

Due to variable relief and geographical location, climate in Croatia is very diverse. It has a strong influence on vegetation occurrence and development. Research on vegetation in connection to some climate parameters was the basis for dividing the area of Croatia into different phytoclimatic territories. Bertovic (1975) (Bertovic 1975) divided Croatia in two major phytoclimatic territories. First territory is covered with continental vegetation and includes the forests of Panonian flatland (pedunculate oak, sessile oak, hornbeam) the middle part of Croatia (beech, sessile oak) and Dinaric mountains (fir, beech). Second territory is submediteranean, covered with thermophilous forests (Quercus ilex, Ostrya carpinifolia). The adoption of tree specious to most unfavourable climatic conditions (low temperatures, lack of water) resulted in different life forms. Tree species in Croatia are generally divided in three characteristic vegetation forms. Evergreen broad-leaved tree species adapted to mild winters and hot and dry summers, deciduous tree species adapted to normal seasonal climate and conifers that adapted to cold and continental climate (Seletkovic and Katušin, D. Rauš 1992).

5.3.2 Soils

A multiplicity of soil forming factors has caused development of a great number of different soil types on the territory of Croatia. The most frequent and productive of the automorphous soil types (soil types that get the water from precipitation) are the luvisols, dystric cambisols, calcocambisols, terra rossa, rendzinas, rankers and others. Of the hydromorphous (occurring on grounds with high level of ground water) forest soils, the dominant types are eugley, semigley, pseudogley and fluvisol. The increasing anthropogenic impacts, such as the hydrotechnical operations, pollution caused by flood or air, result in different anthropogenetic soils with negative consequences for the stability of the existing forest ecosystems (Mayer, D. Rauš 1992).

5.3.3 Beech forests

Beech forests cover the area of 1,000,000 ha in Croatia, which represents 56,5 % of total forest area (Figure 1). Pure beech forests occupy the area of 250,000 ha, sessile oak-beech forests 700,000 ha and fir-beech forests 165 000 ha. 85 % of beech forest is high forest. In optimal conditions beech forests occupy the areas with average year temperatures from 7 – 10°C and precipitation ranging between 600 – 2000 mm. Under these conditions beech grows regardless of substrate (Matic, Oršanic et al., B. Mayer 1996).

Figure 4. Beech in Croatia (Cestar 1986)

Among the native forest tree species in Croatia, beech is characterised by the widest ecological amplitude. High precipitation and air moisture of the oceanic climate are favourable to beech in Dinaric mountains. Beech's distribution here is from 500 to 1450 m above sea level. Beech grows well on Panonian hills too, where there is much less precipitation, but its annual distribution is favourable. Ecological barriers which prevent beech dispersal are: dry, warm sites inhabited by Submediterranean vegetation, zones of steppe climate and sites with high level of ground water occupied by flood and swamp forests.

According to substrate, ecological conditions and floristic composition, beech forests in Croatia are divided into two main communities (Matic, Oršanic et al., B. Mayer 1996):

- *Fagion illyricum* Horv. – beech forests on the base rich ground
- *Luzulo fagion* Lohm., et Tuxen – beech forests on the base poor ground

According to their geographical position and site conditions beech forest are divided into three divisions that are useful also in planning and management process: Dinaric division, Panonian division, intermediate division (Cestar 1986).

?? Dinaric division

Dinaric mountains are composed of limestone and dolomite and reach altitudes above 1500 m. Montane beech forests cover altitudes from 450 – 850 m, fir-beech forests altitudes from 850 – 1250 m and subalpine beech forests altitudes from 1250 – 1450 m. On the Mediterranean side beech forests with *Acer obtusatum* sometimes cover the area between montane beech forest and thermophilous littoral vegetation. Azonal beech forests with *Luzula sp.* and *Blechnum spicant* appear on silicate acid ground.

?? Panonian division

This division covers the eastern area of Croatia. Temperature extremes (hot summers and cold winters), silicate parent material and precipitation up to 800 mm per year resulted in different beech forest types. Beech forests cover altitudes from 90 – 650 m. In lowland belt beech is admixed individually or in small groups in pedunculate oak-hornbeam forest. Pure beech forests cover altitudes from 120 – 400 m. In altitudes above 250 m this area is covered by sessile oak-beech forest. In higher elevations (400 – 650) on colder and moister sites small areas are covered with fir-beech forest.

?? Intermediate division

Central part of Croatia is diverse in climate and parent material. This hilly land is influenced by the Dinaric, Panonic and subalpine climate. Silicate and carbonate substrates are mixed or locally present. Two main types of beech forest developed under these conditions: beech forests on mixed substrate and very acid substrate beech forest. Sessile oak-beech forests and fir-beech forests are present only in smaller areas (Cestar 1986).

5.4 Austria

Forests in Austria cover 3,924,000 ha, which is approximately 47 % of the country area. The forested area has been increasing in last few years on average 2.000 ha per year. Austria's forests are not evenly distributed over the country. The mountain slopes in the Alpine areas and in the highlands are most densely covered with forests. In areas well suited for agricultural purposes forests were cut and remained only in border regions. Almost no forest can be found in the East, where summers are warm, and in the high mountains, where the timberline has been lowered as a result of former intensive exploitation of alpine pastures. The timberline in the Central Alps runs at 1.900 m above sea level, in the limestone Alps some 200 m lower (Anonymus 2000).

Coniferous trees dominate the Austrian forest and because of the predominance of mountain regions their share has been high from the beginning. It was increased in the past for economic reasons, above all by adding spruce and pine.

Table 2. Distribution of tree species in Austria (BMLFUW 2000/Austrian forest inventory 1992/96)

Tree species	Share in %
Norway spruce	61,8
Beech	9,8
Scots pine	7,9
Larch	5,0
Silver fir	2,7
Oak	2,2
Hardwood*	6,4
Softwood*	4,2

* Hardwood = hornbeam, ash, maple, elm, etc
Softwood = birch, aspen, lime, poplar, willow

5.4.1 Climate

The wooded slopes of the Alps and the small portion of the plains of south-eastern Europe are characterised by differing climatic zones: the wetter western regions of Austria have an Atlantic climate with a yearly rainfall of about 1000 millimetres; the eastern regions, in particular those under the influence of the drier, more continental type of climate, have less precipitation. In the lowlands and the hilly eastern regions, the median temperature ranges from ?0.9 °C in January to 20.3 °C in July. In those regions above 3000 m, the temperature range is between ?11.3 °C, with a snow cover of about 3 m in January, and 2.1 °C in July, with about 1,5 feet of snow cover. The prevailing wind is from the west, and the humidity, therefore, is highest in the west, diminishing toward the east.

5.4.2 Relief and substrate

Mountains and forests give the Austrian landscape its character, although in the north-eastern part of the country the Danube winds between the eastern edge of the Alps and the hills of Bohemia and Moravia. Vienna lies in the area where the Danube emerges from between the mountains into the drier plains. The landscape of the eastern Alps offers a complex geologic and topographical pattern, with the highest elevation, the Grossglockner 3,798 m, rising toward the west. The Austrian Alps may be subdivided into a northern and a southern limestone range, each of which is composed of rugged mountains. Those two ranges are separated by a central range, which is softer in form and outline and composed of crystalline rocks. North of this mountain massifs, lies a hilly subalpine region, stretching between the northern Alps and the Danube. To the north of the Danube, lies forested foothill area. The lowland area east of Vienna may be regarded as a western extension of the great Hungarian Plain.

5.4.3 Beech forests

At present, the share of beech in Austria in the production forest (high-forest) is about 9 % (300.000 ha). Potentially mixed spruce-fir-beech forest communities cover an area of about 1.2000.000 ha, natural beech forest associations an area of about 450.000 ha. At present, approximately a third of the potential mixed deciduous forest stands (beech and oak) are occupied by pure coniferous forests (Forest inventory 1992 – 96).

Forest community	Ha	%
Spruce-fir-beech	1.200.000	29,5
Beech	450.000	11,5

Beech is found almost on the whole area of Austria, although at very different densities. It is not present in area of Central Alps and is scarce in the Wienviertel, Lower Austria and Mühlviertel.

In the Allgäuer Alps and in the northern parts of the Tyrolean Alps, beech is commonly found in mixed stands. In the province of Salzburg, mixed beech forests are typical on slaty sites and at high altitudes of the Northern Limestone Alps. Widespread pure stands are common in the foothills of the Salzkammergut. In the Northern Limestone Alps of Upper and Lower Austria, extensive pure beech stands are also frequently found. Pure beech stands are also typical of the Wienerwald, whereas foothills of the eastern Alps (Northern Limestone and Central Alps) are only partly covered by beech in mixed forests. Disjunct beech stands are further found in the hills of the Geschriebestein close to the Neusiedler Lake. Beech is also found in the Southern Limestone Alps, namely in the Karawanken, the Carnic Alps, and the Gailtaler Alps. However, pure stands are more common in the Karawanken than in the rest of the Southern Limestone Alps. As a scattered forest tree species it is indigenous at the southern foothills of the Central Alps, in the Lavantal at the eastern edge of Carinthia, and on elevations of the Klagenfurter Becken. In the Central Alps beech is nearly completely absent. The altitudinal range varies from 170 to 1700 m. The upper limit within the Northern Limestone Alps rises from east to west. Within the Southern Limestone Alps, the upper tree line of beech is generally higher than in the northern Alpine range (Geburek 2000).

5.5 The preindustrial period (12,000 BC – 1800 AD)

5.5.1 Social changes

Not much information is available about forest use in the South Central (SC) Europe (today Austria, Croatia and Slovenia) in pre-industrial period. First data on forest coverage dates in 1689 when Valvasor (Valvasor, E. Francisci 1689) described the forests and their economical value in very general way. However, some general data about human settlements and use of the land and forests exist, and those will be presented in this section.

Up to 6.000 BC people were travelling through the area following game and searching for food. No long-term settlements were established. By 4.000 BC farming was spread throughout the region and first inhabitants planted cereal grains, raised livestock, fished, hunted, wove simple textiles and built houses of wood and mud. After 3.000 BC processing of copper, bronze and after 700 BC iron, resulted in settlements and trade development and increase of human population.

First identified inhabitants of the SC Europe were Illyrian-speaking tribes and later Celts, that came to the area in around 400 BC. A mixed Celtic-Illyrian culture arose producing wheelturned pottery, jewellery and iron tools. At that time no forest management was practised. Forests were used according to present demands in that period.

Around year 200 BC Romans invaded SC Europe and Balkans. Conquered territories were divided into separate provinces. New roads linked fortresses, mines and trading towns. The Romans introduced viticulture, instituted slavery and dug new mines. Agriculture thrived in the Danube basin, and towns throughout the country developed into urban areas with forums, temples, water systems, coliseums, and public baths. Some evidence show, that basic forest management was present, since wood trading was well developed.

Roman empire collapsed before 600 AD and Slavs occupied the present area of Slovenia, Croatia and partly Austria (Lower Austria, Styria, Carinthia, and eastern Tirol). They were characteristically sedentary farming and livestock-raising tribes. They were organised in clans, ruled by a council of family chiefs. All land and significant wealth, including forests, was held in common. Slav settlements were dispersed and belonged to different tribes. They were not united and German nations, dominating in non-Slavic parts of present Austria, conquered them after the year 900 AD

After the year 800 AD feudalism put the property of the land and the forests to the rulers. They had the right to use the forest, but farmers and village communities still retained the rights of using the forest for their own need (wood, pasture, litter). Fights for the rights to use the forest between farmers and rulers were going on through the whole period of feudalism. Some forest areas were assigned to cities and later became city property (Sevnik, C. Remic 1975).

Under the influence of quickly developing mining and ironworks, local rulers asserted their rights for mines and put some of the mountain and surrounding forests to be used by ironworks and mining companies. At the beginning ironworks were situated close to ore deposits, on windy locations, for the purpose of so called wind stoves. Development of ironworks technology enabled them to move to the lower areas, away from original sources of ore and wood. River water energy was used for production of iron, but wood for the stoves was still important. Settlements were built by ironworks workers, close to the ironworks. Workers had to work the land, to get some food. Wood for fire and construction in those settlements was cut from around forests (Johann, J. Diaci 1998).

Up to 1600 AD, deforestation was encouraged by the owners of the land. Agricultural land was more profitable than forests. Mining, iron and glass industry were promoted and forests were rented for use to the industry. Also timber marked developed and forests were heavily cut and wood was transported to Mediterranean ports.

Demands for wood increased and in some areas there was shortage of wood and forests were devastated. Those were the circumstances that encouraged first systematic management of the forests.

Mediterranean towns first encountered the problems with wood deficiency and some of the forest management advices and prohibitions can be found in their legislation soon after the 1200 AD

First forest order, that prescribed the management in all of the forest of the areas of SC Europe, was written around 1770 (Mary Theresa). It was in force up to the year 1852, when first Austrian forest act was passed. Forest order prohibited clearing and reduction of forests and prescribed basic measures for sustainable forest management. Special forest units for order implementation were organised.

5.5.2 Landscape changes

Palinological analyses showed, that in the past, the whole area of SC Europe was covered by forests (after the last ice age). From 13.000-9.000 BC subarctic taiga climate prevailed. Pine, birch, willow and spruce were the tree species that dominated the forests. Warmer climate from 9.000 – 8.000 BC that resulted in elm, oak and lime forests, was followed by last cold period. It lasted until 7.000 BC. A warm and dry climate after 7.000 BC was favourable for beech dispersal. Until 5.500 BC beech was spreading constantly and was most abundant tree species. After that period moister and less warm climate enabled other tree species such as fir, spruce and pines, to invade the beech forests. After 800 BC, no greater climate change occurred, and forests today are changing only on account of human impact (Sevnik, C. Remic 1975).

Up to year 1000 AD, only local changes in landscape patterns were present. Forest was cut around settlements usually in easy accessible walleyes. Tree species and stand structure composition of the original-natural forests, lying mostly in mountain areas, remained unchanged.

In littoral parts, in the karst area around 1000 AD, lack of wood became a problem. Increasing demands for wood of Mediterranean towns, fire, and grazing of goats, resulted in total devastation of the land. With no forest vegetation those limestone well drained areas were faced with erosion problems, lack of water and climate change. Once green forested landscape became dessert like, dry and white limestone rock prevailing land, which was increasing in area.

After the year 1200 AD, lack of agriculture land forced fast growing population of farmers to colonise higher mountain areas. Forestland was much less valued than agriculture land, which resulted in forest clearing and reduced forest area to one third of its original coverage. Forest was cut for pasture and charcoal production for mining and iron industry, on account of which timberline was lowered and first clearing on higher elevation occurred (Johann, J. Diaci 1998).

Land use was more intensive in the area of present Austria and North Slovenia. Areas in present South Slovenia and Croatia were less intensively used and coverage of original-natural forest was greater, especially on Dinaric mountains region.

5.5.3 Use and structure of the remaining woodland

First using of the forests in human history was connected to collecting food and hunting forest animals. Forests, with small consumable animals, frosts fruits and seeds, were important factor in survival for the mankind.

Active production of the food started with the development of agriculture and stockbreeding. At that point importance of forests in human life diminished. Forest areas were used for shifting cultivation. Forest was cut and burned down. Land prepared in that way was suitable for crop producing for two to three years. After that it was used for grazing and slowly overgrown by forest vegetation. After 30 years it was cut again and used in the same way (Mihelic, B. Anko 1985).

Forests that weren't cut for agricultural purposes were used for grazing, litter, forest seed, fire, tool construction and building material. At the beginning no systematic management of forest was applied. Forests were easy available and were concerned more as a trouble or enemy for the man and his agricultural way of life. With the development of craft industry like barrel, wood tool, basket, resin, lime and glass production, wood and forests were becoming more important. The intensity of usage was still relatively low and big remote areas of the country remained untouched and natural. No effort was put into forest management since forests seemed to be present continuously and everywhere.

Industrial exploitation of forests began with the development of mining, glass and iron industry. Big quantities of wood, especially beech wood, were needed for charcoal production. Forests were first cut close to the industry locations and later more and more away from them in remote areas and areas with higher altitude. Big area clearcuts in mountain areas occurred after the year 1200 AD (Johann, J. Diaci 1998). Forests were harvested, some of them were turned into the fields and pastures, and the others left to natural succession. That was changed with first forest orders where more attention was given to sustainable management introducing basic forest tending and forest protection ideas.

5.5.4 Impacts on biodiversity

?? First evident impact of man on landscape level in Roman period 200BC-600AD. Deforestation and pasture changed composition and structure of forest ecosystems and animal and plant species composition. Changes only locally present.

?? Glass and iron industry turns the beech forests into energy source, resulting in big scale deforestation. Biodiversity and natural processes intensively disturbed. Only remote areas stay untouched.

First impacts of man on forest biodiversity were low in intensity and only locally present. Hunting and collecting forest goods, such as berries, mushrooms, herbs and different tree species seeds, had no greater impact on landscape patterns and forest ecosystems. Forests were oldgrowth and had natural species composition with beech as a dominating tree species. Beech forests are presumed to be similar to today's virgin forest stand structure and dead wood share. There where no disturbances in site, habitat, processes and genetic continuity and different animal and plant species were developing with no important influence of men.

First changes that were evident on landscape level in SC Europe occurred in Roman period (200 BC–600 AD). Forests were cut for agriculture purposes close to roads and on easy accessible areas in main river walleyes. Deforestation was sometimes combined with drainage, which resulted in bigger open areas with no forest vegetation. Forests that were used were divided into two categories according to their purpose. First category included oak and beech-oak forests in the lowlands that were used for pig pasture and low quality wood production. Second category was so called common forests used for production of building and ship construction wood (Anonymus 1993). Deforestation resulted in landscape fragmentation and increase of open areas, which were influencing forest ecosystems also. Used forests composition and structure was changed affecting ground conditions and stand structure. As a result plant and animal species composition was changed putting the pressure on dead wood, high water level forests, and dense forest canopy dependent organisms. Untreated forests remained their natural structure and composition. On a landscape level biodiversity was not disturbed greatly, since big areas of wilderness remained untouched by human intervention.

Development of glass and iron industry, trade and urban areas increased the importance of forests. Wood became important energy source. Forests were cut by landowners for market, ironworks for charcoal, and farmers for fire and construction. All the users claimed the right to the forests and in many cases it lead to conflicts. This resulted in uncontrolled usage of forests and rapid deforestation. With the increasing human population forest resources usage expanded to the higher altitudes and uninhabited areas (Anonymus 1993). Deforestation and grazing had great influence on landscape level. Clearcut areas, that could be over 100 ha big, were increasing floods and erosion. Especially in Alpine mountain areas, after long periods of rain, land slides and avalanches occurred. Big open areas increased soil erosion and the danger of windthrow in remaining forests. Pasture, especially goats, prevented natural regeneration and succession, which prolonged the period with no forest cover (Johann, J. Diaci 1998). Intensive usage of forest for different purposes changed the habitat features. No dead wood was left in the forest. Water regimes were disturbed because of the influence of the drainage and large scale felling in higher altitudes. Ground and stand structure were disturbed on account of harvest and pasture. Change of tree species composition was considerable. Especially in mountain areas, beech was replaced with pioneer Norway spruce and larch, since those two tree species regenerated well naturally. Tree species composition change was not so evident in lower areas where beech is more competitive and dominates in all forest development phases. Intensive grazing in the forests influenced ground vegetation species composition. Depending on livestock species and its preference, different ground vegetation species were suppressed or promoted. Because of the clearcut system and pasture after there was no continuity of sites, habitats and forest processes. Living conditions for organisms related to permanent forest cover and natural forest structure living conditions aggravated. Diversity and abundance of open space and forest edge organisms, like birds, increased with the expansion of their habitats. Only few forest areas remained untouched and oldgrowth, usually because of their inaccessibility.

5.6 The industrial period (1800 AD – 1950 AD)

5.6.1 Social changes

Demands for iron in industry purposes increased after the 1850 and old methods of iron production were not efficient enough. Development of technology enabled usage of steam and coal.

Deforestation and forest devastation decreased the wood production, resulting in high wood and charcoal prices. As a result, coal was more widely used also in other industries and home heating. Because of the competition from Scandinavian countries, costs of iron production had to be cut. Costs were lowered by use of coal and concentration of iron production. Big ironworks plants were established and local were abandoned. Coal usage and transport was promoted by the authorities putting wood transport and production into second place.

Not all the local industry was abandoned. A part of the existing buildings were used for sawmills, which were producing technical wood for furniture and construction purposes. Sawmills were often connected with furniture production plants. Wood of smaller dimensions was used in pulp production (Johann, J. Diaci 1998).

After the year 1848 farmers became the owners of more than two thirds of the land. Wars, big taxes, wood industry and market were forcing the farmers to overcut their forests. Basic rules of forest management were only set for the state forests and private owned forests were slowly degenerated and ruined (Remic 1975).

During the Austro-Hungarian Empire, the first Forest Law (1852) was in force in SC Europe until the end of the WW 1. Some principles of forest management were laid down, that are still valid today. Clearings, burning or any other devastation or removing of forest were forbidden and the principle of sustained yield management became the rule.

At the end of 1900's forest management developed under the influence of German forest school. Forest management was more systematic with the emphasis on the maximum land income, promotion of strict space and time order, which lead to planting spruce on beech sites.

Two foresters, Hufnagel and Schollmayer, that have been working in Slovenia in that time, refused to manage their forests in clear-cut and spruce monocultures way. They have developed a Selective cutting management system, which they have believed was the most appropriate for the high Karst region they have been working in. Between 1891 and 1893 forest management plans were made by Dr. Hufnagel, count Auersperg's estates manager. Management plane establishes naturalistic selective management for high-karst fir-beech forest and defines areas to be preserved as virgin forests.

In this period the devastated karst area was reforested. Foresters like Ludvig Dimic and Josef Ressel were organising large area planting activities. Black pine was planted and in many cases successfully growing.

The first Forest Law of the Kingdom of Yugoslavia appeared in 1929. It was in force in present Slovenia and Croatia and eliminated almost all positive articles from the Austrian forest law (1852) and the heavy exploitation of forest continued. The stands marked for harvesting were sold to companies, the obligations of companies to care for natural regeneration and reestablishment of forest vegetation, rarely respected.

After the creation of old Yugoslavia forestry was better organised and the first local forest schools and tree nurseries were established around 1930.

First few years after the WW2 forests were intensively cut. They were the only source of income for ruined countries.

Until 1945, the forests had belonged to the state, villages, communities (agricultural associations and municipalities), the church and private owners. Since 1945, in the Socialist Yugoslavia all forests except for the ones owned by private persons (up to 15 or 30 ha, depending on the region), have been nationalised and became national property. At the same time, all rights of the owners of communal forests have been abolished.

5.6.2 Landscape changes

After 1800 big areas of formal forestland were open with no forest vegetation. Especially in mountain areas, it caused avalanches, landslides and snow or windbreaks. Because of the severe damages in lower densely populated valleys the public started to be more aware of the consequences caused by unregulated deforestation. Change in location of industry caused migration of people that were dependent on the work in the industry into the vicinity of new industry locations. Small farms were not enough productive to provide food for all the habitants. Because of that, pressure on forestland decreased and forest started to regrow open areas. In addition, wood prices lowered and only better quality technical wood was desired. It all lead to stricter legislation, which forced the users to manage the forest in more sustainable way (Johann, J. Diaci 1998).

Since technical wood was needed, Norway spruce was planted in pure monocultures. Norway spruce was natural in some share in mountain areas and it gave good land income. It was promoted and almost all Alpine mountain areas were covered with pure Norway spruce stands.

Under the influence of maximum land income idea, Norway spruce monocultures were established also in lower elevations, mostly on beech sites. Norway spruce was fast growing and provided technical wood, because of which, it was promoted on all forest sites slowly driving out natural tree species.

Dinaric area of SC Europe was not so densely populated and deforestation processes were much less intensive. With the use of selective management forests remained natural tree species composition and structure. Clearcut systems were not generally used and Norway spruce promotion was much less intensive.

First attempts in Karst area reforestation are dated in 1842. Natural broad-leaved species seed was used with no success. After some experiments Black pine (Pinus nigra) showed to be the most appropriate tree species and after 1881 several Karst reforestation laws were adopted resulting in forestland area enlargement (Valencic 1970).

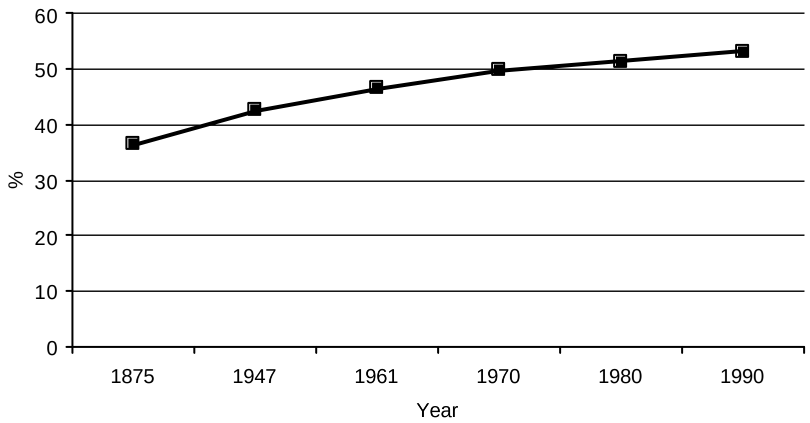

Figure 5. Forest coverage in Slovenia between 1875-1990 (Anonymus 1993)

Landscape changes were very intensive in Slovenia and Croatia. Forestland percentage was fast growing on account of Karst reforestation and thorough migration of people from remote areas. Whole regions like Kocevska and Bela krajina in Slovenia were abandoned and left to natural forest successions (Valencic 1970).

5.6.3 Use and structure of the remaining woodland

Due to development of industry technologies and introduction of coal, demands for beech wood lessened. Charcoal production was reduced and beech was treated as undesirable tree species after 1850. At the same time, needs for technical wood, provided by conifers, especially Norway spruce, increased. As a result spruce was planted in all elevations, mostly on beech sites.

Spruce stands were managed with clear-cut system. According to the size of the managed area and rotation period, different size areas were clear cut and replanted, enabling continuous production of Norway spruce wood. Rotation periods in Norway spruce stands were different according to tree growth. It depends on site conditions, which are, particularly in Alpine areas, connected to elevation. In lowlands Norway spruce rotation period was 70 years and in higher elevations 90 years. After the planting (4000-5000/ha), young Norway spruce trees were promoted and all the other tree species were removed. Stand were thinned several times, first using negative and latter positive selection (Valencic 1970).

Beech forests were managed according to ownership and most of the beech forests were owned by farmers. They used selective cutting in their forests, just taking out what they needed at the moment (wood for fire, construction wood). Rarely beech forests were coppiced or coppiced-with-standards. Beech forests owned by bigger owners or landlords were cut in two phases on large areas. In lower elevations (up to 500 m) all beech stands over 60 years old were cut, while mountain beech forests rotation periods exceeded 100 years. With first cut majority of growing stock was taken out and only bigger trees for seed production were left over. After the establishment of regeneration those trees were cut too (Valencic 1970). Beech forests were regenerated naturally with no special treatment in younger phases. After the establishment of beech regeneration, the rest of the trees were removed. 30 years old stands were thinned several times. Negative selection only removed bad quality trees. Beech wood was to some extend still used for charcoal production, fire, tool production and construction (Pirc 1997).

Fir-beech forests in Dinaric Mountains were managed in selective way. They were owned by landlords who employed educated foresters to manage their forests. First forest plans, made in years after 1890, were prescribing selective management and even protected some forest areas to be left as virgin forest (Hufnagel 1892). Some of the best-preserved fir-beech forest reserves in Europe lie in this area (Hartman, J. Diaci 1998).

5.6.4 Impacts on biodiversity

Beech forests were replaced by Norway spruce monocultures. Pollution and non-native tree species changed basic site conditions. Big changes, of forest area structure and distribution on landscape level, occurred. Development of different groups of organisms (e.g. ground fauna and flora, tree species dependent organisms, dead wood dependent organisms, large undisturbed areas dependent organisms) were hindered or stopped. Forest ecosystems with pure non-native tree species became unstable and problematic.
Dinaric part of SC Europe covered with fir-beech forest was not so severely disturbed. More site conditions (limestone) adapted beech forest management was practised and level of biodiversity remained relatively high.

Impact of man on beech forest ecosystems in industrial period was considerable. Deforestation of beech sites was going on until 1850. After that year change in main energy sources for developing industry, put of the pressure from beech forests. Charcoal was not needed any more and beech forest, being the main source for it, became less important. The migration of people towards industry centres and abandoning agriculture land use, triggered reverse natural processes. Beech forests started to take over open land and forest cover was increasing.

Forest successions created various new habitats in forms of different stages between open land and forest. Tree species composition and stand structures were changing according to development of newly created forest. First pioneer tree and shrub species were prevailing, to be replaced with more demanding ones. Relatively fast changes in stand structure and composition affected soil and stand climate properties creating conditions favourable for certain plant and animal species.

Clear-cutting management on steep slopes of the Alpine mountains increased water, snow and wind erosion. Snow avalanches and landslides changed the appearance of the whole walleyes. Torrents and avalanches were created endangering human settlements and industry. Soil was washed out which caused karst phenomenon's, preventing the vegetation to re-establish. In higher elevations degradation of sites was permanent, resulting in lower altitude timberline.

Tree species composition was changed, due to conifer monocultures establishment. Spruce share in forests increased considerably, mostly on account of oak in the lowlands and beech in submontane and montane altitudonal belt. As an example, today only 50 % of beech sites in Slovenia are covered with beech forest, the others being covered with spruce.

Air pollution was monitored in Austria since 1852. Main air pollutants were big plants using black coal for energy source. Plant damage was monitored in connection with smoke sulphur content, distance from the smoke source, height of the chimneys, relief and climate properties, wind directions, etc. Areas close to industry centres were highly polluted and in some areas over 80 % of trees were damaged. In most polluted areas damages prevented regeneration and forest establishment was no longer possible. Air pollution damages resulted in lower wood and soil quality and increased the number of dead spruce trees. Bark beetle populations increased and caused more damage to the forest (Johann, J. Diaci 1998).

Clear-cutting system in Norway spruce monocultures and beech forests caused great disturbances in forest ecosystems. Big open areas, naturally rarely present in the forest, had changed climate and water regimes and there was no continuity in site, habitats and processes.

Acid Norway spruce needles changed the properties of the soil and the pH level decreased in upper levels of the soil. It drastically changed the soil fauna environment and disturbed soil decomposition processes, sometimes even preventing it. As a result regeneration and ground flora development was disturbed.

In Dinaric parts of the area selective cutting management system was practised. It was much more organic and did not influence the biodiversity so severely as clear-cutting monocultures system. Fir-beech forests remained close to natural structure and human impacts and disturbances were much less intensive, since there were no big industry areas.

5.7 The modern period (1950 AD -) into the future

5.7.1 Social changes

Until 1948 forest management in Slovenia has been strongly influenced by German forestry school.

In 1948 clearcuts in the forest have been forbidden by forest act and close to nature forest management has been adopted (Gašperšic 1995). Beech has been managed as a desired and natural species with small-scale shelterwood and group selection system.

In Slovenia more sustainable forest management was practised after the year 1952 when the first pressure on the forest lowered. Management units were established and by the year 1961 all forests were managed according to forest management plans. Forest management plans were emphasising sustainable and more close to nature forest management. The idea of close to nature and organic forestry was developing and grater importance was put into natural tree species composition, natural regeneration, more locally adopted measures and multifunctional purpose of forests.

As a mountainous country with rugged karst area, Slovenia has a high proportion of not easily accessible forest. This is the main reason why Slovenia’s forest have not been influenced by human intervention to such extend as in most Central European countries. Still, problems with low quality wood, low growing stock, changed species composition, spruce monocultures, and erosion are present in Slovenia forests after the WW2. These problems, the recognition of non-commercial forest functions and rich close to nature forest management tradition (Gašperšic 1995), have been the reasons for development of multifunctional and close to nature forest management in Slovenia.

The forest act in force today in Slovenia was passed in 1994. It's main task is to provide close to nature and multifunctional forest management that will obey the rules of nature conservation and environment protection and to enable sustainable and optimal functioning of the forests in all of its roles.

First five years after the WW 2 forests were heavily cut in Croatia. After that period several changes in forest legislation and silviculture practices were adopted, to more close to nature and multifunctional forest management (Piškoric and Vukelic, D. Rauš 1992).

In today's Republic of Croatia, the ownership status has not changed though there is possibility of denationalisation for particular ownership categories. After Croatia declared independence in 1990 a necessary adaptation of the former law was undertaken to attain optimal production, stability and natural regeneration in Croatia forests (Sabadi 1994).

With the changes in forests and forest industry, growing awareness of environmental problems, new requirements for the conservation of forests have emerged.

Norway spruce monoculture forest management has a long tradition in the area of present Austria. As a result conifers cover almost 80 % of the forest area in Austria with Norway spruce reaching up to 60 % (Anonymus 2000). Management system with conifer planting and clearcutting is well established and changes in management policy are coming slowly. In the last twenty years the demand for fuel wood and beech timber has increased and planting of beech and more close to nature management in beech forests was emphasised.

5.7.2 Landscape changes

Trends in landscape changes that started after the industrial revolution are still continued today. Former agricultural land is less intensively used resulting in reforestation. In the whole area of CS Europe forest area is increasing. The forest area increase is, in some cases, the result of planting, but most of the new forest area is covered with different stages of succession plant associations.

In some countries reforestation is already considered as a problem. Various types of extensive use of land is supported by the countries governments to prevent further reforestation and establish more diverse landscape patterns.

5.7.3 Use and structure of the remaining woodland

Public interest in the goods of forest and forested landscape is steadily increasing, requiring an approach to forest management that will include conservation and enhancement of forest stability and quality and of all their functions. More close to nature approach to beech forest management is used in all three countries in question. The importance and intensity of new management approaches differs between countries according to their beech forest coverage. Major goals and long-term objectives of that management approach are (Beguš 1999):

?? Conservation and establishment of the natural composition of forest biotic communities and enhancement of the resilience of forests
?? Forest management which is directed towards the conservation of all forest functions and is based on efficient natural regeneration of stands
?? Appropriate utilisation of forest sites in accordance with the natural development of forest biotic communities

Recognition of other uses of forest and not only timber production, gave beech forests also ecological and social importance. Beech forest functions depend on the location and structure of the forest. When those functions appear, they should be considered in forest management and influence the measures, which are taken in the forest (Prpic, D. Rauš 1992).

The importance of non-commercial functions and its influence on the management is different among countries. In Slovenia, for example, an approximate evaluation of forest functions shows that, apart from timber production – which is of importance in almost all Slovenia's beech forest (except in highly protective forests on steep slopes and subalpine belt, which cover about 7 % of forest area) – at least one ecological or social function is important in over half of the forest. Considering that forest functions overlap, the protective function (forests preventing erosion and protecting forest soil and natural vegetation) is most important in 20 % of the forest area, the hydrological function in 16 %, the natural and cultural heritage-protection function in 14 %, the tourist and recreational functions in 8 %, and other functions (i.e. climatic, aesthetic, educational, scientific, biotopic, and the function of protecting settlements and infrastructure) in 20 % (Beguš 1999).

Silviculture measures represent the implementation of forest management policy. Some basic silviculture guidelines for more nature based forestry practice in beech forest are (Beguš 1999):

?? Increasing of growing stock by increment accumulation
?? Enhancing natural composition and stand structure
?? Promoting large trees of high quality
?? Moderate and frequent tending measures
?? Promotion of natural regeneration using the canopy protection
?? Obligatory silvicultural planning

According to stand structure and species composition two main management concepts in beech forests of Croatia can be recognised: 1) Management of beech forests on bigger areas with various sizes of seed feelings and 2) management of fir-beech forests in a selective way on smaller scale.

Beech forests in Croatia are cultivated as uneven-aged high forests. Management is carried out by group selection system or group cutting. Lesser part of beech forests is coppice forests. Beech generally regenerates naturally under the canopy. Artificial regeneration using seedlings is very rare. Coppice forests are by natural reconstruction converted into high forests. Tending in young stage forest is general practice in Croatia. Young stands are regularly thinned. The principles of thinning are the following: basal area should not be reduced more then 20 % without special reason and breast diameter of the medium stand tree should not be reduced if not necessary. However, the thinning method is more important than intensity. Trees of low quality are reflected in poor outward appearance and which obstruct the growth of good quality trees, are removed. The objective is to accumulate the stand increment on best quality trees (Matic, Oršanic et al., B. Mayer 1996).

In Austria at present the natural regeneration of beech stands dominates. The classical method is shelterwood cutting on an area up to 1(2) and 3 ha (preparation cutting, seed cutting, several release cuttings and the final cut). The final cut will be done, if the regeneration covers most of the area of the stand and the height of young plants is 30 to 60 cm.

The treatment goal for the young stand phase is to achieve a dense, homogenous thicket with a high number of well-formed trees in a good spacing. Sometimes weeding (reducing the competition of shrubs and undesired tree species) is necessary.

Cleaning, at 3 to 6(10) m top height, should eliminate wolf-trees and forked dominant and co-dominant trees (negative selection). Generally there are discussions about the necessity of treatments (intensity, type) in this stand phase. Therefore treatments are neglected in most cases.

The choice of crop tress and selective thinning, starting at a top height of 15 to 18 m (branch free bottom log of 8-12m) is already current practice. In the second half of the rotation cycle increment thinnings are obligatory up to 20 years before starting shelterwood cutting.

Since two decades alternate silvicultural concepts (shelterwood group selection system, selection forest), based on observations in nature forest reserves, are discussed and also practised in few enterprises. Main topics of the discussion are the quality development and –guaranty in the young stands, which grow up form shelterwood group regeneration (Hochbichler 2001).

In Slovenia, close to nature, sustainable and small-scale forest management has been applied in beech forests for over 35 years. In that period important information about forest reaction to different management techniques have been gathered. Management techniques used today are the result of that knowledge. Described tending and thinning measures are a general description of management practice in submontane and montane beech forest.

First tending measures (tree species composition regulation, removing trees with bad quality or damages caused during the cut) are done after the final cut. At that point regeneration is usually in saplings stage. At least once in next ten years this measures are repeated.

First positive selection thinnings begin in young stands of which trees in average are less than 10 cm in diameter. They are usually 5 – 7 m high and about 40 years old. More than one third, of the total number of the trees, is removed. Tree species diversity is one of the important goals in forests management. Other tree species, like wild cherry, sycamore, ash and oak are promoted. According to their availability, sometimes with no regard to their quality. Thinnings are repeated once in every 10 years. Usually 2 – 3 thinnings are done before the stand turns into the pole stage forest (trees with more than 10 cm in diameter). Stands in pole stage are thinned 4 – 5 times. In one thinning from 20 – 35 % of growing stock is cut. Actual intensity of the thinning depends on several factors such as ice and snow break hazard, stand quality, stand stability, stand accessibility, previous silvicultural treatment and site conditions. Older stands are thinned two times before final cut. Rotation period in beech forests is 130 – 140 years. At the end of the rotation period beech forests are expected to have from 600 – 700 m^3/ha of growing stock and ca. 300 trees with over 60 cm in diameter per hectare. Up to 25 % of wood volume can be of best quality.

After 110 years regeneration felling begin. Its start, location and intensity depends on stand quality, volume increment and site conditions. One third of the growing stock is cut in the regeneration felling and small openings (0,2-0,3 ha, sometimes more) in the canopy are established. When natural beech regeneration reaches sapling stage (usually after 20-30 years), second, so-called, light felling is done and another third of growing stock is cut. Final felling is done ca. 10 years after the light felling and regeneration period lasts approximately 40 years. Small regeneration openings are merged into bigger regeneration area up to 2 ha big.

5.7.4 Impacts on biodiversity

?? First changes towards more nature-based beech forest management are evident after the WW2. In last two decades this type of management is also put into legislation.
?? Different actions and beech forest management guidelines improved the condition of beech forests in terms of ecological and economical stability and biodiversity.

More close-to-nature and multifunctional management, minimising negative effects of human activities on biodiversity, will be introduced in beech forests in the future.

In modern period, on the area of SC Europe, deforestation and grazing are not any more main impact factors to change the natural structure and processes in beech forests. Factors like air pollution, inappropriate game management, resulting in too big populations of different herbivores, remainings of old silvicultural systems and change of species are more important.

Factors intensity differs in space and time and can considerably change the appearance of forest areas also affecting the biodiversity. New knowledge about the other non-commercial functions of beech forest, and impact of man on the forest ecosystems and their boidiversity changed the approach to forest management. More concern is put in other forest functions and biodiversity, changing basic measures taken in beech forest.

Today forest owners and forest managers are more aware of the role of the biodiversity in the stability of the forest. Species, habitat and process diversity is important for normal development of forest and can contribute to establishment of healthy and sustainable managed beech forests. Some actions that were taken also in beech forests with different intensity in different countries are:

?? Introduction of small-scale, locally adapted forestry measures, with the emphasis on natural population of tree species
?? Introduction of big carnivores (bear, wolf, lynx)
?? Management of CWD (different sizes, locations and time distribution)
?? Promotion of fruit-bearing tree and shrub species
?? No management close to water bodies
?? Management of forest edge (structure, composition)
?? Establishment of the net of natural forest reserves

Those actions should provide diverse habitat and process conditions for plant and animal species development, decreasing the negative human impact on natural beech forest biodiversity.

5.8 Summary

?? Beech forests cover almost half of the total forest area in countries of South Central (SC) Europe (Austria, Croatia and Slovenia) and play important role in forest management and landscape structure of this region.
?? Importance of beech forests for man was changing through time, first being food, building material and firewood source, then becoming important energy source and finally being the source for providing quality timber and fulfilling present non-commercial forest functions.
?? Human impact on beech forests was destructive in the past, with negative influence on biodiversity. Changes in landscape patterns, habitat features, and continuity of beech forests had negative impact on development of plant and animal species distinctive of natural beech forest.
?? Modern approach on beech forest management understands forests as a process and not as a product. It is introducing close-to-nature, multifunctional management practices that allow adaptation to local site and forest conditions and will result in healthy and habitat, species and process diverse beech forest.

Beech forests cover considerable forest area in SC Europe. They are represented with 70 % in Slovenia, around 60 % in Croatia and close to 10 % in Austria, regarding to total forest areas of those countries. They cover altitude belt from 300 to 1800 m in area of Southern Alps and altitude belt from 500 to 1450 m in the Dinaric region. Sites that are not suitable for beech are dry, warm sites, sites with high level of ground water and sites with low precipitation, which occur in subpanonian and Mediterranean parts of described countries.

According to their distribution and share in total forest area, beech forests always played an important role in the industrial development in the area of SC Europe. Their role was changing through time. Different periods, according to beech forests importance in human development can be recognised: food and game source, energy source, not wanted species and quality timber source.

- ?? Food and game source period
- ?? Beech forests provided food for different game species. Forests were important as hunting and basic food supply area for the man, also providing building material and firewood. Impact of man on forest area was local, spatially dispersed and not intensive.
- ?? Energy source period
- ?? After the industrial revolution, development of technology enabled usage of steam and coal. Beech forest were main source of energy for developing industry, resulting in great deforestation and beech forests devastation without planning and sustainable management.
- ?? Not wanted species period
- ?? After the beginning of coal use for industry purposes, beech forests became less important. More technical wood was needed and conifers were planted on beech sites. Beech was systematically reduced and beech forests share decreased especially on account of Norway spruce.
- ?? Quality timber source period
- ?? Big problems with Norway spruce and other conifer monocultures and the development of new technological methods for hardwood timber processing increased the value of beech wood. New knowledge about silviculture in beech forests and their role in natural resources protection (water, soil, climate…) enabled the production of high quality beech timber and fulfilment of other beech forest functions. The result was greater interest of forest owners and managers in beech, which increased the share of beech forests in the area of SC Europe.

Beech forests were heavily used in the past for more or less only economic reasons.
New roles and functions of the beech forest appearing strongly in last two decades changed basic management philosophies of the past and introduced different way of thinking. This change is evident from new guidelines that have been settled in the countries of SC Europe, concerning beech forest management.

Modern guidance on beech forest development should be based on the principles of sustainability, the close-to-nature concept and multiple-use. Therefore, the forest management strategy should consist of small-scale systems, which allow a flexible adaptation to natural site conditions and to natural forest development trends. The emphasis should be placed on the conservation of natural populations of forest trees, on the maintenance and establishment of natural diversity and on increasing the growing stock, all of which will contribute to the ecological and economic stability of forests.

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5.10 Case study Brezovara Reber, Slovenia

Interviewer:	Dušan Roženbergar
Interviewed person:	Mr. Žunic Stane, B.Sc. in forestry, The head of Department for silviculture in Slovenia national forest service – unit Novo mesto, Novo mesto, Slovenia
Date and place of the interview:	15th of February 2001, Novo mesto, Slovenia

5.10.1 General description of the area

Forest management unit Brezova Reber is situated on SE part of Slovenia (figure 1) and covers the area of 1739 ha, of which 1718 ha is forestland.

Figure 1. Geographical location of forest management unit Brezova Reber (Pirc 1997)

It is located on karst plateau, above the Krka river and is slowly descending in N and NE direction. Altitude of the unit varies from 200 to 596 m. Parent material is mostly limestone with some smaller areas of dolomite. Typical karst features like dolinas and abysses are common. Deep brown calcareous soils prevail. Some rendzina can be found. Climate of the area is moderate with average year temperatures 8-9 °C, 1200 mm of precipitation, 170-190 day long vegetation period and two month of snow cover per year. Sleet is common and causes ice break damage.

5.10.2 Beech forest communities and types

Beech (*Fagus sylvatica*) is dominant tree species. Three beech forest communities cover 97 % of forest area of Brezova Reber:

oak-beech forest (*Querco-Fagetum*) 57 %
montane beech forest (*Enneaphyllo-Fagetum*) 37 %
submontane beech forest (*Hacquetio-Fagetum*) 3 %
calcareous substrate oak forest (*Lathyro-Quercetum*) 3 %

For management purposes five different forest types were recognised: sessile oak (*Quercus petraea*)–beech stands on oak-beech forest site (*Querco-Fagetum*), beech stands on submontane beech sites (*Hacquetio-Fagetum*), beech stands on montane beech forest sites (*Enneaphyllo-Fagetum*), Norway spruce (*Picea abies*) monocultures on oak-beech forest sites and protective forests on calcareous substrate oak forest sites (*Lathyro-Quercetum*).

?? Sessile oak–beech stands on oak-beech forest site (*Querco-Fagetum*) (830 ha)
This forest type is composed mainly of pure evenaged beech stands that were established with shelter fellings. Some smaller locations were planted with Norway spruce and silver fir (*Abies alba*). Beech prevails with 70 % share in growing stock. It is followed by Norway spruce (15 %), silver fir (7 %), sessile oak (2 %) and Wych elm (*Ulmus glabra*) and sycamore (*Acer pseudoplatanus*) (3 %). Stands have been thinned and quality of broadleaved tree species is good. Regeneration of beech is abandoned, while sessile oak generation is poor. Browsing damages are evident on sycamore regeneration.

?? Beech stands on submontane beech sites (*Hacquetio-Fagetum*) (67 ha)
Evenaged beech stands with Norway spruce in groups in altitudes between 500 - 590 m. Tree species stand composition is following: beech 58 %, Norway spruce 26 %, sycamore 8 %, wild cherry (*Prunus avium*) 3 %, sessile oak 2 %, hop hornbeam (*Ostrya carpinifolia*) 2 %.

?? Beech stands on montane beech forest sites (*Enneaphyllo-Fagetum*) (624 ha)
Beech stands with Norway spruce and fir admixed in groups. Older stands are result of big area shelter cuts. Younger stands have been established by small-scale cuts. Beech and sycamore regeneration is strong. Fir regenerates poorly and is heavily browsed. Stands are composed of beech 58 %, Norway spruce 18 %, silver fir 15 %, sycamore 7 % and sessile oak 1 %.

?? Norway spruce monocultures on oak-beech forest sites (156 ha)
Norway spruce has been planted on agricultural land. Stands are 90-110 years old. Stands health condition is problematic, due to snow break, windbreak, fungi and bark beetle. Broadleaved tree species regeneration is inhibited by abandoned ground vegetation. Norway spruce prevails with 75 %. Other species are beech 11 %, sessile oak 5 %, sycamore 3 % and silver fir 2 %.

?? Protective forests on calcareous substrate oak forest sites (*Lathyro-Quercetum*) (50 ha)
This stands cover steep south slopes above Krka river. They are composed of beech, sessile oak, Scots pine (*Pinus sylvestris*), hop hornbeam, *Quercus cerris*, and other thermophilous tree specie s. Protective function of those forests is very important.

5.10.3 History of beech forest management in the area

Before the 15th century, beech forests of Brezova Reber were mainly exploited by farmers. The development of industry, especially ironworks and glassworks, demanded more beech wood and intensity of exploitation of these forests increased. In 1793, Brezova Reber became the property of count Aursperg. He employed dr. Hufnagel to be his property manager. In 1893 Hufnagel wrote the first forest management plan for the forests of Brezova Reber. According to management plan all beech stands over 60 years old were cut. Ca. 50 % of total growing stock was cut. After the establishment of beech regeneration, the rest of the wood was removed. 30 years old stands were thinned several times. Negative selection only removed bad quality trees. Wood was used for charcoal production. After the year 1930, same principles were used and coniferous tree species (silver fir, Norway spruce) are promoted and planted. After the WW2 Brezova Reber forests were heavily cut. The regeneration started on 15 % of the area. Some major tending guidelines from forest management plan were: 100 years production period, planting of conifers (Norway spruce, silver fir, Douglas fir), using natural regeneration, regeneration development under the canopy (not for too long), thinning thick regeneration, negative selection, more often and less intensive thinnings. Modern principles of tending were introduced after 1965 (Pirc 1997). Special attention was given to young stands (from thicket to pole stand) and selective thinning. Growing stock was increasing steadily during the last 60 years (figure 2), mostly due to change in management regime.

Despite some attempts to introduce more conifers to the area beech share in growing stock increased. Those attempts were abandoned after the year 1965 and today conifer tree species represents 30 % in total wood volume.

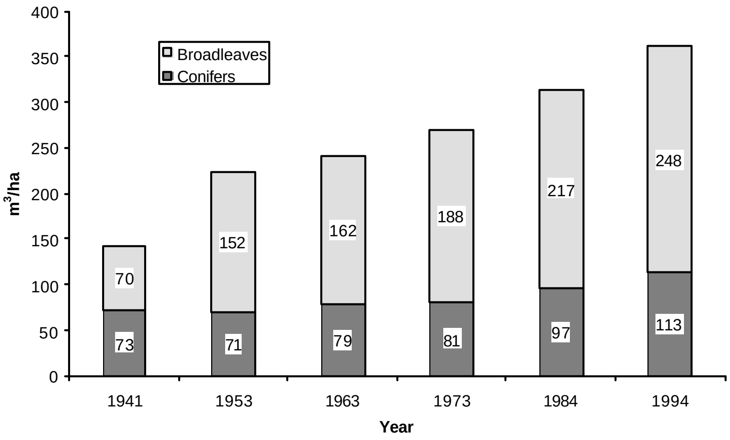

Figure 2. Growing stock change in Brezova Reber from 1941 – 1994 (Pirc 1997).

5.10.4 Principles and methods of beech forest management; management techniques

Close to nature, sustainable and small-scale forest management has been applied in beech forests for over 35 years. In that period important information about forest reaction to different management techniques have been gathered. Management techniques used today are the result of that knowledge. They are presented generally, according to development stage of beech forests:

Young stage forest
Regeneration of beech is vigorous and abundant on the whole area of Brezova Reber. Other natural tree species (sessile oak, sycamore, wild cherry, silver fir) are present, but not so strong. They have to be specially treated to survive the competition of the beech. Spruce is also naturally regenerated from monocultures that have been planted in the area in the past. First tending measures (tree species composition regulation, removing trees with bad quality or damages caused during the cut) are done after the final cut. At that point regeneration is usually in saplings stage. At least once in next ten years this measures are repeated.

Thinnings
First positive selection thinnings begin in young stands of which trees in average are less than 10 cm in diameter. They are usually 5 – 7 m high and about 40 years old. More than one third, of the total number of the trees, is removed. Tree species diversity is one of the important goals in forests management of Brezova Reber. Other tree species, like wild cherry, sycamore, ash and oak are promoted. According to their availability, sometimes with no regard to their quality. Thinnings are repeated once in every 10 years. Usually 2 – 3 thinnings are done before the stand turns into the pole stage forest (trees with more than 10 cm in diameter). Stands in pole stage are thinned 4 – 5 times. In one thinning from 20 – 35 % of growing stock is cut. Actual intensity of the thinning depends on several factors such as ice and snow break hazard, stand quality, stand stability, stand accessibility, previous silvicultural treatment and site conditions. Older stands are thinned two times before final cut. Rotation period in beech forests is 130 – 140 years. At the end of the rotation period beech forests are expected to have from 600 – 700 m^3/ha of growing stock and ca. 300 trees with over 60 cm in diameter per hectare. Up to 25 % of wood volume can be of best quality.

In 1995 average growing stock on the Brezova Reber unit area was 361 m^3/ha. Average volume increment was 11,6 m^3/ha per year.

Annual volume increment increased in last 50 years almost for 100 % from 6,88 m^3/ha in 1941 to 11,60 m^3/ha in 1994. This value is higher than value of annual volume increment calculated for this type of beech forest site mainly because of bigger share of older stands in the unit (figure 3). Allowable cut and its realisation are presented in table 1.

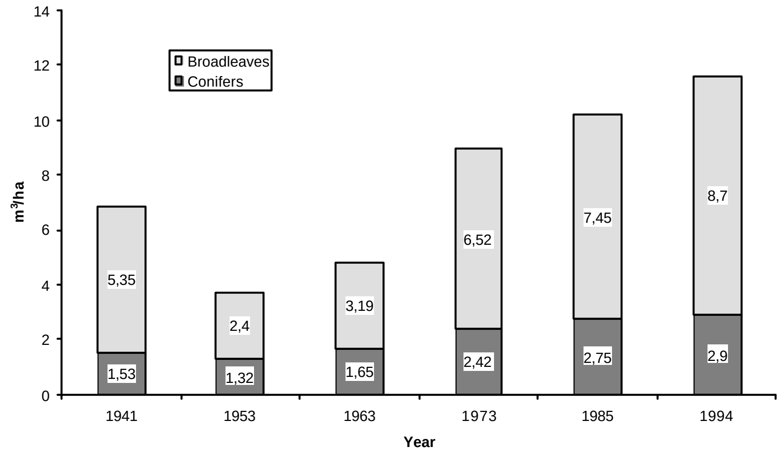

Figure 3. Average annual volume increment from 1941 - 1994 (Pirc 1997)

Table 1. Allowable cut and its realisation from 1942 – 2004 (Pirc 1997)

Year	Allowable cut			Realisation in %	
	Conifers	Broadleaves	Total	Conifers	Broadleaves
1942-1952	1820	7180	9000	161	90
1953-1962	1500	5000	6500	96	96
1963-1972	1750	6050	7800	119	105
1974-1983	2777	7223	10000	108	102
1985-1994	3655	8745	12400	105	88
1995-2004	4068	8548	12616	--	--

In most cases allowable cut was realised and management was intense. According to the model Brezova Reber forests produce 1144 m^3/ha of wood in 120 years. Growing stock of standing trees at this age is 686 m^3/ha. 40 % of the whole stand wood production will be cut during thinnings and 60 % in regeneration fellings.


Figure 4. Beech forest of Brezova Reber

Regeneration

After 110 years regeneration felling begin. Its start, location and intensity depends on stand quality, volume increment and site conditions. One third of the growing stock is cut in the regeneration felling and small openings (0,2-0,3 ha, sometimes more) in the canopy are established. When natural beech regeneration reaches sapling stage (usually after 20-30 years), second, so-called, light felling is done and another third of growing stock is cut. Final felling is done ca. 10 years after the light felling and regeneration period lasts approximately 40 years. Small regeneration openings are merged into bigger regeneration area up to 2 ha big.

Some of the best quality beech forest in this part of the country can be found in Brezova Reber. Due to its relatively remote location, Brezova Reber is not under the pressure of other users of forestland. Close to nature management and production of high quality wood is the priority in those forests. According to current forest management plan, management guidelines are:

?? intensive tending (selective thinnings) of all developmental phases
?? accumulation of growing stock in quality and healthy mature stands
?? regeneration of stands heavily damaged by icebreak with low quality and red heart (figure 4) timber using natural regeneration

Figure 5. Red heart beech wood (Pirc 1997)

Some experimental plots were established in 1970 to educate professional forest employees and approve effects of selective thinning. Three plots were thinned with different intensities and one plot wasn't thinned at all. In present only two plots are monitored – the nonthinned and the most intensively one. Measurements prove that the quality of trees on the intensively thinned plot is essentially higher. The amount of timber wood on the first plot is 71 % and on the nonthinned one only 14 %. The value of average "future" tree is 4,7 times higher on the thinned plot as on the non-thinned.

5.10.5 Conclusion

The change of forest management policy, towards small-scale and close to nature measures, adopted to local site and climate conditions, proved to be the right one. Brezova Reber beech forests stability, growing stock, increment, quality and value increased during the last 50 years. Forests today are in good condition and can provide high quality timber. Healthy and stabile forests also provide sustainable use of other forest functions that are present in this area. They protect forest soil and natural vegetation, promote nature diversity and give basic conditions for recreation.

5.10.6 References

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5.11 Case study: Samobor, Croatia

5.11.1 General description

The area of Samobor is 28 771 ha big and lies ca. 20 km far from Zagreb. It can be divided into two distinctive parts: north-eastern flat land area and south-western hilly part. Flat land part occupies the walley of uper part of the Sava River and hilly part of Samobor and Žumberak Mountain reaching altitudes up to 800 m.

Soils and climate

Substrate is diverse and is composed of acid silicate, slate, sandstone and carbonate limestone and dolomite, which are covering the hilly part. According to substrate different soil types developed; acid brown soils and podsol soils on silicate and carbonate brown soils and rendzinas on limestone and dolomite. The climate is continental with 1100 mm of precipitation, average year temperature 10°C and extreme temperatures from -25 to +36°C.

Forests

Forest cover 12 596 ha of Samobor area, which is 44 % of its total area. Floristically the area is very interesting. Over 890 different plant species have been found, with some endemites too. Flat lands are covered with pedunculate oak (*Quercus robur*) forests and the hilly part with sessile oak (*Quercus petraea*)-hornbeam (*Carpinus betulus*) forest on moderate neutral slopes, sessile oak-sweet chestnut (*Castanea sativa*) forest on south silicate slopes, downy oak (*Quercus pubescens*)-hop-hornbeam (*Ostrya carpinifolia*) forest on steep, south, limestone slopes and beech (*Fagus sylvatica*) on north and north-east, limestone or dolomite slopes.

Species composition in the area of Samobor according to volume shares is: 65 % of beech, 25 % of hornbeam, 7 % of sessile oak and the rest 3 % of sweet chestnut, pedunculate oak, sycamore (*Acer pseudoplatanus*), *Quercus cerris, Alnus glutinosa*, Ash (*Fraxinus excelsior*) and others.

Other tree species mix with beech individually or in small groups. Norway maple (*Acer platanoides*) and sycamore are common. Hornbeam is also commonly present and more abundant in walleys with more moisture. Individual trees of yew (*Taxus baccata*) and holly (*Ilex aquifolium*) can be found. Shrub layer consists of *Daphne laureola, Daphne blagayana, Sambucus racemosa, lonicera alpigena, Rhamnus fallax* and others. Ground vegetation species are *Ruscus hypoglossum, Asperula odorata, Paris quadrifolia, Cardamine bulbifera, Anemone nemorosa, Hacquetia epipactis, Asarum europaeum* and others (Klepac 1992).

5.11.2 History of beech forest management in the area

The first information of intensive use of Samobor forests dates in year 1242. At that time wood was used for fire and construction. Some old records show that majority of the natural forest in Samobor was cut at the beginning of 17th century. The first forest management directions were prescribed by Maria Theresa, archduchess of Austria and queen of Hungary and Bohemia. As a result Salix sp. stands were established for fuel purposes lowering the pressure on beech and oak stands. After the year 1800 first glassworks started operating. Forests were heavily cut and grazed at the same time, which resulted in bad conditions concerning forest resources. Lowland oak forests were cut completely and beech forests were damaged. Unregulated use of forests stopped in 1903 when new regulation was adopted, that for all forest areas management plans must be done and trees have to be planted. Documents from the year 1938 show that 43,5 % of Samobor area was covered by forest of which 56 % was high forest, 32 % was coppice and 12 % was bushes.

After the WW 2 the whole area became the property of the state and management enterprise was established. Whole area was covered by management plans and forests were managed more systematically. Data about the cut and tending activities in the years 1981-1990 is shown in the table 1 and 2 (Klepac 1992).

Table1. Volume of wood cut in the period 1981-1990 in Samobor area (Klepac 1992)

Tree species	m^3
Oak	2634
Beech	171394
Sycamore	1578
Hornbeam	2018
Sweet chestnut	2979
Quercus cerris	2384
Other broadleaves	30846
Conifers	8069
Total	221902

Table 2. Tending activities in young stage forest in the period 1981-1990 in Samobor area

Activity	ha
Ground preparation	716
Reforestation	183
Tending	925
Cleaning	533
Total	2357

In 1990 new Forest act was passed in Croatia that puts bigger concern to natural environment conservation and ecological and social functions of the forest.

5.11.4 Principles and methods of beech forest management; management techniques

Silvicultural treatments used in pure, even-aged stands of beech are divided into regeneration treatments and tending treatments.

Regeneration

Regeneration is conducted with natural regeneration under the canopy employing seed fellings in large areas. Usually the whole process of regeneration is done in three fellings, sometimes more. First regeneration cut (renovation felling) is not so strong (20 % of growing stock), while other two are the same intensity (50 %). The cut is evenly distributed through the whole area. Regeneration period (from first to last cut) is never longer than 10 years. With to intense first cut ground vegetation development could be a problem especially in evenaged stands with no understory. In that cases never more than $150m^3$/ha should be cut at once.

In beech stands with high growing stock, thick dead leaves and raw humus layer prevents germination of beech seeds and regeneration development. In such cases, ground is disturbed and prepared for natural regeneration. Work is done by hand or machinery, rarely with chemicals.

First regeneration cuts (renovation fellings) in smaller areas cutting only few trees or a group of trees and longer regeneration periods are used in beech forests with greater ecological or social value. Due to increase in ecological and social value of beech forests and negative public opinion on big area regeneration cuttings, this small-scale type of regeneration practice will be increasingly important in the future. Small-scale and long regeneration period management in beech forests increases tree species diversity and enables other tree species to develop in mixture with beech. Forest ground is never totally exposed which contributes to protective functions of beech forests.

Regeneration cuts are applied also in coppice beech forest. In that way they are transformed into high forest. Clear cuts are not allowed in Croatia and were never the way to regenerate forest. Natural regeneration is used in areas with good quality coppice forests and seedlings are planted in badly structured and low quality beech coppice forest (Matic, Oršanic et al., B. Mayer 1996).

Tending
Different tending measures are applied in beech stands through whole their development. In general they can be divided into three parts: tending of beech regeneration after the final regeneration cut, negative selection in saplings stage and thinnings.

Beech regeneration tending is done once after the final regeneration cut. All obstacles and remainings of the cut are cleared away and badly damaged young trees are cut. Negative selection and weeds removal is usually done twice until maximum height increment period (usually around 30 years).

Positive selection thinnings are applied from that period to first regeneration cut. Time period between two thinnings is usually 10 years. Average period volume increment is cut. Intensity of the thinning is calculated from following formula: I=1/n*100, where I = percentage of growing stock and n = age of the stand in decades.

Thinning method is established according to biological-economic classification of the stand. Thinning wood volume must be cut in upperstory (dominant trees) in a share that is at least equal to the share of upperstory trees volume in total stand volume. In that way quality development of stand structure and stability is enabled (Matic, Oršanic et al., B. Mayer 1996).

5.11.5 Conclusion

Somobor beech forests are important economically, ecologically and socially to the local area and its inhabitants. With the wood volume of 1 550 000 m^3 and annual increment 50 000 m^3 they have economic power that will be needed in the future. Forests of Samobor have also other important roles: they prevent erosion and site degradation (steep slopes), improve the quality of underground water, enable good recreational conditions and provide sites for educational and research activities. Therefore they must be managed in multifunctional and sustainable way, so they will provide all the goods mentioned above. According to listed facts and the fact that those forests are in the vicinity of Croatia capitol in 1992 the proposal was sent to state government to protect Samobor area as a National forest park.

5.11.6 References

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5.12 Silvicultural and Economic Considerations of Beech in Romania

5.12.1 Introduction

Common beech is the second most common braodleaved species in Europe, occupying about 14.1 million ha (Dinca, 1993). Its range extends from Southern Scandinavia to central Spain, Corsica, Sicily and Greece, westwards to Britain and eastwards to western Russia and Crimea (Figure 1). Romania is among the European countries with the largest area of beech. Because of their area and both market and non-market high value, beech forests are the most important and valuable forests of Romania.

5.12.2 Distribution of beech in Romania

Towards its eastern European distribution area, beech occupies 1,915,657 ha or 30.7 per cent of the total forest area in Romania (MAPPM, 1994) and is the most common forest species of the country. It mainly occurs in the hilly and mountain regions of Romania (Figure 2). The lower altitude limit of compact beech forests is 300-500 m and the upper limit is 1200-1400 m. In south-west Romania beech could be found at lower elevations (100-200 m) along the valley floors with a high air humidity level (Stanescu, 1979). In some parts of Western Carpathians and south-western parts of Central Carpathians, beech forests form the upper limit of the forest vegetation, being found at elevations between 1400 and 1650 m. This is probably due both to the antrophic factors (preferential extraction of conifers in the last centuries) and the climate in these parts of the country (warmer but quite moist) which favours the growth of pure beech stands to greater elevations (Negulescu *et al.*, 1973).

Within its area, beech frequently forms pure stands (especially in Western and Central Carpathians) but at lower and higher elevations it is found in mixtures with other species. According to Decei et al. (1986) the proportion of beech in mixed forests is 25.3 per cent of the total forest area covered by this species. In the low hilly area beech frequently forms mixed forests with oaks (especially sessile oak) and hornbeam and at higher elevations (mountain forests) beech is found in mixtures with Norway spruce and silver fir.

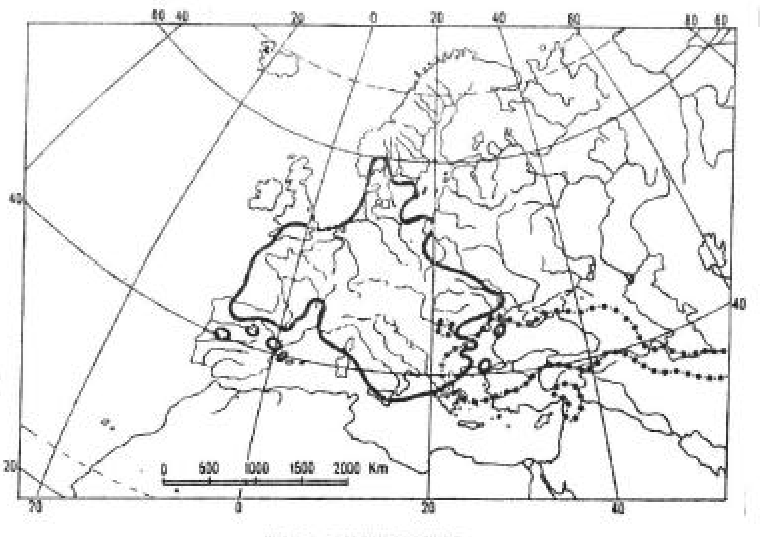

Figure 1. The range of common beech (*Fagus sylvatica* L.) and Caucasian beech (*Fagus orientalis* Lipsky)[Stanescu *et al*., 1997]. __________ *Fagus silvatica* …………. *Fagus orientalis*

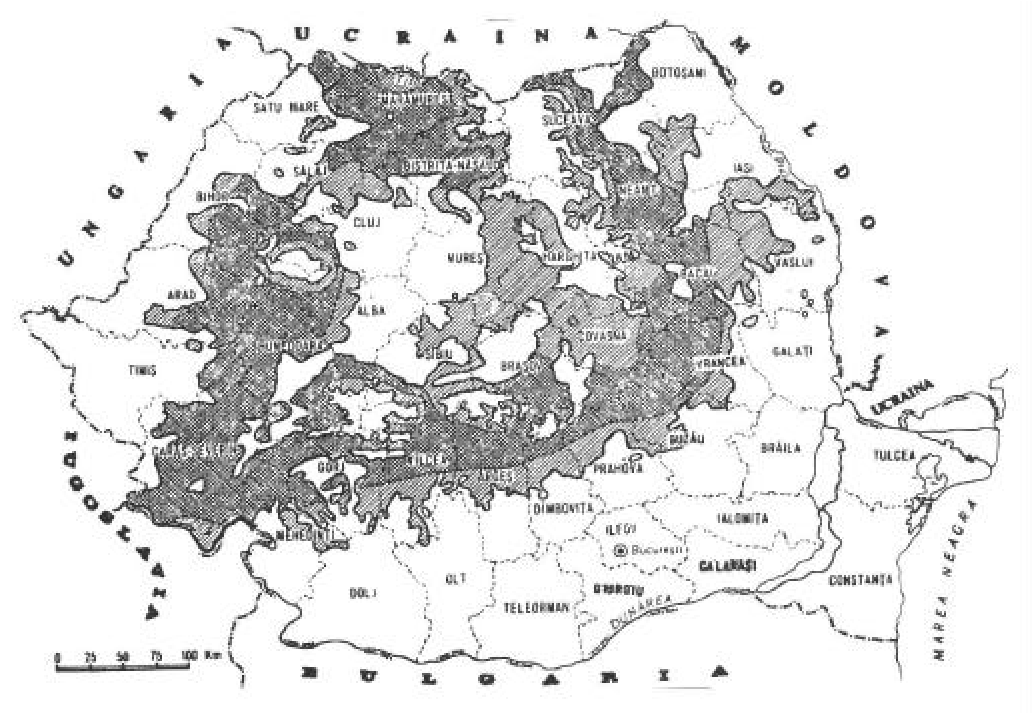

Figure 2. Distribution of common beech in Romania (Stanescu *et al*., 1997)

	High frequency		Low frequency

5.12.3 The main climatic and site requirements of beech

Beech grows well in hilly and low mountain regions of Romania. It does best in moist and rather mild climates and, in general, the range of this species is determined by rainfall and temperature (Table 1). Moisture is important for beech and it is absent where rain is insufficient or where soil is too dry (Stanescu, 1979). Whilst in England, at annual mean temperatures of 5-6^o C common beech requires at least 500 mm annual rainfall, in Romania, at annual mean temperatures of about 10^o C this species requires 900-1000 mm of rainfall (Stanescu *et al.*, 1997). Lower values of precipitation could be partially compensated by greater air humidity; thus, beech descends to lower altitudes along valley floors in hilly regions. Like many shade bearers, it suffers very badly from both early autumn and late spring frosts and can be extremely difficult or impossible to establish on exposed, open ground without nurses (Milescu *et al.*, 1967). Although beech is quite sensitive to frost and heat, it is resistant to severe cold (Stanescu, 1979).

In Romania, beech grows on a very wide range of soils, including acid, neutral and alkaline (Table 1). Best development tends to be on near neutral to slightly acid soils, but poorest growth is found at both extremes - very acid and very alkaline (Stanescu, 1979). Beech dominates the main central part of the moisture / nutrient range of forests. Soil texture ranges from clayey-loam to loamy-sand. Beech is frequently dominant on well-drained loams and sands and unsuitable sites are either 1) heavy and waterlogged, or 2) infertile, dry and sandy, on both of which it may suffer badly from drought in dry years. Beech is found neither on soils with pseudogley, nor when reducing conditions are found within 20 cm from the soil surface (Milescu *et al.*, 1967).

5.12.4 Flowering, seed production and nursery conditions

The flowers appear in April-May at the same time as leaves and are sensitive to late frosts. Seeds ripen in September-October. The earliest age at which the tree bears seed is 70 to 80 (5-10 years earlier in open ground) and the mast years are usually at intervals of 4-6 years. There are between 3000 and 5000 seeds/kg and the germination capacity is usually 50-70 per cent (Stanescu *et al.*, 1997). Beech seed cannot be stored for long periods (normally less than 6 months) and is sown most commonly in the autumn. Although very rarely, seed can be sown next spring and in such situation it has to be stored carefully to ensure it does not heat or "sweat".

In Romanian forestry beech seed is mainly used for direct seeding in areas where through the application of the silvicultural systems the species regeneration does not occur naturally. Very rarely beech seedlings are produced in forest nurseries (in spring 1999 there was only one nursery all over the country producing beech seedlings). This is due both to the easy natural regeneration of beech and the difficulties in producing seedlings in nursery.

In nurseries, the seed is sown in the autumn (immediately after seed collection) or next spring, after the late frost period, when the mean temperature is higher than 4^0C. Seeds are usually sown by hand in drill marks at depths varying from 5-6 cm in the case of autumn sowing to 2-3 cm for spring sowing at a rate of 150- 200 seeds/m. The seedlings cannot survive without nurse and are very sensitive to heat and drought especially in the first year. They re usually planted at the age of 2-3 years.

5.12.5 Growth, production and productivity of beech

Beech grows very slowly for the first 5-7 years. After this age the height growth accelerates and the growth rates are greater than for silver fir but less than for Norway spruce (Haralamb, 1967). In pure stands, the current annual height increment reaches the maximum values at the age of 25 - 30 years and the maximum mean annual height increment occurs between 60 and 80 years (Table 2).

Table 2. Summary of yield tables for common beech (Giurgiu *et al.*, 1972)

Yield class	Main crop						Thinnings	Total	Volume increment	
	Age	Height	Dbh	Stem number	Basal area	Volume	Volume	volume	C.A.I.	M.A.I.
	year	m	cm		m^2	m^3	m^3	m^3	m^3	m^3
I	20	10,4	7,8	4300	19,4	113	6	119	9,4	6,0
	40	20,5	17,8	1242	30,9	321	72	393	15,1	9,8
	60	27,3	26,4	681	37,3	508	187	695	14,4	11,6
	80	31,3	33,4	469	41,1	640	314	954	12,1	11,9
	100	34,1	39,1	366	43,9	744	422	1166	9,5	11,7
	120	35,9	43,2	312	45,8	813	507	1320	6,9	11,0
V	20	3,6	3,2			21		21		1,1
	40	8,2	7,1	3940	15,6	75	17	92	5,2	2,3
	60	12,8	12,0	2016	22,8	157	57	214	6,2	3,6
	80	15,9	16,0	1308	26,3	218	117	335	5,7	4,1
	100	17,8	19,0	996	28,2	259	176	435	4,5	4,4
	120	19,2	20,9	862	29,6	290	217	507	3,0	4,2

At 100 years, the mean height of beech forests averages 17.8 m in YC V and 34 m in YC I (Giurgiu *et al.*, 1972). At the same age, the mean diameter varies between 19 cm (YC V) and 39 cm (YC I). Decei and co-workers (1986) found that, generally, the height of common beech in mixed stands is less than for pure stands (Table 3).

Table 3. Growth dynamics of the mean height in mixed and pure stands of YC I and YC III (Decei *et al*., 1986).

Species	Yield class	Mean height at the age of 20, 40, 60, 80 and 100 years in pure and mixed stands									
		2	0	4	0	6	0	8	0	10	0
		pure	mixed	pure	mixed	pure	mixed	pure	mixed	pure	mixed
Common	I	10,4	8,1	20,5	18,5	27,3	25,9	31,3	30,8	34,1	33,6
Beech	III	7	6,3	14,4	14,3	20,1	20,1	23,6	23,8	25,9	26

In YC I the total volume production of beech forests reaches 550 m^3 ha^{-1} at the age of 50, and 1320 m^3 ha^{-1} at the age of 120 (Table 2). The total volume production is much lower in YC V: 150 m^3 ha^{-1} at the age of 50 and 507 m^3 ha^{-1} at the age of 120.

In pure stands, the maximum value of the current annual volume increment is reached between the age of 40 and 50 in the forests of the Ist yield class (15.7 m^3 ha^{-1} yr^{-1}) and the age of 55 and 70 in the forests of the Vth yield class (6.2 m^3 ha^{-1} yr^{-1}). The mean annual volume increment has maximum values at ages between 70 and 85 years in the forests of the Ist yield class (11.9 m^3 ha^{-1} yr^{-1}) and between 95 and 105 years in the forests of the Vth yield class (4.4 m^3 ha^{-1} yr^{-1}).

According to Decei and co-workers (1986) the dynamics and the size of the current annual volume increment of the common beech in mixed stands is different in comparison with pure stands. The maximum value of the current annual volume increment is reached at ages between 50 and 70 years; afterwards the values of the current annual volume increment fall more slowly than in pure stands. At the age of 100 years, the current annual volume increment is 2-4 m^3 ha^{-1} yr^{-1} higher in mixed stands than in pure stands.

5.12.6 Silvicultural aspects: Regeneration, silvicultural systems and tending operations

In Romanian forest practice, common beech is almost entirely regenerated naturally. Climatic and site conditions are very favourable to natural regeneration almost all over the country and shelter-wood system is the most common system applied in production forests, especially in pure even and relatively even aged forests. In mixed forests the groups ("progressive felling") system is dominant, allowing the regeneration of the constituent species in good conditions (Table 4 and Figure 3).

In protection forests, taking into account the management goals, more intensive systems/fellings are applied: conservation felling, selection system and group selection system (Table 4).

In all situations, beech regeneration requirements should be taken into account; thus the application of each system should be adapted to the local regeneration conditions. Soil conditions should be favourable (no weeds, loose soil etc.) and seedlings require protection during the first years (normally provided by the crowns of the standing trees) until they reach 40-60 cm in height. After this stage, they can develop properly in an open environment (Haralamb, 1967).

Table 4 presents the choice of silvicultural systems in pure and mixed beech forests according to forest function, productivity and age structure as specified in the Romanian technical norms (MS, 1986). As shelter-wood system is specific to pure beech forests and groups system is the most common in mixed beech forests, being the most applied systems in Romanian production beech forests, their main characteristics are presented in Figure 3.

Table 4. Choice and application of silvicultural systems/treatments in pure and mixed beech forests (MS, 1986a).

Forest formation/ Age structure	Productivity	Functional group/category I/ 1	 I/ 2	 I/ 3	 I/ 4	 *II/* *5*	 *II/* *6*
<u>A.Pure beech forests:</u>							
- *Uneven and relatively*	High and medium	NF	C	S	S	*S/GS*	*S/GS*
uneven aged forests	Low	NF	C	S	S	-	*S/GS*
- *Even and relatively*	High and medium	NF	C	S	S/GS/P	*S/GS/P*	*S/GS/P/US*
even aged forests	Low	NF	C	S/GS	GS/P	-	*S/GS/P/US*
<u>B1. Mixed forests:</u> (Norway spruce-beech, silver fir-beech, beech-conifers)							
- *Uneven and relatively*	High and medium	NF	C	S	S	*S*	*S*
uneven aged forests	Low	NF	C	S	S	-	*S*
- *Even and relatively*	High and medium	NF	C	S	S/GS	*S*	*S/GS/P*
even aged forests	Low	NF	C	S	S/GS	*GS*	*GS/P*
<u>B2. Mixed forests:</u> (beech-oaks, beech – other species)							
- *Uneven and relatively*							
uneven aged forests	High and medium	NF	C	S	S	*S*	*S/GS/P*
	Low	NF	C	S/GS	S/GS	-	*S/GS/P*
- *Even and relatively*							
even aged forests	High and medium	NF	C	S/GS	S/GS/P	*GS/P*	*GS/P*
	Low	NF	C	S/GS	GS/P	-	*GS/P*

Note:
1. Functional groups:
I – protection forest
II – production forest
2. Functional categories:
1 - forests with special protection functions in which felling is forbidden by law
2 - forests with protection functions in which only conservation felling is allowed
3 - forests with protection functions in which only intensive silvicultural systems are allowed
4 - forests with protection functions in which extensive silvicultural systems are allowed but with specific restrictions
5 – production forests specially managed to produce high quality timber
6 – production forests
3. Silvicultural systems/fellings: NF – No felling; C – Conservation felling; S – Selection system; GS – Group selection system; P –“Progressive” or Groups system; US – Uniform shelter-wood system

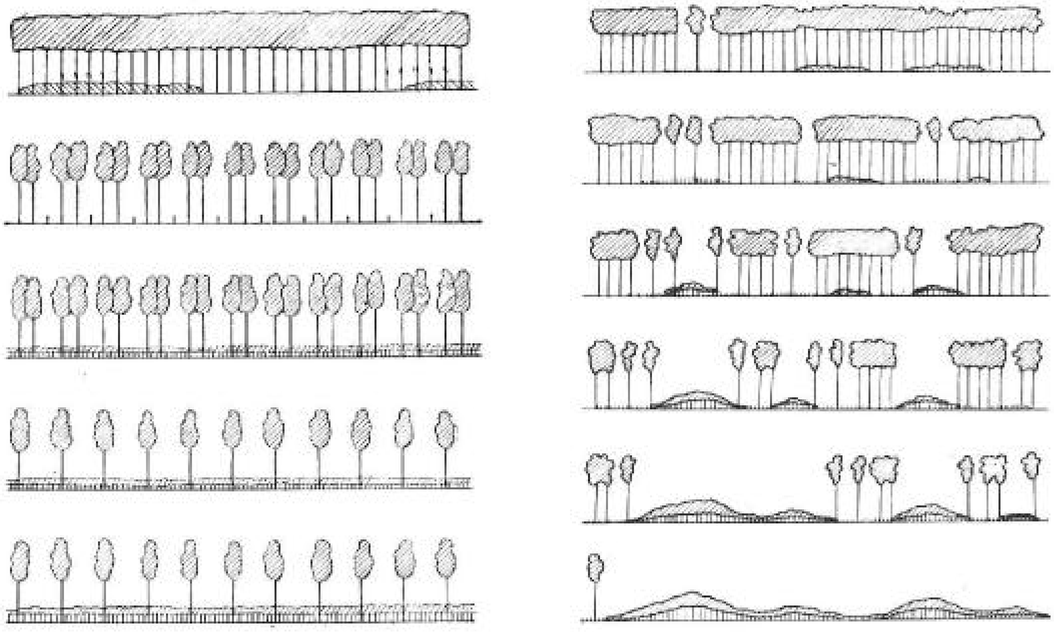

Figure 3. The main characteristics of the uniform shelter-wood and groups systems (Negulescu et.al., 1973).

Uniform shelter-wood system	Groups or "progressive felling" system
Characteristics: 2 or 3 fellings; maximum regeneration period: 20 years; -1st felling ("seeding" felling): in a mast year, during the following winter; stand is "open" uniformly in order to allow seeding; intensity (by volume) : <20% in a "moderate" intervention (when 3 fellings are performed) and <40% in a "heavy" intervention (when 2 fellings are performed); if the regeneration is not satisfactory another "seeding" felling can be performed in the next mast year or the gaps are regenerated artificially; -2nd felling: although theoretically it should be uniform, this felling should be performed according to the regeneration obtained during the "seeding" felling; thus the degree of "uniformity" varies according to the regeneration; 2-5 years after the "seeding" felling; in a mast year if the regeneration is not complete; 20-40% of the volume is extracted; -3rd felling (final felling): when more than 80% of the area is regenerated and the age of the seedlings is 4-8 years and the height is 40-60 cm; - When the regeneration after the "seeding" felling is very good, the 2nd felling could be the final one.	***Characteristics:*** 2 or 3 fellings; maximum regeneration period: 20 years; -1st felling ("gap opening" felling): gaps are opened where regeneration ocuured in order to allow seedlings to develop; gaps are opened in a mast year; size of the gaps depends on the regenerated area/ mean height of the trees (usually ½ mean height) in order to offer sufficient protection to the seedlings; intensity (by volume) : according to the existent regeneration; up to 50% of the standing volume; -2nd felling ("gap enlargement"): 3-5 years after the "gap opening" felling; in a mast year; according to the regeneartion situation; thus in most cases is not uniform; up to 50% of the standing volume extracted; -3rd felling ("gap connecting" felling): when more than 80% of the area is regenerated; after a mast year; - In situation when after the "gap opening" felling regeneration occurs satisfactory between "gaps", the 2nd felling could be the final one.

Beech silviculture in Romania is a traditional, ecological-oriented one, involving low-moderate intensity tending operations (spacing/weeding, cleanings and thinnings) and leading to quite long rotations (Table 5).

Table 5. Rotation ages of Romanian beech forests (MS, 1987).

Yield class	I		II		III		IV	V
Wood assortment	a	b	a	b	a	B	c	d
Rotation (years)	120	140-150	120	140-150	110	140-150	100	90

Note: a - sawmill quality, b – veneer quality, c – medium/low sawmill quality; d – pulp and paper, construction etc.

In most beech stands, after a mast year more than 300,000 seedlings/ha normally survive till next year (Stanescu *et al.*, 1970). In the first 10-20 years the high number of seedlings per hectare and the intense natural competition and elimination are specific characteristics of beech forests in Romania (at ages of 20 years the number of trees reduces to about 10-15,000/ha). Thus, spacing and weeding are performed later than for other species, especially in pure beech regeneration. Sometimes they are not performed, the first tending operation (cleaning or thinning) taking place at ages of 17-22 years or later. In mixed species regeneration, spacing/weeding are performed earlier and at 2-4 year intervals, usually in August-September, one of their roles being the adjustment of species composition (Table 6).

Table 6. Tending operations and their characteristics for Romanian beech forests (Negulescu *et al*., 1973).

Regeneration/Forest development stage	Seedling -Sapling	Sapling-Pole	Pole-Young / Mature High Forest
Tending operation - Selection: - Age: - Number: - Canopy closure index:	*Spacing/weeding* - negative - 3(5) – 7(10) years - 1-2 - 0.8	*Cleaning* - negative - 7(10) – 17(22) years - 1-2 - 0.75-0.8	*Thinning* - positive - 17(22)-70(85) years - up to 6 - 0.7-0.8

Cleaning starts at ages between 17-22 years (sapling-early pole stage) when the height reaches 8-10 m and the natural pruning begins. As in the case of spacing/weeding, the characteristic of cleaning is the "negative" selection: undesired species or the trees with defects are extracted in the second part of the growing season. After cleaning, the canopy closure index is normally reduced to 0.75-0.8. No more than two cleanings are normally performed (Table 6). After the last cleaning, the number of trees per hectare is reduced to about 2500-3000 and basal area to18-20 m^2/ha (Tarziu, 1970).

Thinning is the most important tending operation performed in beech forests. This is because of both its role and characteristics ("positive" selection) and the fact that due to financial constraints in many beech forests of Romania spacing/weeding and cleaning are not applied.

Combined thinning is the method recommended for beech forests and has the following characteristics:

- it starts at ages between 25 and 30 years
- it is recommended to choose the "future" trees (threes that are going to be maintain in the stand until exploitation) during the first thinning (250-300 trees/ha)
- the thinning intensity (by volume) is moderate to heavy during the first thinnings (periodicity of 6-8 years and closer to "crown" thinning) and light to moderate afterwards (periodicity of 8-12 years and closer to "low" thinning)[Table 7]
- the canopy closure index could be reduced to 0.8-0.7

- thinnings are applied till the stand reaches 70-85 years (about six thinnings); afterwards sanitary felling is performed as required till the exploitation age.

Table 7. Thinnings intensities by volume in Romanian beech forests (MS, 1986b).

Age	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100
Intensity by volume (%)	15	14	13	12	10	9	8	7	5

As mentioned before, this type of thinnings are specific to traditional silviculture and differs than more "dynamic" silviculture (heavy interventions, longer periodicity, shorter rotation etc.) specific to other parts of western and central Europe (Lanier, 1986; Bourgau, 1991; Neckelmann, 1992, Kerr and Evans, 1993).

5.12.7 Economic importance of beech in Romanian forestry

As mentioned before, beech is the most wide spread forest species in Romania. The total standing volume of beech amounts to 488,6 million m^3 and its distribution by age and productivity class is presented in Table 8.

Table 8. Total standing volume of beech by age and site class (m^3x1000).

Productivity	Age class **(years)**						Total
Class	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**>100**	
I	146	1 296	1 343	1 559	2 077	3 255	**9 676**
II	1 437	10 560	19 543	29 558	21 084	58 889	**141 080**
III	3 985	13 023	45 935	48 655	44 175	107 779	**263 555**
IV	223	2 807	9 717	13 047	11 344	24 920	**62 059**
V	43	319	1 310	2 395	2 608	5 558	**12 243**
Total	**5 835**	**28 006**	**77 851**	**95 213**	**81 288**	**200 411**	**488 605**

Beech timber has many uses in the furniture industry (veneer, bent furniture, particleboards), parquet, carpentry and building, the pulp and paper and the chemical industries, mining, tool handles etc. It is also more durable when entirely under water than most Romanian timbers (Haralamb, 1967). When preservative treated, beech timber is extensively used for railway sleepers. It is intensively used to produce charcoal, both for general use and the metallurgical industry. Also, after hornbeam, the wood of beech is considered as the best fuel in general use.

Table 9. The volume of timer harvested in Romania in the period 1994-1998 (Statistical Yearbook, 1998).

Volume	**Year**				
(m^3x1000)	**1994**	**1995**	**1996**	**1997**	**1998**
Total	12 952	13 813	14 803	14 519	13 708
Beech	4 037	4 215	4 266	4 263	4 208

About 4.2 million m^3 of beech is harvested annually from Romanian forests (Table 9). As a consequence of the evolution of the beech timber market, more than a half of this volume has been exported in the last three years as timber or log (ASFOR, 1999).

The prices of logs sold as standing wood or roadside have increased significantly (up to 250-300 USD for roadside log-veneer quality) in the last 2 years after the restrictions on timber and log exports were removed in December 1997, although this affected negatively the local processing industries. A lot of small and medium private logging and primary processing companies have developed in the last years and export to Middle East and Western markets (especially Germany and Italy) appears to be a flourishing business in the recent years. On the other hand investments have been made in the primary processing sector (modern sawmills, steamers, kiln-dryers etc.) leading to high value exports of high quality products to Western markets.

Apart from wood production, beech forests have very important protective functions. The majority of the forests are situated in hilly and mountain regions where they have an important role in soil, climate and watershed protection (Giurgiu, 1975). Beech litter reduces surface drainage so the quantity of water infiltrated in the soil is the greatest compared to other forest types in such regions (Damian, 1978). In mixed forests, especially in beech-conifer mixtures, beech has an important role in ameliorating soil conditions - litter, soil composition, surface drainage and water infiltration (Abrudan, 1997) and increasing the esthetical value of the forests (Negrutiu, 1980). Apart from these values, Romanian beech forests are of ecological and scientific importance to Europe, in south-west Romania being located some of the last virgin forests of the continent.

5.12.8 References

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6. List of interviews conducted for the report

This appendix provides a list of all the interviews, which have been used for this report. All interviews were conducted in local languages either as text or by voice recording and are therefore not included in this report.

6.1 Northwest European Lowland

Date:	15/11 2000, Little Dean, Cinderford, Glos.
Interviewer:	Rik Pakenham
Interviewee:	Keith Wallis, Chiltern Forest District Manager (Dec. 1985 – Dec. 1997)
Position:	Responsible for 3238ha of which 1532ha are in the Chilterns AONB and 30% is beech of varying age class.
Organisation:	Forestry Commission (State Forest Service)
Region:	UK

6.2 North European Lowlands

Date:	12/2 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. Michael Krüger Jacobsen, assistant forest officer
Organization:	Randbøl state forest district, state forest district, 4670 ha, 720 ha is beech
Region:	Western Denmark (Jutland)

Date:	12/2 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. NN (anonymous), private forest owner
Organization:	Private forest district, 1 owner, 375 ha, 120 ha is beech
Region:	Denmark, eastern Jutland

Date:	13/2 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. Niels Peter Dalsgaard Jensen, forest officer
Organization:	Salten Langsø forest district, private forest district, 42 owners, 3700 ha, 375 ha is beech
Region:	Western Denmark (Jutland)

Date:	19/2 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. Bjarne Jensen, forest manager
Organization:	Fanefjord forest district, private forest district, 166 owners, 225 ha dominated by beech
Region:	Eastern Denmark

Date:	19/2 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. Jens Kristian Poulsen, forest officer
Organization:	Sorø Akademi forest district, independent foundation, 4245 ha, 1510 ha is beech
Region:	Eastern Denmark

Date:	1/3 2001
Interviewer:	Katrine Hahn
Interviewee:	Mr. Bent Egede Andersen, head of office
Organization:	Office of Planning, Dept. of Forest and Nature, Ministry of Environment and Energy
Region:	Denmark

6.3 Central European Uplands

Date:	15/9 2000, Karlsbad
Interviewer:	Josef Fanta
Interviewee1:	Mr. Schafer, Director
Organization1:	Forstamt Karlsbad
Interviewee2:	Mr. Hauck, Director
Organization2:	LFV Baden-Wurttemberg, Dienst Forsteinrichtung, Karlsruhe/Freiburg
Region:	Germany

Date:	19/7 2000, Krtiny
Interviewer:	Josef Fanta
Interviewee:	Ing. J. Truhlár, Manager
Organization:	Training Forest Enterprise Masarykuv Les, MUAF-Forestry Faculty, Brno
Region:	Czech Republic

Date:	27/7 2000, Liberec
Interviewer:	Josef Fanta
Interviewee:	Ing. J. Hušek, Director; Ing. Vl. Vršovský, Manager
Organization:	Administration of the Protected Landscape Area Jizerské hory Liberec
Region:	

Date:	24/11 2000, LS Bohunice
Interviewer:	Josef Fanta
Interviewee:	Ing. J. Farkaš, Assistant Director
Organization:	Forest Entreprise Levice, Slovakia
Region:	Slovakia

6.4 Southeast European Mountains

Date:	April 2001
Interviewer:	Jurij Diaci
Interviewee:	Prof. dr. dr. h.c. Slavko Matic
Organisation:	Forestry faculty, Zagreb
Region:	Croatia

Date:	March 2001
Inerviewer:	Jurij Diaci
Interviewee:	Dr. Eduard Hochbichler
Organisation:	Institut für Waldbau, Universität für Bodenkultur, Wien
Region:	Austria

Date:	Februar 2001
Inerviewer:	Dusan Rozenbergar
Interviewee:	Dr. Diaci Jurij
Organisation:	Biotechnical faculty, University of Ljubljana
Region:	Slovenia

Date:	Februar 2001
Inerviewer:	Dusan Rozenbergar
Interviewee:	Mr. Zunic
Organisation:	National forest service
Region:	South Slovenia

7. List of case studies in the report

The Chiltern Hills, United Kingdom	chapter 2.8
Sorø Akademi Forest District, Denmark	chapter 3.5
Forstamt Karlsbad, Germany	chapter 4.6
Masarykuv Les, Czech Republic	chapter 4.8
Jizerskohorské buciny, Czech Republic	chapter 4.9
Bohucine, Slovakia	chapter 4.11
Brezovara Reber, Slovenia	chapter 5.10
Samobor, Croatia	chapter 5.11