Ancient Woodlands and Trees: A Guide for Landscape Planners and Forest Managers

2018

IUFRO

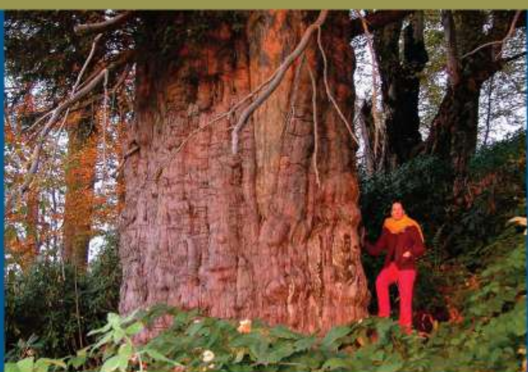
Ancient Woodlands and Trees: A Guide for Landscape Planners and Forest Managers

Editors: Alper H. Çolak, Simay Kırca, Ian D. Rotherham

IUFRO World Series Volume 37

TÜBA
Turkish Academy of Sciences

IUFRO


TURKISH ACADEMY OF SCIENCES

IUFRO World Series Vol. 37

Ancient Woodlands and Trees: A Guide for Landscape Planners and Forest Managers

Editors: Alper H. Çolak, Simay Kırca, Ian D. Rotherham

Jointly published by International Union of Forest Research Organizations (IUFRO) and Turkish Academy of Sciences (TÜBA). Funding support for this publication was provided by the Turkish Academy of Sciences. The views expressed within this publication do not necessarily reflect official views of the respective institutions.

Recommended catalogue entry:
Alper H. Çolak, Simay Kırca & Ian D. Rotherham (eds.), 2018.
Ancient Woodlands and Trees: A Guide for Landscape Planners and Forest Managers
IUFRO World Series Volume 37. Vienna. 272 p.

ISBN 978-3-902762-91-7
ISSN 1016-3263

Jointly published by:
International Union of Forest Research Organizations (IUFRO) and
Turkish Academy of Sciences (TÜBA - Türkiye Bilimler Akademisi)

Available from:
IUFRO Headquarters
Secretariat
Marxergasse 2
1030 Vienna
Austria
Tel: +43-1-877-0151-0
E-mail: office@iufro.org
Website: www.iufro.org

Turkish Academy of the Sciences (TÜBA - Türkiye Bilimler Akademisi)
Piyade Sok. No: 27
06690
Çankaya/Ankara
Turkey

Language editors: Ian D. Rotherham & Simay Kırca

Layout: Simay Kırca, Alper H. Çolak

Cover photographs (from left to right):
1. The Burnham Beeches by Birket Foster
   (copyright personal collection of Ian D. Rotherham)
2. Common yew (*Taxus baccata*) (Gümeli Nature Monument - Alaplı/Zonguldak) by
   Necmi Aksoy.
3. Old Oaks on Wickham, Common Kent after painting by S. Johnson.
   Raphael Tuck & Sons, Oilette, 1920s to 1930s, unused final.
   (copyright personal collection of Ian D. Rotherham)

Printed in Turkey

Preface

Ancient woodlands, trees and forests are at the very core of many global landscapes. However, understanding the resource which these living landscapes provide requires genuinely multi-disciplinary research. Furthermore, our interest in and understanding of ancient woodlands and trees has grown significantly over recent decades. Therefore, it is a challenge to keep abreast of current developments and ideas. The production of a major review volume which brings together key researchers and writers from across Europe and beyond, is immensely valuable to landscape planners, forest and woodland managers, and to a wider audience such as policy makers and educators too. It also contributes to international efforts towards identifying, recording and developing globally important agricultural heritage systems.

This book comprises fifteen major contributions by leading scholars on the ecology, history, heritage, and management of ancient trees, ancient woodlands and forests. Taking trees, woods and forests as eco-cultural resources, the authors explore ecology and nature, history, tradition and heritage, and the evidence base of archaeology, literature, and archives. The book is dedicated to the memory and works of the late Professor Oliver Rackham OBE whose research and writing triggered an interest in this field by the many that followed.

It is a great pleasure for IUFRO to be involved in the production and publication of this book since it is highly relevant to the aims and objectives and visions of the organisation. Furthermore, many of the authors are actively involved in IUFRO activities. Finally, I would like to extend my thanks to TÜBA for this fruitful collaboration.

Alexander Buck
IUFRO Executive Director

Preface

Nature offers endless inspiration and wisdom to all sciences, and trees are one of the unique elements of this ever-changing source of knowledge. Nature has also been subject to human development over thousands of years, an intimate interaction that has generated cultural landscapes with often strong elements of local, regional, and national character. Being one of the oldest continually inhabited regions in the World, Europe and Anatolia contain diverse cultural landscapes with ancient woodlands and trees rich in biodiversity. Ancient woodlands and trees are strongly influenced by human activity reaching back far into history, an interaction which was often fine-grained and sustainable, but which sometimes also caused degradation of these unique resources. For instance, relict ancient woodlands and trees found in various regions of Turkey today are considered as the witnesses and hosts of the many civilisations that flourished in Anatolia. But especially in recent times, the landscapes and their biodiversity have been affected by over-exploitation and long-term degradation. Today, the greatest concentrations of ancient woodlands and trees in Anatolia and Europe are mostly found in traditionally-managed forests, wood pastures, parklands, wooded commons, village squares, cemeteries, residential gardens, hedgerows, meadows, and even in urban areas like squares, parks and streets.

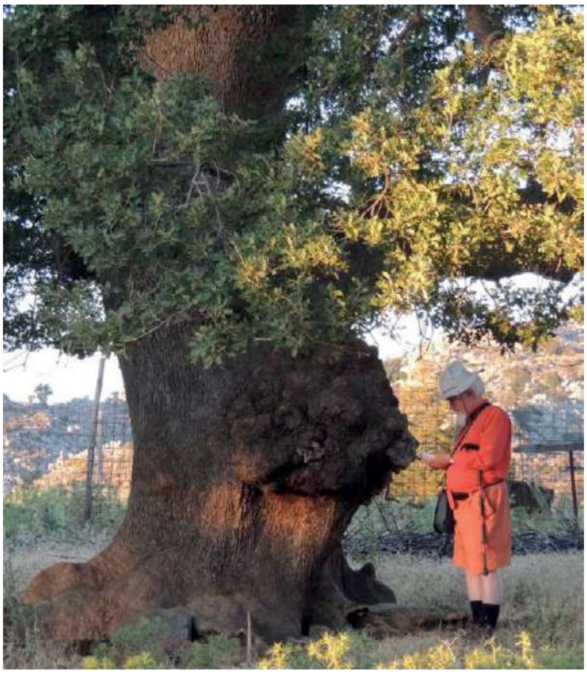
Ancient woodlands and trees have long been and will remain important elements of our cultural landscapes; a living archaeology and often relics of former land-use and distinctive countryside. These ancient woodlands and trees, widely considered as the “common heritage of mankind”, have been some of the most typical components of diverse landscapes over hundreds and even thousands of years. Furthermore, the woods, trees, and forests reflect the close contact between mankind and nature and in some cases connect to specific historic events or people. One of the most fascinating examples of such a specific ‘witness’ is in northern Turkey where hundreds of ancient yew trees with a probable maximum age of 4,000 years (the yew in Alaplı (Zonguldak) is thought to be our oldest tree, ca. 2,500 – 4,000 years old) form a unique ancient treescape - almost a symbolic ancestor of ancient woodlands and forests of Europe today.

Ancient woodlands and trees are known as one of the richest habitats in terms of associated fauna and flora diversity. However, these highly valuable habitats are continually threatened both in rural and urban environments. This is why we have to take urgent measures to conserve these irreplaceable survivors that link us with our past and our future.

This publication has been prepared as a result of ambitious studies of twenty-two scientists from prestigious institutions from Turkey, UK, Austria, Germany, Netherlands, Sweden and Denmark. It is also an important outcome of fruitful international and inter-disciplinary studies. It has been a pleasure for TÜBA to support this publication as a successful cooperation and we hope that it will draw attention to transferring ancient woodlands and trees not as one country’s heritage but a world heritage. I would like to thank IUFRO for this joint publication.

Prof. Dr. Ahmet Cevat ACAR
President of Turkish Academy of Sciences (TÜBA)

Dedication



Oliver Rackham communing with an ancient deciduous oak (*Q. brachyphylla*), Pano Ambeli (above Anogia) Crete, June, 2012 (Photo: Jennifer Moody).

This book is dedicated to the memory of ***Professor Oliver Rackham OBE FBA.*** *Oliver was one of the originators of the concept of 'ancient woodland'; a prodigious and brilliant writer with a wide-ranging intellect. His death cut short a long and productive career and we are saddened by the loss of a giant on the world stage with his enthusiasm for "ancient woodlands" and one of the most original thinkers and leading scientists in his field. Oliver is greatly missed by all those who care for trees, woods, history and the landscape, and more widely. Not only did he inform and influence our professions, but he has been a great advocate too. We salute Oliver and all that he has done.*

Oliver Rackham in an ancient and burnt cypress stool, Mavrodassos, Anopoli Sphakia, July, 2010 (Photo: Agnieszka Helman-Wazny).

"We will miss him very much in our exchange of thoughts in order to disentangle the riddles of nature and trees in particular"

Frans Vera

"Oliver Rackham is one of the very few academics who has changed the way that everybody thinks; a rare talent indeed"

Oliver Gilbert

Contents

Prefaces 4 & 6

Executive Summary 11

1 Ancient woodland in concept and practice 16
George F. Peterken

2 The Cultural Heritage of Woods and Forests 28
Ian D. Rotherham

3 Archaeology of Trees, Woodland, and Wood-Pasture 40
Oliver Rackham

4 Ancient Rights in Ancient Forests 64
Graham Bathe

5 The importance of an Open Grown Tree – from Seed to Ancient 78
Ted Green

6 Ancient and other trees of special interest: indicators of old growth biodiversity and heritage 86
Jill Butler

7 Worked Trees and Ecological Indicators in Wooded Landscapes 94
Ian D. Rotherham

8 Ancient Forests in Germany: Distribution, Importance for Maintaining Biodiversity, Protection and Threats 106
Monika Wulf and L. Zalf

9 Tree Abundance, Density and Age Structure: The Key Factors Which Determine Species-richness in Saproxylic (Wood-decay) Invertebrates 124
Keith N.A. Alexander

10 Old Growth and Dead Wood as Key Factors for Nature Conservation in Managed Forests. Basics and Practice 136
Harald Schaich, Thomas A.M. Kaphegyi, R. Lühl, N. Schmalfuß, Mathias Rupp, T. Waldenspuhl and Werner Konold

11 The Diversity of Ancient Woodlands in Austria: Historical Developments and Contemporary Social Importance 156
Elisabeth Johann

12 The Wood Pasture: for food, wood and biodiversity 184
Frans Vera

13 The Ancient Woodland Concept as a Practical Conservation Tool: the Turkish Experience 214
Simay Kırca, Alper H. Çolak and Ian D. Rotherham

14 Using Pollen Data and Models to Asses Landscape Structure and the Role of Grazers in Pre-agricultural Denmark 242
Anne Brigitte Nielsen

15 Tanneries and Treescapes: The Influence of the Tanning Industry on Woodland Management 250
Christine Handley and Ian D. Rotherham

16 A hidden Treasure in Turkey - Old Oaks with Unique Values 260
Nicklas Jansson, Ogün Türkay and Mustafa Avcı

17 European Woodland History and Management: some concluding thoughts 268
Ian D. Rotherham, Alper H. Çolak and Simay Kırca

Executive Summary

Tree landscapes, woods and forests, are complex and long-lived. Indeed, the process leading from birth to death of ancient trees and wooded landscapes may mask a complexity nature's 'web of relations and inter-relations' and the often-defining roles of people too. The truth is all trees are born, grow and die. Yet the process of becoming 'ancient', however defined, is a web of relations involving a complex combinations of influences between (1) ancient trees and woodlands and other organisms, (2) ancient trees and younger trees in a forest stand, (3) ancient trees and woodlands and the landscape, and, last but not least, (4) ancient trees and woodlands and people. Long before the time of scientific studies attempted to understand these relations, the English landscape painter Jacob George Strutt beautifully depicted the various aspects of ancient trees and woodlands in the introduction of his book in 1830 as; "*Among all the varied productions with which Nature has adorned the surface of the earth, none awakens our sympathies, or interests our imagination, so powerfully as those venerable trees which seem to have stood the lapse of ages -silent witnesses of the successive generations of man, to whose destiny they bear so touching a resemblance, alike in their budding, their prime and their decay*."

From ancient times until today, these trees and woods have inspired artists, writers and scientists. Such venerable ancient trees are generally portrayed by ecologists and in many works of art and literature, with a wide and hollowing trunk (in some species more than one trunk or a wide trunk reaching up to the sky), epiphytes such as fungi, mosses and lichens, a lessening of the canopy with large dead branches and deadwood on the ground. This means, a single tree provides a vast array of habitats which are an integral part of the complex co-evolutionary relationships evolved over its lifetime and even during its sometimes long afterlife. So, as trees age, they become ecologically more rich and full of life, and their relations with other organisms including people become more complex.

After picturing giant hollow trees in mind and admiring their wisdom and beauty as portrayed in the paintings of Barend Cornelis Koekkoek, Jean-Baptiste-Camille Corot, and Ion Andreescu for example, it is easy to think of a "virgin forest" composed of ancient trees when one hears the concept of "ancient woodland". However, in reality, this would not be more than a mirage, since across the world, almost everywhere, people have managed the land and transformed its ecologies. With the exceptions of some remote islands the human footprint is indelibly pressed into the landscape. Forest cover has declined dramatically in the last 1,000 years or so, and what remains of tree covered land has been more or less altered from its original condition. Today, 'virgin forests' are only to be found on a few sites unreachable by humans, and even then they are affected by climate change, atmospheric pollution, and sometimes species extinctions; human influence is all-penetrating. Although the concept of an "ancient tree" or a "veteran tree" can be directly related with the age of a tree, (though this may vary with species), an "ancient woodland" does not necessarily need to be composed of old or ancient trees. Ancient woodland is generally defined as land that has been continuously wooded for hundreds of years (e.g. since the Middle Ages or early industrial in Britain (post-1600 AD or post-1700 depending on the authority), over 200 years in Germany, and from hundreds of years to the Neolithic Age in Turkey). Very often the key is habitat continuity, rather than any precise age, and even this concept of continuity masks the ebbs and flows of crisis and continuum in the landscape.

What does continuity bring? Why is it so important? Answers to these questions are hidden in the aforementioned web of relations. Many rare woodland plant species have existed in ancient woodlands continually over long periods, and have a localised distribution, and are not found in woods of recent origin. These are thus are identified as "ancient woodland indicators", which are vulnerable to direct or indirect changes (i.e. exploitative timber harvesting, biomass extraction, over-grazing, land conversion, climate change, etc.) in the landscape pattern.

The enormous variation in the types of vegetation in ancient woodlands and in the combination of human uses of these landscapes has, in recent years, attracted great interest. These areas are very rich in wild plant and animal species, and this diversity is associated with continuity. However, in terms of the concept of the ancient woodland, we are not solely talking about spatial continuity that creates connection between ecological components and capacity for organisms to move across a landscape, but also a continuity of traditional human uses and practices such as wood pasturing, coppicing and pollarding. Such traditional forest management practices helped create structurally rich forest stands, today very valuable for biodiversity conservation and the provision of forest-related ecosystem services.

The aim of this book is to help an understanding of the web of connections relating to ancient trees and woodlands, and to offer techniques to ensure effective conservation and sustainability of this precious resource. The approach is aided by considering the issues from different aspects and varied geographical locations. In this respect, the concept of ancient woodland is handled in detail in Chapter 1 by George Peterken. This provides a wide array of knowledge on how the concept developed in Britain and its strengths and limitations for ecologists and conservationists. This chapter also considers the use and limitations of this concept in mainland Europe and eastern North America. Since the idea of ancient woodland is closely related with the human history, Ian Rotherham in Chapter 2 stimulates an interest to 'read' the story of the woods and follow the footprints of abandoned and forgotten traditions in order to develop approaches to '*reading*' the evidence of species, archaeology and other heritage. Here, conservation issues and concerns are also introduced. Complementary to Chapters 1 and 2, Oliver Rackham in Chapter 3 defines the major terms and habitats related to the concept of ancient woodland and it also introduces the methods of 'historical ecology' for establishing the history of the countryside. This contribution deals with the resources of woodland archaeology by drawing attention to the roles from the tiniest plants to the whole ecosystem, and considers the importance of understanding former and current practices, traditional uses, written and visual records, and scientific methods. Graham Bathe continues to address the issues from the historical use of wooded landscapes as hunting forests throughout much of Europe in Chapter 4. This approach is in order to reveal important points, which, if they are to be successful, modern conservation efforts may need to emulate. This chapter examines how hereditary use helped shape the royal hunting forests, drawing especially on examples taken from forests in Britain.

After providing a conceptual and historical perspective for ancient woodlands, in Chapter 5, Ted Green deals with the individual history of an open grown tree as a source of biodiversity through ages. This chapter tries to set out and describe some of the vast array of habitats provided on and within a single tree which are an integral part of the complex co-evolutionary relationships with other organisms. From a similar perspective to Chapter 5, Jill Butler draws particular attention to the biodiversity and heritage value of ancient trees by emphasizing the importance of large-scale surveys - like the Ancient Tree Hunt held in the UK - in order to describe a practical and necessary approach on 'Where to find what?' as well as to determine old-growth hotspots for effective nature conservation in Chapter 6.

In Chapter 7, Ian Rotherham handles the issue from a different perspective by considering the signs that ancient trees and woodlands indicate on cultural history and use of trees. This chapter provides an introduction and overview to the use of worked trees and ecological indicators as a mid-layer between nature and cultural landscape for developing effective planning strategies based on woodland history, use and management. It also invites us not to look far for finding some evidence on woodland history, while such information may even be hidden in our gardens.

Germany has been one of the pioneer countries in Europe which pioneered ideas relating to ancient woodlands as a crucial component of natural and cultural heritage. So, Monika Wulf reports the German experience by describing the status of ancient forest and recent forest inventories, the importance of maintaining plant species richness in ancient forests, and need for the protection of ancient forests in Germany in Chapter 8. The potential threats like habitat fragmentation and alteration are also described.

Keith Alexander considers the specialised habitats provided by decaying wood in Chapter 9. In this context, these ancient landscapes are hotspots of species richness; but even today, these are barely considered much modern forestry since planning and practice generally concentrate on living and healthy trees. Yet in the ancient woodland concept, the saproxylic faunas are markers of the continuum of land-use though long time-periods. This chapter provides detailed information on the key factors which determine species richness in saproxylic (wood decay) invertebrates as well as management and conservation techniques for decaying wood habitats.

Following ideas introduced in the previous chapter, Harald Schaich, Thomas A.M. Kaphegyi, Rudolf Lühl, Nicole Schmalfuß, Mattias Rupp, Thomas Waldenspuhl and Werner Konold derive practical and policy recommendations on how to foster old growth and dead wood features in complex, human-shaped forest landscapes and how to mesh this important issue with other goals of ecosystem service provisioning in European forests in Chapter 10. This is discussed with a regional perspective from the federal state of Baden-Württemberg, Southwestern Germany.

Elisabeth Johann presents a closer look at the Austrian forests, which are an important part of the European forest network in Chapter 11. She does this by presenting two case studies. Although these forests have at times been intensively utilised and exploited (as is the case across Europe), the chapter suggests that understanding socioeconomic and ecological factors in the past which were responsible for developments that contributed to the modern landscape. Furthermore, an understanding gained from the study of these processes can help improve the knowledge base for decision-making at the interfaces of energy, biodiversity, and forest policy as well as in forest resource management.

Wood pastures, which play a particular role in the ancient woodland concept by providing enormous

variation of habitats to a large number of species, are handled in detailed by Frans Vera in Chapter 12. Wood pastures are described as the wilderness taken into use by mankind in order to fulfill the needs of its household. So, this chapter describes how the wood-pasture as system works, how it provided mankind his living and how it is related to the originally present wilderness.

Simay Kırca, Alper Çolak and Ian Rotherham introduce these issues from the perspective of the southeastern end of Europe, Turkey in Chapter 13. The authors provide detailed insight to the interactions between different civilizations and woodlands in Anatolia through history in order to clarify how the ancient woodland concept has developed in Turkey. With two case studies, this discussion also raises the question of, in terms of restoration and conservation, "How to handle highly valuable ancient woodlands as natural and cultural heritage?"

Anne Brigitte Nielsen, in Chapter 14, concentrates on a particular methodology for understanding how the landscape looked like in the past and what were the reasons behind it as to develop planning strategies for the future. In order to do this, simulated landscapes were created based on landscapes without and with different levels of grazing impact. Pollen deposition in these landscapes was simulated using a model of pollen representation, dispersal and deposition, and the resulting pollen spectra were statistically compared to existing pollen records from Denmark from the Atlantic period (*ca*. 6,800 - 3,900 BC). This is an important contribution to debates on understanding European wooded landscapes, past, present, and future.

Christine Handley and Ian Rotherham focus on the relationships between supply and demand for wood, timber and bark in different markets by using examples from the UK and the USA in Chapter 15. These different examples reveal the effects of the tannery industry on woodlands varied depending on the longevity and intensity of the industry at particular points in time. Thus, this knowledge is significant because of the way in which these relationships have influenced the form, structure and management of woodlands through the ages.

Lastly, in Chapter 16 Nicklas Jansson, Ogün Ç. Türkay and Mustafa Avcı concentrate on the diverse beetle fauna associated with the old oaks of Turkey in Chapter 16. They also try to draw attention to the degradation and loss of old trees and deadwood, which provides valuable habitats for these species while little is known about the Turkish beetle fauna in comparison to the other European countries. Essentially, this chapter is a call for further scientific research on the highly valuable but shrinking oak habitats in Turkey.

Overall, given the urgent need to discover, understand, conserve and where necessary restore ancient woodlands and trees, it is hoped that this publication provides a modest step to raise awareness and enthusiasm. There is so much more to learn and to read through understanding the web of relations in the mysterious world of ancient woodlands and ancient trees. In addressing this hugely important topic and most fascinating subject in our European ecology and our continent's landscape, the editors humbly dedicate this volume to the memory of the greatest pioneer and enthusiast for ancient woods and ancient trees, the late Professor Oliver Rackham.

Simay Kırca, Alper H. Çolak and Ian D. Rotherham
January, 2018

Chapter 1
Ancient Woodland in Concept and Practice

George Peterken

Abstract

During the 1970s, British ecologists adopted what they thought was a new concept, ancient woodland, which broadly meant medieval and pre-medieval woodland that still existed in the modern landscape. The concept developed out of an expanding interest by ecologists in the history of the habitats they studied, epitomised by influential works on the *Pinus sylvestris* woodland in Scotland (Steven and Carlisle, 1959) and the woods of the New Forest (Tubbs 1968). At the same time, ecologists were realising that some rare woodland plant species were found in woods that had existed for centuries, but not in woods of recent origin (Pigott, 1969; Ratcliffe, 1968). Ancient woodland quickly became a key concept in nature conservation, partly because the species associated with such woodland were clearly vulnerable to changes in the pattern of woodland. Indeed, these associated species acquired an identity of their own as 'ancient woodland indicators' and were used to evaluate woodlands for nature conservation purposes (Peterken, 1974).

The concept, however, was easily misunderstood. In particular, many people thought 'ancient woodland' meant woodland with ancient trees, whereas ecologists meant 'land that has been continuously wooded since the Middle Ages', i.e., the concept referred to habitat continuity and not the age of the trees, though of course some ancient woodland was in fact dominated by large, old trees. The other misunderstanding was to assume that the term 'ancient woodland indicator' could be taken literally, i.e., that, if any of the species known to be associated with ancient woodland were found in a wood, then that wood must have enjoyed a continuous existence back to at least the Middle Ages.

Despite the confusions, the concept of ancient woodland has since become important in British ecology and conservation. It helps explain the distribution of wildlife species; links ecology with cultural and landscape history; and forms a key element in forestry policy. Allied to this, the concept of ancient woodland indicators has also lodged in the public imagination. Such species tend to be rare and local; they implicitly require land to have remained wooded for several centuries; and for both these reasons they tend to be a priority for nature conservation.

This chapter describes how the concept developed in Britain and its strengths and limitations for ecologists and conservationists. It also considers its use and limitations in mainland Europe and eastern North America.

Defining Ancient Woodland

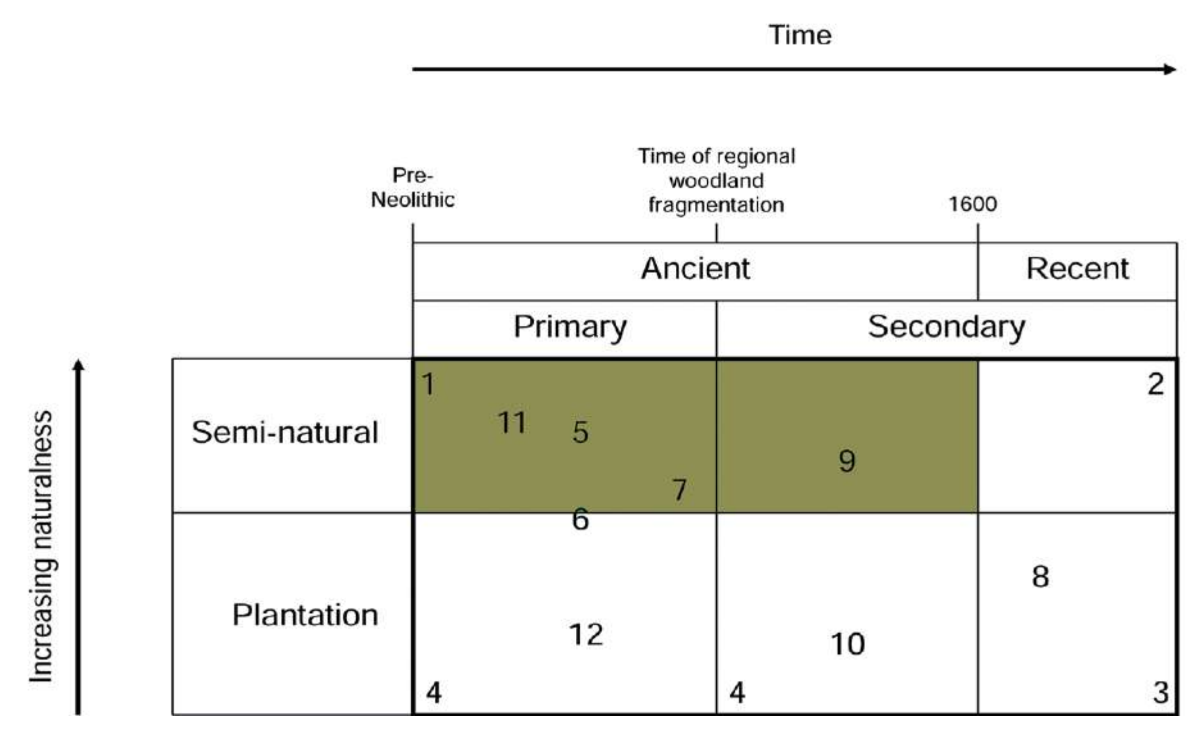
In the late 1960s, we usually used the term "primary woodland" to describe remnants of the original, pre-Neolithic woodland cover and contrasted these with "secondary woodland", which had developed on former agricultural land, i.e., land that has formerly been cleared. However, it is difficult and time-consuming to prove that a wood has always been there, so about 1970 we developed a corresponding pair of terms, "ancient woodland" and 'recent woodland', the former being woodland that existed before 1600, the latter being woodland that originated since 1600. On this basis:

- Any primary woodland would fall within ancient woodland.
- All recent woodland is 'secondary'.
- Any woodland originating on farmland before 1600 would be both 'ancient' and 'secondary'.
- 'Recent woodland' potentially covers a very wide range of ages, from woodland started 400 years ago to new woodland planted last year.

The relationship between these terms is shown in Figure 1.1. The somewhat arbitrary threshold between ancient and recent woodland was set at 1600 because (i) tree planting and the deliberate creation of new woodland only became commonplace after that date, (ii) advances in map-making during the late 16th century enabled accurate maps to be made showing individual woods, so

Summary of terms describing woodland origin (horizontal axis) and naturalness (vertical axis).

Figure 1.1



Both axes are regarded as continuous variables. The green zone represents 'ancient, semi-natural woodland'. The place of several woodland types is indicated by way of example: 1) The original-natural woodland. 2) Naturally-regenerated woodland on former pasture, arable, etc. 3) Plantations of non-native conifers on former pasture, arable, etc. 4) Ancient woodland replanted with non-native conifers. 5) Traditional mixed coppice in woodland of medieval origin or older. 6) As 5, but replanted with locally-native broadleaves and now grown to maturity. 7) Traditional coppice improved by planting locally-native species. 8) 18th-century amenity plantation of native and non-native tree species. 9) Former coppice in woodland on land formerly cultivated by pre-medieval farmers. 10) As 9, but replanted with non-native conifers and some native broadleaves. 11) Wood-pasture of medieval or earlier origin. 12) As 4, but replanted with locally native tree species.

it is relatively easy to identify which woods originated after that date and to define their boundaries, and, (iii) for broadly explanatory purposes, it was reasonable to equate 'ancient woods' with 'medieval woods'.

This distinction between ancient and recent was also useful because the distribution of many wild species could be explained. In particular, we found that some species grew only or mainly in ancient woodland, and we tended to think of these as survivors from the pre-Neolithic 'wildwood' that had rarely been able to colonise new woodland developing on formerly unwooded land at some distance from any ancient wood. These quickly came to be known as "ancient woodland indicators". Some were widespread and fairly common species, but many were rare and uncommon. In contrast, most of the species found in recent woodland were common and widespread, and many were not even confined to woodland. Once we recognised that most of the species of conservation concern were found mainly in ancient woodland, the priority for nature conservation in Britain became the protection and proper management of ancient woods. If we wanted to maintain the full variety of woodland species in Britain, these were the woods that required the greatest care and attention.

The development of the ancient woodland concept in the 1970s refreshed both woodland ecology and studies of landscape history, but it was not a new idea. The early ecologists were broadly aware of the distinction between ancient and recent woodland, though they did not use the terms, until Boycott (1930) used them in more-or-less their modern sense in an important review of the distribution of Mollusca. Much earlier, agricultural and forestry writers in the late 18th and early 19th centuries had distinguished between "woods" and "plantations", and this was tantamount to distinguishing ancient from recent woodland (Watkins, 1988). The beech-oak wood-pastures of the New Forest, one of the most important collections of woods – historically and biologically – in Britain, were actually protected by a statute of 1877 as 'Ancient and Ornamental Woods'. 'Ancient woodland', therefore, was a concept that lapsed in the late 19th century and was revived in the 1970s.

Ancient Woodland Indicators

The idea of ancient woodland indicator species caught the public and professional imagination every bit as much as the idea of ancient woodland itself. Taken literally, these were wildlife species whose presence in a wood confirmed that the wood in question was ancient. Their significance for ecologists and conservationists was that such species must be reluctant to colonise new woodland and so had to be protected where they were found. For landscape historians, they offered a new method for identifying old features in the landscape, which would be useful in the absence of other evidence. To the general public, they were species with an aura around which conservation activities could identify.

Ancient woodland indicators, however, cannot be treated literally. The perfect indicator would be present in all ancient woods, absent from all recent woods and absent from all other habitats. In Central Lincolnshire (Peterken and Game, 1984), *Anemone nemorosa* (Photograph 1) came nearest to this form of perfection. It was present in 75 ex 89 ancient woods, 20 ex 273 secondary woods and scarcely occurred in other habitats. A few species were absolutely confined to ancient woodland, the least-rare of which was *Paris quadrifolia* (Photograph 2) which was present in 9 ex 89 ancient woods, i.e., absent from 81 ancient woods. Nevertheless, even though both species were closely associated with ancient woods, even *Anemone* would have misclassified 34 of the 362 woods in the study area and *Paris* was useless as an identifier of 81 ex 89 ancient woods.

The general points to emerge were (i) that few, if any, species are absolutely confined to ancient woodland, and (ii) any that are so confined prove to be so rare that they cannot be used on their own as indicators. Another flaw in the idea that ancient woodland indicators could be used to identify ancient woodland becomes apparent when one recognises that, by the time we could identify which species were indicators, we had already determined which woods were ancient by using historical and archaeological evidence. More significantly, *Anemone*, Paris and the many other 'indicators' were evidently very slow to colonise recent woodland in Central Lincolnshire and thus vulnerable to change in the distribution of woodland.

Similar studies matching independent evidence of woodland history against plant distributions confirmed that both the range of habitats occupied by species and their ability to colonise vary across their ranges. In Britain, for example, *Anemone nemorosa* also occurs sparingly in meadow grasslands and heaths, but in Central Europe it can be widespread in meadows. *Primula elatior*, which in Britain is abundant mainly in ancient woods, and only occasionally occurred in grassland and fens, is a grassland species in Continental Europe. *Hyacinthoides nonscripta*, which is an abundant and characteristic woodland herb in eastern and Midland England with a limited colonising ability, spreads out over unwooded hillsides, upland meadows and coastal grassland in Wales and western England. The implication was that the list of ancient woodland indicators identified in Lincolnshire could not be used elsewhere: one must identify the slow colonists region-by region.

Photograph 1: *Anemone nemorosa* (G. Peterken).

Photograph 2: *Paris quadrifolia* (G. Peterken).

The detailed historical and archaeological studies needed to identify ancient woods are time-consuming, but a quick approach to identifying slow colonist species is possible by looking on the other side of the coin. In any region, one can easily identify a sample of woods that originated in the last 200 years, find out which species have colonised them, and then the remaining woodland species in the region, i.e., those that were not or rarely seen in the recent woods, would be likely to be slow colonisers.

Photograph 3: *Lamiastrum galeobdolon* (G. Peterken).

Using such informal means, we were able to recognise that many of the slow-colonising species in any region were those on the margins of their ranges and/or on the limits of their ecological tolerance, where they have a narrower habitat amplitude. In both circumstances, growth and reproductive vigour decline and a species is more vulnerable to extreme episodes. This implied that the Lincolnshire list would apply in neighbouring districts, but would become increasingly unreliable with increasing distance from Lincolnshire. One test of this was in nearby East Anglia, where Rackham (1980) reckoned that thirty-five of the fifty ancient woodland indicators identified in Lincolnshire also had a reasonably strong affinity with ancient woodland in East Anglia, but fifteen did not, including *Chrysosplenium oppositifolium, Ranunculus auricomus, Allium ursinum, Veronica montana* and *Primula vulgaris.*

Not all slow colonists were species reaching their ecological limits. Some appeared to be slow colonisers throughout their ranges, e.g., *Lamiastrum galeobdolon* (Photograph 3), *Paris quadifolia* (Wolf, 1997). Ancient forest species tend to be associated with intermediate pH and nitrogen availability; to be more tolerant of shade than most forest species; to be low-growing (geophytes and hemicryptophytes); to use short-distance dispersal mechanisms, e.g., by ant; and to have limited seed and fruit production (Hermy et al., 1999).

In addition to dispersal mechanisms and ecological tolerances, we also needed to take landscape history and woodland management into account when explaining the occurrence of species in recent woods and inferring from that their colonising ability. For example:

- Habitat amplitude of individual species and the habitat history of individual recent woods must also be taken into account when interpreting the distribution of a species in terms of habitat continuity. For example, *Conopodium majus* grows in woods, meadows and heathy pasture, so, if a new wood develops on an abandoned meadow or heathy pasture, this species will be present. It may or may not be a slow colonist, but in this instance the woodland colonised the *Conopodium* population.
- Likewise, both *Anemone* and *Hyacinthoides* grow well and survive indefinitely in hedges, so they can thrive in farmland on field boundaries, even if there is no woodland. If this farmland is planted as new woodland, they may already be present and waiting to expand. Hedges are just one example of semi-woodland habitat (i.e., habitats outside woodland that offer refuge for some woodland species), other examples being stream sides, screes and rocky ground.
- The absence of slow colonisers does not necessarily mean that a wood is recent. Slow coloniser ground flora species are usually absent from ancient woods that were once wood-pastures; and conversely saproxylic indicators are infrequent in ancient woods with a coppice history.

We also needed to remember that some soil types are extreme enough to limit the variety of plant species capable of growing on them. Thus, for example, even ancient woods on strongly acid, sandy soils have a very limited range of plant species, and many of these survive in the grassy heathland that historically was the alternative land type on such ground. Recent woodland on former heaths has few woodland species, but because of the soil, not the inability of species to colonise.

Against this background, we concluded that ecologists and historians should not use species to identify which woods are ancient. Rather, ecologists should use knowledge of woodland history (and the history of non-woodland habitats) to learn about species' capacity to respond to habitat change. In doing this, they should look carefully at the distribution of species within woods, as well as between woods, for this may alert them to small refuges (e.g., ancient hedges, small remnants of ancient woodland in a matrix of recent woodland) from which slow-colonising woodland species have been able to spread. The soil pattern should also be considered when interpreting species distributions. Also, bearing in mind the differences between coppice and wood-pasture, ecologists should recognise that trees, underwood and ground vegetation (and the species that depend on them) may have different histories, i.e., that a wood could be ancient for old trees and recent for ground flora (wood-pasture) or recent for old trees but ancient for ground flora (coppice).

Species can exceptionally be used to identify ancient woods in the early stages of woodland survey. If an unknown wood is found to include many species that have been demonstrated to be slow colonists in the same region, or nearby on similar soils, one can safely assume that the wood is ancient. Equally, if several acknowledged slow colonists are concentrated in certain parts of a wood that will probably be the ancient portion. This informal 'ecological wisdom' should be verified from historical sources if the historical status of the wood is an important factor in research or forest management.

Listing Ancient Woods

The importance of ancient woodland for nature conservation was quickly recognised by ecologists, but the pace of recognition amongst foresters was slower. Nevertheless, many foresters and woodland owners were sufficiently interested to say they would make special efforts to protect species in ancient woodland if they knew which woods were ancient. Thus encouraged the Nature Conservancy Council experimented with a simple approach to identifying ancient woods (Goodfellow and Peterken, 1981) and then, from 1981, to list and map all the ancient woods in Britain, using maps of different ages. By the late 1980s a complete, but provisional, Inventory of Ancient Woodland had been developed for the whole of England, Scotland and Wales.

The key objective was to make it possible to develop a site-specific forestry policy that recognised the importance of ancient woodland and provided incentives and advice to facilitate its conservation. Conversely, and just as important, other woodland could be 'released' from special obligations for nature conservation to give priority to timber production, recreation and other objectives. The inventory also made ecological surveys more efficient by directing effort at the most rewarding sites, and provided a basis for monitoring and judging changes in forest cover. The site-specific forestry policy was introduced in 1985 as the UK Government's Broadleaves Policy.

The methodology and outcomes were recently reviewed by Goldsmith et al. (2011). Briefly, we used Ordnance Survey maps to filter out secondary woods originating after about 1800. Then, secondary woods originating before 1800, but after 1600, were filtered out using older maps – if available – and other indications, such as wood name, shape and location in the landscape pattern. The outcome was the 'provisional' inventory.

We also attempted to determine how much of each ancient wood was semi-natural and how much had been converted to plantations, using air photographs and any recent field surveys. Inevitably, there were gaps in the information and many stands on the borderline, so the result was approximate. Decision rules were needed. For example, plantations of native trees were recorded as 'plantations' when they were young, but 'semi-natural' when they had matured and developed a more natural stratification.

The inventories were thus provisional and approximate, but they were accurate enough to show the amount and condition of ancient woodland, and to use as a basis for dialogue with owners and foresters when making decisions about what should be done on the ground. The initial inventories have been continuously updated as new information has become available. Their strength is that they are always provisional, in the sense that users agree that they can be changed if new information becomes available. So, if an owner knows more about the history and condition of his/her wood than the inventory shows, the inventory will be modified. In general, when management plans are being developed, they alert all involved to the need for careful consideration of the nature conservation needs, but they do not dictate any particular form of management.

Ancient Woodland Concept in Practice

The revival and development of the concept in the 1970s, was largely due to Rackham and myself, who were both based in eastern England. There, ancient woods were sharply defined and the sources of historical information were relatively good, but elsewhere a variety or problems became apparent in both the concept of ancient woodland and the ability to define its boundaries.

The least troublesome was the choice of 1600 as a threshold date for defining ancient woodland. The main need was to separate younger from older woods and to define a category, within which all primary woods must fall, that was as limited as possible. By doing this we had the option of economising on survey and historical searches. We could not have chosen an earlier threshold because estate maps only started to become reasonably frequent in the late 16th century, so there was little cartographic evidence of woodland distribution before 1570. Fortunately, this also pre-dated enclosure of commons and extensive pastures and the habit of tree-planting which gave rise to numerous small woods from the 18th century onwards. In practice, 1600 was a notional date, and what this really meant was 'in the 17th century'. When we listed ancient woods for the Inventory, we actually used the first comprehensive maps, the Ordnance Survey 1st edition, dating from the early 19th century. In Scotland, we had the earlier Roy maps, so we used those. Similar dates-of-convenience were adopted elsewhere.

One commonly-asked question was easy to resolve. If a wood was clear-felled, did that break the continuity of woodland? Our answer was that for both ecologists and foresters, clear-felling and natural stand destruction (e.g. by wind or fire) was part of the forest cycle and that it did not break continuity if the stand was replanted or regenerated naturally. This was particularly true of coppice, which simply regenerated from the stumps of the previous stand – new trees, but the same individuals and patterns. The only problem was that some maps of the mid-twentieth century mapped recently-felled woodland as not-wooded.

Another issue related to small clearances. If a clearing or a forest road within an ancient wood filled with trees, should the ground be classified as new woodland? If it were, small patches or strips within ancient woodland would be classified as recent. Technically, such woodland is indeed recent, but in practice such small inclusions have no ecological isolation from ancient woodland and were counted as part of the ancient woodland for conservation purposes. In fact, most ancient woods have small recent inclusions which are quickly colonised by woodland species and eventually merge into the surrounding ancient woodland. They differ only if the soil or hydrology was altered when the patch or strip was open.

Similar issues arise with new woodland that develops next to ancient woodland. Small adjacent ancient woods were notionally 'adsorbed' into ancient woodland, but larger adjacent new woods were recognised as recent. Many species colonise from ancient woodland at less than 1m per annum, so large, new woods next to ancient woods take much longer to occupy than small additions (Bossuyt et al., 1999).

More difficult was the treatment of wood pasture. Should it count as woodland and do woods that originate from pre-1600 wood-pasture count as ancient? This was important, because much of the western uplands and many lowland medieval forests and commons were wood-pasture for centuries. Moreover, many saproxylic species were strongly associated with pre-1600 wood-pastures, so such places were exceptionally important for conservation.

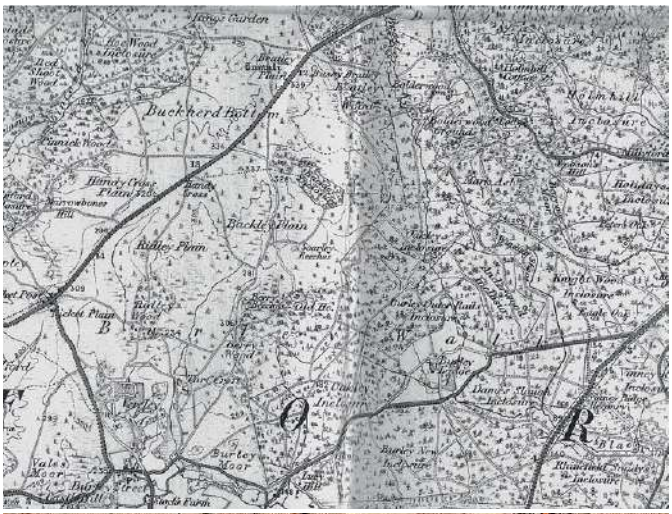
Wood-pastures are grazed woodlands in which grazing so limited regeneration that the woodland become open and often thinned to parkland, i.e., pasture with scattered trees. The trees were often large and old, but the underwood and woodland ground vegetation was replaced by pasture species and scattered shrubs, often thorny, such as *Crataegus monogyna* and *Prunus spinosa*. In many cases, wood-pastures became so open that they were not mapped as woodland. If such parkland later fills with trees and become closed woodland, should that woodland be 'secondary' because the land was previously open, or 'ancient' because trees have always been present on the ground?

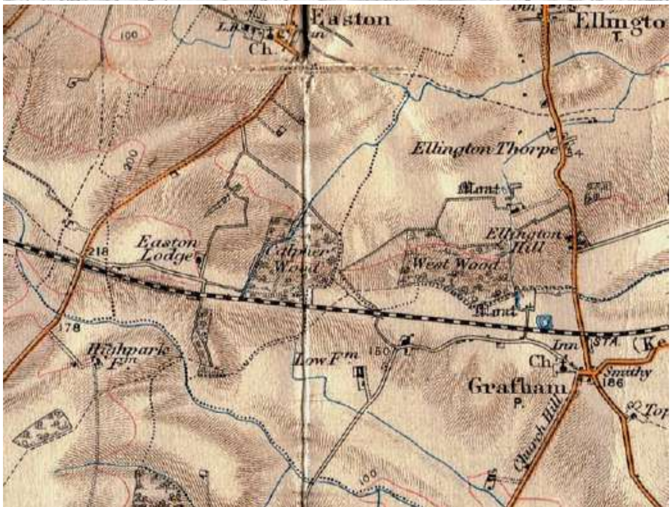
The problem is illustrated by two maps (Map 1 and 2). One shows a wood-pasture landscape (Photograph 4) where, as is often the case, the trees in wood-pastures stand in a diffuse mosaic with unwooded ground. Here woodland boundaries are difficult to define and map. In contrast, the second map shows a landscape of scattered, sharply-defined woods, in which the ancient woods were coppices (Photograph 4). Here, woods are easily delimited and changes can be quickly identified.

In practice, GB usage has been inconsistent and needs to be rationalised. Wood-pastures that have filled with younger trees have generally been regarded as ancient, but sometimes not. This is obviously unsatisfactory, but it can be resolved with a more discriminating analysis that recognised different histories for different components of the stand. In most wood pastures, large trees and dead wood habitats have been continuously present, so for these components the wood is ancient. The underwood, on the other hand, has usually not been continuously present and the ground vegetation has passed through a pasture phase, so for these components the wood is recent secondary. In woods which have had a coppice history, the woodland ground flora and the underwood have been continuously present, but the mature timber habitats usually have not. The two management regimes are thus complimentary: an inventory of ancient woods should aim to distinguish between those with a wood-pasture history and those that have been coppices.

Summarising, the ancient woodland concept works best in the UK when:

- Woodland covers well below 30% of the landscape, preferably 5-10%. Without this, there will be little ecological isolation in the landscape and good colonists will not be favoured. The 30% threshold is not sharp and depends on the predominant shapes of woodland, but in 30% wooded landscapes where woodland is well-distributed, almost any new woodland will be adjacent or close to an existing woodland.
- There is in fact some woodland in the landscape dating from before 1600, as well as some dating from later. Obviously, there is no point in separating ancient from recent woods if only one class is present. If all woods are pre-1600 or post 1600, age as woodland is unlikely to differentiate their characteristics.
- The reduction to well below 30% woodland cover happened several centuries ago. In such landscapes, isolation has been long-lasting, but, more to the point, enough time has elapsed for new woodland to have developed.
- Woodland boundaries are sharply defined. Without this, woodland itself is hard to delimit and discrete patches that might be ancient or recent are hard to define.
- The ancient woodland has been managed as coppice or high forest, rather than wood-pasture. Partly this is because pasture woodlands are often diffuse and hard to delimit (see above). Also, coppice and high forest stands tend not to be grazed, so the woodland ground flora has not been transformed into a pasture. The logic is reversed for pasture woods where saproxylic species are being considered.
- The matrix (intervening land) has been used for arable cultivation, which is hostile to almost all woodland plants and animals. Where the matrix is pasture, heath or meadow, some woodland species thrive in these habitats. If a two-habitat species is found in a wood then at most is indicates continuity of woodland + the other habitat.
- Semi-woodland habitats are uncommon in the





Map 1 and Photograph 4 (above): A portion of the New Forest, which is a wood-pasture. Here, the woodland is generally diffuse and boundaries are difficult to define.

Map 2 and Photograph 5 (below): A predominantly agricultural landscape in which woods are sharply defined. The two ancient woods, Calpher and West Woods, were treated as coppices.

intervening landscape. These are habitats that are not classified or mapped as woodland, but nevertheless support a range of woodland species. Hedges form a widespread semi-woodland habitat in farmland. Others include river and stream banks, cliffs and railway embankments.

These conditions are fulfilled in much of lowland Britain, which is primarily agricultural, but not in the wood-pasture enclaves, such as the New Forest, nor in the few places with a long history of woodland cover above 30%, such as the Lower Wye Valley and the Chiltern Hills. These are districts which have always been well-wooded and have a long history of both wood-pasture and coppice. In upland and northern Britain, the conditions are rarely fulfilled, because (i) boundaries not sharply defined; (ii) the long and widespread history of pasturage and wood-pasturage; and (iii) the higher frequency of semi-woodland habitats in the landscape. Nevertheless, even in the districts where the conditions are poorly fulfilled, it has been possible to recognise woodland species with only limited abilities to colonise new woodland isolated from old woodland, e.g., the Atlantic bryophytes (Ratcliffe, 1968).

Primary Woodland

One reason why ancient woodland is important is that it will include any primary woodland that survives. Primary woodlands are – or would be, if they exist - remnants of the original, pre-Neolithic forests, and these would obviously be of interest to ecologists if they could be identified. The general problem is that, to prove a wood is primary, one must demonstrate that it has existed continuously throughout 5,000 years, which is really only possible with localised pollen records, and then these apply only to the immediate vicinity of the sample.

Archaeologists have usually taken the view that primary woodland could not have survived. The scale, intensity and duration of prehistoric land use is considered to have been such that woodland must have been removed from every patch of ground at some time. This view is supported by examples of woodland that undoubtedly go back 1,000 years or more in the historical record, but which nevertheless occupy land that was once a prehistoric field system or a fortified settlement. It has also been reinforced by pollen studies that have demonstrated pre-1600 open phases in ancient woods, and by recent LiDAR images, that enable even faint earthworks to be seen under vegetation. The latter in particular have opened everyone's eyes to hitherto unsuspected activity in ancient woods.

Nevertheless, there is good reason to entertain the possibility that some ancient woods are indeed primary, even if they have passed through relatively open phases. Not all ancient woods are found to overlie earthworks, even in LIDAR images, and woods with a pollen record showing a continuous trace of woodland are known. In any case, there has always been a need for timber, and it is far easier to keep the woods one has already than clear them away and create new ones elsewhere.

Whilst only a minority of ancient woodland may be primary and it is rare to find evidence of continuity of a particular wood back to the pre-Neolithic, there is a sense in which the question of continuity back beyond the Neolithic is not crucial for an ecologist. Consider a district where forest was much reduced in the early Neolithic, but tree-cover remained as an open patchwork of wood-pasture, scrub and marginal woodland amongst which there were cultivated fields and habitations. If, in the later Neolithic, this reverted to closed woodland, together with its characteristic species, any fragments of that late-Neolithic woodland that remained today would technically be secondary and might contain the remains of houses and field systems, but habitats for all components of the original woodland would still have been present continuously. In any case, a few thousand years have elapsed in which something like the original woodland could have been reconstituted. It is only when the woodland of a district has been so reduced, that the development of any restored woodland is limited by isolation from remnant woodland that it matters for ecologists.

In any case, pre-Neolithic forests were not wall-to-wall trees. They certainly had substantial openings in wetland and locally elsewhere, and there is the unresolved issue of whether large herbivores maintained wood-pasture on ordinary ground, as maintained by Frans Vera (2000). Accepting that Vera-type glades and scrub were present on some site types implies that we do not have to be too literal about the question of whether a particular patch of current woodland is, or is not, primary. If it has existed continuously since the Bronze Age, that's old, and it is highly likely to incorporate a direct habitat link to pre-Neolithic woodland.

Mainland Europe and North America

The concept of ancient woodland has proved to be useful in several countries in mainland Europe. A particularly strong research interest developed in Belgium around Martin Hermy and others working with him. He and other ecologists in Netherlands, Germany, northern France, Denmark, southern Sweden, Czechoslovakia and Poland have all used the concept in the British sense, although they have frequently used other labels, such as 'older woodland', etc. In each case, the threshold date has been dictated by local historical sources, usually the first systematic maps of the regions being studied, so 'ancient woodland' has tended to be woodland that existed in the mid – late 18th century and has survived ever since. This, in practice, is how we used the term in Britain when developing the ancient woodland inventory, where threshold dates were determined largely by the first comprehensive Ordnance Survey maps.

The common factors in all these countries and regions is that woodland has been reduced to a small proportion of the landscape and much of the matrix land has been used for intensive agriculture, i.e., they match the woodland and landscape history over much of lowland England, where the concept was developed. Elsewhere in Europe, (to the best of my knowledge) the concept has not been used, even by Oliver Rackham, who was as closely associated as anyone with the concept in Britain, and it is easy to understand why not:

- In the Mediterranean region, much of the arboreal vegetation is open woodland and scrub on irregular ground subject to grazing and fires. Being open and subject to a long history of use and modification, woods themselves are difficult to delimit. Sheltered, humid conditions are found only in specialised locations in ravines and on north-facing slopes (Rackham and Moody, 1996; Grove and Rackham, 2001).
- In boreal districts, trees cover a great deal of the landscape. Naturally and historically, they were subjected to fire and extensive grazing, leaving them open and constantly changing in their patterns. The non-forested habitats are forms of heath and mire, not unlike the ground vegetation of the open woodland. Today, with fire-suppression and intensive forestry, the forest stands are dense and landscape patterns are more sharply defined (Many examples in Sweden).
- In montane districts, wooded ground is disturbed by rock falls and avalanches, and most is grazed by stock with freedom to range into all habitats. In many regions, the forested ground occupies much of the land below the tree line. Elsewhere, the forested patches are often open and difficult to delimit.
- In some other kinds of lowland landscape, woodland is also poorly delimited and has fluctuated in distribution. For example, extensive lowland deciduous woodland in regions around the Baltic Sea have long been used as wood-meadow, which will be ancient, but the precise boundaries of woodland are hard to define, even when one is walking in them. In the now well-wooded Landes region of SW France, woodland was reduced to small remnants amongst heath, yet some well-defined ancient woods survived, e.g., Biscarrosse.

In north-eastern USA there has also been some interest in how forest history has influenced the distribution of plant species, and this has involved identifying those patches of forest that were never cleared by European settlers. In 1860, Henry David Thoreau knew such patches as 'primitive woodland' or 'second growth' (Torrey and Allen, 1962) and modern authors refer to them as 'primary' or 'old growth' in contrast with 'secondary' or 'old field' woods (Marks, 1995; Whitney and Foster, 1988; Whitney, 1994). In the modern landscape, where settlements and houses are mostly islands in a matrix of forest, these remnants can be identified from maps, by the presence of pit-and-mound micro-topography and by how they relate to the walls and other remnants of abandoned farms.

Rather than recognise ancient woodland in the British sense, ecologists and conservationists in most of Europe and North America recognise 'old-growth' stands, 'Urwald' or its equivalent, and in each case the terms refer to stands of mature trees that have not recently been managed, and which now usually possess a high volume of dead wood and a diverse vertical and horizontal structure. Such stands are 'ancient' in the British sense, but most British ancient woods are neither 'old-growth' nor Urwald. Many of these Urwälder survive in densely-forested regions, where there would be little meaning in recognising ancient woodland in the British sense.

The British have often translated 'Urwald' and 'old-growth' as 'virgin forest', implying that they are natural forests that have never been influenced by people, but this is rarely, if ever, justified. Most old growth boreal forests have changed in the 20th century with fire-suppression and restrictions on grazing. Many sub-montane Urwälder in central Europe were are least used and modified in the past, some as wood-pasture or wood-meadows. And, in the USA, the old-growth stands have changed since they were abandoned by indigenous Americans at the time of settlement by Europeans.

Conclusions

The British concept of ancient woodland has limited application. Ancient woods are easiest to define and delimit in temperate lowland landscapes where forests have at some time been reduced to much less than 30% of the landscape and the cleared land has been used for agriculture, leaving the remaining woods sharply defined in space and time. In such regions the concept has proved to be most useful when defining nature conservation priorities, based on protecting sites with (i) a direct link to the primitive landscape (ii) links to local history and culture, and (iii) biodiversity values connected to species that are least resilient in the face of radical and rapid habitat change. In montane, Mediterranean and Boreal landscapes, as well as in those landscapes where forests have always remained abundant and/or have been used for extensive pasturage, the concept has proved to be less useful, though, with modifications, it can be applied where old habitats and a long, uninterrupted continuity of habitat is significant, e.g., old-growth remnants in Boreal forests.

One can turn this conclusion back onto British conditions. In the wider context, one can appreciate that the difficulties in applying the concept of ancient woodland to sub-montane and boreal regions and districts with a history of extensive wood-pasturage are similar to the difficulties that would apply in many parts of mainland Europe.

The German concept of Urwald has frequently been translated into English as 'virgin forest', implying that such woodland has never been altered by people. Perhaps this expressed an unconscious hope that such woodland really does survive, but archaeological and palynological studies have repeatedly confirmed what common sense dictates, that no present-day woodland can have escaped some direct or indirect modification by people in the last 5000 years. But, taking a less black-and-white view, we recognise land that has always been reasonably well-wooded, bearing stands whose composition is little altered the late Mesolithic (and then only in a way one might have expected with post-Mesolithic species movements and soil maturation)> Such woodland is 'primary', 'ancient' and 'semi-natural'. If it is left untouched until its structure and processes show little sign of earlier human influence, it would become as much Urwald as most, perhaps all, Urwälder in mainland Europe.

References

Bossuyt, B., Hermy, M. and Deckers, J., 1999. Migration of herbaceous plant species across ancient-recent forest ecotones in central Belgium. *Journal of Ecology* 87: 628-638.

Boycott, A.E., 1934. The habitats of land Mollusca in Britain. *Journal of Ecology* 22: 1-38.

Goldberg, E., Peterken, G., & Kirby, K., 2011. Origin and evolution of the Ancient Woodland Inventory. *British Wildlife* 23: 90-96.

Goodfellow, S. and Peterken, G.F., 1981. A method for survey and assessment of woodlands for nature conservation using maps and species lists: the example of Norfolk woodlands. *Biological Conservation* 21: 177-195.

Grove, A.T. and Rackham, O., 2001. *The nature of Mediterranean Europe. An ecological history*. Yale University Press, New Haven and London.

Hermy, M., Honnay, O., Firbank, L., Grasof-Bokdam, C. and Lawesson, J.E., 1999. An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation. *Biological Conservation* 91: 9-22.

Marks, P.L., 1995. Reading the landscape: primary vs. secondary forests. *Arnoldia* 55: 2-10.

Peterken, G.F., 1974. A method for assessing woodland flora for conservation using indicator species. *Biological Conservation* 6: 239-245.

Peterken, G.F. and Game, M., 1984. Historical factors affecting the number and distribution of vascular plant species in the woodlands of central Lincolnshire. *Journal of Ecology* 72: 155-182.

Pigott, C.D., 1969. The status of *Tilia cordata* and *T. platyphyllos* on the Derbyshire limestone. *Journal of Ecology* 57: 491-504.

Rackham, O., 1980. *Ancient woodland*. Arnold, London.

Rackham, O. and Moody, J.A., 1996. *The making of the Cretan landscape*. Manchester University Press, Manchester.

Ratcliffe, D.A., 1968. An ecological account of Atlantic bryophytes in the British Isles. *New Phytologist* 67: 365-439.

Steven, H.M. and Carlisle, A., 1959. *The native pinewoods of Scotland*. Oliver and Boyd, Edinburgh and London.

Torrey, B. and Allen, R.H. (eds.), 1962. *The journal of Henry D. Thoreau*. Dover, New York.

Tubbs, C.R., 1968. *The New Forest: an ecological history*. David and Charles, Newton Abbot.

Vera, F.W.M., 2000. *Grazing ecology and forest history*. CABI Publishing, Wallingford.

Watkins, C., 1988. *The idea of ancient woodland in Britain from 1800*. In: Salbitano, F., (ed.) Human influence on forest ecosystems development in Europe. Pitagora Editrice, Bologna, 237-246.

Whitney, G.G., 1994. *From coastal wilderness to fruited plain. A history of environmental change in temperate North America 1500 to the present*. Cambridge University Press, Cambridge.

Whitney, G.G. and Foster, D.R., 1988. Overstorey composition and age as determinants of the understorey flora of woods of central New England. *Journal of Ecology* 76: 867-876.

Wolf, M., 1997. Plant species as indicators of ancient woodland in northwest Germany. *Journal of Vegetation Science* 8: 635-642.

Chapter 2
The Cultural Heritage of Woods and Forests

Ian D. Rotherham

Abstract

Contrary to popular belief, our ancient woodlands in Britain and across much of Europe, are not 'wildwoods', nor even are they remnants of a 'wildwood'. These truly cultural landscapes mix nature and human history, woven together as a unique and rich tapestry of ecology and history (Rackham, 1976, 1980, 1986, 2006; Smout et al., 2005). The story of the woods is there to be 'read' if you have the time, the enthusiasm. The types of landscapes, the geology and the climate, and even to differences in industries and in manufacturing history, have placed varying demands on woods resulting in strong regional distinctiveness. This eco-cultural evolution led to woods with strong, local character depending on the ecological types of woodland present originally, and then varying uses over the centuries. From South Yorkshire's wood colliers, to the Chilterns bodgers, the tanbark merchants of Cumbria, and the clog makers of North Yorkshire, they each left a unique and indelible footprint in the landscape (Jones, 2003, 1998; Jones and Rotherham, 2012; Jones and Walker, 1997).The crafts and the evidence in the woods of former activities are a unique cultural resource, and like many such aspects of living heritage, are under imminent and on-going threat. In order to safeguard this unique heritage, essentially a living landscape, you first need to find it, and then recognise it, and then care for it (Rotherham, 2013b).

There is widespread popular and academic interest in woodlands, their history and the associated archaeology (Rackham, 1986; Rotherham et al., 2012; Muir, 205; Peterken, 1981; Hayman, 2003; Fowler, 2002; Perlin, 1989; Hare, 1998). However, there is currently very little literature that addresses the history, heritage and archaeology of woods in a coherent and holistic way. With the publication in 2008 of the Woodland Heritage Manual (Rotherham et al., 2008), there is now an accepted approach to this subject across Europe and even in the USA, and the interest in this long-neglected field is growing rapidly. The subject covers a wide range of topics from extractive industries in woods to the crafts based on the extraction or harvesting of woodland products and their processing. For centuries, these crafts were at the centre of British and European societies and cultures, and were fundamental in the creation and protection of many landscapes that we value today.

However, as technologies changed and as markets for products evolved, many of the woodland traditions and crafts were abandoned and forgotten; just a few surviving to the present day. However, the footprints of these craftsmen are indelibly etched into every 'ancient wood' across the continent. The only problem then is in recognising and understanding the evidence. Even the woodland wild flowers and their distributions reflect the one-time uses of the sites, as do the formerly 'worked' trees; even the humps and bumps of soil now present as archaeology. These woods contain uniquely rich diversities of 'features', ancient and modern, from Bronze Age carved stones, to hilltop enclosures and field systems, woodbanks and ditches, trackways, charcoal platforms, Q-pits, bell-pits, quarries, building platforms, and more (e.g. Ardron and Rotherham, 1999; Rotherham and Ardron, 2006; Rotherham, 2007a). The heritage includes archaeology 'in' the woods and archaeology 'of' the woods. The former is the mix of features protected in the landscape because in the wooded area there has been only limited gross disturbance and destruction. The latter is the heritage associated directly with woodland management and resource use.

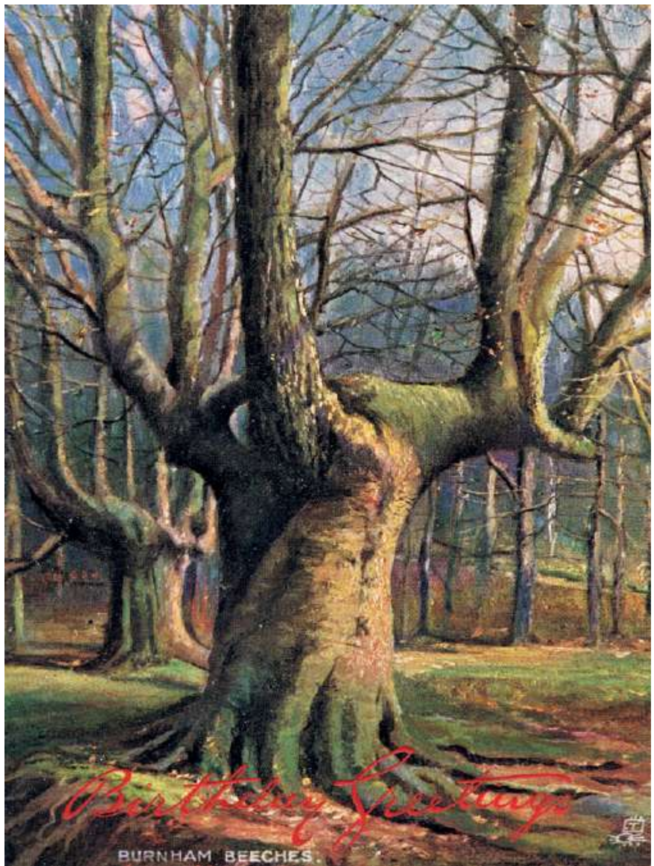
This chapter introduces ideas and concepts of the cultural landscapes of wood and forest. It develops approaches to 'reading' the evidence of species, archaeology and other heritage. Conservation issues and concerns are also introduced.

Reading the woodland landscape

Sometimes, reading these landscapes can take the researcher back over four thousand years or more of history, even in urban ancient woodland. Small-leaved limes (*Tilia cordata*) can be 3,000 years or more old (e.g. Pigott in Beswick and Rotherham, 1993). This rich diversity of human artefacts, evidence of activities and the ecology itself, can help in reconstructing an image of a local landscape and its unique history. The evidence is physically imprinted into the environment around us, but it is also in our woods and wooded landscapes are also recorded in place-names, settlement names, and field-names such as Wood End, Wood Lane, Hagg Side, Hollins End, Woodside, Endowood, Woodseats, Woodthorpe, Willowgarth, Owlerton, Owler Carr, and the like. Woodseats for example would be 'the cottages deep in the wood', Gleadless 'the woodland clearing with the red kite' and Clayroyd a 'woodland clearing with clayey soil'. From the early medieval times, woods were themselves named: Park Spring or Parkwood Springs (the park coppice wood), West Haigh Wood (the enclosed wood), Newfield Spring (the coppice wood by the new field), Ecclesall Woods (a woodland in Ecclesall parish split into several medieval 'woods'), and many others. Family names also reflect our wooded past with Underwood, Woodward, Herst, Hirst, Hurst, Hirsthouse, Heston, Frith, Frith, Wood, Turner, Collier, Greenwood, Tanner, Wood, Woodman, Woodhouse, Woodreve, Forester, Frith, Warren, Warrener, Warrender, Stubbs, Park, Parkman, Parkhouse, and Parker, being just a few examples (Rotherham, 2013b).

To walk through an ancient wooclod is to tread in the footsteps of the ghosts of those who once lived and worked in the medieval and early industrial countryside (e.g. Rotherham and Jones, 2000). The ancient wood is frequently part of a greater landscape of medieval park, of common or heath, of chase or forest (Rotherham, 2007c, 2007d). Identifying ancient coppice stools, stubbed boundary trees, or veteran pollards from a long-forgotten deer park or old hedgerow will aid an understanding on how the countryside looked and functioned in times past (Photograph 1 and 2). These wonderful ancient landscapes come to life as we unfurl the history of woodland workers and others over a thousand years or more. In many cases, there are strong regional differences and identities that persist in the woods of today. These may relate to particular industries and intensive uses such as the Derbyshire and South charcoal makers who worked so hard to fuel the early Industrial Revolution (Photograph 3). With practice, these regional identities can be recognised and identified. Fragments of ancient woods are to be found as broad 'hedgerows' along old sunken lanes and trackways in urban and countryside areas, often still with veteran trees and woodland indicator plants (Photograph 4). They are found close to rivers and streams, in green-spaces such as recreational parks and leisure grounds, golf courses, and even on modern housing estates. You just have to look (Rotherham, 2013a).

Finally, the study of woods and woodlands lends itself to the local community-based group and the local enthusiast (Rotherham et al., 2008). Importantly, almost everyone will have one or more suitable sites on their



Photograph 1: Burnham Beeches fuelwood pollards.


Photograph 2: Burnham Beeches fuelwood pollards.

doorstep and accessible for study and enjoyment. Yet many sites remain poorly known and little understood. Studying your local patch can make a real and lasting contribution to our knowledge and understanding of these most iconic and important, but often misunderstood, landscapes. Step inside your local wood and, with practice, you can read its landscape and its ecology like the pages of a book. Ancient woodlands are remarkable repositories of history and archaeology, of the woodland and its management, but also of people and communities who have lived in that landscape perhaps back to prehistoric times. Remarkably, they have until recently been largely overlooked by archaeologists. This is not

Photograph 3: A Hearty Meal – Charcoal Burners, Balcombe Forest, West Sussex; 1908.

Photograph 4: Big Belly Oak, Savernake Forest, Marlborough.

always the case when there is obvious major heritage on a site such as some of the Chiltern beech woods. Here the massive prehistoric fortifications are well documented. Yet in the heart of the city of Sheffield, in Ecclesall Woods, an entire hilltop enclosure, a Romano-British field system, a medieval deer park boundary, and hundreds of charcoal hearths, lay undiscovered until about ten years ago (Rotherham, 2012; Rotherham and Avison, 1998; Rotherham and Jones, 2000).

More recently, two other more modern forms of woodland archaeology have come to light. These are the extensive but sometimes enigmatic remains of wartime and military use of the woods, from bomb craters, to trenches and gun positions. These date from the Napoleonic wars to the Cold War military activities of the 1950s and 1960s. The second type is what Paul Ardron and I have described as 'community archaeology', which is made up of the dens and play areas of children and young people. These include BMX tracks and for example, the rough shelters sometimes built for war-gaming or by itinerants. All these activities are adding to the centuries-old palimpsest of the woods.

Many woodland crafts, having survived as oral traditions down the centuries, have succumbed quickly to urbanisation and industrialisation during the early twentieth century (Rotherham, 2007a; Rotherham and Egan, 2005). This loss began in developed Western Europe but has now spread both east and south in to Mediterranean countries. Of some of these once commonplace crafts, we know very little. However, often in the 1950s, in cases such as charcoal making, the skills were rescued and recorded, from the brink of oblivion. In this way, some of the old skills and traditions have been demonstrated, recorded, passed on, and even re-kindled. Some crafts were written about in estate records and aspects of use can be elucidated from the archives. Mel Jones' archival research in South Yorkshire for example, has given a fascinating insight into the precise and particular management of sites and trees (Jones, 2009). This can be down to the exact day on which trees were cut and used, the people involved in both buying and selling, and the actual price paid. Some crafts and their products remain shrouded in mystery, and even if records were made and survive, they often use words to describe materials and amounts, which are obscure and difficult for us to decipher. These are lost crafts and skills that will never be re-created, and for which, even their products are long-since obsolete.

Today a there is a growing interest in rediscovering the old uses and the old ways. However, only a few people actually make a fulltime living from woodland crafts. The work is hard, and often requires attention on-site twenty-four hours a days, seven days a week. This is the case when a charcoal burn is on. Aside from the satisfaction of traditions maintained and jobs well done, the rewards are scant. New craftsmen make their living from the craft and education; selling both product and process (Rotherham, 2013b; Jones, 2009).

The losses affected not only the people but the woods too. As old crafts and skills died away, whilst many woods have survived, just, others have been destroyed. Frequently, especially between 1940 and 1980, sites were converted into conifer plantations, or ploughed up for agriculture. The woods that remain hold a unique archive, the footprints and ghosts of the men, women and families who lived and worked the woods for centuries. Today there are moves to re-discover old woods and remove the imposed conifers or hardwoods such as sycamore. In a few cases, there are attempts to put the craftsman or woman back into the woods as well. Yet this can only be a token gesture since the work is hard and poorly paid. In addition, for now at least, we simply do not depend on the working woods as we once did. However, there is an emerging new breed of woodland craft workers, the wood carvers, who harvest timber and work with grain. Perhaps in future decades these people can help build a spiritually and financially rewarding bridge to the woodland crafts of the past. This is a new forward-thinking approach that can join green wood turners, charcoal burners, hurdle makers, clog makers, local people and conservation managers in growing new awareness and attachment to local woods

You might think that all is well in the twenty-first century woods, but in many countries, that is not the case. On the one hand, the woods have regenerated and are rejuvenated by abandonment and so tall trees grow where once there was a scrubby coppice. However, as the high canopy or the outgrown coppice become dense, the light is closed out and ground flora is suppressed. Consequently, the glorious mats of woodland ground flora, the bluebells, anemones and wild garlic, disappear. Furthermore, as governmental planners and others such as industrialists, turn their eyes to biofuels from the woods, an even worse and more damaging fate awaits them. It is argued that this use is in keeping with their origins as 'working' woods. However, the differences between traditional coppice management and twenty-first century biofuel harvesting are stark indeed. Today, instead of employing manpower, horses and oxen to work the modern woods, these contemporary industrialists apply a single man on a huge tracked vehicle. This individual can extract and process large timber all at once and importantly too, has no long-term relationship with the landscape in which he or she works. The impact on the ground can be devastating and landscapes, sometimes several thousand years old, and protected from major disturbance by the presence of traditional woodland, are obliterated forever in a single afternoon. The itinerant machine driver has no connection to the place or the craft, whereas the traditional woodland worker was frequently a resident of the local village. Moreover, these skills and crafts were mostly oral traditions passed down over generation with close ties to the particular craft but also sometimes to the place too.

Photograph 5: Clog block makers in the woods.

The woodland crafts and other industries in the woods

Early peoples would always have been involved in using trees and woodland, and in a great many different ways (Rotherham, 2005, 2013b). The people involved in managing woods, grew over the centuries into specialist craftsmen and their families, often undertaking particular crafts for specific markets. Some occurred widely across Europe and for example, all across medieval Britain. Others were localised or regionally distinctive. They included charcoal burners or wood colliers, white coal makers, clog makers, bodgers, tanners, tan-bark merchants, timber merchants, firewood merchants, potash makers, basket makers, and others Photograph 5). Alongside the woodland crafts were other industries based on particular resources found where woods were located: mining for mineral coal and ironstone, digging and quarrying building stone, sand and gravel, and quarrying for rock including refractory ganister. All these activities, some on as local, small-scale operations and others industrial, left marks as scars on wooded landscapes. Whilst these crafts and industries sustained woods and employed local communities, they frequently changed the woodland ecology forever. When exploitation ended, often quite abruptly, the surviving woodland began an often-slow change in its ecology through a predictable pathway known as a 'succession'. By understanding such changes and the ecological requirements of species such as ground floor flowering plants, we can use them as 'indicators' of woodland type, history and quality (Photograph 6).

Abandonment of traditional management followed by successional change, means that todays' woods look and feel very different to those in the past (Rotherham, 2005, 2011). If we were to step back into a working medieval wood or even an English coppice wood from the 1920s or 1930s, it would hardly be recognisable to our twenty-first century eyes, noses and ears. These were locally important resources managed in the same ways, and by the same families, for decades or even centuries. Working woods bustled with life and activity; people and animals working in harmony and varying with the seasons and longer management cycles. There were people working and families living in and around the woods, felling trees, cutting coppice, peeling bark, making besom brooms, constructing hurdle fencing, tending pigs, herding livestock, warrening the rabbits, watching over deer, and harvesting nuts. Other workers dug mineral coal and stone, or shallow-mined ironstone or gravel; each dependant on whereabouts in the country you were and who owned the wood. The woodland workers varied from region to region and the Chiltern beech-woods for example, were home to numbers of chair-leg manufacturers or 'bodgers'. These men supplied part-finished chair-legs cut inside the

Photograph 6: Red campion - a wild flower of woodland edge and hedgerow but not necessarily indicative of ancient woods.

working wood on pole-lathes from green coppice wood. The rough legs were then sent to factories for finishing; a bodged job is not a bad one, but simply incomplete.

Other people worked in and around the coppice wood, including the woodman, cutting timber and wood, perhaps for fuel-wood markets and for constructional work. The timber was for specific big constructional jobs, sometimes a specific tree harvested for a particular client, or regular supply to local sawmills. Cutting smaller wood inside the woodland, and bigger timbers often outside, would be sawyers working in teams. The so-called 'top-dog' stood above the timber in the sawpit, directed the big-handled, two-man saw. The 'underdog' stood in the sawpit and below the timber to pull the great saw downwards, probably getting eyefuls of sawdust. This was thirsty work and sawyers were renowned beer-drinkers. The woodward oversaw these activities on behalf of the landowner and in Britain, from the 1700s onwards, was joined by gamekeepers and others involved in the rapidly growing game management. The earlier onus was on hunting deer and small game, and key people were the parker who ran the deer park, and the warrener who dealt more with small game like rabbits and hares. By the 1800s, a significant part of this community would be gamekeepers, often employed as hired thugs to keep the commoners, now poachers and trespassers, out of what had once been their woods.

Decline and fall

From the 1800s to the 1950s, with changing society, economy and technology, woodland craftsmen declined rapidly and dramatically. In Sheffield for example, many coppice woods ended their last cutting cycle in the mid-1800s (Rotherham, 2007a). Across England, this occurred sometime between 1800 and 1950, as centuries-old traditions died. Since most of these activities were oral traditions passed down from generation to generation, as they ended they were lost. Now, with woods either changed or their function lost, were themselves vulnerable to destruction (Rotherham, 2005, 2008; Rotherham and Egan, 2005). Therefore, across Britain, from the 1800s to the 1980s, huge numbers of ancient woods were abandoned and / or grubbed up, or were re-planted with exotic tree species. Many old coppices, which were retained, were converted to 'high forests' or modern 'forestry'. This is essentially, modern European, industrial, plantation-based timber production and not to be confused with the ancient, medieval 'forests' (Rotherham, 2008).

However, whilst even if the woods survive their purpose and functions have changed, it is important to appreciate that some of the people who populated our woodlands past left defining marks still visible today. This is manifested as archaeology in the contemporary sites and can often be tracked back to specific uses and times (Rotherham, 2011). In other cases, the features are vague and indefinable in terms of a particular use of date. Remarkably, some users of the woods, for example the once almost ubiquitous tanners, left almost no obvious trace actually in the woods.

Woodlands, timber and construction

In modern-day, Western European countries, it is hard to imagine the central roles of wood and timber in earlier civilisations. Of the obvious functions, those associated with building and construction, are amongst the most obvious. Only in the 17th century did stone and brick widely supplant timber and wood as the main building materials. Timber held prime place ever since the first permanent settlements were built in Neolithic times. Even substantial buildings such as castles and parish churches were constructed of timber. Sometimes they were later rebuilt in stone, but even then, the core structures were often around great timbers. Huge numbers of trees from Britain's medieval woods still survive in timber-framed houses and barns and the dendrochronological analysis of these can be hugely informative. The builder of these medieval houses and grand buildings was a house carpenter or housewright. Unlike his equivalent today, he did not get his timber as ready-sawn or shaped planks and beams. This master craftsman went to woods (or indeed hedges), and chose his trees carefully and individually to match his requirements. This timber would, with the minimum of shaping, roughly square up to the dimensions of the components required with large trees for beams and smaller trees for materials such as rafters. The timber used was mostly oak and sometimes elm or sweet chestnut, sawn or shaped with an axe or adze while still 'green', which made it easier to work. Metal nails were not used because the tannic acid in unseasoned oak would quickly corrode them. Instead, the craftsmen used thousands of oak pegs (sometimes called treenails).

In most cases, constructed in the house carpenter's yard or 'framing yard', timber-framed buildings were taken pre-fabricated for on-site assembly. As constructed and originally assembled, every piece of timber for the house or barn was marked to make sure each part was placed correctly for re-erection on the final site. Carefully examine timbers of old buildings, and the carpenter's marks are often visible. In England, there are two traditions of timber-framed building, the 'post-and-truss' (or box frame), and 'cruck building', the later often used for large barns and similar buildings.

Charcoal and whitecoal making in England

Activities that left indelible imprints on the woods that persist today if the sites survive, include charcoal and white coal manufacture (Ardron and Rotherham, 1999). As discussed earlier, some impacts of industries and crafts were more obvious than others were, and manufacture of charcoal and 'whitecoal' are especially significant. The former was very widespread and the latter was rather localised. Wood charcoal was widely manufactured but particularly close to iron smelting areas was made on an industrial scale. In regions such as the English Lake District to supply the Furness iron works, and North Derbyshire or South Yorkshire, to supply iron and steel factories, the charcoal woods were managed intensively and industrially. This had massive, long-term impacts, so whilst the woods survived because they were economically important, they were changed in character, their ecologies transformed. The impacts of these activities, in the case of charcoal, extending back over two millennia, and for whitecoal just two to three centuries around the 1500s, have left a remarkable heritage. Not only did they change the treescape by coppicing and burning the wood, but they stripped the woods of centuries-old soils and the living fabric of the vegetation too. Turf and sods were cut from the woodland floor to cover the woodmen's wigwam buildings, and they were used to cover and seal the charcoal burns themselves. Go into one of these woods today and there is no topsoil, just a few centimetres of black charcoal dust and then subsoil. Now, very gradually, after fifty to sometimes a hundred-and-fifty years after the last charcoal burns, the vegetation slowly creeps back. Some plants like bluebells recover quite quickly but others such as wood anemone or the diminutive wood melick grass take much longer.

Charcoal making for iron smelting is the oldest recorded woodland industry in many places. This is not surprising, as being essential to metal smelting and working, it took place since prehistoric times. Markets for iron-smelting charcoal gradually disappeared during the 18th century as mineral coke replaced it. Some markets remained and others expanded. Most importantly, charcoal was used in making blister steel in cementation furnaces where successive layers of bar iron inter-bedded and charcoal were heated to high temperatures for up to eight days. Another charcoal-based industry was gunpowder manufacture, using alder, willow, and alder buckthorn. Charcoal was also used in large quantities as blacking by moulders in iron foundries. Away from industrial areas, charcoal was also hugely important for cooking and heating, especially in great halls and houses and before the advent of modern chimneys. It burns predictably hot and clean. Wood fuel is variable and messy, and coal can give off unpleasant and even dangerous fumes; in open or primitive fireplaces, neither is ideal for cooking. Artists, medicinal uses, and gas masks for example, all demanded high-quality charcoal.

During the 'coaling' season, generally from April to November, charcoal burners or 'wood colliers', lived isolated lives, often with their families, deep in the woodlands. Their work consisted of burning carefully stacked lengths of coppice poles in the absence of enough air for complete combustion. During this controlled burning, moisture was driven off followed by volatile elements of tar and creosote. The process left behind a residue of black carbon with a little ash. Everything was saved, the ashes used as covering for subsequent burns.

Using traditional methods but with subtle variations in layout a level spot was chosen and the turf removed, or on a steep site, was dug out from the hillside. This was about fifteen feet in diameter and called the pitstead, pit, or hearth. There are different traditions of building the stack. One way, perhaps a southern tradition was to lay three short billets on the ground as a triangle and then build this up as a central flue. A northern method was to drive in a long central stake, removed when the stack was ready. The rest of the stack was built by stacking cordwood (four-foot lengths of coppice poles and branch-wood) facing inwards to form a stack looking like an upturned pudding basin, fifteen feet diameter, five feet high. This is shown in the pictures of charcoal stacks under construction and during a burn (Photograph 7 and 8). The wood was then covered by straw, grass, bracken, and turves, which in turn were covered by dust and ashes. Virtually all air was excluded and the burn could be controlled.

Red-hot charcoal and a few dry sticks were dropped down the central flue. When the stack was alight, the wood collier sealed the flue, and fire spread through the stack. It was important the burn was steady and fire did not break through to the surface allowing air in. The burner had to be in constant attendance during the burn, with hurdle fencing and sacking to protect his stack from sudden wind changes; closing gaps in the stack with bracken, turf, and soil; again, this is shown in the pictures (Rotherham, 2013b) (Photograph 7 and 8). Burning lasted anything from two to ten days depending on stack size, weather

Photograph 7: Charcoal Burners' Hut, New Forest; F.G.O. Stuart, 1123; around 1910s or early 1920s.

Photograph 8: Charcoal Burning in the Lake District; James Atkinson Publisher, Ulverston; 1904, posted Bardsea.

conditions, and wood greenness. The burn emitted clouds of white smoke, gradually turning blue and then dying away altogether. Each stage indicated to the collier how the burn was progressing. When the firing was over, the stack was uncovered with a rake to cool and the charcoal, a valuable product but liable to fragmentation, packed carefully into sacks or panniers for transportation.

The same charcoal hearths and the charcoal makers' hut sites were reused repeatedly at the end of each coppice cycle for a particular area of woodland. As shown in the photographs, the huts were conical in shape built on a framework of poles like a wigwam around a low, stone wall perimeter. This is one of the oldest and most primitive forms of building known to humanity and its survival to the twentieth century in industrial cities like Sheffield is quite remarkable. A wooden lintel was lashed into place over a gap left as a doorway into the primitive shelter. The remains of these huts in the form of a circle of stones (the remains of the low perimeter wall with a gap for the doorway), can still be found in some parts of north and west England. Each particular craft, be it wood collier, clog maker, or bark stripper had their own distinctive type of hut; each related and similar but different and distinctive.

Alongside charcoal making, was another woodland industry making fuel for metal smelting in woods in North Wales, Southern Scotland, the Yorkshire Dales, South Yorkshire, and North Derbyshire. This was more localised than charcoal manufacture and occurred mostly between the late 1500s to the mid-1700s, associated with lead smelting. Lead ore was smelted with a mix of this dried wood called 'whitecoal' or 'chop-wood' (Rotherham, 2013). In South Yorkshire, the lead was carried from Derbyshire, from the relatively poorly wooded Peak District to water-powered ore-hearths located on the fast-flowing rivers near the region's coppice woods (Jones, 2009; Rotherham and Egan, 2005). Whitecoal was small lengths of wood, dried in a kiln until all the moisture was driven out. Charcoal and whitecoal were mixed together to smelt lead, because charcoal gave too high a temperature and wood not high enough. Whitecoal might be used alone in smelting lead ore with charcoal used to re-smelt the slag.

Characteristic large depressions or craters in the ground confirm the former presence of whitecoal making in a wood. These can be anything from three to five metres in diameter and with a noticeable 'flue' at one end. The flues face downhill, varying in length and construction. These are the remains of whitecoal kilns sometimes also known as Q-pits. The name Q-pit has been given because the letter 'Q' mirrors the shape of the archaeological remains. In Sheffield, there remains a persistent rumour or myth that these are the bomb craters from the German bombers, which blitzed the city in the Second World War.

Oak bark leather tanning

Other woodland workers included tanners and bark peelers who stripped the bark off timber and coppice wood; giving rise to the surnames Tanner and Barker. This was vital, along faeces, for manufacturing leather; again essential in pre-petrochemical society. The bark peelers were separate from the charcoal burners and this can be recognised in the differing shapes and styles of their temporary buildings now reduced to archaeological remains; each is distinctive. Bark peeling for tanning was of such national importance that in 1603 there was passed 'An Act concerning Tanners, Curriers, Shoemakers and other Artificers occupying the cutting of Leather'. This act stated that '…..for as much as barke is of late become verie dear and skarce, which happeneth partlie by reason that divers persons do ingrosse and buy great quantities thereof……..', and goes on the explain in detail the regulations and controls over cutting, peeling and selling bark; it was not repealed until 1808.

Just as salt and wood were hugely important in medieval societies, tanned leather was a massively valuable and essential product. Christine Handley has researched the history of wood-bark tanning (see this volume). During the 150-year period from 1680 to 1830, the production of leather and leather goods was, by value, the second most important industry in England after textiles. It was one of the largest employers outside agriculture.

Woodlands played a major role in supplying tree bark, which before the introduction of chemical substitutes, was the main agent, in the form of a liquor, used in the preparation or 'tanning' of the animal hides. This was prior to their conversion into such everyday articles as boots, shoes, clogs, harnesses, saddles, breeches, aprons, gloves, bags, cases and bottles, and for use in industry for bellows and belting. Bookbinders were also important customers for fine leather. The tannic acid from ground bark seeps slowly through the pores of the hide, draws out the water, and coats each fibre with a preservative. The tannin content of oak bark made it the most efficient and therefore the most important tanning agent in medieval Britain. Other sources of chemical were used elsewhere around the world depending on the available tree species and their suitability.

When a compartment of woodland was coppiced the wood might be de-barked. The bark was peeled in large pieces from both the timber trees and the underwood poles. This was done by scoring a tree round its trunk at about two feet intervals, and then making a longitudinal slit along the trunk. The bark could then be levered off in large plates with a bark peeler called a spud. It was often the practice to remove as much of the bark as possible while the tree was standing, then felling it to strip the rest. The peeled bark was stacked to dry and then, as tannin is soluble in water, it was protected from rain in thatched stacks until sold to tanners. The woodland historian and archaeologist should also be on the lookout for the remains of tanneries in well-wooded areas, which contained bark mills worked with horse or waterpower, where the bark was ground up and tan-pits, through which the hides were successively passed. These tan-pits would have contained increasingly strong tannin solutions. Today, there are very few tanneries in England, which still use oak tannins for leather production.

Potash manufacture

In a pre-petrochemical age, alkali made from the ash of green plant material was hugely important. This was used in the preparation of textiles and in various dyeing processes. Potash, as it was known, was also used with other ashes for domestic soap, and was an important fertiliser. Until recently, the process of potash making was unclear, but we now know it involved two stages, which left very different evidence. There were massive stone–built kilns, open at the top and bottom, for burning leaves and other green vegetation. This produced base-rich ash taken and boiled in large metal cauldrons seated in pits cut into earthen banks. To produce caustic potash the mix was heated on a metal plate over a hot fire. Potash and ashes mixed with animal fat or tallow were used for the soap manufacture. Evidence can be seen in variable and often shallow depressions and pits, which may have been where the 'elying' took place or could be the sites of less industrial ash burning (Photograph 9).

Potash makers probably occurred quite widely but in Britain are only known in detail from Cumbria. Here the process was industrial to supply Lancashire's textile manufacturing.

Photograph 9: Potash kiln site Cumbria.

The small crafts

Less well-known but once widespread, are a number of specialist, often-outdoor woodland crafts. These have now almost disappeared because either the product is no longer required, other materials are used, or because the products now are made in factories. Such crafts included turnery, coopering, chair bodging and the manufacture of wheels, clogs, baskets, hurdles, thatch spars, rakes, besoms, hazel hoops (to put around barrels), and brush handles (Rotherham, 2013b; Jones, 2009). Numerous other activities could be added to this list.

Turners made not only wooden dishes and plates but also a wide range of kitchen and dairy implements. The few now working today are more likely to be making decorative objects and toys. Until forty years ago, turners also made wooden clothes pegs and clothes wringer rollers. Like turners, coopers also made vessels for food: dry coopers made casks to hold non-liquid goods, white coopers made articles for domestic use and wet coopers produced casks for storing liquids. The wet cooper made a whole range of specialised vessels including pails and piggins, for carrying water and milk, churns for making butter, tubs called keelers for cooling liquids, tubs called kimnels for general use, lidded kits for holding milk, and hogsheads for storing ale.

Clog makers used alder, willow, birch, sycamore and beech trees. Alder was preferred because it was water proof and easy to work. Short lengths of tree trunk were riven (split) into sole blocks by the clog-sole maker and shaped with a special tool called a stock knife.

Besom making was also a widespread local craft until the beginning of the 20th century. Besoms were indispensable for sweeping flagged cottage floors and factory floors. The besom handles made from young ash, birch or hazel poles and the brooms from bundles of twigs. The later were from birch or hazel, heather or broom. These were tied together originally with strips of willow, riven oak or even bramble. Basket-making was also a widespread craft with great regional variation in the type of basket made, from swill baskets made of thin strips of boiled oak to fish 'kiddles', made of willow and used for trapping fish.

Many crafts occurred widely across Britain and Europe, but their occurrence varied in time and intensity. Some industries such as potash manufacture in south Cumbria, chair-leg bodging in the Chilterns and whitecoal production in or near lead mining areas were important regional specialisms (Photograph 9). These regional and local variations are reflected by documentary records and in archaeology of local woods.

Other manufacturing and extraction of mineral and stone

Other industrial remains occur alongside industrial processes, which directly used woodland resources. Examples of these other industries include glass-making, metal smelting and working, quarrying and brick-making, found extensively in woods and on wooded heaths.

Since the Neolithic flint miners of Norfolk's Brecklands, people have quarried, mined and dug for minerals and stone. Sometimes these sites were in wooded landscapes, and in other cases, following abandonment of the post-minerals sites the woodland has re-established to cover the wounds of industrial activity. Either way our wooded landscapes are often pockmarked with anything from small stone-getting pits for local wall building, to major bell-pits for mineral coal or ironstone, to extensive survey cutting of coal and large quarries for ganister or limestone. Others sites have large gravel pits, clay sites and sandpits. Many small stone-getting or other pits and features are not easily defined or classified and you just accept them as an intriguing part of the wood's long history.

Conclusions: conservation and the future

Conservation of these eco-cultural landscape, rich in both ecology and heritage features, remains problematic (Rotherham, 1996, 2008, 2011, 2013a; Jones and Rotherham, 2012). The first challenge is in recognising sites and their characters, then secondly understanding what they are and their inherently dynamic natures (Peterken, 1990), and then thirdly implementing sensible programmes of conservation protection and management. Many of the features are unseen and if seen are misinterpreted - by ecologists, foresters and by archaeologists. There is a further problem too in that the richness of the heritage relicts the histories of individual woods and forests as working landscapes. Today however, with increasing cultural severance (Rotherham, 2008), the sites are stripped of their traditions and

Photograph 10: The Burnham Beeches by Birket Foster 1800s.

Photograph 11: Woodland and pollards.

subject to abandonment and dereliction, intensive industrial exploitation, or amenity and recreational uses. None of these produces the conditions needed by the ecology, and many activities are positively damaging to the archaeological heritage. Furthermore, much of the irreplaceable heritage is that of living trees, some in excess of a thousand years old. These once 'working trees', (coppices, pollards, shreds, stubs, and others), are now 'worked trees', 'retired veterans' and the biological processes of death, decay and rot take their tolls (Photograph 10 and 11). Yet these slowly decaying giants are eco-monuments, which allow people to touch the past and to place the future in a perspective. Addressing the vital issues of recognition and conservation remain very pressing indeed (Rotherham, 2012, 2013a).

References

Ardron, P.A. and Rotherham, I.D., 1999. Types of charcoal hearth and the impact of charcoal and whitecoal production on woodland vegetation. *Peak District Journal of Natural History and Archaeology* 1: 35-47.

Beswick, P. and Rotherham, I.D. (eds.), 1993. *Ancient Woodlands – their archaeology and ecology - a coincidence of interest*. Landscape Archaeology and Ecology, 1.

Fowler, J., 2002. *Landscapes and Lives*. The Scottish Forest through the Ages. Canongate Books, Edinburgh.

Hare, A.D.R., 1998. Woods Ancient and Modern. *Arboricultural Journal* 12(2), 177-180.

Hayman, R., 2003. *Trees, Woodlands and Western Civilization*. Hambledon and London, London.

Jones, M., 1998. *The rise, decline and extinction of spring wood management in south-west Yorkshire.* In: Watkins, C. (ed.) European Woods and Forests: Studies in Cultural History. CAB International, Oxford. 55-72.

Jones, M., 2009. *Sheffield's Woodland Heritage*. 4th Edition. Wildtrack Publishing, Sheffield.

Jones, M. and Rotherham, I.D., 2012. Managing urban ancient woodlands: a case study of Bowden Housteads Wood, Sheffield. *Arboricultural Journal*, 34(3): 215-233.

Jones, M. and Walker, P., 1997. From coppice-with-standards to high forest: the management of Ecclesall Woods 1715-1901. *Peak District Journal of Natural History and Archaeology*, Special Publication No. 1, 11-20.

Muir, R. 2005. *Ancient Trees Living Landscapes.* Tempus Publishing Ltd, Stroud, Glos.

Perlin, J., 1989. *A Forest Journey.* Harvard University Press, Massachusetts.

Peterken, G.F., 1981. *Woodland Conservation and Management.* Chapman and Hall, London.

Rackham, O., 1976/1992. *Trees and Woodland in the British Landscape.* Second edition, Dent, London.

Rackham, O., 1980/2003. *Ancient Woodland: its history, vegetation and uses in England*. London: Edward Arnold, 1980. (New, updated edition by Castlepoint Press, 2003)

Rackham, O., 1986. *The History of the Countryside*. Dent, London.

Rackham, O., 2006. *Woodlands*. Collins.

Rotherham, I.D. (ed.), 2007. *The History, Ecology and Archaeology of Medieval Parks and Parklands.* Wildtrack Publishing, Sheffield.

Rotherham, I.D., 1996. The sustainable management of urban-fringe woodlands for amenity and conservation objectives. *Aspects of Applied Biology*, 44: 33-38.

Rotherham, I.D., 2005. Fuel and Landscape – Exploitation, Environment, Crisis and Continuum. *Landscape Archaeology and Ecology* 5: 65-81.

Rotherham, I.D., 2007. The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: a UK case-study. *Forest Ecology and Management* 249: 100-115.

Rotherham, I.D., 2008. *The Importance of Cultural Severance in Landscape Ecology Research*. In: Editors: Dupont, A., Jacobs, H. Landscape Ecology Research Trends, ISBN 978-1-60456-672-7, Nova Science Publishers Inc., USA, Chapter 4, 71-87.

Rotherham, I.D., 2011. *A Landscape History Approach to the Assessment of Ancient Woodlands*. In: Wallace, E.B. (ed.) Woodlands: Ecology, Management and Conservation. Nova Science Publishers Inc., USA, 161-184.

Rotherham, I.D., 2012. *Traditional Woodland Management: the Implications of Cultural Severance and Knowledge Loss*. In: Rotherham, I.D., Jones, M., Handley, C. (eds) 2012: Working and Walking in the Footsteps of Ghosts. Volume 1: the Wooded Landscape. Wildtrack Publishing, Sheffield, 223-264.

Rotherham, I.D., 2013a. *Searching for Shadows and Ghosts.* In: Rotherham, I.D., Handley, C., Agnoletti, M., Samoljik, T. (eds) 2013: Trees Beyond the Wood – an exploration of concepts of woods, forests and trees. Wildtrack Publishing, Sheffield, 1-16.

Rotherham, I.D., 2013b. A*ncient Woodland: History, Industry and Crafts.* Shire Publications, Oxford, 64 p.

Rotherham, I.D. and Ardron, P.A., 2006. The Archaeology of Woodland Landscapes: Issues for Managers based on the Case-study of Sheffield, England and four thousand years of human impact. *Arboricultural Journal,* 29 (4): 229-243.

Rotherham, I.D. and Avison, C. 1998. *Sustainable Woodlands for people and Nature? The relevance of landscape history to a vision of forest management. In: Woodland in the Landscape: Past and Future Perspectives.* Atherden, M.A. and Butlin, R.A. (eds.). The proceedings of the one-day conference at the University College of Ripon and York St John, York, UK, 194-199.

Rotherham, I.D. and Egan, D., 2005. The Economics of Fuel Wood, Charcoal and Coal: An Interpretation of Coppice Management of British Woodlands. In: Agnoletti, M., Armiero, M.,Rotherham, I.D. and Jones, M. 2000: Seeing the Woodman in the Trees – Some preliminary thoughts on Derbyshire's ancient coppice woods. P*eak District Journal of Natural History and Archaeology*, 2: 7-18.

Rotherham, I.D., Handley, C., Agnoletti, M. and Samoljik, T. (eds), 2013. *Trees Beyond the Wood – an exploration of concepts of woods, forests and trees.* Wildtrack Publishing, Sheffield, 378 p.

Rotherham, I.D. and Jones, M., 2000. *The Impact of Economic, Social and Political Factors on the*

Ecology of Small English Woodlands: a Case Study of the Ancient Woods in South Yorkshire, England. In: Forest History: International Studies in Socio-economic and Forest ecosystem change. Agnoletti, M., Anderson, S. (eds.), CAB International, Wallingford, Oxford, 397-410.

Rotherham, I.D., Jones, M. and Handley, C. (eds), 2012. *Working and Walking in the Footsteps of Ghosts. Volume 1: the Wooded Landscape.* Wildtrack Publishing, Sheffield, 264 p.

Rotherham, I.D., Jones, M., Smith, L. and Handley, C. (eds), 2008. *The Woodland Heritage Manual: A Guide to Investigating Wooded Landscapes.* Wildtrack Publishing, Sheffield.

Smout, T.C., MacDonald, A.R. and Watson F., 2005. A *History of the Native Woodlands of Scotland*, 1500-1920. Edinburgh University Press, Edinburgh.

Chapter 3
Archaeology of Trees, Woodland, and Wood-Pasture

Oliver Rackham

Introduction: the myth of Virgin Forest

'Virgin Forest', like 'Primitive Man', is one of those phantoms that haunt the imagination of scholars. The belief that there exist in remote parts of the world, and even in Central Europe, areas of forest that have never been affected by human activity is a powerful idea. One meets the doctrine that conservationists ought to abandon whatever else they are doing and turn all their attention to preserving virgin forests, or in countries where none is left to restoring virgin forest (Hambler and Speight, 1995). 'Unaltered' forest is sometimes used as a base-line against which to estimate the success of conservation practice.

In reality, woodland ecology is not so easily separable from human culture. The category of virgin forest recedes in the face of archaeological discoveries, which establish the antiquity and pervasiveness of people's land management almost everywhere except on remote islands. Nearly all the world's forests have been used by people and altered in some way, usually since prehistoric times. Homo sapiens, even in Palæolithic times, had the unique power to act at a distance, if only by exterminating significant animals, such as the super-elephants that lived in previous interglacials, and by altering the natural frequency of fire where fire is possible.

The last large areas of wildwood to have been affected by humanity would have been on New Zealand, which appears to have had no human contact before about 750 years ago. A few smaller forested islands seem to have had no human contact until Europeans discovered them in the eighteenth century.

The American concept of 'old growth' is not quite the same as 'virgin forest'. In practice it usually means forests that appear to have grown up without 'significant' direct human influence for a century or more, or (in America) since European settlement (Peterken, 1996). However, they often have been used and managed in earlier periods, especially by Aboriginal peoples, and may have been much changed by withdrawal of these earlier activities, even within the lifetime of existing trees.

Relations between people and trees are to be found almost everywhere; this chapter is on how to investigate them. Usually such investigations should be based on individual sites, only later (if at all) drawing generalized conclusions.

The archaeology of trees is usually a matter of the last few hundred years, sometimes extending back into prehistory, and at most to the beginning of the Holocene (the period of about 12,000 years since the last ice age). However, the inherent properties of trees are based on evolution over a much longer period, including adaptation to ecological factors that no longer operate, such as elephants.

Relations between people and trees are to be found almost everywhere; this chapter is on how to investigate them. Usually such investigations should be based on individual sites, only later (if at all) drawing generalized conclusions.

The archaeology of trees is usually a matter of the last few hundred years, sometimes extending back into prehistory, and at most to the beginning of the Holocene (the period of about 12,000 years since the last ice age). However, the inherent properties of trees are based on evolution over a much longer period, including adaptation to ecological factors that no longer operate, such as elephants.

Tree-land: woodland (forest), savanna (wood-pasture) and maquis (trees in the form of shrubs)

Woodland

For the purpose of this chapter I shall use the terms woodland and forest more or less interchangeably to mean areas of closely set trees - what a forester would call a forest (Wood(land) and forest mean a number of

Photograph 1: A plantation, where the trees are not related to the natural vegetation and are there because someone has planted them. They are all of the same age and all of the same species. The one multi-stem tree is a coppice stool and is a relict of the ancient wood previously on the site (Borley Wood, Cambridgeshire, England, October 1999).

Photograph 2: Savanna (called dehesa) of evergreen oaks in grassland. Such ecosystems cover much of south Spain and Portugal. They involve grazing of cattle and pigs, pollarding the trees in a distinctive style, and (if the trees are *Quercus suber*) harvesting the bark to make bottle-corks. Although this is a mainly cultural savanna, and much of it modern, its antecedents go far back in the Holocene.

different things, even within the English-speaking world. 'Woodland' in Australia often means the denser kinds of savanna. 'Forest' often has to do with keeping deer). The word 'wood' means either (1) a defined area of woodland, sometimes with a name (Called in America a wood-lot), or (2) wood as a material, typically in small sizes (large sizes being timber). The term plantation implies an area of trees that some person has planted or sown, whether on the site of a wood (Photograph 1) or otherwise.

Wildwood means tree-land before it began to be affected by human activities. It may or may not still exist anywhere in the world.

A common mistake made by historians and ecologists is to equate trees with forest (that is, with closely-set trees). There are several other possibilities (Grove and Rackham, 2001). Many languages are vague about what is and what is not forest: thus in Spanish, although the word monte means 'forest', it can be used any kind of woody vegetation, as well as for 'mountain', its original meaning. Statistics of forest area are meaningless unless accompanied by a statement of how big and how close together the trees have to be to count as forest. Reported changes in a country's area of forest may result from the definition of forest becoming more or less restrictive, independently of whether there have been changes on the ground.

Savanna

This is where trees grow, but not close together to form forest (Photograph 2). Savanna is one of the world's most widespread and least understood classes of ecosystem. Trees are most often scattered in grassland, but in the Mediterranean (and in mediterraneoid climates elsewhere, such as California) they may be scattered among undershrubs (species of *Cistus*, *Salvia*, *Sarcopoterium* etc.). Trees scattered in grassland were formerly widespread in Northern Europe: they formed much of the historic 'woodland' of Scotland (Smout et al., 2005), and survive in the ancient deer-parks and royal Forests of England. They are often to be found at high altitudes, below the alpine tree-limit. The true extent of savanna, especially in Europe, is only now becoming apparent through the medium of Google Earth, in which scattered trees are easily distinguished from forest.

In this chapter, the distinction between forest and savanna is that in forest the vegetation under the trees consists of shade-bearing plants, but in savanna the trees are widely enough spaced to allow the growth of plants that do not tolerate shade. In many savannas the grassland under the trees is different from the grassland between the trees.

Savanna trees contrast with forest trees, even if both are the same species. Forest trees tend to be tall and often straight, without low branches. (Sometimes, especially in North America, they may be sny, growing in a regular curve.) Savanna trees, not having neighbours, spread sideways: they are low with sideways-spreading branches. Sometimes, as with some Acacia species in Africa and some *Eucalyptus* in Australia, there are special savanna-adapted species that branch near the base.

The difference between savanna and forest is due to one or more of a number of factors, which may be environmental (such as limited moisture), ecological (such as large herbivorous animals), or cultural (where people have decided to use the same land for pasture and trees). Savannas are often regarded as 'degraded forest', meaning forest from which some of the trees have been removed. If this is so, the remaining trees will display forest-type architecture, the shape of trees that grew up when they had neighbours (Photograph 3). In most cases, however, savanna trees are spreading in shape, showing that they have been isolated all their lives.

Photograph 3: Subtraction savanna. These trees, with their tall straight trunks, are all that is left of a forest that has been destroyed and made into a field (SW Australia, December 1996).

Photograph 4: Another classic tropical savanna, in NE Australia: Eucalyptus trees in grassland which is grazed and frequently burnt. The black objects are termite mounds (Laura, Cape York Peninsula, July 2001).

It used to be said that in the 'classic' savannas of the tropics, such as Africa or Australia (Photograph 4), the determining factor is natural, especially drought or fire, and that wood-pastures in Mediterranean and temperate countries, such as the 'parkland' of England, are a cultural artefact and not 'real' savanna. This distinction is now difficult to uphold: most savannas have both a cultural and a natural component which are often difficult to separate. Much of the savanna of Australia and North America was maintained for most of the Holocene by burning instigated by aboriginal peoples as part of their land management. When burning stops the savanna infills into forest as new trees spring up in the gaps between the old ones. Much of the 'primæval' forest of West Africa used to be savanna maintained by indigenous peoples, and infilled into forest after slave-traders murdered or carried off the inhabitants (Fairhead and Leach, 1998). Conversely, on the Vera theory of wildwood, the vegetation of Europe in the early Holocene was not continuous forest but a dynamic equilibrium of areas of forest and areas of grassland, maintained by the grazing of wild cattle and deer.

In many savannas, especially in the Mediterranean, the main limiting factor appears to be drought. Above ground the trees appear to be scattered, but their roots extend out

Photograph 5: Drought-determined savanna on an Ægean island. The roots of the large oak-tree on the right extend at least as far out as the red marker at bottom left (Lésbos/Midilli, September 2004).

from beneath the canopy into the space between the trees (Photograph 5). Consequently the trees benefit from rain falling between the trees as well as on them. Browsing animals may also play a part. When large herbivores are excluded, the savanna infills, but often not into forest: once the infilling trees get beyond a few metres high they die back through drought.

Savanna is a transition zone, often a very wide transition, between forest and non-forest. The limiting factor may be drought, browsing, fire, or cold (immediately below the alpine tree-limit). It may be a more or less deliberate cultural creation (as with much of the montado and dehesa savannas of Portugal and Spain: Grove and Rackham, 2001).

In its European manifestations savanna is often termed wood-pasture (sometimes called pasture-woodland). Pasturing animals (cattle, sheep, goats, large numbers of deer) in woodland creates two problems. The shade of the trees reduces the pasture, and the animals will eat the regrowth of the trees. Combining trees and domestic livestock is a different land-use from trees only.

Hedgerow, field, and farm trees

Farmers encourage or tolerate the growth of trees for many reasons. In many countries the boundaries between fields are hedges or fence-rows, either periodically cut down low or allowed to grow up into tall trees. These may have been deliberately planted or allowed to establish themselves along fences, walls, or terrace walls. When planted, hedges are normally of only one or two species, but they may acquire other species as they age; when accidental, they are usually of a mixture of species from the start. Their function may be to mark a property boundary, to confine domestic animals within a stock-proof enclosure, to provide timber and wood, or to be a shelter from wind (Photograph 6).

In countries where hedges are rare, as in Ethiopia, there may be occasional big trees in fields, as well as rows of trees along watercourses.

Photograph 6: Landscape of hedges and fields. The small irregular fields, massive hedges, and scattered farms are the result of centuries of piecemeal growth and alteration: their date of origin is unknown, but is at least 500 years ago. Note a few trees in fields: in the past there were more trees in fields and fewer in hedges than there are now (Border between England and Wales, June 2011).

Photograph 7: Ancient olive-tree, about 2000 years old, standing on an older terrace wall (Loutró, Crete, July 2006).

Another category of land-use is orchards and groves of olive, chestnut, carob, and many species of tropical fruit-trees. Many of these cultivated tree-lands do not last long enough to become archaeological, unless they are abandoned. Some trees are long-lived and continue to be productive: these include chestnut (*Castanea*), carob (*Ceratonia*), and especially olive (probably the longest-lived of all cultivated plants) (Photograph 7). In southern Europe vines in the past, and occasionally still today, vines were grown as climbers up specially-planted support trees.

Although orchards, in the sense of areas of land devoted to this type of production, are often thought of as the normal way to grow these trees, in the past fruit-bearing trees were often established on ordinary farmland. In Crete, for example, pre-1700 records usually show olive-trees not as a separate land-use but scattered among other crops. In Italy, coltura mista (mixed cultivation) involves trees mixed with perennial and annual herbaceous crops.

Maquis

This consists of trees reduced to the state of shrubs by some combination of browsing, woodcutting, drought, and fire. A classic example is *Quercus coccifera* (=*calliprinos*), one of the commonest plants of the east Mediterranean: it can exist in any form from a giant oak-tree down to a shrub a few cm high, and can change from tree to shrub or from shrub to tree according to circumstance.

North European writers think of forest as the normal state and regard maquis as 'degraded forest', meaning forest that once had tall trees which through human activities were replaced by shrubs. This claim is usually made as a generality, without demonstrating that any particular area of maquis was indeed forest in the past. (The word 'scrub' is often used for any ecosystem involving woody plants of medium stature: maquis, low trees, young forest, and the taller undershrubs such as *Phlomis* and *Cistus* species.)

Adaptations to the maquis state are widespread among Mediterranean trees: *Quercus coccifera* performs all its vital functions, including producing acorns, when less than 1 metre high. There are parallels in California and in the dwarfed mallee states of some Australian eucalypts. Maquis is really another kind of semi-natural transition from forest to non-forest. Some maquis probably goes back long before human intervention. Of the limiting factors, drought has been (so far) independent of human action; there was no lack of browsing and fire in wildwood times; even woodcutting probably has a natural parallel in the activities of elephants. One limiting factor may reinforce another: thus browsing may be more effective in places where drought limits the annual growth.

Other components of the ecosystem

Woodland, savanna, hedges, and maquis do not consist of trees alone. Shrubs, undershrubs, and herbaceous plants are an integral part of their functioning and may have archaeological significance. A third component, often overlooked, are the mycorrhizal fungi which attach themselves to the roots of all trees and most other plants and which are an essential part of the functioning of the individual host tree and of the ecosystem. There are two main groups. Ectomycorrhizæ produce visible toadstools and other fruit-bodies, like the well-known fly agaric (*Amanita muscaria*) which enables pine and birch trees to function. Glomeromycetes are invisible, except to specialists, but are essential adjuncts to many trees, like lime and ash, and to most herbaceous plants. They go back to the Palæozoic origins of land plants.

Ancient and Recent Woodland

There is a distinction between Ancient Woodland, woodlots that have been in existence for several centuries, and secondary woodland that has sprung up on land that used

Photograph 8: (a) Hayley Wood, Cambridgeshire, England in the Ely Coucher Book, a land register dated 1251 CE., (b) Hayley Wood in Google Earth 2009. The triangular area at the NE corner is a 20th-century addition to the wood.

to be used for something else. For example Hayley Wood near Cambridge is first documented in AD 1251 and still exists. This is not by an oversight: it has been intensively used for most of the last 750 years and has been cut down many times, but it has remained as a wood and has not been made into fields. The wood has expanded on to a field abandoned in the 1920s, but this recent wood, though attached to an Ancient Wood, is very different in structure and vegetation (Photograph 8).

Ancient Woodland is not to be confused with virgin forest or old-growth. Most ancient woods have been cut down, often so many times that a felling-and-regrowth cycle has become part of their normal dynamics. What matters that they have remained as woods and have not been dug up. Trees grow again: it is a common mistake to confuse felling the trees with destroying woodland.

Forests shrink, mainly because people dig up the trees to make farmland, but they also expand whenever people abandon farmland. As North Americans know well, the easiest way to create a new woodland is to stop cultivating a field. This has happened many times in the historic and also the prehistoric past. An abandoned field is soon invaded by trees and turns into forest typically in 50 years or less; but it may be centuries before it acquires the characteristics of ancient woodland.

Woods are not necessarily stable, even without direct human action. Catastrophic events such as fires, windstorms, and avalanches can be a rare but normal part of their dynamics. In recent decades woods in many countries have been altered, and their future threatened, by events outside normal dynamics: especially the abnormal multiplication of deer, and the seemingly inexorable, global spread of foreign tree diseases subtracting tree after tree from the ecosystem. (At the time of writing all the plane-trees (*Platanus*) in Greece and Turkey and in the cities of western and southern Europe were imminently threatened by an aggressive fungal parasite, *Ceratocystis platani*) In Europe many woods have lost their lower branches (below a browse-line at 1 to 2 m depending on the species of animal) to excessive deer browsing. In North America the investigator needs to recognize the remains of chestnut (*Castanea dentata*) killed by the fungus Cryphonectria parasitica, introduced from the Far East a century ago. In Japan the pinewoods (*Pinus densiflora*), historically maintained for their mycorrhizal mushroom *Tricholoma matsutake*, are being eliminated by the parasitic eelworm *Bursaphelenchus xylophilus*, supposedly introduced from North America. Here too it is important to be able to recognize where the dead trees have been and what has filled the gaps they left.

Properties of Trees

Trees are wildlife, not environment, and are not all the same. Any ecological researcher on trees has to find out and take account of their properties and behaviour, especially the trees' reactions to what people do to them. Some of the more important properties are these.

Reproduction: trees do not necessarily reproduce by seed. Many are clonal, sending up stems called suckers from the roots (for example, most elms (*Ulmus*)). A clonal tree begins with a natural seedling or a planted individual; it then tends to grow out into a circular patch of genetically identical stems (Photograph 9). Trees that grow from seed may establish themselves tree by tree, giving rise to a forest of a mixture of ages. Alternatively they may function as areas of trees (such as pines) all of the same age, dating from the last time a disturbance occurred, such as felling or fire.

Reaction to felling. Some trees, such as most pines, are killed by being cut down. Some, such as ash (*Fraxinus*) sprout from the stump, a process called coppicing (Photograph 10); the stump develops into a stool, growing bigger and bigger with each cycle of felling and regrowth. Clonal trees sprout by suckers, shoots that arise from the roots. Pollarding is like coppicing, but the tree is cut 2-4 m above ground instead of at ground level. Coppicing and pollarding are important in woodland management over much of the world and throughout history. Trees so treated live indefinitely (often longer than trees that are not cut) and develop massive permanent bases. The ability to coppice, pollard, and sucker is an inherent genetic feature of many of the world's trees; what use (in evolutionary terms) did trees make of this capacity before people invented axes?

Adaptation to fire. The ability to burn is not a misfortune but an adaptation. Pines and eucalyptuses burn because they make flammable chemicals: they either survive the fire in various ways or begin again from fire-stimulated seed. Elms and beeches (*Fagus*) are not flammable. The business of fire-adapted trees is to catch fire from time to time (from lightning, if no other ignition is available) and burn up their non-adapted competitors.

Adaptation to browsing animals. Trees and other plants are adapted to being bitten in various ways. Some, like most grasses, readily grow again. Some defend themselves by spines or make distasteful or poisonous chemicals. These adaptations vary with the animal as well as the tree. The investigator needs to watch goats, cattle, deer etc. and see what species they prefer and which they reject. It is useful to see how the vegetation of cliffs, which animals cannot reach, differs from the rest of the landscape - this is especially instructive in Crete, with its profusion of inland cliffs (Photograph 11). Most browsing adaptations, especially in trees, are likely to result from at least hundreds of thousands of years of evolution, and will therefore be originally determined not by the present domestic livestock but by their wild predecessors, including elephants.

Annual rings: some trees produce annual layers of wood which can be counted and measured and form an independent historical record.

Gregariousness: some trees, such as many pines, tend naturally to form areas all of the same species; others are randomly scattered among other species; others tend to avoid each other's company and are rarely found two together.

Photograph 9: A clonal tree, *Populus alba*. All the stems arise from a common root system and are, in effect, all parts of the same individual (Tasmania (where Populus is exotic), July 2001).

Photograph 10: A coppice-wood less than one year after felling. The stools are of different species: *Salix caprea* commonly grows at 5 cm a day (Bradfield Woods, Suffolk, England, 15 August 1986).

Photograph 11: Thérisso Gorge, Crete, with its richly wooded cliffs. The vegetation on them has been out of reach of sheep and goats for thousands of years, and out of reach of the island's special mammals (including elephants) for 2 million years before that.

Modern Forestry and its Legacy

Human use and management of trees, for a great variety of purposes, goes back at least to the Neolithic beginnings of settled civilization. Woods and wood-pastures have often been subject to complex and interacting local rights, customs, and regulations. This began to change in the eighteenth century, as modern forestry grew up both as a science and as a philosophy. The idea got about that forests were an affair of state which governments ought to try to control and regulate. Forests came to be specialized for a narrow range of purposes, separate from other interests of rural people.

Tenets of modern forestry

- Trees should grow closely spaced in forests (Photograph 12), not scattered or mixed with other land-uses.
- Forests should belong either to the state or to private individuals (depending on which state).
- Orchards and orchard-like practices (such as rubber and palm-oil plantations) are a different land-use from forests - though some of them may be counted as forest for statistical purposes.
- Common-rights and communal land-uses are bad.
- The purpose of trees is to produce commercial timber and paper-pulp, not fuel, bark, leaves for farm animals to eat, etc. In consequence trees should be felled in early middle age, at one-tenth to one-third of their natural life-span.
- Tree growth and harvesting can be, and should be, predicted and controlled.
- Trees should be cut at ground level; the stumps should die and be replaced by a new generation of trees, either by 'natural regeneration' from seed or by being planted.
- Coppicing and especially pollarding are bad.
- Old (pre-twentieth-century) trees are bad.
- Hollow trees are bad and should be destroyed.
- Dead and decayed trees are bad (from a vague notion that they will 'infect' living trees, rather than from evidence that they promote any specific disease).
- Mixtures of tree species are bad (except for 'nurse trees' intended to be taken out when the main crop of trees has grown up).
- Grazing animals are bad.
- Fire is bad (rather than a normal part of the behaviour of certain trees) and needs to be suppressed.

Photograph 12: Modern forestry, treating trees as a farmland crop: a plantation of *Pinus sylvestris* (Norfolk, England, 1975).

Photograph 13: *Eucalyptus* plantation in Ethiopia. The trees are periodically cut to produce the many millions of poles on which Ethiopia depends for all kinds of construction and fuel. Each tree has been felled several times and has produced a stool base some 2 m in diameter. This site, near the then imperial palace, was probably one of the original plantations begun by Menelik II in the 1890s. The ground under the trees has eroded, leaving the stools perched on pedestals (Entoto, Ethiopia, September 2012).

This philosophy was most fully developed in Germany; it developed in a less rigorous form in France and (independently) in Japan. Other states took up either German or French forestry, depending on which state - regardless of whether it was appropriate for the local tree species, climate, or society. For example Britain introduced German foresters to India (to teach German forestry practices, not to learn Indian ones) and from there took the ideas to British Cyprus (in a mainly French form) and then (in the German form) to Britain itself. In countries such as Sweden and Slovakia, modern forestry has penetrated to the extent that earlier practices have almost been eliminated; in others, such as Greece and England, it has been less successful and 'traditional' tree-management, although marginalized, still continues. Ethiopia, unusually, invented its own tree-management, based on coppicing plantations of an exotic species, *Eucalyptus globulus* (Photograph 13).

Forestry philosophies have proved resistant to political upheavals. Thus the forestry of the Austro-Hungarian empire has survived the break-up of the empire, the Communist takeover of most of the successor states, the collapse of communism, and still continues in the successor states.

The mind-set of modern forestry has come to dominate much academic writing, to the extent that even natural forests have been brought within it: they should consist of young, close-set, tall, straight stems, as if they had been provided by a benevolent Providence for the north European timber market. German travellers used to reproach Greece for, in effect, not having trees like Germany's.

Foresters themselves are coming to realize that such narrow-minded ideals are unsustainable in the face of globalization of tree diseases and of the fact that trees, however fast they grow, are intended for a market that may have disappeared by the time the trees have grown. They are inconsistent with the wider significance of trees both as wildlife themselves and as habitats for other wildlife.

Archaeologists should not try to make their observations fit the agenda of modern forestry. They are dealing with a wider range of phenomena and processes, of which forestry is only a part.

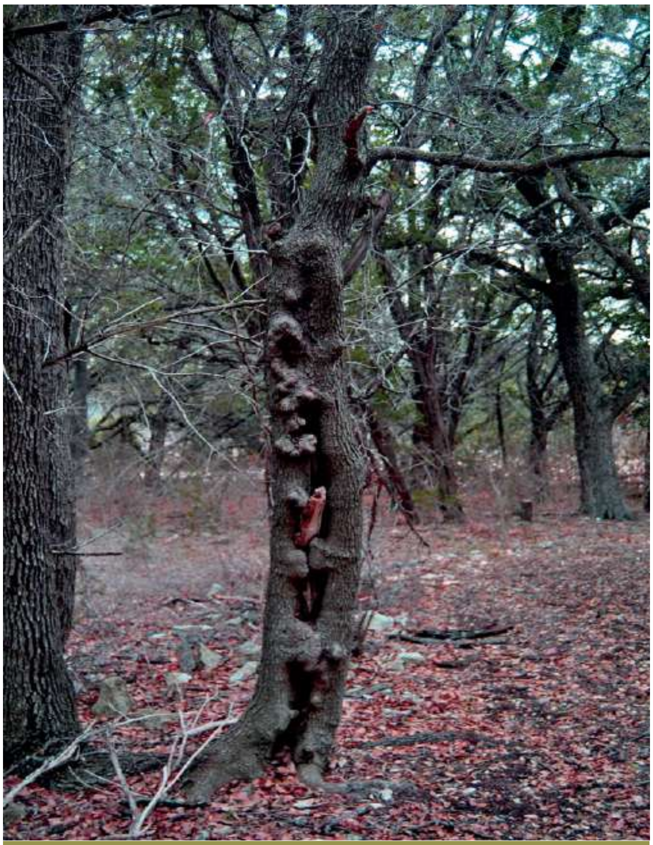
Trees as Archaeological Objects

Ancient trees are not synonymous with ancient woodland. Some ancient trees are in forests, but most are either coppice stools in woodland or are in savanna and other non-woodland situations. The lives of trees are often shortened by competition: as soon as a forest tree begins to die back the space vacated is taken over by neighbouring trees. Longevity is promoted where trees have no close neighbours (at least above ground) and are able to recover from dieback periods.

Trees can be archaeological objects in themselves: they contain a record of past land-uses and of natural event occurring round them. Of particular interest are culturally modified trees, that have been used in ways that alter their structure, leaving marks that persist on the tree and outlast the use.

Old trees are a most important part of the world's tree'd ecosystems. When a tree acquires dead branches or goes hollow it provides a habitat for many specific plants and animals: hole-nesting birds, bats, fungi, insects that feed on rotten wood or on fungi, spiders that feed on such insects, lichens that require old dry bark under overhangs, mosses that live on the hard interior surface of hollow trees, and many other categories. A single oak that is 400 years old is a series of ecosystems in itself for which a hundred oaks only 200 years old are no substitute. The conservation of old trees and dead wood should be a priority for ecologists as well as archaeologists.

In England a distinction is made between veteran trees, that have outlived their utility as timber and have begun to develop cavities and dead branches (Photograph 14), and the sub-category of ancient trees that are fully developed as antiquities and as a habitat (Photograph 15). The ages at which these categories are reached varies with the species: thus a birch (*Betula*) may become a veteran tree at 50 years and an ancient tree at 100, whereas with oak these ages may be 200 and 400.



Photograph 14: A veteran tree of ash (*Fraxinus texensis*) in middle Texas. Even quite small trees are hollow and are an important habitat (January 2013).

Photograph 15: Some of the 4000 ancient oaks (*Quercus robur*) in a deer-park, where in the 13th century CE the noble Bigod family kept semi-domestic fallow deer. These are culturally modified trees: they were pollarded long ago, hence the massive short hollow trunk. This is a savanna, not forest, situation (Staverton Park, Suffolk, England, April 2004).

Ancient trees in forest

Some of the world's most famous ancient trees are now in forest and appear to have been so throughout their lives: they have tall, mostly straight trunks without low branches. Examples are the giant redwoods (*Sequoia sempervirens)* and giant sequoias (*Sequoiadendron giganteum*) in California, and the giant karri (*Eucalyptus diversicolor*) of SW Australia (though the ages of the latter are uncertain, as they do not produce good annual rings). The forest in which these trees are now may not be the same as that in which they grew up: giant redwoods are often scarred by past fires, although there is now not enough combustible material to sustain a fire.

Photograph 16: Ancient *Cupressus sempervirens* at the alpine tree-limit; it is about 3 m high (West Crete, 2011).

Photograph 17: Infilling of tropical savanna. The big trees are all eucalypts; their bases are blackened by fires. Originally they were scattered in grassland which was periodically burnt by Australian Aborigines. When Europeans came they suppressed fire, and in consequence the grassland was invaded by young trees of rain-forest species, not *Eucalyptus*. These will not burn and in time will replace the eucalypts (Kuranda, Queensland, Australia, August 2001).

Ancient trees in savanna

The world's oldest living upstanding trees, bristlecone pine (*Pinus aristata* and *P. longæva*) are not in forest but scattered among the rocks at the alpine tree-limit of the mountains in the SW United States. Having no above-ground neighbours, they undergo cycles of dieback and recovery and can live for at least 4800 years. Similar are the cypresses (*Cupressus sempervirens*) at the alpine tree-limit in Crete (Photograph 16), among the oldest trees in Europe. Other ancient savanna trees are baobabs (*Adansonia digitata*), with their improbably massive trunks, although having no annual rings they cannot be dated.

In Europe many ancient trees are in wood-pasture; typically they are pollards. Examples are the medieval deer-parks and royal Forests of England, such as Epping Forest with thousands of pollard oaks, beeches, and hornbeams (*Carpinus*); and the rare surviving examples of Hudewald wood-pasture in Germany. Mediterranean savannas often contain ancient oaks and other trees. Spanish and Portuguese dehesa and montado, with pollard trees in a distinctive style, go back at least to the middle ages, but much of what is there now was deliberately created c.1900 and its trees are not old.

Savanna was widespread in central North America, in a wide transition zone between forest to the east and prairie to the west; its almost complete destruction was a great ecological tragedy of the mid-19th century.

When savanna infills into forest, the 'savanna-shaped' trees contrast with their younger, upright neighbours; they may retain traces of their savanna history as charred bases and fire scars (Photograph 17), or evidence of pollarding. Infilling of savanna is an important cause of loss of ancient trees; savanna trees may survive by putting on an extra flush of growth in height, giving a very distinctive shape.

Photograph 18: Coppice stool of ash (*Fraxinus excelsior*). It is thought to be about 400 years old , and has been felled many times (Hqyley Wood, Cambridgeshire, England, February 1967).

Coppice stools

Some trees are a self-renewing resource. They can be felled and grow again many times, forming a multi-stemmed stool which grows a little bigger at each cycle (Photograph 18). The sizes of such stools set a minimum age for the wood. They can be calibrated either from annual rings or by looking for the largest stools in a wood of known origin. Thus stools of Eucalyptus globulus at Entoto, Ethiopia, are about 2 m across, and are likely to date from the original introduction of the tree by the Emperor Menelik II c.1890 (Photograph 21); but this species is exceptionally fast-growing and stools of this size of other trees will usually be centuries old. Coppicing is widespread in Europe and Asia; it was introduced by Europeans to North America and Australia.

Occasionally coppice-like stools result from something other than woodcutting. Some trees, such as species of *Tilia*, *Corylus*, and *Magnolia*, self-coppice: the original stem dies and is replaced by a ring of sprouts round the

Photograph 19: Ring of lime (*Tilia cordata*). The stems are all parts of an individual tree, which would be equivalent to a coppice stool thousands of years old (Westonbirt Arboretum, derived from the medieval Silk Wood, Gloucestershire, England, May 1987).

Photograph 20: The practice of plashing or laying, one of the distinctive ways of managing a hedge (Hayley Wood, Cambridgeshire, England, March 1994).

base. Such rings may date from before human coppicing and be among the world's oldest trees: examples are the rings of rings of stems in Californian Redwood (*Sequoia*), the giant ring of lime (*Tilia cordata*) in what is now Westonbirt Arboretum, England (Photograph 19), and perhaps the Hundred-Horse Chestnut (Castagno di Cento Cavalli) on Mount Etna in Sicily. Periodic fires, especially in savanna, can kill trees to ground level and produce what are, in effect, coppice stools. They can also arise from avalanches when huge masses of snow slide down mountains shearing off everything in their path; avalanche tracks, however, usually have a border of uprooted or bent-over trees.

Hedgerow trees are often managed as coppice stools. In some cultures there is the practice of plashing or laying, partly cutting through stems and bending them horizontal to form a barrier to farm animals (Photograph 20), which creates a permanently distinctive shape.

Photograph 21: The boundary of the estate of Llanteilo Pertholey, Wales, of date c.600 CE, went from left to right along the ridge of Mount Skirrid and descended at the end of the mountain through the wood that is still there (June 1999).

Pollards

Many of the world's ancient trees are pollards, which normally arise from woodcutting, although pollard-like trees can result from fire or from breakage by wind or elephant. Pollarding, like coppicing, prolongs the life of a tree, which often goes hollow.

Pollard cycles, which may be revealed in the annual rings, may be shorter or longer depending on whether the product was leaves (for feeding domestic animals) or wood.

Pollarding requires more labour than coppicing per unit of wood produced. It tends to be used in non-forest situations, especially savanna and farmland trees, where the regrowth of a felled tree would be exposed to grazing animals. Pollards have also been used as distinctive markers for property boundaries in woodland.

There are many variants of pollarding, each creating a tree of distinctive shape. There may be one pollarding point, sometimes 10 m or more above the ground ('giraffe-pollarding'), or many points. Shredding is the practice of harvesting the side-branches of a tall tree leaving a tuft at the top (Photograph 18). Pollarding is widespread in Europe, Asia, and Africa; it is rare in North America and Australia (though it occurs in Tasmania).

Ancient cultivated trees (olive, carob, chestnut) are often pruned into a pollard-like shape, especially in conjunction with grafting to cultivated varieties.

Other practices

Many other practices leave a permanent mark on the tree. Pines have often been tapped for resin, by cutting into the bark in various styles and sometimes charring the tree to stimulate the flow of resin. Bark harvesting for food (pines in arctic Scandinavia) or roofs for beehives (cypress in Crete) creates a distinctive scar. In Australia and perhaps North America there are still marks cut into trees by surveyors to define property boundaries.

Trees and erosion

Trees are sometimes thought to prevent erosion, sometimes to promote it (especially *Eucalyptus*). Which of these (if either) is correct will vary with the climate, soil, tree species, etc. Trees undoubtedly record erosion: a tree on a site that has lost soil or soft bedrock is left on a pedestal, with its base and roots exposed; if the site has gained soil the base of the tree with its root-buttresses are buried. Roots may be somewhat exposed even if the soil has not changed, because shallow roots break through the soil surface as they grow thicker.

Pollen Analysis (Palynology)

Many trees and other plants produce large quantities of distinctive pollen grains, which in the right conditions can be preserved for thousands, indeed millions, of years. The pollen analyst looks for a place that is permanently wet, a lake-bottom or peat-bog, where there is a stratified deposit: every year a new layer of mud or peat is added on top of the previous layers. A core is taken using a suitable tool for the particular kind of sediment, divided centimetre by centimetre, and passed to a microscopist who extracts, identifies, and counts the pollen grains. The result is presented as a series of graphs, giving the amount of pollen of each type from the bottom to the top of the deposit. Dates can be provided from samples taken for radiocarbon dating, from volcanic ash fallout, or from archaeological material embedded in the deposit.

Pollen analysis is a specialized craft; archaeologists do not usually attempt it themselves, but make use of the findings of palynologists elsewhere. It can give the fluctuations of trees and other plants through the Holocene (or occasionally in previous glacial cycles or geological periods) and the effects of climate change and human activity, the advance and retreat of forest and changes of species, the beginnings of agriculture, and the introduction of new crops and new trees.

Palynology has its complications and limitations. In dry climates, such as the Mediterranean, it necessarily records the wettest spots in the landscape. Pollen grains are usually identifiable to genus (*Quercus, Tilia, Ulmus*) but often not to species: thus evergreen and deciduous oaks can be separated, but not usually single species of oak. Wind-pollinated trees and plants produce more pollen than insect-pollinated: thus *Quercus* is over-represented in pollen diagrams but Tilia is under-represented. Some pollens, such as Pinus, can be blown long distances; Tilia is unlikely to be found far from the tree.

Palynology is most useful in the prehistoric and especially the pre-Neolithic period, for which it is often the only source of evidence. In historic times pollen deposits may be absent, because drainage or peat-digging has destroyed the upper layers; they are also more difficult to interpret as the human cultural landscape becomes more complex.

One of the reasons for preserving wetlands is that they are, in effect, historic and prehistoric archives. Even if a deposit has been cored and studied, future investigators may extract further evidence from more detailed work.

Annual Rings

Many trees create their own historical record in the form of annual rings, which avoid the uncertainties inherent in other dating methods such as radiocarbon. Reading tree-rings is called dendrochronology, and has grown to be a branch of science which can be only briefly summarized here.

Caution may be needed when reading tree-rings. In temperate countries with a seasonal climate, like Britain, most tree species produce well-conditioned rings, one ring per year. Many trees elsewhere have indistinct rings or none that are visible at all. Some species produce false rings, with two or more phases of growth in a year, often detectable as a sequence of distinct rings alternating with less distinct rings. A few, such as lime (*Tilia* species) may miss one or more rings; this is detectable when rings that are distinct on one side of the stem merge on the other side.

Ideally tree-rings should be read in a slice from the base of the trunk, being counted and measured in two directions at right angles. Dendrochronologists usually work on stumps of trees that have already been cut by someone else. An alternative is to take a core with a hollow borer which leaves a hole 6 mm in diameter, not much injuring the tree. Coring tools are designed for youngish conifer trees and may not work well on trees with harder wood, or on hollow trees. A section from a branch or from higher in the trunk may be useful if nothing better is available.

These are some of the uses that dendrochronology has been put to:

- Age of the stem or of the tree. As well as the problem of false or missing rings, it may be necessary to estimate the number of rings in a missing part of the record. For example, there may be 237 rings present in a section, plus (estimated) 50 in the hollow interior of the tree, plus (estimated) 15 since the section was cut, plus (estimated) 20 years that it took the tree to grow to the height at which the section was taken; total 322 years, giving a starting date around 1690 CE. With a core, unless the operator is both skilled and lucky, the tool will miss the pith of the tree, and it will be necessary to estimate how many rings are missing from the beginning. Annual rings of trees are usually widest in the early decades of growth and diminish thereafter. Dating trees is not always an exact science, but incomplete or inexact information is often better than no information. With coppice stools and pollard trees, the age of the tree is greater (often much greater) than the age of the individual stems. Although coppice-stool bases or the bases of pollards are usually hollow, annual rings in the remaining shell of wood may give a measure of how fast the base has been expanding, from which the age of the tree itself can be estimated. It is also possible to estimate the growth-rates of stools by looking for the biggest stools in a wood of known date of origin.

- Dating events in the life of the tree. A ring count in the current generation of stems will give the date of the last time the tree was pollarded or coppiced. The dates of previous coppicings or pollardings can be ascertained from a core or section of the base. Every time the tree was cut, the growth rate suddenly falls, gradually returning to 'normal' as the tree regenerates its leafage. A more or less regular sequence, such as a fall in growth every 14 years, distinguishes this process from other events that reduce growth, such as caterpillar attack, Elm Disease, storm breakage, or bad weather. The fire history of an area can be reconstructed from sections of fire-damaged trees, counting how far back each fire scar is embedded in the subsequent annual rings. The same would apply to other events that damage the stem, such as harvesting pieces of bark.
- History of weather and climate. Trees are affected by the good and bad weather of individual years. If cold shortens the growing season, or drought weakens photosynthetic activity, the tree will make less substance to put into wood, and the annual ring will be narrower. By comparing the width of the ring of a particular year with the average of the years before and after, it is possible to identify the good and bad years, and sometimes to find out which of the possible weather variables is responsible for the difference. Climate history is different. To investigate it, the effects of weather are eliminated by taking 10- or 20-year moving averages of ring-width, to take out the variation of individual years. The result may record medium-term changes of climate, such as the phases of the Little Ice Age between 1320 and 1840 CE, or droughts in the SW United States, or (potentially) faster growth in the last few decades due to increased atmospheric carbon dioxide.
- Dating (and provenancing) archaeological timber. In principle the irregular sequence of wide and narrow annual rings, corresponding to good and bad years, should be the same for all the trees of a particular species within a particular geographical area. This gives a means of identifying the growth of individual years. For example, future dendrochronologists will recognize the two very dry years 1975 and 1976 in eastern England, followed after twelve unremarkable years by the droughts of 1989 and 1990, and then after five unremarkable years that of 1996, and so on.

The early annual rings of an old living tree can be correlated with the late rings of a piece of timber in a historic building. This method is extended back with successively older samples of timber to date archaeological wooden artefacts. Thus the famous tomb at Gordion in Turkey was built of juniper timbers within two or three years of 740 BCE (and therefore cannot be, as popularly supposed, that of King Midas) (Kuniholm et al., 2005). It is also possible to determine where a timber came from: thus in medieval English buildings some of the oak timbers fit the English dendrochronological standard, while others are imported 'Baltic oak' which fits the standard from Poland.

Dating and weather history both require the highest quality of dendrochronological data: it is essential to be sure that a particular ring is that for CE 1349, not 1348 or 1350.

Documentary Records

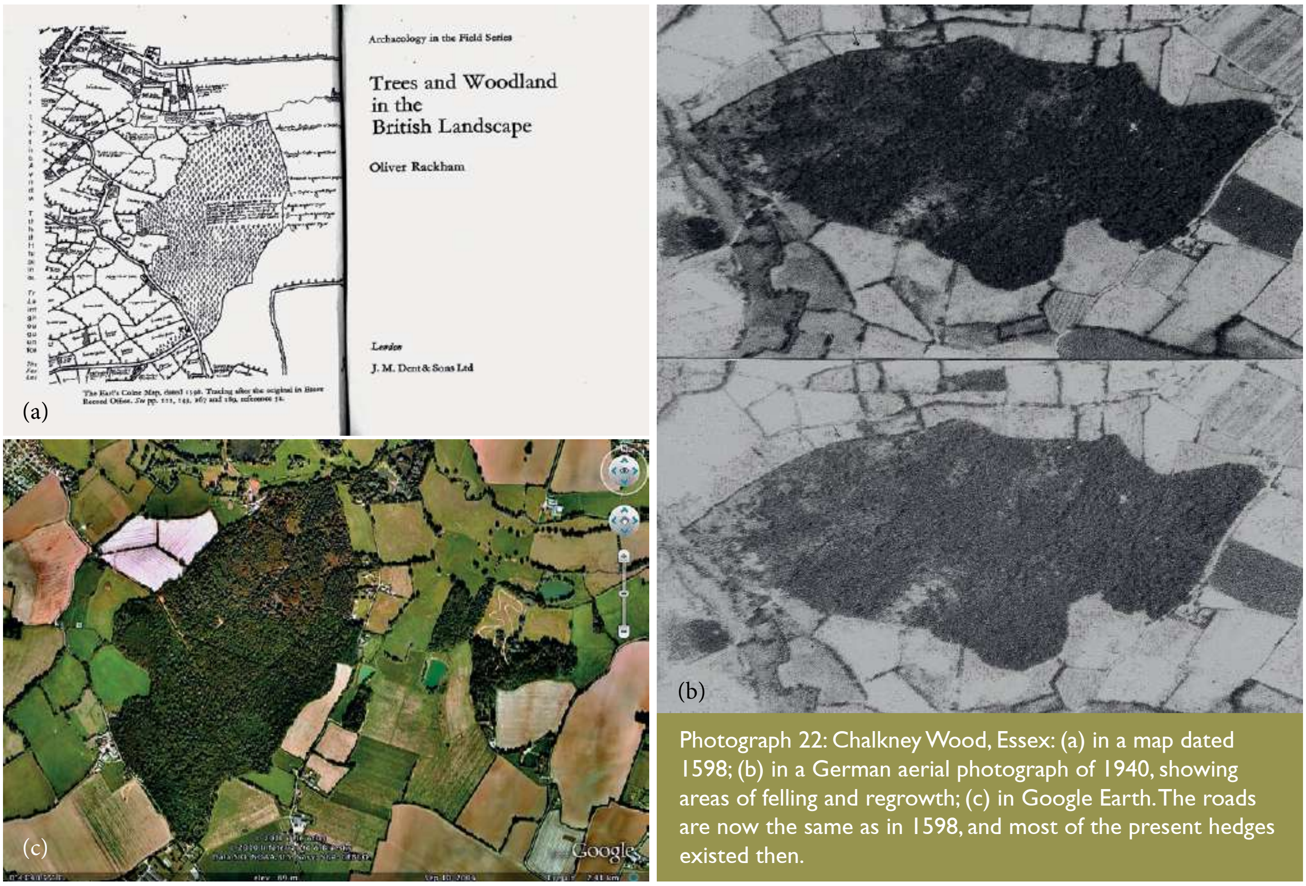
Countries vary enormously in the scope and extent of their archives. The most useful records are those that can be localized as to place. Some of the earliest are perambulations, descriptions of the boundaries of estates or political divisions which proceed from point to point describing features including trees, hedges, and the edges of woods, some of which can be identified on the modern map. The Ancient Greeks used to write even ordinary land transactions on tablets of stone or bronze, from which it appears that Hellenistic Greece (the last 3 centuries BCE) was little if any more wooded than Greece today. The Welsh perambulation of Llanteilo Pertholey, c.600 CE, which can still be followed on the ground, mentions one wood-lot, which is still there (Photograph 21). Perambulations have been especially useful in the forest history of Hungary (Szabó, 2005).

In England, Domesday Book appears to record all the woodland in most of the country in 1086 CE. England then, though it had more woodland and wood-pasture than now, was already one of the least wooded countries in Europe.

Other archives include accounts of the produce of particular estates, with details of, for instance, firewood and bark sold, the wages of men felling timber for use on the estate, or (rarely) the cost of contractors making a new boundary bank. Leases of woodland to wood-merchants or industrialists may lay down conditions as to what trees may be felled or how the regrowth is to be protected. In many countries travellers' accounts mention or describe any woodland or savanna that they encountered.

The rising cost of fuel and other woodland products has often been taken to indicate general scarcity of trees, but three other factors need to be considered: inflation (the falling value of money), and the costs of labour and transport, which often outweigh the cost of trees.

Early maps vary in quantity from country to country. As far as I know the earliest surviving map to show identifiable wood-lots, albeit sketchily, is the map of Boarstall (England) in c.1445 CE. Maps in Britain become abundant from the late 16th century (Photograph 22), reaching a peak in the nineteenth century, when the



Photograph 22: Chalkney Wood, Essex: (a) in a map dated 1598; (b) in a German aerial photograph of 1940, showing areas of felling and regrowth; (c) in Google Earth. The roads are now the same as in 1598, and most of the present hedges existed then.

Ordnance Survey produced maps at a scale of 1:2500 that portrayed every wood, and attempted to portray every non-woodland tree, in Britain and Ireland (Photograph 23). Other countries with a good map record are Italy and Sweden. Japan has immense archives of early maps which appear to have been very little studied.

Pictures and photographs

Pictures are a variable source of information. At best they are careful depictions of particular places, sometimes from exactly identifiable viewpoints, like those by John Constable in England c.1800 which can be compared with the same scene today (Photograph 24). However, trees in works of art are often sketchy and generic, mere space-fillers, not identifiable to species or individuals. Depicting a tree is an artist's most difficult task, and only a few European artists mastered it: Chinese and Japanese pictures of trees are much more convincing.

Early photographs are a valuable source, especially where the site can still be identified. Especially important are aerial photographs from World War II; the British material is now in the National Archives of Scotland, and the German material in the United States National Archive near Washington. Both cover many different countries.

Problems of interpretation

It is important, wherever possible, to go back to the original records, rather than using modern interpretations of them. What exactly did the original writer say? Was he writing from his own experience? Was he writing of events at the time, or of centuries before? What are the reasons for believing him?

Words are often used in unexpected technical senses. Many European languages draw a distinction between timber (French bois d'œuvre, Latin meremium, Italian legname), meaning tree-trunks suitable for beams and planks, and wood (bois d'industrie, lignum, legna), meaning coppice poles, tree branches, etc. suitable for light construction, fuel, or charcoal. American English does not make this distinction. The Ancient Greek drymos, which should mean a wood composed of oaks, seems in practice to have been used for coppice-woods in general. Forest may mean a place of trees or a place of deer. The investigator should be cautious in accepting other people's translations, which may often involve mere guesses at difficult words, or even be tendentious, exploiting uncertainties in the language to uphold a preconceived point of view.

Photograph 23: British Ordnance Survey map of c.1876, in the mountains of south Wales. It shows every field and every wood, distinguishing broadleaved trees and conifers. It appears to show every tree and every bush outside woodland. Similar maps cover nearly the whole of Britain and Ireland. Original scale 1:10,560. Most place-names are in the Welsh language.

Photograph 24: The famous picture The Hay Wain, painted by John Constable in 1821, and the same scene in 1998. Note the increase in trees and other vegetation (and also the artist's error in the house, which has not changed).

Place-names

Toponyms often embody woodland history, especially if they are in a previous language or an earlier form of the present language. For example Pencoed, 'End of Wood' in the Welsh language, is the name of several places in parts of Wales and western England where Welsh is no longer spoken; sometimes the wood is still there, sometimes not. Places like Penshurst embody the term hyrst, one of the many words for woodland in the Old English language: its exact meaning is uncertain.

Place-name study is a separate discipline which has its own methods and procedures. It is essential to go back to the earliest available documents. The modern form of a name may be misleading, especially if it is a misinterpretation of an earlier name in a different language.

Woods themselves have names, which may embody their history: thus in England a wood called Lound or Lownde has a name derived from lúndr in the Old Norse language of a thousand years ago. Wood-names may refer to management: thus in England Copse or Tailz, both derived from medieval Norman French, imply coppicing. A wood called Plantation is unlikely to be an ancient wood.

In England every wood, even if only a few hectares, has its own name which appears on maps. This appears to be unusual: for example on French maps only the larger woods are named, although this may be a matter of mapmakers' convention.

Wood-names may refer to trees. Sometimes the name implies a wood composed of the particular tree: thus English Oket, French Chesnaye, and German Eichat mean a tract of oak-trees (implying, perhaps, that other woods in the area were not all oak). More common, but ambiguous, are woods with names like Birkrigg ('Birch -Betula- Ridge'): does this mean a wood composed of birch-trees, or one distinguished by having a single conspicuous birch-tree?

As far as I am aware the oldest named wood in Europe is Skotitas in the Peloponnese in south Greece, described and located by Pausanias, the traveller of the 2nd century CE. It is still there and is a coppiced oakwood.

Archaeological Features in Woodland and Savanna

Features related to previous land-use

Archaeological survey - finding and mapping scatters of potsherds and other artefacts lying on the surface - is one of the most powerful methods of establishing the history of the countryside at large (as opposed to the excavation of individual sites). However, archaeologists tend to shun woodland, either because of the physical difficulty (vegetation and leaf-litter hide artefacts) or because they believe that woodland has always been woodland and will not yield evidence of people's activities.

Forests and savannas can contain almost any kind of archaeological material related to a previous non-forest land-use. Tens of thousands of square km of forest in eastern North America, from Florida to Canada, contain field boundary walls resulting from a short-lived period of agriculture in the first two centuries of European settlement. In most of the European Mediterranean, terrace cultivation has shrunk during the twentieth century, resulting in thousands of square km of abandoned terraces built at various times between the Bronze Age and the nineteenth century, much of which is now forest: the terraces may be revealed after a forest fire (Photograph 25). In England, a significant area of what is now classed as Ancient Woodland is underlain by ridge-and-furrow, the distinctive earthworks produced by medieval cultivation. In western Turkey, deserted Hellenistic and Byzantine cities are embedded in what is now forest.

Land abandonment can occur at any period. Even Hayley Wood, a classic example of Ancient Woodland in England, is underlain by faint earthworks, thought to be of prehistoric date, which indicate that at least part

Photograph 25: Abandoned terrace cultivation, which turned into a wood of *Pinus brutia*, which then burnt, revealing the terraces. This is common in Mediterranean countries, where abandoned land is often invaded by pines, which are fire-promoting trees (West Crete, July 1988).

Photograph 26: Neolithic tomb, of about 2500 BCE, in what was then open land but has been woodland for at least 1500 years (Wychwood Forest, Oxfordshire, England, 1999).

Photograph 27: Woodbank, made about 1000 years ago by the monks who then owned the wood (Bradfield Woods, Suffolk, England, February 1973).

Photograph 28: Woodbank separating the ancient wood on the right from 19th-century woodland on the left (Cheddar Wood, Somerset, England, February 1979).

of it was not woodland in the Bronze or Iron Age (1800 BCE - 40 CE). In western Europe, stone circles of the late Neolithic and Bronze Age, such as Stonehenge, indicate sites that were treeless at the time, especially as many of them have astronomical relations requiring a clear horizon. Round barrows (burial mounds, typically of the Bronze Age) commemorated the mighty dead and are in places where they were highly visible, even though some of the sites are in what has been woodland for the past thousand years or more (Photograph 26).

Some archaeological remains may be indifferent as to whether the site was wooded. In south Wales, medieval coal-mines could be as well within woodland as outside it.

Features related to woods as such

Woods, especially where they were private property, had definite limits, sometimes marked by permanent earthworks or walls. Characteristic of medieval woods, especially in England, is the woodbank, an earthwork typically 10 m in total width, with the ditch on the outside of the bank (Photograph 27): this defined the property boundary and made it easier to fence out domestic animals which would eat the young shoots. Where a woodbank is now in the interior of a wood, it may indicate a division of ownership, or may result from the wood enlarging (Photograph 28). The earliest woodbanks are thought to be Roman. They continued to be made down to the nineteenth century, but later ones (for example where part of a wood has been grubbed out, creating a new boundary) are less massive and less worn-down than early ones.

A famous example of what are interpreted as wood boundaries are the imperial boundary stones of the Forest of Lebanon, erected by the Emperor Hadrian (117-138 CE) (Abdul-Nour, 2001). However, these inscriptions mark the limit of the land on which the emperor claimed certain trees, and it would be unwise to assume that they coincided with the limit of the tree-covered area.

Wood boundaries, like other features, tend to reflect people's interest or lack of interest in geometry. The Romans liked straight lines and regular grids and sometimes imposed them on conquered territories. For

Chinese and Japanese regular orientations had a spiritual significance. In Europe, wood boundaries of the medieval period tend to run in irregular curves or zigzags. Interest in straight lines revived in the post-medieval period and was transmitted to America, where whole states are rigidly divided into sections one mile (1.6 km) square regardless of the terrain.

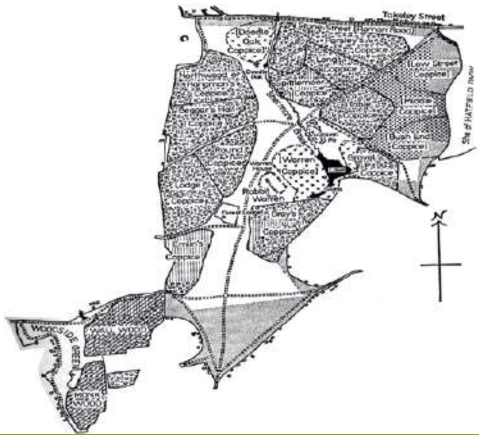
In England ancient roads do not normally traverse woodland: if they appear to, the road divides the wood into two woods, with a woodbank on each side. Sometimes the edge of the wood is set back from the road, with a narrow clearing, typically about 50 m wide, between. These clearings were made (and required by statute in the 13th century) to give travellers a sense of security against highwaymen hiding in the bushes. They establish that both the road and the wood existed in the middle ages. Similar roadside clearings in France are attributed to the 17th century.

Charcoal-burning sites are a common feature of forests and savannas, or of places where forest or savanna has been in the past. Charcoal has been made in various ways: the most widespread is by making a stack of logs, covering it with turf or straw and earth, and igniting it from within, after which over a period of several days it will turn into charcoal. Charcoal sites are difficult to detect in flat terrain, but if the ground is sloping a flat area had to be made. This leaves a platform, typically around 10 m in diameter, scooped into the hillside, usually with an access track and sometimes near a water source. The platform is covered with remains of charcoal, from which the species and size of wood can be determined, and (in principle) the length of the felling cycle and a radiocarbon date.

In Mediterranean countries pocket terraces can be made round individual olive or other valuable trees, especially where these are natural trees growing on rocky hillsides.

Large areas of woodland tended to attract fuel-using industries, exploiting the woods on a cycle: an area of wood would be cut each year, so that by the time the last area had been cut the first would be ready to cut again. Many of the large wooded areas of Europe have remains of furnaces and other iron-making and iron-working installations, of Roman to early-modern date: until the eighteenth century charcoal was needed to make iron because it produced a higher temperature than other fuels.

Any archaeological investigation of a wood or savanna should begin by making a map of the surface features, including distinctive trees. This may be done using the Global Positioning System, which however may not work where trees, cliffs, and other obstacles obstruct the view of satellites. If GPS is ineffective or not available, features may be mapped by the traditional method of walking along compass bearings and counting paces, starting from fixed points derived either from a large-scale map (where available) or from a Google Earth image.



Photograph 29: Compartmented wood-pasture. Hatfield Forest, Essex, is divided into coppices and plains. The coppices are ordinary woods with woodbanks round them. Each coppice was felled in turn and then fenced to keep out the cattle, sheep, and deer until the new growth was big enough not to be harmed. The plains were open to animals all the time, so the trees in them were pollarded instead of coppiced.

Savannas and wood-pastures

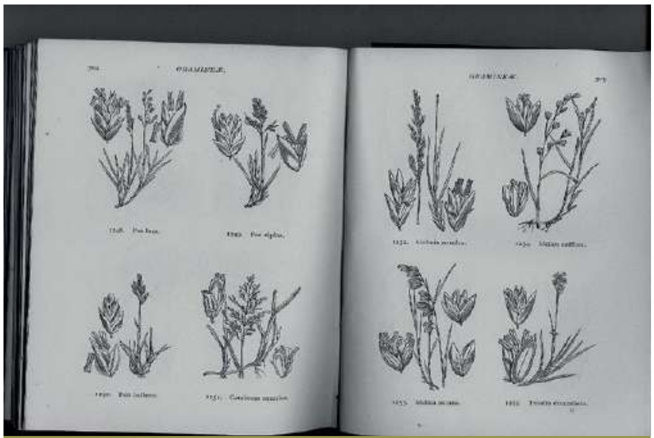
These features often have a history as common-land - that is, land on which particular persons other than the landowner have rights of pasture, woodcutting, etc. They are often diffuse in shape, with roads crossing them: any banks along the boundaries belong to the surrounding fields. Any trees will normally be pollards.

In England some wood-pastures have a history of compartmentation. Parts of the land would be maintained as woodland, surrounded by woodbanks. These would be felled in rotation and enclosed by fences on the banks for 6-9 years until the underwood had grown up again, when the fences would be removed and the commoners' animals allowed to eat the grass and other herbaceous plants between the trees. Any trees outside the enclosed coppices, exposed to livestock all the time, would be pollarded (Photograph 29).

Another form of wood-pasture was parks, places where the landowner kept deer. Keeping deer and other semi-domestic animals goes back to Roman times (Lucius Iunius Moderatus Columella) and probably to Bronze Age Crete. Parks had an expensive deer-proof perimeter fence or wall, typically of a compact shape (such as a rectangle with rounded corners), which often leaves a boundary earthwork.

In England many wood-pasture commons were designated as Royal Forests, places where the king (or some other very great magnate) kept deer - but not enclosed by a boundary fence. The term Forest does not imply woodland: many mountain Forests had few or no trees. The legal extent of the Forest (as defined by a perambulation) usually included a wide tract of surrounding farmland much greater than the physical Forest itself. Forests were not 'reserved to the king for hunting': most English medieval kings rarely hunted, but

Photograph 30: *Paris quadrifolia*, a plant which in England is characteristic of Ancient Woodland. Like many such it is clonal and rarely starts from seed (Buff Wood, Cambridgeshire, England, May 1985).



Photograph 31: One of the strongest indicators of Ancient Woodland in England: the grass *Melica uniflora*. It is both clonal and has seeds dispersed by ants.

Photograph 32: A 'coppicing plant': *Primula elatior*. This is a perennial, present all the time, which flowers in abundance in the years after the wood has been cut (Hayley Wood, Cambridgeshire, England, April 1987).

feasted on deer caught by professional hunters, and the deer in their Forests were added to whatever else was going on on the land. The various parties in a Forest were often in dispute, which is a fruitful source of records of topography and management.

In many countries deer (and bear, wild pig, and other huntable beasts) were less common than today. They and their habitat often had a special Forestal status; but the social and practical organization of hunting and deer consumption, varied widely and cannot be extrapolated from country to country. The presence of deer and pig is often taken as an indication of forest (meaning tree-land), but this need not be so: modern deer do much of their feeding outside woodland, and wild pig flourish in the semi-desert of south-east Spain.

What Trees and Plants Have to Say

When a new wood is formed, it does not suddenly acquire all the characteristic plants of woodland. Many trees behave as pioneers, rapidly taking over land that is no longer cultivated, grazed, or burnt: thus in Texas the local juniper, Juniperus ashei, is a tree that is sensitive to fire but resistant to grazing, and occupies land on which prairie fires have been suppressed. Other trees are slow to spread: thus in southern Greece the oak Quercus frainetto is characteristic of long-established woodland, as in England are lime (*Tilia cordata*) and service (*Sorbus torminalis*).

Many herbaceous plants are distinctive of woodland that has been long in existence: in English woods more than a hundred species have been so identified. Others are distinctive of recent woodland. The reason may have to do with the environment. For example, farm crops normally require higher fertility, especially in phosphate, than most wild vegetation: so woodland on former artificially-fertilized farmland may be suitable for high-fertility plants, such as nettle (*Urtica dioica*), but unsuitable for the low-fertility plants of ancient woodland - either for the plants themselves or their mycorrhizal fungi.

Another factor in ancient-woodland indicators is dispersal. Many ancient-woodland plants are clonal, growing from roots and underground stems and rarely starting from seed (Photograph 30). Or their seeds may be adapted for dispersal by some specific animal, especially ants, that is inefficient at moving them long distances (Photograph 31). Studies in a number of countries find the same two factors - clonal behaviour and ant dispersal - in plants missing from recent woodland.

Plants of ancient woodland are not the same as plants of old-growth or virgin forest. Many, perhaps all, survive periods when the wood has been cut down (but merely cut down, not converted to some other use). Some ancient-woodland indicators require the wood to be periodically felled. In England many herbaceous plants flourish in coppice-woods in the years after each felling (Photograph 32). Some of these are invisible between fellings, persisting as long-lived seed in the soil from plants that flowered after the previous felling. A number

Photograph 33: A buried-seed plant. *Euphorbia amygdaloides* is a light-demanding plant: each time the wood is felled it comes up from seed shed after the last felling. Between fellings it is invisible. Several other Euphorbias behave in this way, including one in Greece (Bradfield Woods, Suffolk, England, June 1987).

Photograph 34: Infilled savanna on Mount Athos, the Holy Mountain of north Greece. The big spreading oaks were originally not in forest but were scattered in pasture, where the mules and bulls belonging to the Christian monks grazed. Only recently have they become embedded in forest (May 2001).

Photograph 35: A roof probably of the 14th century CE. Each timber represents one small oak-tree. Medieval woods were managed for a continuous supply of such trees (Canterbury, England).

of these, such as the spurge *Euphorbia amygdaloides* and others of its genus, are also ancient-woodland indicators (Photograph 33).

Listing ancient-woodland indicators can be a lengthy task, comparing species lists from many woods whose history is known. One short cut, where material is available, is to ask 'What are the plants that are found in ancient woods but not in ancient hedges?' The answer may form the nucleus of a list of ancient-woodland species.

Plants of recent woodland include nettle (see above) and the European umbellifer Anthriscus sylvestris. In North America the vast extent of recent woods is the preferred habitat for poison ivy (*Toxicodendron radicans*).

Individual trees tell the story of their past uses and of events around them, especially those that are coppiced or pollarded. The woodland archaeologist should be on the watch for discrepancies between the form of living trees and their environment. One of the commonest changes of recent centuries is infilling of savanna. This produces a forest in which old trees of savanna shape - spreading, low-branched, often pollarded - are surrounded and hemmed in by younger, taller trees. Conversely, trees with tall, straight, branchless trunks, scattered in farmland, are likely to be relicts of a forest that has otherwise been dug up (Photograph 34).

The main dating standard for trees is annual rings: in areas such as Australia where trees seldom form good rings it may be difficult to arrive at a time-scale. In public places graffiti cut into the bark sometimes give a clue, taking into account the style of the lettering - early graffiti may be carefully and calligraphically incised - and the degree of stretching as the tree grew bigger.

Off-Site Archaeology

Archaeological excavations produce tree and plant material, preserved either in waterlogged sites (like the imperial palace of Nara, Japan) or under the sea (as in shipwrecks) or in permanently dry conditions (like tomb furniture in Egypt) or as charcoal. These can often be identified as to genus (less often to species) and give information about the use of trees for structures, fuel, or food (acorns, nuts etc.). The timbers of standing buildings, ships, waterfronts, and other structures can be dated by dendrochronology and reveal the species and many other properties of the trees that they came from.

In many cultures the custom is to fell trees when they are small enough to be handled by two men (Photograph 35). Each beam is made from the smallest tree that will serve; often the corners are waney where they intersect the curved surface of the log. Although some cultures, such as ancient Japan, subdivided trees lengthwise by sawing or splitting, this was often expensive or impracticable. Cultures without power tools tend not to make use of

Photograph 36: An ordinary timber-framed house of c.1400 CE. The timber frame is made partly of cheaper species than oak, and of recycled timbers. The spaces between the timbers are filled with coppice poles covered with clay (Flatford, Suffolk, England).

Photograph 37: The biggest medieval buildings that could be built from ordinary trees were the great barns. This one was built c.1200 CE from some 450 mostly small oak-trees. It was a storehouse for the agri-business of the Knights Templars, military monks (Cressing Temple, Essex, England, 1989).

Photograph 38: The modern equivalent of ancient shipbuilding. The bottom of the Mediterranean is littered with thousands of ancient sunken ships, but so far these have not been much investigated for what they reveal about the origin and management of the timbers (Near Bozburun, Turkey, July 1996).

Photograph 39: If you haven't invented power tools there is one thing you can make from a giant tree (Panamá, April 1998).

forest giants, except for special purposes where a big tree is essential, such as dugout boats.

Timbers of buildings, and coppice poles used as infill between the timbers, can reveal details of woodland management. For some purposes particular species are preferred. Thus oak was a high-status timber in medieval England (Photograph 37), other species being used, along with recycled oak, in less expensive buildings (Photograph 36). In cultures that build structures out of horizontal logs, as in the Alps and Scandinavia, conifers are preferred if available. For other purposes, such as the wattle-and-daub infill of medieval buildings, the species did not matter much. Annual rings reveal the felling cycle.

Most of these studies have been done on land carpentry. Another aspect is shipbuilding (Photograph 38 and 39). Although much is now known about the construction of ancient ships, investigation of the trees that went into them has not usually been given high priority by underwater archaeologists.

Timber was not always of local origin: thus much of the oak in English medieval buildings was imported -ready cut into planks- from the huge straight-grown oaks of eastern Europe. Pine was preferred in Spanish buildings, even where it had to be brought from distant mountains. Some building timber in the Ægean is pine from Turkey or larch from the south-eastern Alps.

Sacred and Civic Trees and Groves

In many religions particular species of tree or particular individual trees are objects of respect, veneration, and pilgrimage, although often by custom rather than for formal theological reasons. Examples are the ancient yews (*Taxus baccata*) around churches in England and Wales. Many of these appear to go back to the foundation of the church 11-15 centuries ago; some are claimed (implausibly) to be older than Christianity itself.

In Japan, where there are two very different established religions (Buddhism and Shinto), both have sacred groves. Around Shinto shrines individual trees are marked with sacred ropes and ribbons as the dwelling-places of minor gods. These are usually veteran or ancient trees, but youngish trees can also be designated. Buddhist and Shinto sacred groves can range in size from a fraction of a hectare to several square kilometres, and in character from formal urban gardens to seemingly natural forest. They have often existed for many centuries. However, it is wrong to regard them as untouched natural wildwood: they show signs of past management and of fashions in tree-planting, such as the nineteenth-century vogue for sugi (*Cryptomeria japonica*). Sacred groves have their own trajectory of development, which is different from that of secular woodland.

One of the largest sacred landscapes is the peninsula of Mount Athos in Greece, which for a thousand years has been inhabited solely by Orthodox Christian monks, who (in theory) kept no female animals and thus did not have sheep, goats, or pigs. Travellers used to remark on the sudden contrast between the forested peninsula and the deforested secular mainland, inhabited by ordinary secular farmers and pastoralists. The distinction is now no longer visible as mainland agriculture has declined and the land has grown back to forest. The monks themselves have modified their forests by a thousand years of management, especially producing large coppice poles of chestnut from which they now make a living.

Ancient trees mark the centres of historic towns: probably the biggest tree in Crete is the plane-tree in the village square of Krási. One of the world's largest trees is the famous 'cypress' (*Taxodium mucronatum*) in the city of Santa María del Tule, Mexico. Other trees are associated with historic events, such as Kett's Oak near Norwich, England, associated with the rebellion of 1547, or the plane tree in Khaniá, Crete, whereon the bishops were hanged in the rebellion of 1821. In Japan are kusonoki (*Cinnamomum camphora*) and other trees planted by various emperors, which are preserved even when dead.

An Example

I write these words on the edge of a canyon (a small limestone gorge) in middle Texas. The rocky surroundings are a near-impenetrable wood of many species of little trees, 5 m or so high. The stems date mostly from the 1930s, but there remain the rot- and termite-resistant juniper stumps of a previous generation of trees, bearing the axe-marks of pioneer settlers 150 years ago. Dwarf ashes and oaks form small coppice stools and bigger clonal rings, which are probably centuries old. Interspersed among them are junipers, a few of which are big veteran trees, the specific habitat of the Golden-Cheeked Warbler (*Dendroica chrysoparia*), a rare bird endemic to Texas. The flat bottom of the canyon, reached by rare floods, is wooded with taller, mostly short-lived trees, including ash (*Fraxinus* species), pecan (*Carya illinoensis*), hackberry (*Celtis* species), bo'd'arc (*Maclura pomifera*), and elm (Ulmus crassifolia - many small hollow trees).

Photograph 40: Mott savanna, middle Texas: a cultural landscape that has passed through at least four successive human cultures (Valley Mills, January 2013).

Above the canyon is a limestone plateau of grassland (prairie) interspersed with scattered trees (Photograph 40). It is not quite a typical savanna: the three principal trees -live-oak (*Quercus fusiformis*), elm, and soapberry (Sapota) -are all clonal, so that they occur as patches of stems, called motts, rather than single trees. Much of the grassland has become invaded by young junipers.

What is the history of this area? Settlers, some from Britain and Norway, others of European descent from other parts of North America, colonized in the 1840s and began European-style cultivation. They acquired land as their personal property, set up farms and for a time made a living, but European-style agriculture was not sustainable: the climate was harsh, the soil thin, and rainfall unreliable. Most of the farms were abandoned and are now represented by ruins with European artefacts, sometimes with a few cultivated trees. They were replaced by cattle and sheep ranches, which in turn have declined.

Local archives record the rectangles of land that were allocated to settlers by the new State of Texas or its Mexican predecessor, and the T- and L-shaped plots between them that nobody wanted until later. The boundaries were defined by perambulations, which when they came to a corner recorded the two nearest trees: Cedro as Spanish for juniper, Nogal for pecan (*Carya illinoiensis*), Encina for live-oak (*Quercus fusiformis*) etc., how many varas (a Spanish-Mexican unit of 84.7 cm) away each tree was, and in what compass direction. This reveals a landscape that in some respects has not much changed in 170 years. The trees near the corners are of much the same species, occasionally the same individuals, as the witness trees of the surveys. Where the survey found only one witness tree the site is still savanna. Where there was no witness tree -'Mound in Prairie' may be noted instead- the site is either still prairie or overgrown with juniper.

The settlers, like all Europeans, feared fire, but did not succeed in suppressing it until about 1900; many of the

Photograph 41: A small clonal mott of *Quercus fusiformis* (Valley Mills, Texas, December 2007).

old juniper stumps and fence-posts are charred by prairie fires. Previously the grazing animals had been migratory herds of buffalo (*Bison bison*) and wandering deer, but these were replaced by sedentary cattle, sheep, and goats - with disastrous effects on the native grasses and lesser effects on the trees. From c.1875 onwards, land-holdings and their many subdivisions were demarcated by barbed-wire fences, which now form a museum of successive patterns of barbed wire. There have been two main changes in the trees. Trees of all kinds have increased in the savanna, much of which has become infilled with juniper. Juniper is fire-sensitive and used to be confined to the canyons, but has now spread on to the plateau. At the same time, fenced boundaries, even in prairie, have turned into hedgerows of trees and bushes, especially as birds have sat on the fence-posts and excreted the seeds of fleshy tree fruits such as hackberry and wild plum.

The landscape that the settlers moved into, 170 years ago, was not virgin forest or natural steppe. It was already a cultural landscape maintained by a succession of Native American cultures: most recently by Tawakoni, Waco, and other nations who had acquired horses from Spanish conquistadores and settlers elsewhere, but before them by thousands of years of other cultures whose stone implements are still to be found in and near the canyons. There can be little doubt that they all managed the grasslands and savannas by burning to favour the buffalo, deer, and other animals on which they fed. Fires, noted by Euro-American travellers such as the Santa Fé expedition of 1841, then spread over nearly the whole landscape except for the fire-sheltered canyons.

A relic of ancient savanna fires are the motts. The individual stems of a *Quercus fusiformis* mott (Photograph 41) are typically 80-100 years old and are the regrowth from settlers felling the previous trees. Occasional trees, preserved because of historic links with the original settlement, may be 200 years old. But the larger motts themselves, often 50 m or more in diameter, must be thousands, rather than hundreds, of years old, periodically burnt to the ground by an unusually fierce fire but sprouting from the roots. The savanna landscape, though certainly cultural (as shown by its turning into forest when not managed), has passed through several successive human cultures during most, if not all, of the Holocene. Whether there has ever been virgin forest on this land within this interglacial is doubtful.

Conclusions

Historical ecology uses information from various sources: written records; place-names; study of pollen and other plant fossils; sizes, shapes, and ages of trees: presence of particular plants; archaeological features on and off site. It is essential to use as many as possible of these in conjunction. Even in the best-documented places, writings alone, without fieldwork, do not tell a complete story. They will not reveal what was happening in periods when people were not writing things down; and they often fail to record things, like terraces, that were commonplace and taken for granted.

The object is to study the history of particular sites, and from these to arrive at the history of a region as a whole. Ecologists should beware of generalized accounts by earlier writers, who may have been poorly informed or have drawn the wrong conclusions from their information.

How to write a false version of history?

- Do no fieldwork.
- Confine yourself to written documents.
- Use contemporary documents of a generalized nature, rather than those relating to specific sites.
- Pay plenty of attention to forest laws, and use them as direct evidence of what was or was not done.
- Rely on other people's translations from originals in other languages.
- Pay much attention to contemporary writers who had much to say for themselves.
- Assume that everything presented as 'legend' or 'oral history' is really what it claims to be.

How to write a false version of ecology?

- Confuse trees and other plants and animals with 'the Environment'; do not investigate their behaviours.
- Assume that all trees are alike.
- Confuse the history of the countryside with the history of country folk or of what people have said about the countryside.
- Copy what previous authors have said.
- Expect the history of the landscape to be simple.
- Take official statistics at face value, without reading the small print of how they were arrived at or what exactly they mean.
- Never admit you don't know something.

Acknowledgements

This chapter summarizes a lifetime's researches and travels. I am especially indebted to the late Dr. David Coombe and Dr Clifford and J Evans; Professor Peter Warren; Susan and the late Colin Ranson; Ann and the late James Hart; Dr Jennifer Moody and Wick Dossett; Dick Grove; Professor Jun-ichi Ogura; Dr. Katsue Fukamachi and Dr. Hirokazu Oku; Melissa Moody; Dr. Philip Oswald; Professor Gloria Pungetti; and many, many others.

References and Further Reading

Abdul-Nour, H., 2001. Les inscriptions forestières d'Hadrien: mise au point et nouvelles découvertes. *Archaeology and History of Lebanon* 14: 64-95.

Beals, E.,W., 1965. The remnant cedar forests of Lebanon. *Journal of Ecology* 53: 679-94.

Fairhead, J. and Leach, M., 1998. *Reframing Deforestation Routledge*, London.

Grove, A.T. and Rackham, O., 1991. *The Nature of Mediterranean Europe: an ecological history.* Yale University Press.

Hambler, C. and Speight, M., R., 1995. Biodiversity conservation in Britain: science replacing tradition. *British Wildlife* 6: 137-147.

Hepper, F.,N., 2001. The Bsharré Cedars of Lebanon as seen by travellers. *Archaeology and History of Lebanon* 14: 96-106 .

Kuniholm, P.I., Newton, M., W., Griggs, C.,B. and Sullivan, P.J., 2005. *Dendrochronological dating in Anatolia. The Second Millennium B.C. significance for early metallurgy*. In Anatolia III, Der Anschnitt, Beiheft 18, edited by Ü. Yalçın; pp. 41–47. Deutsches Bergbau-Museum, Bochum.

Peterken, G.F., 1996. *Natural Woodland: ecology and conservation in northern temperate regions.* Cambridge University Press.

Rackham, O. 1986: *The History of the [British and Irish]* Countryside Dent, London.

Rackham, O., 1990. *Trees and Woodland in the British Landscape*. 2nd ed Dent, London.

Rackham, O., 2001. *Trees, Wood, and Timber in Greek History*. Leopard's Head.

Rackham, O., 2003. *Ancient Woodland: its history, vegetation and uses in England*. 2nd ed Castlepoint Press, Dalbeattie, Scotland.

Rackham, O., 2006. *Woodlands*. Harper Collins, London.

Rackham, O. and Moody, J.A., 1996. *The Making of the Cretan Landscape.* Manchester University Press.

Smout, T.,C., MacDonald, A.,R. and Watson, F., 2005. *A History of the Native Woodlands of Scotland, 1500-1920*. Edinburgh University Press.

Szabó, P., 2005. *Woodland and Forests in Medieval Hungary*. Oxford: Archaeopress.

Vera, F.W.M., 2000. *Grazing Ecology and Forest History.* CABI Wallingford.

Chapter 4
Ancient Rights in Ancient Forests

Graham Bathe

How ancient practices have shaped the forests surviving today

The ancient forests of Europe are recognised as making significant contributions to biodiversity, landscape, recreation, tourism, climate, flood control, and other ecological services alongside their value for timber. Such forests are often the product of centuries or millennia of multi-purpose exploitation, shared by communities through the exercise of common use-rights. A comprehension of historic use adds a social dimension to the cultural importance placed on such forests, and provides the context of management which has generated the biodiversity and environmental features valued today, which modern conservation effort may need to emulate.

The hunting forests, through their resistance to change until modern times, exemplify a situation appertaining throughout much of European history, with local settlements deriving their basic needs from a complex mixture of shared and exclusive resources. Early societies established rules or laws which governed the ability to extract such goods, hence ascribing (and limiting) the notion of defendable 'rights'.

The significance of different commodities (e.g. the relative importance of pastoral, hunted or harvested goods), and the proportion of shared and exclusive resources, fluctuated through time. Tensions would arise within and between communities, when the exercise of certain rights affected the entitlements and interests of others. However, the commons and shared use-rights remained an enduring feature of the hunting forests for more than half a millennium. This chapter examines how hereditary use helped shape the royal hunting forests, drawing especially on examples taken from the Forest of Savernake in central southern England. It also makes comparisons with the New Forest, near the southern English coast, one of the few surviving examples of the royal forests.

Royal hunting forests of England

The royal forests once covered more than 25% of England (Langton and Jones, 2009). Whilst hunting was clearly enjoyed by the earlier Anglo-Saxon and Danish kings, who could sport in certain great unfarmed tracts of land remaining, the concept of 'royal forests', as areas set aside and subjected to unique forest law, was unknown in England prior to the Norman conquest of 1066. The invading Norman kings were probably able to import a mature system, already fully developed, from their homeland, with its complex, ritualistic judiciary and administration. This in turn appears to have had its progenitor in Frankish institutions which secured the protection of game for the exclusive privilege of the king. It is estimated that some 40% of the Carolingian landscape had been uncultivated, with most of this wooded, and large areas in royal hands and maintained as hunting reserves (Verhulst, 2002). The laws or 'capitularies' of the Carolingian dynasty relating to the 'forestis', have close parallels with the later English Assizes of the Forest (Petit-Dutaillis, 1915).

Whilst surviving documentation is sparse, charters from the mid-11th century relating to the Forests of Evereux and Cherbourg confirm that William, the future king of England, held forests in Normandy prior to his invasion (Fauroux, 1961). Evidence from the early 12th century, when continental sources are more plentiful, shows that forests on both sides of the English Channel were being governed by directly comparable legislative regimes (Petit-Dutaillis, 1915).

The royal hunting forests were not necessarily areas with dense or even significant tree cover. Whilst variable, they generally involved unenclosed tracts of land, often kept open by deer and commoners' animals, and with a mosaic of scrub, heath, trees, woodland groves or coppices. Landscapes in the New Forest probably retain characteristics once typical of the royal forests (Photograph 1 and 2). The universal distinguishing feature of the royal forests is that they were protected

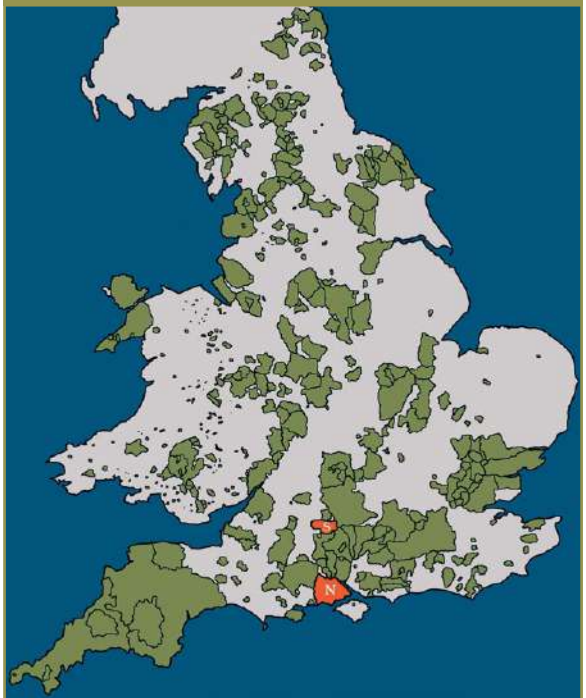
Photograph 1 (above) and 2 (below): Two views of the New Forest, which newly came under Forest Law in 1079, and has retained the name 'New' into the 21st century.

through unique laws, which had the interests of the king at their core. Forest Law was imposed on great swathes of the English countryside from the end of the 11th century. In some cases, established hunting grounds recognised and managed during the previous Anglo-Saxon era, such as the Forest of Galtres, formed the basis for royal forests. In other cases, such as the New Forest established in 1079, extensive heaths and woodland held by the king were newly incorporated within Forest Law. By the time of the Domesday Book, a massive record of landholdings compiled for taxation purposes in 1086, some twenty-five forests were listed. Savernake Forest, situated in southern England, was established at some time between 1086, and its first parenthetic mention on a surviving parchment from 1130 (Calendar Pipe Rolls). In due course there were at least 648 royal forests in England and a further 332 in Wales (Figure 4.1).

Whilst the protection of game, especially on the King's own land, constituted its conceptual rationale, Forest Law became equally important for other functions. It conferred prestige and social exclusivity, which could also be extended to those currently in royal favour. More importantly, it massively strengthened the monarch's

Figure 4.1

The royal hunting forests of England and Wales in medieval times, after Langton and Jones (2009)



The forests shown here are at their maximal extent (not necessarily contemporary). Darker shading shows case study of Savernake Forest (S), with New Forest (N) also shown.

authority and ability to generate revenue. Forests were also closely associated with castles. They provided constructional timber and other building materials for erecting and maintaining castles, whilst also offering food for the larder, fuel for heating, and opportunities for recreational hunting.

Shared resources in the royal hunting forests

Despite the supreme power of the monarch, the landscapes of the royal hunting forests were moulded by a complex web of relationships in which different rights, privileges and obligations were shared amongst diverse individuals and communities, ranging from the king to the local peasant. The notion that land ownership conveyed autocratic exclusivity was unfamiliar throughout most of England's medieval history. People could have rights and privileges associated with office, status, landholding or tenancy, and exercising such rights was usually conditional on providing military, religious or labour services, or on the provision of commodities or (generally much later) money. Of particular importance in the historic management of forests is commoning, a form of shared property right whereby one person has the ability to exploit a product on land which they do not hold. The range of rights and privileges appertaining in Savernake Forest in medieval times is shown in Table 4.1.

Rights of the King

The Normans exercised rule through feudal tenure. The king was the lord of every part of the conquered lands, and others could occupy or 'hold' (not own) land only from the king in chief, generally by fulfilling duties, such as protecting the king's interests, or providing military or other services. Through forest law the king held the exclusive right to hunt game, and anyone caught taking deer without authorisation could, in theory, be executed, suffer amputation or be maimed. In Savernake, forest proceedings show that in practice such draconian punishments were not implemented, and perpetrators were normally bailed and then subjected to fines. The main quarry species in Savernake and probably most of the other royal forests was the fallow deer, *Dama dama* (Photograph 3). In Britain, there are extremely few, intermittent remains of this species dating from before the 11th century. Strong circumstantial evidence suggests that the Normans introduced and populated the royal forests with fallow deer, where they rapidly established and naturalised (Yalden, 1999). Wild boar, *Sus scrofa* (Photograph 4) were also regarded as game, but may have been exterminated as early as the 13th century (Rackham,

Table 4.1

Shared rights and responsibilities in the Royal Forest of Savernake

Beneficiary Origin of role	Responsibilities	Rights and Entitlements
King Hereditary		Royal game (deer, boar) – exclusive rights Timber trees –exclusive rights (widely disregarded) Great cablish (wind-thrown trees and timber) Monies from additional grazing Pannage – fee for depasturing pigs
Warden Hereditary	Protection of forest from unauthorised hunting and damage, clearance and cultivation Preside at local attachment courts. Attend Forest Eyre (courts)	Hawks from eyries (for falconry); Honey; Nuts; Rose hips Fern all year; Heath Tree stumps; Small wood for house repairs and fencing Free warren (small-game): hares, foxes, wildcats, badgers, and pests or vermin Depasturing pigs (quit of pannage) all year except in the fence month Depasturing all domestic stock except goats and mature sheep, all year except fence month Fines imposed for taking small game, using nets, and taking deadwood without authority Fines imposed for releasing stray domestic stock Money charged to maim dogs to prevent them hunting
Foresters Hereditary, and linked to land-holding	Protection of forest from unauthorised hunting and damage, clearance and cultivation Attend local attachment courts and Forest Eyre (courts). (In certain cases) provide military service – providing one man in armour on horseback	Collection of standing deadwood for nine weeks each year; Fallen sticks (except great cablish) Small wood for house repairs and fencing; Lop-and-top of trees felled by command of king Certain timber trees each year; Fees charged for firewood or small wood for making ploughs First acre of each coppice felled; Deadwood hedges when no longer needed Fern all year; Sand – one man digging all year Depasturing pigs (quit of pannage) in the autumn season Depasturing draught animals (oxen/horses) Fees charged for pigs in early winter (retro-pannagium) Cheminage -tolls charged for use of forest roads
Commoners Rights normally attached to land, with occupiers able to exercise rights	Attend or send representatives to local commoners courts	Variable, but include: Estovers – sticks, firewood, fern, heath, furze, small wood Right to cut tree limbs and bushes for browse Botes – rights to take small wood for house repair, fuel, ploughs, fences, carts Depasturing pigs in autumn (pannage) – small charge may apply Pasturage – grazing animals (sheep, cattle, horses). May be quantified or not. Locally also rights to take minerals, peat for fuel, and fish for personal consumption.

Photograph 3: Fallow deer (*Dama dama*) were introduced to England by the Normans to populate the royal hunting forests, and became rapidly naturalised.

Photograph 4: Wild boar (*Sus scrofa*) were probably exterminated in the early years of the royal forests, although there were local attempts at reintroduction.

1986). Later records of boar in documentation relating to Savernake probably concern reintroductions.

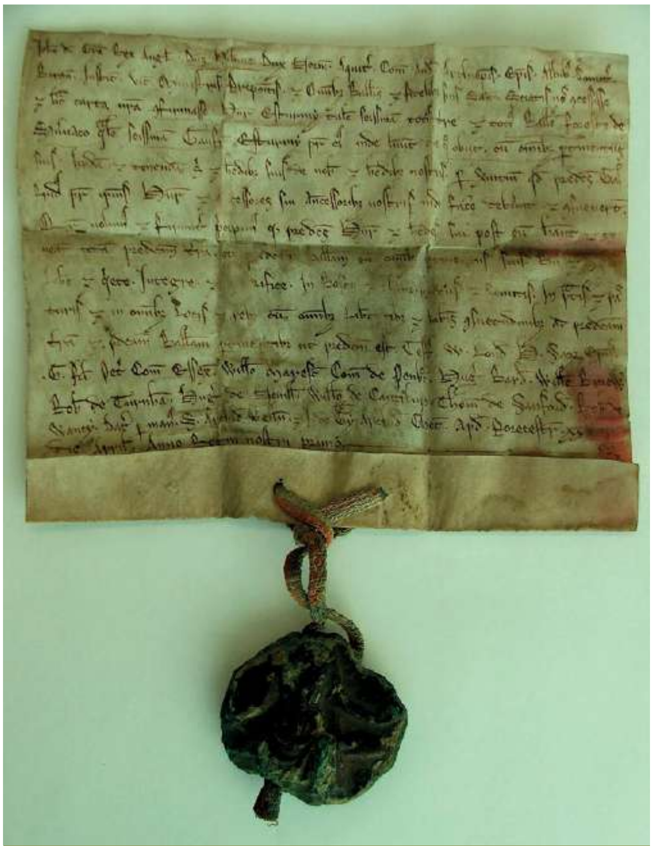
The king also had the right to all timber trees. In Savernake the most valuable timber trees were oaks, mainly *Quercus robur* with fewer *Q. petraea* and hybrids. At times of castle construction and rebuilding, and during the tension of war, timber exploitation was considerable, involving thousands of trees. Although the king theoretically held exclusive rights, in practice there was a culture of the widespread taking of timber, and perpetrators could receive modest fines or have their equipment confiscated, without further retribution unless they were 'persistent malefactors'. The king also had the right to wind-thrown trees and timber, known as 'great cablish'. In 1222 a massive storm wreaked havoc throughout the royal forests, felling numerous valuable trees. Henry III sent instructions to each of the affected forests, including Savernake, to see that 'the cablish of ours which was flattened in the forests should be inspected, and a valuation submitted under seal', prior to sale (Calendar Patent Rolls). Timber could be sold, but venison and hunting were not traded in this way. However the king frequently conferred gifts of venison and recreational hunting on close supporters, hence displaying his exclusive power and strengthening allegiance through patronage. The king also bestowed gifts of timber to religious institutions for building cathedrals and priories and to certain favoured nobles for major projects.

The king had income deriving from agistment (the admission of grazing animals into the forest), and other payments and fines for clearance or cultivation. In 1370 the king was entitled to all payments for pigs (known as 'pannage') in Savernake during the autumn season, which extended for forty days between the festivals of Holyrood Day and the Feast of St Martin (WSA 1300-153A). However the warden and certain commoners were permitted to keep pigs in the forest 'quit of pannage'.

Privileges and Obligations of the Forest Warden

Through the system imposed by Norman kings, local officials held positions on a territorial basis within the forests, deriving lucrative benefits in return for serving as custodians, and guarding the king's interests. These officers did not hold salaried appointments, but nevertheless maintained profitable positions, enabling their occupiers to generate or extort substantial revenue and other benefits. Such offices conferred a badge of honour and were sought vigorously. The most senior local officer in each forest was the warden, who had overall responsibility for the site (or sometimes two or more forests). In a high proportion of the forests, the warden held the position on a hereditary basis. Savernake Forest is probably unique in that the wardenship has stayed in the same family throughout its entire history. Hence Richard Esturmy, who was mentioned in the Domesday Book of 1086, was almost certainly the ancestor of all wardens right into the 21st century.

Wardens were proud of their appointments, and guarded their posts jealously. Whilst wardenship was often hereditary, the king personally sanctioned transfer to each new heir, exacting fees for issuing such licenses. A charter of April 1200 records a transfer of wardenship of Savernake after the death of Geoffrey Esturmy (Photograph 5). It relates that 'John, King of England, Lord of Ireland, Duke of Normandy and Aquitaine, and Count of Anjou, conveys to Henry Esturmy such seisin [possession] in the Forest of Savernake as Geoffrey, his father, had held at his death, subject to the same duties that Geoffrey and his ancestors had always performed'. Henry was granted all the land in 'wood and open country, in roads and paths, in meadows and pastures and in all places and things with all liberties and free customs pertaining' (WSA 1300-12).



Photograph 5: Charter through which John, King of England and Duke of Normandy, confirmed Henry Esturmy as warden of Savernake, with the same rights and duties that his father and ancestors had always held (WSA 1300-12). Courtesy of Wiltshire and Swindon History Centre.

Most forest wardens had positions established through a feudal tenure known as 'grand serjeanty', and undertook specific duties for the king. Amongst forest duties, the warden had the general responsibility of maintaining the king's peace. He protected the deer, ensuring that browse was cut for them in times of shortage, and arrested poachers. He presided at inquests of trespasses against the vert (vegetation) and venison (deer), and at the local attachment courts where offenders were indicted for formal judgement at the itinerant national court, the 'Forest Eyre'. He prevented unauthorised purprestures (enclosures and buildings), threw down houses, and seized assarts (cultivated land), in both cases 'attaching' offenders to appear at the Forest Eyre. The warden of Savernake also held specific duties as a forester in one of the divisions or bailiwicks of the forest, and this also carried military obligations. Hence Sir Henry Esturmy, who died in 1295, had to provide one man armed with a hauberk (chain-mail armour), whenever the king demanded military service 'within the seas' (usually in Wales) (WSA 1300-6574).

The warden also ensured that commoners did not exceed their established rights. He was frequently commanded to provide venison for the king's table, or to supply a royal gift, or occasionally to take live deer for stocking parks. He would supervise the cutting of trees upon instruction to provide constructional timber for castles or other works, and the supply of fuel.

The forest warden was entitled to a range of privileges in association with his office (Table 4.1). He could take the eyries (broods) of hawks used in falconry, honey, nuts (mainly hazel, *Coryllus avellana*) and rose-hips (fruits of *Rosa* spp). He could take animals regarded as pests or vermin, and had free chase of hares (*Lepus europaeus*), foxes (*Vulpes vulpes*), wild cats (*Felis sylvestris*), and badgers (*Meles meles*), whilst retaining fines levied in the Forest court on anyone taking these or partridges without authorisation. He was also entitled to fines imposed for the use of nets and traps for rabbits (*Oryctolagus cuniculus*), or the unsanctioned taking of deadwood, and the straying and escape of animals except in the 'fence month' in the middle of the year when deer were fawning and were not to be disturbed. He could take timber for repairing buildings, and wood for fencing. These rights were known as 'housebote' and' haybote'; the word 'bote' comes from a redundant Old English word meaning 'good' (from which the modern term 'better' has survived). He was also entitled to tree-stumps, after each inspection of the forest known as a 'regard', and the collection of fern (mainly bracken, *Pteridium aquilinum*) and heath (*Calluna vulgaris, Erica* and other low shrubs) for animal bedding or thatch. He could depasture pigs, and all domestic animals except goats and 'two-toothed' (ie mature) sheep, all the year except during the fence month, without payments. He was also entitled to retain money charged for the deliberate maiming of dogs, so that they were unable to hunt (WSA 1300-153A).

In the case of Savernake, even within a forest extending (at its greatest) to 250 square kilometres, it is unlikely that these privileges were viewed as substantial. Indeed, it is uncertain whether an entitlement to take certain products, like rose-hips, was valued or exercised, and such produce may have been adequately available to everyone who wanted them anyway. Whilst the utilitarian right to depasture grazing stock and pigs had a value, it provided limited foundation for wealth. It is likely that the real value of wardenship, which caused it to be revered and ruthlessly protected, was the despotic power it conferred on its holder, who was capable of ruling a minor baronry under the king's banner. Through his authority to hunt or take produce denied to others, he ostentatiously asserted his eminence within the king's close circle. This power also extended to the ability to impose fines and attach offenders for trespasses against the vert and venison. The fear of the courts, especially the Forest Eyre, whose draconian penalties theoretically extended to execution or maiming during the early years of the royal forests, provided opportunity to extort monies or other favours for overlooking misdemeanours. By controlling all roads, erection of buildings and fences, every use of the plough, grazing of animals, cutting of vegetation and hunting, he exercised power over the local populace, who found that money could be demanded for every minor activity.

Privileges and Obligations of the Foresters

Each division or bailiwick was overseen by local officers called foresters-of-fee, who answered to the warden. In Savernake there were five bailiwicks. The foresters occupied their positions as hereditary entitlements attached to specified parcels of land which were held from the King. A parchment roll that can be attributed to 1245 states that the 'foresters of fee in Savernake hold their office anciently from the conquest of England' (i.e. 1066) (PRO E146-2-33). The foresters were required to protect the vert and the venison, to report offenders and attach them at local courts, and appear at Forest Eyres, where they had to swear allegiance.

The foresters had the right to collect dead wood without using metal tools during each of the three-week periods before Christmas, Easter and Michaelmas. They were entitled to take fallen wood except great cablish (wind thrown trees) which belonged to the king. They could also take reasonable small-wood for housebote (minor repairs to houses) and haybote (fencing). In certain areas they held specific rights, including collecting fern all year (for bedding) except in the fence month. They could graze draught animals, whilst also retaining fees charged to others who grazed stock. They could graze pigs without payment in the autumnal pannage season when animals fed on acorns and beech-nuts, and could keep fees known as 'retro-pannagium' paid for pigs from the festivals of Martinmas to the Purification of the Blessed Virgin Mary (early winter). Some foresters were permitted to take a certain number of oak each year, retain fees charged for taking fuel or timber for making ploughs, have an acre of underwood from every coppice cut, and have the old deadwood hedges after they were no longer needed to protect young growth. They could have lop and top (small branches and leaves) of trees felled for the use of the king or queen, or where timber was gifted by royal warrant. Some could have a man digging sand all year. They were also entitled to charge toll monies known as 'cheminage' levied on goods carted through their bailiwick. If foresters left their bailiwick, the warden was entitled to seize their 'equitatura', comprising horse, saddle, bridle and horn (PRO E146-2-33; E32-348; WSA 1300-153A; 1300-6574).

The Rights of Commoners

The forest did not affect the different strata of society evenly. Whilst it severely constrained ploughing, it provided a stable resource for commoners from bordering settlements, whose ancient rights were fully protected within the forest system. Despite the subservience of the peasant population, the protection of commoning may have meant that they were net beneficiaries of forest law. It is almost inevitable that commoning pre-dated the establishment of Savernake and most of the other royal forests. However, because such rights were ancient, long established by custom and practice, they are unrecorded. It is only when new rights were established by express grant that they feature significantly in documentary sources, mainly from the 13th century. Forests were initially established on those lands retained by the king, and not transferred to lords for management by agricultural communities within the manorial system. The lands least suited for the establishment of manors were those with natural constraints on farming imposed by unfavourable soils, drainage, or climate. These areas, whilst difficult to plough productively, had extensive resources for grazing, fuel, heath and fern. It is probable that use in Saxon and prehistoric times mirrored that which is traceable throughout most of the second millennium, when bordering settlements had well-established rights throughout the landscape, moving their animals significant distances to make use of the pasture, or to collect fuel. Hence, the cumulative circumstantial evidence suggests that forest law simply applied a mantle above the existing pattern of common usage.

Hunting forests, like other commonable lands, provided distinctly different benefits for the right-holders and land-holders (in this case – the king). The former derived largely agricultural and domestic products. The forest provided, more than anything else, pasturage for their animals. Lopped or pollarded trees also supplied browse, and could provide nutrition even outside the growing season. The forests also provided fuel and animal bedding. Coppice poles, which had to be purchased rather than taken as a right, were partly used to make fence hurdles, and faggots of firewood, while furze and thorn, together with deadwood, provided domestic fuel. In contrast, the landowner derived benefit from the deer and the prestige associated with them, and from constructional timber and sale of wood products, including coppice and bark for the tanning industry. The landowner's interests suffered from the activities of the borderers, whilst they, in contrast, found that the deer, which they were not entitled to take, competed for browse and trespassed into their arable lands. Although acorns and beech mast provided fodder for pigs, any large, unlopped and spreading trees could be a nuisance to the commoners by shading out the lush grazing, whilst they had no authority to take timber anyway. Indeed, in most cases borderers were forbidden from taking any oak or 'great trees' without authorisation, even on their own holdings.

The commons were managed in accordance with societal customs, which could be recognized and enforced by judgments and decrees of the courts. Where local decision-making was challenged, higher courts (at county or hundred level) could determine issues. In due course however, where custom and precedent were unclear or inconsistent, parliament could draw up legislation. Common lands and rights hence exemplify the transition whereby the ancient laws of England were derived from custom, recognised in the courts during the development of common or universal law, and transposed into national statute. Some of England's oldest legislation relates to common land, including the Commons Acts of 1235 and 1285 – named 'The Statutes of Merton and

Westminster' – (the latter of which stayed in force for 721 years until its repeal in 2006). Despite their antiquity, even these Acts included no new provisions, and simply confirmed through statute something long recognised in practice. Local courts, focused either on the manors where these existed, or forest courts (on the king's extra-manorial land) provided a meeting place of commoners and the lord's or king's representatives. They established rules and byelaws, oversaw the rights of tenants, and administered fines on miscreants, either as a punishment or in the form of a licence to exceed their normal rights. Such laws were often unwritten, although occasionally specific attempts were made to set out in writing the memory of such traditions as a 'custumal' (customs of the manor or holding). Despite their local and often unwritten nature, custom and practice carried the weight of law.

Even within the royal forests, where it might be anticipated that the king's prerogative need have little regard to commoners, their rights were given protection in law. The 'Carta de Foresta' (Charter of the Forests) of 1217 makes explicit reference to the commoners. The Charter had been drawn up alongside the Magna Carta, a cornerstone of English (and American) law. Article 1 of the Carta de Foresta states: 'Those woods which belong to the King, which have been afforested, shall remain forest, saving the common usage of pasture and other matters, to those who were accustomed to the same' (McKechnie, 1914). In 1592 the barrister John Manwood, who attended some of the last itinerant courts or Forest Eyres held in England, produced 'A Treatise of the Lawes of the Forest', the first book on Forest Law. Drawing heavily on the Carta de Foresta and other early proclamations, he confirmed the rights of the commoners. He stated, 'where the King doth afforest his own woods or lands, he must not … prejudice any man to have common in the same that used, or by right ought to have common therein, but does still reserve the common of herbage, as it was at the Common Law'. Such rights of common were again asserted through a summary of forest law known as the 'Ordinatio Forestae' (Assize of the Forest) of 1305 (Young, 1979).

Of the seven main categories of common right generally encountered in England, three occur frequently in the royal hunting forests. These are: estovers, the right to take sticks, bracken and other minor products; pannage, the right to put pigs into woodland in autumn; and pasturage, the right to graze animals. Three other rights - turbary, the right to cut peat for fuel; piscary, or the right to fish; and also the entitlement to take minerals (known as a 'right in the soil') may have occurred locally. A further category, the ability to catch wild creatures for personal consumption ('animals ferae naturae'), was probably rarely a common right within forests, because of the protection of game, and existed solely as a privilege conferred on the warden and certain favoured nobility.

Photograph 6: The collection of fern and heath, mainly for animal bedding, was an important component of the common right called 'estovers'. Postcard of Savernake, 1916.

Estovers – the collection of sticks, fern, heath and minor wood products

The right of estovers, named from an Old French word meaning 'necessary', is a common right to take sticks, small wood, shrubs, bracken, rushes or other minor vegetation for personal use in buildings or on farms (Photograph 6). Such rights were attached to land where the benefits could be used – for example, the right to firewood could apply only to the household where it was to be burned, and it could not be sold to others. The ability to take small products in the forest could become an inalienable common right, when it was formally granted by the lord of the manor, or had been carried out through custom and practice for a sufficient period to be recognised by law. For traditional practice to be properly codified as a common right, the law required such usage to meet the three tests of 'nec vi, nec clam, nec precario' (without force, without secrecy, without permission).

Where documentary sources are available, these generally relate to new rights being formally granted, rather than established custom and practice. Many such rights of estovers were conferred on neighbouring religious institutions. In Savernake for example, in 1223 Henry III granted to the brothers and sisters of the hospital of St. John the Baptist, Marlborough, the right to have 'for ever, one man going daily for dry and dead wood into the Forest of Savernake, to collect as much as he can by hand, without using any iron tool or axe, and to carry the same to the hospital on his back for their hearth' (Calendar Patent Rolls). The Priory of St Margaret's had common rights to collect firewood in the forest, taking as much as one man with one horse could carry to the priory every day except on holy days, between the Feasts of All Saints and the Invention of the Holy Cross (WSA 9-2-388).

Rights were also sometimes granted to neighbouring nobility. When staying at Marlborough castle in 1231, the King granted the Countess of Pembroke reasonable estovers from Savernake, to maintain her manor, wherever sufficient could be taken without nuisance to the forest (Calendar Close Rolls). The right to take firewood was not necessarily free. At an inquisition at Marlborough in 1361 it was found that the Abbot of Hyde had always been accustomed to take 100 loads of fuel at Christmas, and 100 at Easter, for which a charge of 14 shillings was made, under the name of 'stocksilver' (Stokes, 1914).

It was normal practice for commoners to take small wood from the commons to maintain their buildings; they could face eviction if their properties were not maintained. The entitlement of 'botes' operated at all levels of the social hierarchy, and from the lowliest hovel to prestigious royal buildings. For many centuries Savernake was associated with Marlborough castle, and seen as essential to its upkeep. In 1254 a mandate was issued to Ernaldo de Bosco, Justice of the Forests, to permit the constable of Marlborough housebote and haybote in the Savernake, as accustomed for the safe keeping of the castle (Calendar Close Rolls).

The entitlement of poor people to take wood in the forest was recognised in the forest courts, and any infringement of the right could be challenged in law. However, it was also recognised that the collection of these minor products could damage Forest interests. In 1340 the regarders reported that undergrowth was suffering from rights called 'wood-leave' and 'fern-leave', as men from the adjoining townships entered the forest in search of dead wood and bracken (PRO E32-217).

Bracken, the commonest fern of Savernake and much of Britain, was used for bedding, and was stored for winter use when harvested dry and brown in the autumn. Bracken could also be used for thatching (WSA 192-44). Bracken for thatch typically used the hard shiny stems, stripped of their fronds, collected in late summer (Winchester, 2006). Forest documents record many incidents of people from neighbouring villages removing the outer branches ('exbranchatura') of oak – probably 'shrouding' the trees to provide small wood and fodder for domestic animals (PRO E146-2-27). Some people received minor fines for this, but in other cases the practice was recognised as a right or there was implied licence. Sometimes such rights were quantified through tenancy agreements. In 1578 Crofton tenants were allowed "two lots of shroud wood [lopped limbs] from the common of Crofton" (WSA 9-14-223). Forest keepers were required to cut and store branches and shrubs for winter use. This was sometimes called 'hart-hewing' when used as winter fodder for deer or other stock, or 'fuel-hewing' when intended for domestic purposes. The cutting of browse resulted in large quantities of sticks after the animals had stripped them of leaves, bark or buds, which were then available as firewood. In later centuries the keepers were allowed to make faggots of sticks after the deer had browsed them (WSA 1300-1500).

Photograph 7: Pigs snuffling amongst leaf litter in the New Forest, in association with the right of 'pannage' exerciseable in autumn, when they fatten on acorns and beech-nuts.

Pannage – the right to fatten pigs

Pannage was originally a fee charged for allowing pigs into forests in the autumn when they could fatten on acorns, beechmast and other nuts (Photograph 7). However, by the 13th century pannage was sometimes applied colloquially to a common right to depasture pigs without payment (Manwood, 1615).

Whilst most pigs were released during the autumn, when acorns lay across the Forest floor, or could be knocked from trees, some were present in other seasons. For example in 1344 Queen Philippa granted to the Priory of St. Margaret's, common of pasture for 100 demesne swine, quit of pannage, together with pig-sties in the queen's Forest of Savernake at all time of the year except the fence month, and except in her lawns there, 'for ever' (Calendar Patent Rolls). In 1399 Walter Hungerford was granted a lifetime privilege of turning as many pigs into Savernake, as could be supported at the Barton of Marlborough during the winter (Calendar Patent Rolls).

Pigs could present particular difficulties in the Forest. During the fawning season they had capacity to kill young deer. At a court held on the 19 June in the 6th year of the reign of King Edward VI [1552] the Ranger John Berwyck reported that pigs had killed fawns in his bailiwick (WSA 1300-86). Pigs could also cause significant damage to the Forest by rooting. In 1331 the forester Robert de Bilkemore was mentioned in court for his piggery from which 35 pigs wandered into the forest to the lord king's damage and to the detriment of the pasture of his beasts of chase (E32-217). In March 1595 it was reported that "Nicholas Kember hath suffered nine hogs or swyne to go at large in the forest and that they have dug the ways in the forest in the bottoms and hath done much harm and hunted the most part of this winter" (WSA 1300-87).

Unringed or pegged pigs could cause particular damage. In 1577 it was "ordered that the keepers finding any hog between Holyrood Day and Saint Martin's day unringed should bring them unto the pound and there keep them until the owner has payed such penalties as are contained in the statute". It was also ordered that "in the fence month every person must keep his hogs out of the forest on pain to forfeit 4d for each" (WSA 1300-87). It seems likely that fines were treated as occasional routine charges rather than punishments, and enabled regulation of normal practice. At a forest court of 1563, fines of 4 pence were imposed after hogs were impounded on 32 occasions. All of the borderers involved were repeat offenders. One man had to pay fines on five occasions after his hogs were impounded. The court book stated that all were unringed (WSA 9-22-240).

Pasturage – the right to graze animals

Common grazing was the greatest single asset available to borderers living in settlements around the forests (Photograph 8). In Savernake common pasturage was almost certainly of ancient origin, and long pre-dates the first written material from the 12th and 13th centuries. The survival of documentary evidence of such rights is probably a reflection of their atypical origin through formalised legal grants, often to religious institutions. Frequently grants were made in 'frankalmoin', which was a tenure bestowed upon those in the service of God, in exchange for divine services or the performance of a religious duty. For example, in c1250, for the well-being of his soul and the souls of his ancestors, Geoffrey Esturmy granted to the Priory of Easton and the 'brothers serving God there, 50 acres of his wood in Savernac, … with full common of pasture for all kinds of beasts there' (WSA 1300-1). The parcel of Savernake can be traced subsequently, and became known as Priory Wood. In 1540 it was described as a common wood thinly set with great oaks. Some of these giant spreading trees, grown in open conditions maintained by grazing animals, have survived into modern times (Figure 4.2).

The grant of 'full common of pasture for all kinds of beasts in Savernac' is an example of common rights 'sans nombre' (without number). This does not mean that the rights were wholly unconstrained, but that they were not formally quantified. Right holders could still be accused of surcharging a common if they put out so many animals in a Forest that it prejudiced the browse of deer, or pasture by the king or lord (Manwood, 1615). The quantification of rights became increasingly frequent during medieval times.

Grazing commons were universal throughout the forest and manors of the Savernake area. A principle employed to ensure that grazing did not become excessive was termed 'levancy and couchancy'. This limited the animals that could be depastured in summer, to the number that the right holder could accommodate and feed on their own farm in the winter. This enabled the lord to exercise control, facilitating sustainable management, whilst allowing flexibility. An indenture of one farm in 1376 included the right of pasture for as many bulls, cows, bullocks and heifers in Savernake Forest as the lessee

Photograph 8: Common grazing, mainly by cattle and ponies, is still the predominant feature governing the management and appearance of the New Forest today.

could maintain in forage during the winter, plus pasture of one cow for the keeper of the animals (Calendar Patent Rolls). Whilst such rights were not expressed in number, infringements could still be identified. For example in 1601 the commoners' court known as the 'Forest View' reported a cottager for pasturing 20 beasts, which was 16 more than his tenement could sustain in winter (WSA 1300-87). 'Levancy and couchancy' was a widely applied mechanism in England for at least 600 years. In Savernake it often existed alongside quantified rights, using separate systems for different stock, even within the same tenancy. For example, in 1540 tenants from neighbouring villages could depasture as many beasts horses and cows in the summer as they could feed in the winter, whilst sheep-rights were quantified at between 30 and 300 (Longleat House, Seymour Papers, vol 12).

Rights of common could become established when new cottages were built. In 1580 a Forest Court heard that 15 smallholders had each established cottages and a few acres of ground on the waste 'and every of them claims and prevaileth to have common pasture in all the Forest of Savernake' (WSRO 1300-87).

Whilst common rights were often attached to property, which might be rented or held in exchange for goods or services, the rights themselves were not contingent upon payment. This was in contrast to agistment, where grazing was purchased. Through such licence, those without rights or wanting to exceed their rights could depasture stock in the forest. Hence a complex system arose, where some animals were present by right, and some by licence. Agisters were recognised forest officials, who worked alongside the foresters, and were required to collect dues. Despite the payment, which suggested a temporary and discretionary licence, agistment became recognised as a custom, and hence could not be lightly withdrawn. Agistment rents could be set according to the size of smallholdings, suggesting that the principles of 'levancy and couchancy' applied here too.

Engraving of the King Oak in Savernake by J.G. Strutt, 1822, in a woodland granted to Priory of Easton in c1250.

Figure 4.2

It was described as being 'common land with great oaks thinly set' in 1540, and was later called 'Priory Wood'.

The rights of commoners needed to be accommodated within estate plans. Forest documents frequently relate to customary practices which were 'held by right', and 'ought to be held by right', implying a certainty respected on all sides. Attempts were sometimes made to acquire rights, or to negotiate agreements amongst right holders to permit division and exclusive management. In 1270 Henry III had granted the Priory of St Margaret's at Marlborough the right to depasture sixteen oxen and four cows in the Forest of Savernake, excepting the lawns 'for ever', without having to pay the usual fine (known as 'exchapium') if the cattle accidentally strayed, but instead driving them back into the forest pasture (Fry, 1908; Calendar Close Rolls). These rights remained attached to the site of the Priory when it was closed and converted into a farm in 1539. The rights must have been perceived as a considerable encumbrance on the Estate, as William, later second Duke of Somerset, agreed with the occupants of the new St Margaret's Farm to relinquish their right to collect firewood for £120, and their right to graze 20 cattle for £270 (WSA 9-2-388).

Where common rights were conveyed through a legal grant of the monarch during medieval times, such rights were not geographically constrained, suggesting a theoretical entitlement to graze or collect firewood in all areas. However other rights established through prescription (custom and practice) probably always applied to a specific area. The forest courts heard accusations of commoners exceeding their bounds. Certainly by 16th century there was recognition that the borderers from neighbouring settlements had common rights in defined parts of the Forest, where they could be expected to oppose trespass by neighbouring villages. Areas of the forest were named after the settlements which were entitled to depasture their stock, even when such villages were some kilometres away (WSA 9-2-388).

The number of commonable animals fluctuated as new properties were established or tenancy agreements made. The grazing of animals over protracted periods (centuries) could result in major landscape-scale changes, perhaps barely perceptible within one lifetime. This was especially the case as populations increased and new common rights were recognised. Such rights could become established when new cottages were built. In the 16th century a Savernake Forest court heard that 15 smallholders had each established cottages and a few acres of ground on the waste 'and every of them claims and prevaileth to have common pasture in all the forest' (WSA 1300-87). In extreme cases prolonged grazing prevented regeneration of trees, and woodlands gradually converted to open pasture. An awareness of timber shortfalls led to the introduction of legislation to protect woodlands throughout Europe from the late 15th century. However it was not until the Statute for the Preservation of Woods was passed in 1544 that attempts were made to address timber shortfalls and its economic implications in England (35, Henry VIII, chapter 17). The pre-amble to the Act gives emphatic expression to the parlous state of the woods. It states 'The King perceiving the great decay of timber and woods universally to be such that unless speedy remedy be provided, there is great and manifest likelihood of scarcity and lack, as well of timber for making, repairing and maintaining of houses, as for ships for the necessary relief of the whole community'. The Act required that, during clearance, coppices should retain twelve uncut standard trees per acre. These had to be at least 10 inches (25 cm) in diameter before they might be felled. Young coppices had to be enclosed to protect them from grazing animals for at least four years after clearing; those over 14 years old had to be enclosed for six years, and older coppices for seven. An Act of 1558 (Elizabeth I) extended the closure period to nine years. Once standard trees were a certain height, they were out of reach of both deer and domestic stock, and could continue unhindered. In ideal conditions this would lead to coppice-with-standards woodland, in which great trees formed an intermittent canopy over an understory of coppiced hazel and other poles.

Although the long term reduction in tree cover may have been tolerated whilst such sites remained royal hunting forests, in England such sites were transferred into private estates, especially during the 16th century. In the case of Savernake, the paucity of trees was thrown into sharp relief when the new owner, Edward Seymour, resolved to build a grand mansion in the 1570s, and asked his steward about where his best trees were. The response was shocking. Despite owning a forest of thousands of hectares, he had no timber trees left (Longleat House, Seymour Papers, Volume V). He was in the absurd position of having to purchase 640 oak from a neighbour (WSA 9-26-512).

The records reveal chronic deterioration and abuse of the woodlands, coupled with commoners' traditional determination to guard their rights jealously. Seymour's officers reported that there had been "great decay and spoil of woods so that much woodland is converted into pasture … whilst the Great Wood in Savernack is empty and old, and the underwood much decayed". They continued that the "deer were great annoyances and caused destruction to the wood, whilst the borderers oppress the forest with more cattle than in former times, and many connive to bring cattle from foreign townships [ie those without true rights] …and spoil the first spring of wood as well of coppice, which were formerly preserved" (WSA 1300-104).

In 1594 Seymour instructed his officers to find a suitable location for inclosing part of the Forest, and planting it with oak, ash (*Fraxinus excelsior*) and hazel, and "to increase the same to thick and strong wood; and not to suffer any cattle". The whole forest however was common land, and the commoners threatened to prevent any workmen from banking, ditching and erecting fences. They resisted the planting programme, which had to be abandoned. In a general tirade against the destruction of estate woods the steward bewailed "these commoners do marvellously murmur and grudge", and continued: "this realm will, in short time, rue the waste of it, and yet how lamentable a case is it to see the perverse disposition of the people" (WSA 1300-104).

It is clear that, in this particular instance, the interests of the landowner, and those of the borderers, had become diametrically opposed, establishing barriers related to status and class. This can be interpreted as part of the occasional antagonism between lord and peasant found throughout much of Europe. This antipathy, which persisted for centuries, was part of a land-use system later described in a parliamentary journal as "a perpetual struggle of jarring interests, in which no party can improve his own share without hurting that of others" (House of Commons, 1788). However, despite occasional conflicts caused whenever one party tested how far their rights might extend, commoning was an enduring practice in the royal hunting forests for most of a millennium (and possibly much longer), from which nearly the whole community could derive benefits. Its eventual demise brought disruption to the fabric of local society, and inflicted hardship on those least able to suffer.

Although the new landowner's attempt to extinguish common rights was abortive, the transfer of forests from state to private hands marked the beginning of a gradual change in which landowners progressively gained control. Inclosure of the extensive commons of Savernake and its environs spanned 200 years, and mirrored movements elsewhere in Britain and Europe. Whereas common rights had formerly extended over most of Savernake, by a combination of negotiation and legislation, they were ultimately extinguished almost everywhere. In many of the former royal forests this finally enabled planting of trees, hence perpetuating the (fundamentally wrong) impression that such forests had always been cloaked in trees.

In general, during the decline of the commons, it was the least productive land that was most likely to survive: it had been the last of the King's lands to be allotted to subjects, the last parcel (the 'waste') of any manor to be cultivated, and the last to have its common rights extinguished through inclosure. When inclosure took place, certain less productive land was occasionally retained as a token 'Poor's Allotment' where peasants could collect firewood or plant crops, a futile gesture to those made destitute, and often of short duration. The private Savernake Estate was undoubtedly a colossal beneficiary from inclosure. By parliamentary inclosure

Photograph 9: The King of Limbs, one of many giant named oaks in Savernake. The girth is larger than trees known to be 1000 years old.

alone it was allocated c2,800ha (Sandell, 1971), and may have achieved many times this figure through private negotiation. Corporately these inclosures caused a massive change in landscape and society. The substantial rise in estate income enabled the pursuit of ambitious building, landscaping and woodland planting programmes. In contrast the landless poor could be driven further into poverty and desperation. John Aubrey, travelling through Wiltshire in the 17th century, remarked on the poverty caused by inclosure and disafforestation: "... the cry of the poor was … lamentable. I knew several that did remember keeping a cow for four pence per year. The order was, how many they could winter they might summer, and pigs did cost nothing. Now travellers on highways are encumbered by beggars" (Jackson, 1862).

The legacy of the commons and royal hunting forests

The New Forest, one of the first areas to come under Forest Law in 1079, is still managed by the state. It survives as a large tract of unenclosed land, a mix of heath, bracken, gorse, acid grassland, scrub and trees, grazed by commoners' cattle and ponies, and with pigs feeding on acorns during the pannage season. The area of the New Forest available for common grazing is 22.000 ha. It is browsed by herds of wild deer, although hunting, the underlying purpose of its establishment, has ceased. Its appearance today may be little changed from that of 900 years ago (Photograph 2 and Table 4.1). The great majority (perhaps 99%) of other former royal hunting forests have long been transferred to private hands, and in most cases the commons extinguished. However, they still exhibit centuries of shared use and common rights, which are fundamental to their value for biodiversity. In particular, such areas frequently have ancient oaks, with spreading crowns, which have grown in open conditions, and bear the marks of centuries of pollarding or shrouding, both practices of removing limbs from standing trees without felling, suitable for grazed landscapes. These trees with abundant deadwood are important for lichens, fungi, invertebrates and hole-nesting birds. Surviving veterans have often acquired names. Ancient named trees in Savernake include the Big-bellied Oak, Cathedral Oak, Duke's Vaunt and King of Limbs (Photograph 9). Such trees have great social and cultural significance, are prominent landmarks and are depicted on maps. It seems probable, based on a comparison of girth sizes with trees of known age, that a few of the veterans surviving in Savernake predate the Norman conquest of 1066, and the establishment of the royal hunting forests themselves. The spreading, low growing and ancient trees are unable to survive well amongst dense, modern plantations, and need space to photosynthesise, especially as they age and an increasing proportion of foliage is produced close to the trunk. It is important that the conditions which established such trees is either re-established or emulated, ideally by permitting the reintroduction of grazing, or by cutting back neighbouring trees to allow these relics to persist for centuries to come.

References

Printed Sources

Fauroux, M., 1961. *Recueil des Actes des Ducs de Normandie.* Societie des Antiquairies de Normandie, France, 911-1066.

Fry, E.A., (ed) 1908. *Abstracts of Inquisitions Post Mortem.* British Records Society, London, 1242-1326.

Gover, J.E.B., Mawer, A. and Stenton, F.M., 1992. T*he Place Names of Wiltshire*. English Place Name Society. Nottingham, UK.

House of Commons, 1788. *Journal 43*, p 561.

Jackson, J.E.J., (ed.) 1862. *Wiltshire: The Topographical Collections of John Aubrey 1659-1670.* Wiltshire Archaeological and Natural History Society, Devizes.

Langton, J. and Jones, G., 2009. *Forests and Chases of England and Wales c. 1000 to c. 1850*. [http://info.sjc.ox.ac.uk/forests/Index.html, accessed 2013]

Manwood, J., 1615. *A Treatise of the Lawes of the Forest*. Society of Stationers, London.

McKechnie, W.S., 1914. *Magna Carta: A Commentary on the Great Charter of King John, with an Historical Introduction.* Maclehose, Glasgow.

Petit-Dutaillis, C., 1915. *Studies and Notes Supplementary to Stubb's Constitutional History*. Manchester, UK.

Rackham, O., 1986. *The History of the Countryside*. Dent, London.

Sandell, R.E., 1971. *Abstracts of Wiltshire Inclosure Awards and Agreements*. Wiltshire Records Society, Devizes, UK.

Stokes, E., (ed) 1914. *Abstracts of Wiltshire Inquisitiones Post Mortem, King Henry III, 1327-1377*. Wiltshire Archaeological and Natural History Society, Devizes, UK.

Verhulst, A., 2002. *The Carolingian Economy*. Cambridge University Press, Cambridge, UK.

Winchester, A., 2006. *Village byelaws and the management of a contested common resource: bracken (Pteridium aquilinum) in highland Britain, 1500-1800*. IASCP Europe Regional Meeting.

Yalden, D., 1999. *The History of British Mammals*. Poyser, London.

Young, C., 1979. *Royal Forests of Medieval England*. University of Pennsylvania Press.

Printed Calendars

Pipe Rolls

31 Henry I: 1129-1130

Patent Rolls

7 Henry III: 1222.

8 Henry III: 1223.

23 Edward III: 1350.

1 Henry IV:1399.

1 Richard II: 1376.

Close Rolls

1 Henry III: 1227-1231.

39 Henry III: 1254.

55 Henry III: 1270.

Acts of Parliament

Statute for the Preservation of Woods, 35 Henry VIII, chapter 17.

Primary sources

Wiltshire and Swindon Archives.

WSA 9-2-388: Lawsuit Extent St Margaret's Common 1762.

WSA 9-14-223: Survey of the manor of Crofton Fitzwarren c1597.

WSA 9-22-240: Presentments at the court of 'Morleighe Savernack', 1565, concerning forest animals.

WSA 9-26-512: Bargain and sale of oak trees, 1575.

WSA 192-44: Account book of the Earl of Hertford's Savernake Estate.

WSA 1300-1: Grant c1250, of Geoffrey Esturmy to hospital of Easton 50 acres of his wood in Savernake.

WSA 1300-12: Charter of King John, c1200, granting Henry Esturmy wardenship of Savernake.

WSA 1300-86: Savernake Forest Court Book 1541-1557.

WSA 1300-87: Savernake Forest Court Book 1577-1609.

WSA 1300-104: c1598, Legal Papers Savernake Forest.

WSA 1300-153A: Plea of the Eyre held at Amesbury, 1490 (citing earlier records).

WSA 1300-1500: Instructions to forest keepers at Savernake.

WSA 1300-6574: Notes by H.C. Brentnall relating to military service of Sir William Esturmy.

Longleat House

Seymour Papers, Volume V, fos 56, 57d: Correspondence Sir John Thynne and the Earl of Hertford.

Seymour Papers, vol XII: Tenancy agreements.

National Archives (Public Record Office)

PRO E32-217: Forest Plea Rolls Edward I – Edward III.

PRO E32-348: Portions of a forest eyre roll for Savernake forest.

PRO E146-2-27: Roll of Henry Esturmy, warden of Savernake Forest, c1350.

PRO E146-2-33: Pleas of Savernake Forest at an attachment court held at Wilton 1245.

Chapter 5
The Importance of an Open Grown Tree – from Seed to Ancient

Ted Green

A Tree is merely a unique dynamic individual support system for Fungi and other micro-organisms.

Abstract

This article is an attempt to illustrate the importance of open grown trees for biodiversity. Initially there was no intention to make comparisons between the two extreme growth forms of trees i.e. the open grown form versus the forest form shade tolerant tree of a similar age, especially because of the vast range of conditions affecting their growth to speculate on. However in preparing the article it became clear that there might be interesting to speculate on some of the comparisons to be drawn between the two forms at either end of the spectrum. In the exercise the challenge has been of setting out and describing some of the vast array of habitats provided on and within a single tree which are an integral part of the complex co-evolutionary relationships with other organisms.

Introduction

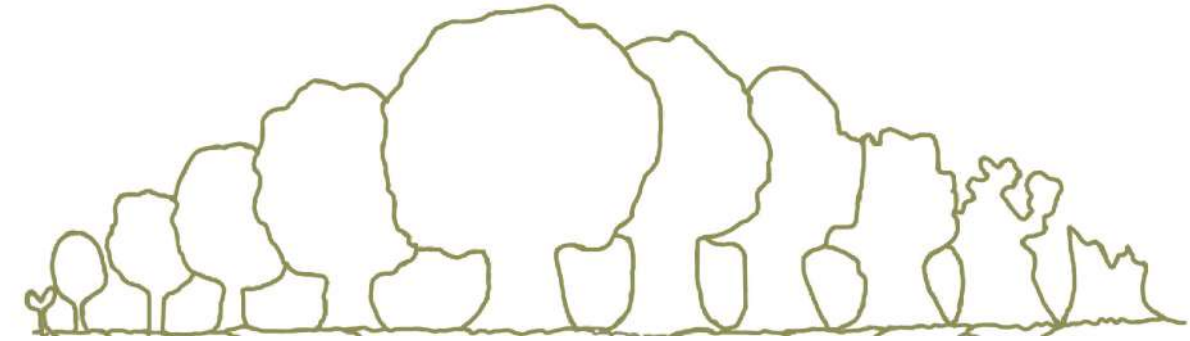
Old, open grown trees in open, park-like landscapes are an essential component of the Vera (2000) hypothesis and include any treed landscape that has light demanding and shade tolerant tree species. These open grown trees have provided biological continuity for visible and invisible, old growth biodiversity down the centuries and perhaps even millennia. As early as the 1960s the late distinguished ecologist in the UK Francis Rose, from his specialist knowledge of lichens, was expressing doubts (pers comm.) about the concept that prevailed at the time amongst European ecologists that dense, continuous, closed canopy forests extended across the whole of northern Europe. The importance and conservation of the open grown tree as natural, cultural and literary icons (Spector et al., 2006) is now gaining recognition across the world. In Australia, for example, the best working definition of woodland is 'ecosystems that contain widely spaced trees with their crowns not touching' (Lindenmayer et al., 2005). Bergman (2006) emphasises the importance of open grown oaks in conservation of their biodiversity in Swedish archipelagos.

Across Temperate Eurasia, and the Mediterranean region, these open landscapes have been extensively replaced by arable farmland and man-made dense canopy commercial forests comprised of mainly shade tolerant species That open grown trees of all ages often in ageing parkland and including hedgerow trees remain in the UK in such numbers is therefore one of the most important contributions to the biodiversity of Europe.

Description and comparisons

An open grown tree is a tree that may have grown virtually all its life without competition from other trees. It usually has a short, squat, fat trunk with a very large diameter, often with large spreading limbs especially in the lower crown of which some grow out almost horizontally.

Sequential changes of the crown area/volume and trunk girth/volume of an individual open grown oak (*Quercus* spp.) **Figure 5.1**



Overall time span could be up to 500 years and might be up to 1000 years. Given ideal soils and conditions.

They generally have a large dome-like crown compared with a forest form tree that is tall with a narrow trunk and a small crown. The forest form tree may often retain dead limbs below the crown (depending on species and growing conditions) which have died primarily through competition for light dependant on the extent and depth of it's own canopy and that of it's of neighbouring trees. The degree to which the tree is a light demanding or shade tolerant species will also have some influence on its growth form especially where it is influenced by surrounding trees. This is especially relevant when comparing light-demanding trees such as oaks (*Quercus* spp.) and pines (*Pinus* spp.) with shade-tolerant trees such as beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) for a comparison of light requirements of tree species, the mass and diversity of canopy in woodland and crown might in many instances be very similar. However per tree, the production of leaves and roots will be far greater in the open grown form. Recent research (Kaetzel et al., 2012) comparing the biomass production an open grown oak with a forest form oak found. The vitality (crown structure), mortality rate and the ecological function (habitat structures of wood for insects and fungi) of those oaks were observed between 1992 and 1994 as well as between 2010 and 2012. The vitality of trees was found to be closely related to free range distance and existence of competing neighbouring trees. Likewise, the mortality rate was strongly determined by the pressure of competition exerted by younger adjacent trees. The observed survival rate confirms the considerable adaptability of these old oaks compared to younger, denser oak stands. The mass of leaves is ca. 20 times larger in solitary oaks compared to equally sized oaks from dense populations. Physiological biomarkers confirm the high adaptive potential of free-standing oaks.

The volume of wood in the trunk of a forest form tree might be greater than the trunk of an open grown tree of the same age but the open grown tree will have a greater volume of wood overall, with much of which is in its large spreading limbs giving a far greater and diverse surface area when compared to the single trunk with fewer and smaller limbs of a forest tree. Therefore one can assume equally that an open grown tree of other species of trees compared with a tree of similar age growing in confined woodland conditions will have a far greater diversity of organisms and a greater biomass production.

Figure 5.1 and Photograph 1 obviously there are situations and conditions where trees have to search for water and resources and will produce an extensive root system often extending substantial distances both vertically and horizontally.

The dome of an open grown tree is perhaps the most efficient shape for collecting energy and the greater the leaf area the greater the photosynthesis. The root system below ground is accepted to equate proportionately to the crown above ground. An open grown tree usually has little or no competition from other trees for resources including water, whereas woodland trees face constant stress from neighbours and consequently have shorter lives and if root grafting with neighbours has taken place then the transfer of minerals, nutrients and water from one tree to another through competition could accelerate the

Photograph 1: An open grown Oak (*Quercus robur*) over 400 years old with a full crown spread of over 35 meters. The large spreading lower limbs indicate the tree has grown it's whole life unrestricted in the open.

decline of any weaker individual trees. The former may therefore have a far greater life span and be productive also providing an ever changing habitat with age perhaps for as much as several centuries longer

Pollen

It is very clear today that our ancestors discovered the benefits of the open grown tree and the evidence is all around us today in the form of our tree fruit and nut orchards and fields full of shrub and soft fruits. Even cabbages benefit from being individually spaced. This knowledge probably extended back to hunter gatherers, when man would have found that open grown trees and shrubs could produce vastly more fruit than their equivalent in a grove or shady woodland. Naturally before fruit comes flowers and pollen and it therefore begs the question whether the analysis of pollen diagrams today has recognised the quantity and mobility of pollen production from an open grown tree with a large crown compared with the smaller, less productive crowns and reduced mobility of pollen from woodland and close grown trees? It begs the question on how we have arrived at presumably 'the assumed tree and shrub cover of species' when comparing 63 Eurasian species 46 species are either hermaphrodite or insect pollinated and only 17 wind pollinated!!!

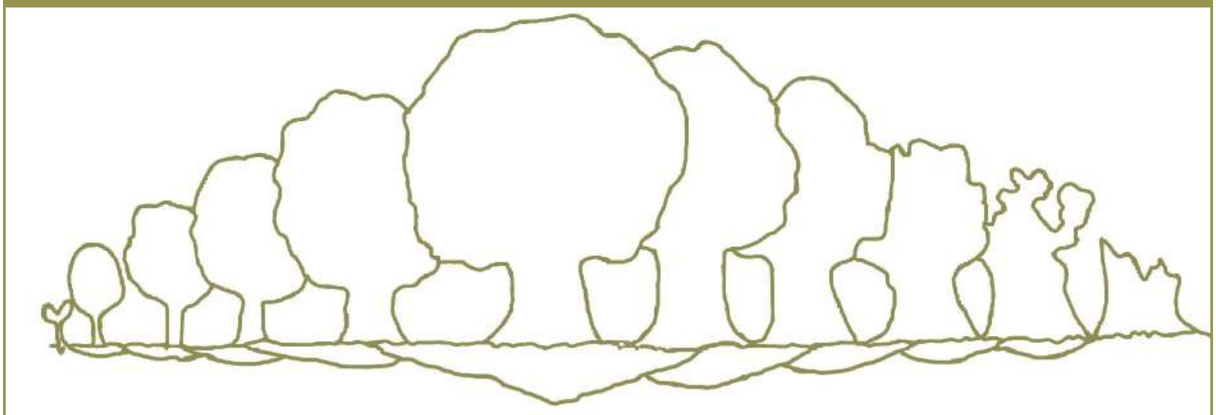
The roots

Underground it is very difficult to assess the extent and volume of any individual root system. However there are some examples to be found. In the UK the Ancient Tree Forum traced roots from an ancient open grown oak in a recently cultivated and destroyed ancient grassland sward. The roots were still 2.5 cm in diameter over 50m from the trunk of the tree. There are also good examples showing the extent of exposed roots; beech trees (*Fagus sylvatica*) that are growing on steep banks along old sunken lanes or quarries; granny pines (*Pinus sylvestris*) on eroded river banks and hillsides; and in the case of ash (*Fraxinus excelsior*) it appears to regularly produce extremely large diameter roots several metres in length just on the surface often the volume and extent of the roots exceeds the crown area and spread. With the exception ash usually the extent of the root area is much greater than the area of the crown The majority of the roots can be found in the top 30cm of the soil, although there are examples in Spain of roots growing down to 9m and still with their mycorrhizal associations! (G. Pasola pers comm.). Even in the semi arid mountainous region of northern Portugal, with regular summer temperatures for 3 months of up to 40 c, there are substantial areas of beech (*Fagus*) woodland and broadleaved wood pasture with ancient open grown oaks (*Quercus* spp.) (said to have been retained as shade trees for shepherds). To survive in these apparently hostile growing conditions it's reasonable to assume that from the time of the seed germination of these trees has responded to these conditions and have been able to put sufficient roots deep into the soil and rock crevices in search of a guaranteed supply of ground water. From the limited research undertaken roots are thought to extend out 1.5 to 2.5 times the radius of the canopy ie well beyond the drip line.

Perhaps a tree's roots can be likened to an inverted, much flattened tree. The 'branches, twigs and leaves' of the root system expand and then contract with age and conditions, probably in direct correlation with the crown and probably brought about through stress for example from prolonged droughts outbreaks of disease or pest infestations which include root herbivores, nematodes and roots broken or damaged during periods of very strong winds. It appears that subterranean dead roots can have a distinct decay (recycling) ecosystem with the main drivers perhaps being fungi bacteria and invertebrates (Figure 5.2).

Forest form trees growing in close competition with small canopies still appear to be capable of gathering sufficient energy to produce often large volumes of wood in the trunk. However trees on the margin with a greater and more efficient leaf area may be able to provide extra energy and resources to their neighbours on the inside

Sequential changes in the root area in relation to crown area of an individual open grown oak **Figure 5.2**



Sequential changes in the root area in relation to crown area of forest form trees

Figure 5.3

of the group via their network of grafted roots and their mycorrhizal partners in fact it may be they are actually be continually robbed of resources (Figure 5.3).

In dense beech (*Fagus* spp.) or other woodland of other shade tolerant species or groves of any or varied age, presumably the greater the number of trees, the greater density, the greater the competition, the greater the progressive self-thinning and subsequent death, the greater the production of non-living wood (deadwood), the greater the recycling of minerals and nutrients from the decaying wood. Therefore there is a constant supply of nutrients to the survivors through this recycling. Actually with non-intervention by man it is a natural structural; successional; sustainable; supply of decaying wood from seed to ancient. By having a very efficient, co-evolutionary, micro-organism support system it may be the trees only require a relatively small root area especially feeder roots. Individual trees do not require large spreading buttress roots for support as they are growing in dense tight conditions. They give each other group support against the elements reducing the need for each tree to adapt individually to caused by wind exposure. However the situation is similar to that in the canopy and there is intense competition for any available space from other trees and plant roots to colonise in these far more restricted dense grove conditions.

It is generally accepted that open grown trees develop substantial buttress roots in response throughout its life to movement through the continual exposure to wind events. It will therefore have a greater number, diversity and mass of micro-organisms associated with the roots simply through the greater area available to individual species to colonise the roots.

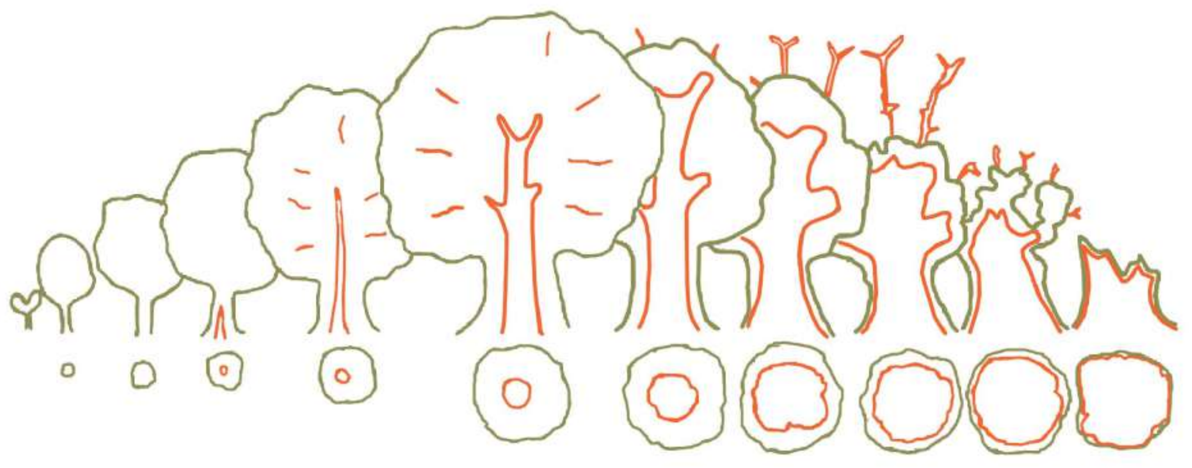
Fungi and other micro-organisums in the soil and decay

Decaying wood is the woodland soil of tomorrow'. One also needs to take account of essential mycorrhizal associations (Merryweather, 2001). They may extend over very large areas and can be interconnected with other trees of all ages and even different species of trees and other plants. It is assumed that many species are warmth loving and therefore can benefit from exposed areas under open grown trees. These complex relationships can be ever changing and are now increasingly being recognised for their fundamental importance in natural ecosystems.

The biodiversity of the decay (recycling) system is extremely complex and poorly understood. It's diversity of species both visible and invisible that carry out essential roles in the breakdown of all non living matter and comprise the major players - 'the bio-engine of recycling', can only be speculated on. We know it would include bacteria, fungi, invertebrates (of which nematodes must be singled out for their importance) and presumably any single organism could be the primary coloniser which might then facilitate an ever changing succession of other micro-organisms. All these organisms will provide food for other organisms. Fungi are considred to be a major part of the essential bio-engine of all plant ecosytems and can be divided into the decayers (recyclers) of dead matter and Mycorrhizal fungi (the food gathers) which in a co-evolutionary complex symbiotic partnerships with trees perform a fundamental role by providing minerals, nutrients and trace elements which are often not available to the tree or other plants by ant other means. Also because of their longevity fungi and trees are an excellent example of providing biological continuity for future generations perhaps spanning centuries and even millennia. The fruit bodies produced by fungi in the ecto mycorrhizal group are an interesting example. The soft fleshy annual mushrooms usually appear from the end of summer through the autumn and into early winter. Not only are they a source of food for animals including man, slugs, several species of insects (beetles and flies) and nematodes. The insects, often flies, are emerging from the fruit bodies at the time when the bulk of other insects are finished for the year. Therefore they can provide a succession of food especially for birds, bats and small rodents at a period when other insect food is declining. The endo-mycorrhizal group equaly fundamental and essential to their tree partners remain a mistery to scientists, infact as does most of the' world of the soil. Other fungal fruit bodies that have a woody texture are usually perennial and associated with decaying wood and do not necessarily produce adult insects in the autumn months. It must be mentioned that he wholesale picking of fruit bodies for commercial reasons is on the increase. The distructive impact of this continual removal on the tree and woodland ecosystems as a whole appears to be totally lost on society.

In most situations especially in woodland the smaller the volume of wood, either standing, dead or fallen the more rapid the decay process. This is especially relevant in species such as beech that have ripewood and not heartwood as in oak. However non-living wood in open exposed areas generally decomposes much slower including true heartwood which has been air dried and very desiccated in the crown or trunk of a tree through exposure can be sound or only just in the process of

Sequential changes to the deadwood and hollowing of an individual open grown oak (*Quercus* spp.) **Figure 5.4**



slowly hollowing. In the latter case the outer shell can take centuries to decay.

Depending on tree species the length of the decay cycle can be far shorter in the more humid conditions found in woodlands and groves. A mature fallen beech or other tree species forming ripe wood with a trunk diameter of 1m could well disappear back into the woodland soil within 30-40 years. However a large fallen oak limb mainly comprised of heart wood of about 60cm diameter in open exposed conditions might still be present after 50-100 years. Therefore the time-lapse of decomposition of live wood to dead wood ratio is far shorter in woodland shade compared with open grown trees. Regardless of whether the centre of the tree is ripewood or heartwood it will decay more quickly in woodland.

The diverse, often dynamic and ever changing species of fungi and other associated micro-organisms of the decay process present in any tree population, a proportion of the trees will be in the process of hollowing is considered perfectly natural. There is evidence that the greater the volume of decaying non-living wood (the heartwood or ageing ripewood) the increasing importance to biodiversity such as fungi and invertebrates especially in old open grown trees with short fat trunks.

Hollowing of living trees is now widely accepted as a perfectly natural co-evolutionary function in the non-living wood of most plants including palms. It is usually associated with the aging process of the annual growth rings. In deciduous trees the non–living wood is either heartwood or ripewood which can be decayed by many species of fungi that may be associated with other micro-organisms during the decay process. There are circumstances where some species of saproxylic beetle and other insects including tree ants - behaving in a similar fashion to termites, which may also play important roles. The decay of non-living wood in the centre of trees can be an added benefit to the tree by releasing nutrients locked up in the non-living heart- or ripewood. In rainforest systems, minerals and nutrients trapped in the contents of hollow trees eg mould, bat and bird droppings, are very important as a source of nutrients that in other locations would be leached away through high rainfall (L. Boddy, pers comm.). Also a succession of different organisms will benefit from different size cavities created by the progress of hollowing. Not forgetting what must be a rare and tenuous mini ecosystem that has evolved to live solely in 'rot pools' that is water filled cavities found in the mainly in the main stem, larger limbs and hollows created between large buttress roots (Figure 5.4).

"*A supply of succession, structural, sustainable decaying wood from acorn to ancient*".

The decay process of the heartwood can begin when the tap root begins to die, however the hollowing process may also begin in other areas of the tree by totally different species of fungi and other micro-organisms (Figure 5.5 and Figure 5.6).

In most situations especially in woodland the smaller the volume of wood, either standing, dead or fallen the more rapid the decay process. This is especially relevant in species such as beech that have ripewood and not heartwood as in oak. However non-living wood in open exposed areas generally decomposes much slower including true heartwood which has been air dried and very desiccated in the crown or trunk of a tree through exposure can be sound or only just in the process of slowly hollowing. In the latter case the outer shell can take centuries to decay.

Conclusions

It has been a very thought provoking exercise to try and encapsulate the differences between open grown and forest form trees over time. It has thrown up more questions than answers. In fact no attempt has been made to explore comparisons between under crown and canopy ground cover or understory trees and shrubs in relation

Figure 5.5 Sequential changes to the hollowing of forest form trees

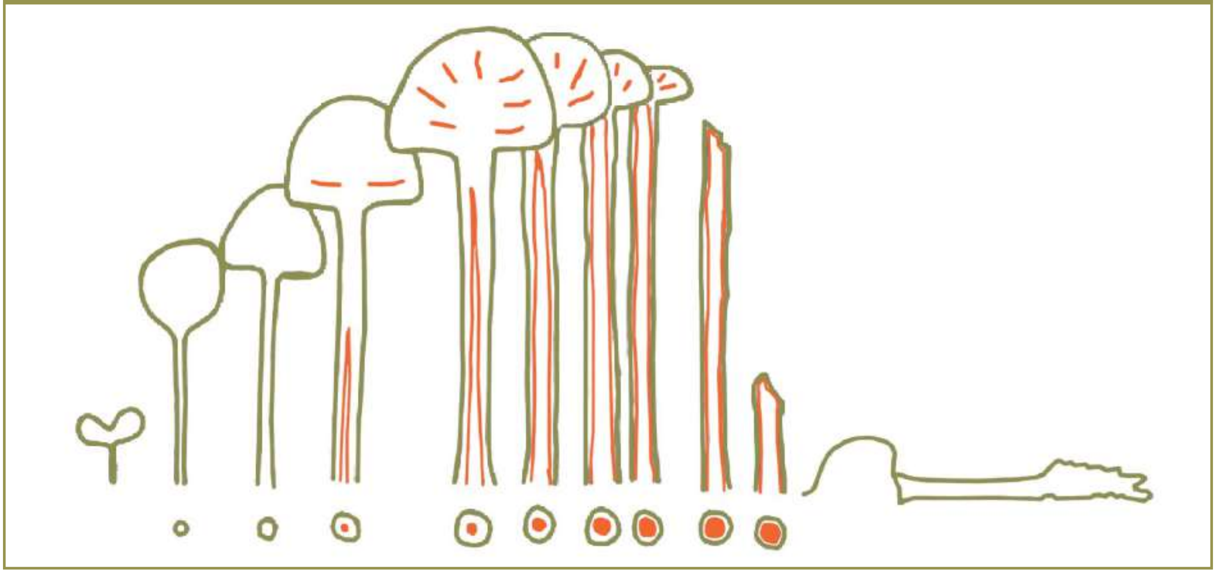
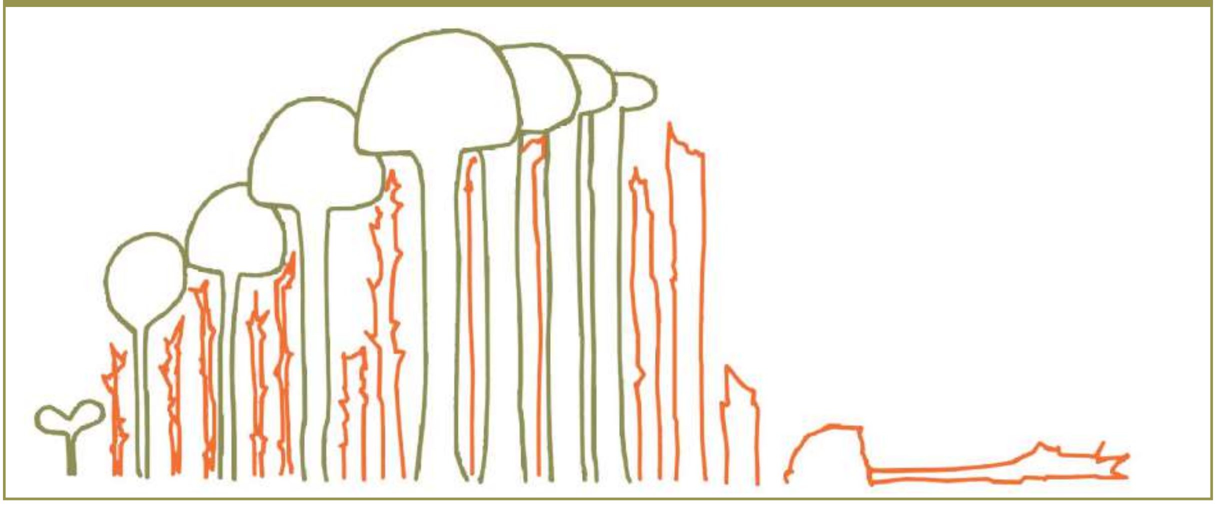


Figure 5.6 Sequential changes to deadwood from self-thinning through competition from neighbours in dense woodland



to light demanding or shade tolerant species However, one important question is answered and that is that our old open grown trees of open treed landscapes and wood pasture hold the key to the past. And it is hoped the debate will continue.

Acknowledgments

I would like to thank the late Francis Rose for his encouragement to think 'outside the box' to Keith Alexander, Jill Butler, Mick Crawley and other members of the Ancient Tree Forum for sharing their knowledge and experiences. Special thanks to Frans Vera for his inspiration and as the late Francis Rose said 'His work is Landmark'. This paper is a revised version of The Importance of Open Grown Trees from Acorn to Ancient- British Wildlife June 2010.

References and Further Reading

Alexander, K.N.A., 1999. The invertebrates of Britain's wood pastures. *British Wildlife,* 11: 108-107.

Alexander, K.N.A., 2008. Tree biology and saproxylic coleoptera: issues of definitions and conservation language. *Revue d'Ecologie* (La Terre et la Vie) Suppl. 10: 9-13.

Bergman, K.O., 2006. *Living coastal woodlands. Conservation of biodiversity in Swedish archipel*agos. [www.svo.se/episerver4/dokument/og/life%20project/]

Lindenmeyer, D., Crane, M. and Michael, D. 2005. *Woodlands, A* disappearing *landscape*. CSIRO publishing, Australia.

Merryweather, J. 2001. Comment: Meet the Glomales- the ecology of mycorrhiza. *British Wildlife,* 13(2): 86-93.

Kaetzel, R., Löffler, S., Becker, F., Kesler, K., Schroder, J., Zander, M. and Strzelinski, P., 2012. V*itality, history, growth and genetics of old oaks in Germany.* Proceedings of Trees beyond the wood. Sheffield Hallam Sept 2012.

Rayner, A.D.M., 1993. The fundamental importance of fungi in woodlands. *British Wildlife,* 4: 205-215.

Vera, F., 2000. *Grazing ecology and forest history*. CABI Publishing.

Chapter 6
Ancient and other trees of special interest: indicators of old growth biodiversity and heritage

Jill Butler

Introduction

"10 000 oaks of 200 years are no substitute for one 500 year old oak"
Oliver Rackham

Despite ancient trees being among the longest lived and some of the largest organisms on the earth, many UK ecologists are only beginning to catch up with understanding their significance to biodiversity and heritage. As trees age, usually from maturity onwards, they provide different habitats for a host of species from different Kingdoms that are not found on younger trees:

- The heart- or ripe-wood decays and the trees become hollow,
- Columns of dysfunctional sapwood develop,
- Stag-headed dead wood occurs in the crown,
- Decaying wood breaks off and falls to the ground,
- The bark ages and its pH changes and
- The roots age and hollow.

Tree populations are constantly aging and it is important that the habitats they provide are adequately replenished. One break in the timeline may result in extinction of species locally and even nationally.

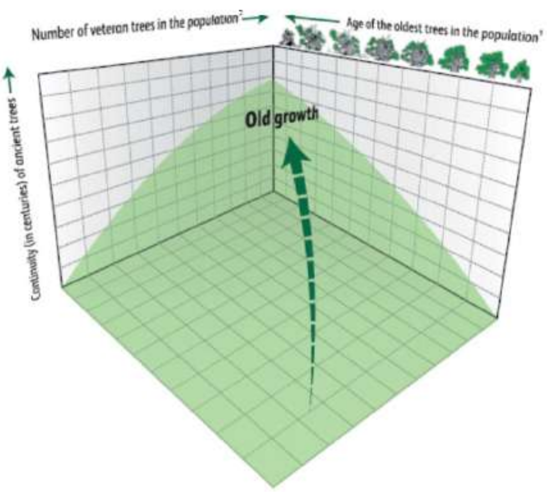
The aging trees and their decaying wood habitat together with the associated, specialist decay and mycorrhizal fungi, lichens and invertebrate species is known as old growth. The Convention on Biological Diversity (CBD) defines old growth as stands in primary or secondary forests that have developed the structures and species normally associated with old primary woodland of that type that have sufficiently accumulated to act as a woodland ecosystem distinct from any younger age class (Alexander et al., 2003) (Figure 6.1).

Some Swedish research looked at the habitat requirements for hermit beetle *Osmoderma eremita* and found that a minimum area of 57 ha, containing 160 hollowing oak trees, is necessary to sustain this species but that for more demanding species the minimum area would be 954 ha, including 2,670 hollowing oaks.

For old growth to be fully expressed, a proportion of the trees must be allowed to grow full crowns which can retrench or 'grow downwards' in the latter stages of their long lives especially if the species are very light demanding such as pine or oak. An open crowned tree provides habitat that is not found in closed canopy forest such as large lower horizontal limbs in various light conditions depending on their orientation to the sun. Also, if too closely spaced, the aging trees are overtopped as their crowns retrench and are out competed especially in the presence of more shade tolerant trees especially hornbeam and beech. Old growth stands in the UK usually have a very wide diversity of tree and shrub species across the whole range of light demanding to shade tolerant. They also have a long history of grazing and look like parkland with scattered open crowned trees – the open forest hypothesis (Vera, 2000). In the UK the rich habitats in which old growth species have survived are usually not on the UK Ancient Woodland Inventories which represents woods comprising young trees in a coppice or plantation structure. In the UK, stands of old trees and their associated specialist species are commonly found in historic landscapes such as:

- Remnants of mediaeval Royal Hunting Forests – places such as Windsor Great Park and Forest and Sherwood Forest with a wide diversity of native species principally oak, beech, birch, alder, sweet chestnut and lime plus shrubs providing nectar such as hawthorn standing in pastures and heath.
- Caledonian forest – characteristically widely spaced granny pines with birch, alder, rowan and juniper standing in bilberry and moor.
- Mediaeval deer parks – oak with many other species of tree with more recent non-native ancient and veteran trees of great value in grassland but in recent years sometimes converted to arable.
- Ancient hedgerows, old commons and wood pastures

A conceptual representation of current knowledge about habitat quality in relation to tree age and tree population size **Figure 6.1**



The richest diversity, typical of "old growth" occurs where ancient open-grown trees of successive generations have continuosly formed part of a substantial tree population for many centuries. Since some of the species that depend on ancient trees have very limited powers of dispersal, many of these are confined to a few sites where continuity of their habitats has not been broken (Lonsdale, 2013).

Note: The properties shown on the axes of this graph represent generalised concepts only, as indicated by the following key to the asterisks:
[1] The "age of the oldest trees" could be calculated in various ways; perhaps as the average age of the oldest 5 or 10 per cent of trees in population. Such a calculation would, for example, help to avoid over-estimating the contribution of a single ancient tree in a population of much younger trees.
[2] The number of "veteran trees in the population" could, for example, be calculated as the number of verifiably identified open-grown veterans that each occurs within a given distance of one another. This distance could be decided in order to take account of the dispersal ranges of decay-dependent species of low mobility. The distance could be adjusted in order to help identify sites that merit designation for protection and for future enhancement.

of pollards of a wide variety of native species including oak, beech, ash, hornbeam, alder, holly, rowan.

Unfortunately, few sites retain the grazing conditions that are characteristic of the best old growth areas such as the New Forest where commoning still provides traditional mixed grazing by large herbivores - ponies, cattle and pigs as well as wild deer and rodents. Many old growth Forests are being lost to secondary tree establishment, especially of shade tolerant species, that are suffocating the old trees or have been subject to arable or grazing intensification with serious consequences for the trees.

Old growth stands are not recognised on any inventory in the UK, even as wood pasture or parkland. Up until recent times parkland old growth has been labelled rather apologetically as a 'cultural' or rather man-made habitat and not a semi-natural one and its value has been severely diminished. Although at its best could be said to be the closest to the wildwood before man had a significant impact. By comparison with woodland, there is often for old growth sites documented historical evidence back to Anglo Saxon times i.e. hundreds of years prior to 1600 the cut-off year off date for the Ancient Woodland Inventory. The result is that in planning and landscape scale strategies it is all too easy for old growth or landscapes rich in ancient and veteran trees to be invisible to non-specialists and overlooked.

What are ancient and other trees of special interest (TSI)?

"*The man of science and of taste will discover beauties in a tree which the others would condemn for its decay.... Sometimes he will discover an aged thorn or maple at the foot of a venerable oak; these he will respect, not only for their antiquity, being perhaps coeval with the father of the forest, but knowing the importance of the oak is comparatively increased by the neighbouring situation of these subordinate objects*"
Humphry Repton, 1806

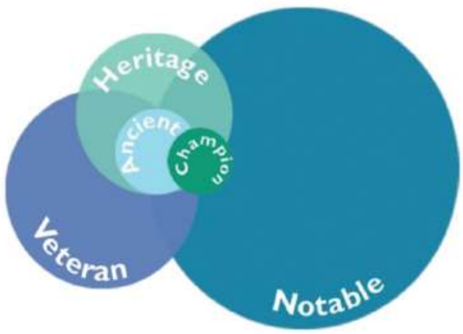
The Ancient Tree Forum, an NGO established in the 1990s, grew from the increasing awareness of the role of these trees for biodiversity. They have been the leaders in the UK in defining what distinguishes ancient, veteran and notable trees.

Ancient trees are defined by their age and are trees in the third and last stage of three stages of development - young, mature, ancient. Veteran trees are those trees of any age which exhibit important decaying wood habitat – hollow or hollowing trunks or branches, decaying wood in the crown or already fallen to the ground, crevices or flaking bark. All ancient trees are also veteran trees but not all veteran trees are ancient. Notable trees are those that are large girthed, mature trees by comparison with trees of the same species, but are not old enough to be considered ancient nor exhibiting veteran characteristics. They are still valuable as the generation of trees that will soon have veteran features or become ancient. Traditional pollards will often have deceptively smaller girths than a similar aged maiden tree but because of past management are likely to be rich in veteran characteristic habitat. All ancient or veteran trees are important including non-native trees. There are other categories of special interest such as champion, rare or other heritage trees, where these trees do not also have characteristics of ancient, veteran or notable trees, their records are kept by the Tree Register of the British Isles (www.treeregister.org) (Figure 6.2).

Diagram to indicate the way different categories of tree value relate to one another

Figure 6.2

Collectively these trees are called Trees of Special Interest (TSI) (Woodland Trust, 2008).



Additional information on the features and values of trees of special interest is provided in "Ancient Tree Guide no 4: What are ancient veteran and other trees of special interest " and also "Ancient and other veteran trees: further guidance on management" (Lonsdale, 2013).

Mapping ancient and other trees of special interest - the Ancient Tree Hunt

During the Veteran Tree Initiative (1996-2000), a UK wide awareness raising project led by English Nature (now Natural England) with other partners including the Ancient Tree Forum, many organisations were inspired to undertake veteran tree surveys. These varied in scope and depth – some involved detailed site surveys based on the Specialist Survey Methodology (Fay, 2003) by professional surveyors, others covered larger administrative areas and were often citizen science based, gathering only basic information about the trees and their location. All of the surveys demonstrated the growing need to do something tangible like mapping and recording trees as part of the process of conserving them.

The Woodland Trust in partnership with the Ancient Tree Forum and the Tree Register of the British Isles went on after the end of the Veteran Tree Initiative to develop the Ancient Tree Hunt (ATH). The aim of the ATH was to inspire more ordinary people in mapping the most valuable trees in the UK landscape and that the process of collection would inspire owners, government agencies and authorities at national and local level, NGOs, communities and individuals to take action to secure their future (no further avoidable loss) and to establish new trees so that this heritage could be taken forward into the future.

Outcomes from Ancient Tree Hunt

At the end of December 2012, a British, European citizen added a 112,000th hand-picked, special tree to the growing UK Ancient Tree Hunt database. Thousands of people have so far participated by contributing their favourite tree record. Dedicated recorders continue to explore the length and breadth of the British countryside to seek out and capture the vital statistics of the UK's most special trees, take long lasting 'fixed point' images of their find and upload the information to the live database, mostly in the hope that this action will raise awareness of the value of each and every remarkable tree to the landscape and help to secure its future. On average 20,000 tree records are added each year and the likelihood is that there are so many trees of great interest yet to find in the UK that the process could continue for the next decade if the capacity can be maintained to embrace this level of engagement.

Each record is a special tree that by its shape and presence speak to us from out of the past, is a living ecological encyclopaedia and a grand master in its own right. They are keystone historic and ecological structures playing unique and exceptional roles that are not provided by younger trees (Figure 6.3).

The Ancient Tree Hunt has been a success especially from a citizen science perspective in terms of direct engagement of the public and wider public relations awareness raising (Table 6.1).

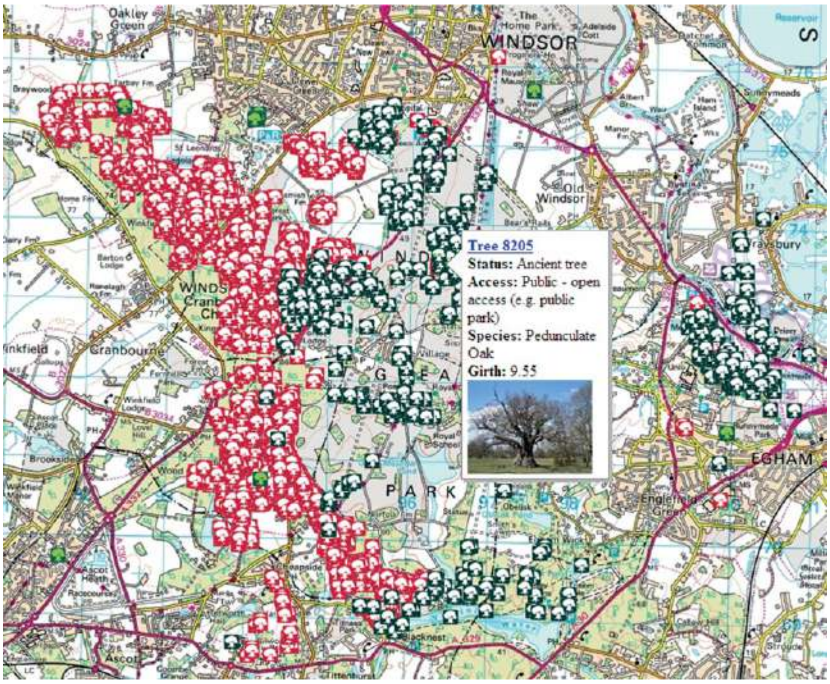
One of the priorities for the project was to develop a team of trained volunteers who could review data added by the general public and amend it where necessary to ensure that the data collected was as robust as possible.

Targets and actual outcomes for the first five years of the Ancient Tree Hunt Project 2006-2011

Table 6.1

Objectives	Target	Actual
National and regional partnerships	15	100
Website visitor sessions	600,000	1,000,000
Audience Reach	95,000,000	300,000,000
Training events	126	240
Trained recorders from events	1890	3000
Public events	150	530
Participants on events	2250	77,570
Tree records on the map	100,000	100,199
Observations including images	50,000	62,700
Active volunteer verifiers	15	130
Numbers of people actively participating	40,195	70,000
Curriculum-based resources for schools		15, 583

A screen capture from the Ancient Tree Hunt map — Figure 6.3



Individual tree locations in Windsor Great Park. Each tree has a more detailed record linked to the tree icon.

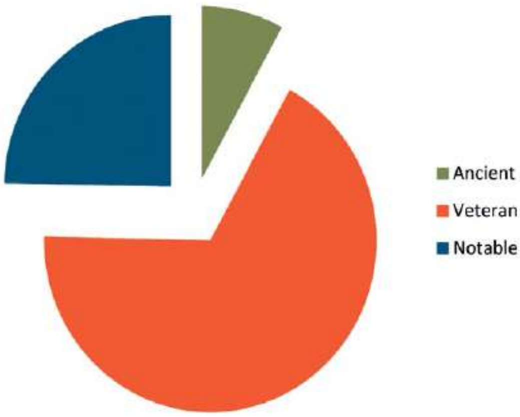
In addition

- 1,000 local and national champion trees were recorded
- 68 per cent of all trees recorded were verified as being ancient or veteran (Figure 6.4)
- 61,000 individual photos were uploaded
- 19,000 trees were recorded as pollards - an historic form of tree management
- 45,000 of the trees recorded were oak
- The top five tree species recorded were: Oak (*Quercus robur* and *Quercus petraea*), Beech (*Fagus sylvatica*), Ash (*Fraxinus excelsior*), Sweet chestnut (*Castanea sativa*), Yew (*Taxus baccata*)

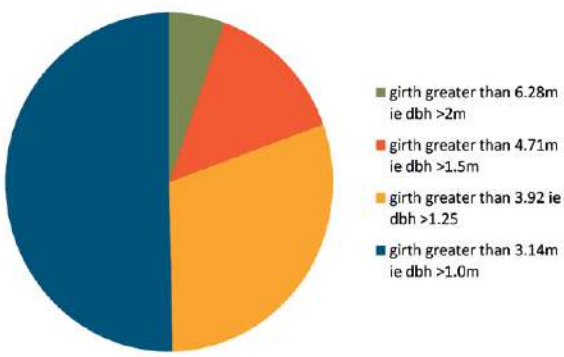
At the end of 2012, 103,642 trees (approximately 75%) had been verified largely by 130 active volunteer verifiers. Trees that are unverified are marked by a different symbol on the map.

The original English Nature (later Natural England) document from the Veteran Trees Initiative states: "..a rule of thumb is that most trees over 1m dbh are potentially interesting, the majority of trees over 1.5m are valuable, and all native trees over 2m dbh are truly ancient." (Figure 6.5).

Pie chart showing the proportions of different categories of trees recorded by the ATH — Figure 6.4



Pie chart showing the proportions of trees categorised due to their girth and diameter recorded by the ATH — Figure 6.5



Old growth hot spots

One of the primary outcomes of the ATH project has been to use the results to help identify important concentrations of trees i.e. potential old growth hotspots around which to focus landscape scale action.

An analysis of the data took place in August 2011 when there were approximately 100,000 records on the database. The results only provide a provisional assessment of the resource as the dataset is still incomplete. Expert qualitative assessment of the UK TSI trees suggests that the database may at present contain 20% of the ancient, veteran and large diameter (greater than 1.5m dbh) trees – ie the most individual, special and valuable trees in the UK landscape. The Specialist Survey Method Review (Fay, 2003) from English Nature estimated that there were 9 million trees with dead wood habitat value in British Isles.

The analysis was based on a Joint Nature Conservation Council protocol (JNCC 2006) to be used in the assessment of nationally important Sites of Special Scientific Interest for biodiversity. The protocol is based on priority criteria which are the numbers of ancient and veteran trees and trees with a dbh greater than 1.5m (Table 6.2).

The development and refinement of this protocol benefits the identification of valuable old growth sites. The trees used are large and permanent and are therefore very simple to record and a one off record lasts for the lifetime of the tree. This is a very straightforward exercise compared with detailed surveys most commonly for rare invertebrates or lichens and very occasionally for important fungi.

The protocol should be considered provisional as it has yet to be properly tested against a significant number of sites of known biodiversity value. There are also issues related to the thresholds. For example the requirement for a significant number of trees to have large diameters favours those sites with trees, such as oak and beech, that may grow to a large size in the lowlands. The cut off point between a high and other value sites should be more graded. A site may have 14 ancient, 99 veteran and 14 large diameter trees and be categorised as medium quality and yet would be only two trees different from a high value site. In addition the protocol does not allow for a mix of categories. In the examples below an intermediate category, orange, which lies between high and medium, has been identified for sites with 1-2 primary field measures in the high category but not all three.

Analysis of the data was undertaken initially on 125m, 250m and 500m radii around the trees see Figure 6.6.

At a more local level the individual trees that make up the collection can be seen. As the hotspot is built up by connectivity between the trees, its shape does not follow ownership, geographical or political boundaries. Both of these factors encourage wider landscape scale consideration (Figure 6.7).

Protection

A red hotspot should be considered equivalent to a Special Area of Conservation (also known as a Natura 2000 site in other European countries). However the EU Habitats Directive does not contain a description that matches the UK, parkland, old growth habitat on Annex 1. Nor does Annex 2 contain any lichens or fungi and only a limited range of saproxylic beetles - the primary species which should be used to confirm primary, old growth habitat. Even many old growth National Nature Reserves cannot be designated as SACs as a consequence. In the absence of adequate recognition in EU legislation, perhaps another more appropriate landscape designation such as Biosphere Reserve should be used or a new one created such as Important Tree Area to match Important Bird Areas.

Many of the high value concentrations of ancient and other veteran trees in the UK lack any national or local protection. It is well known that the wood pasture and parkland (or old growth) priority habitat is poorly recognised in the suite of sites designated as Sites of Special Scientific Interest or Special Areas of Conservation despite this new evidence.

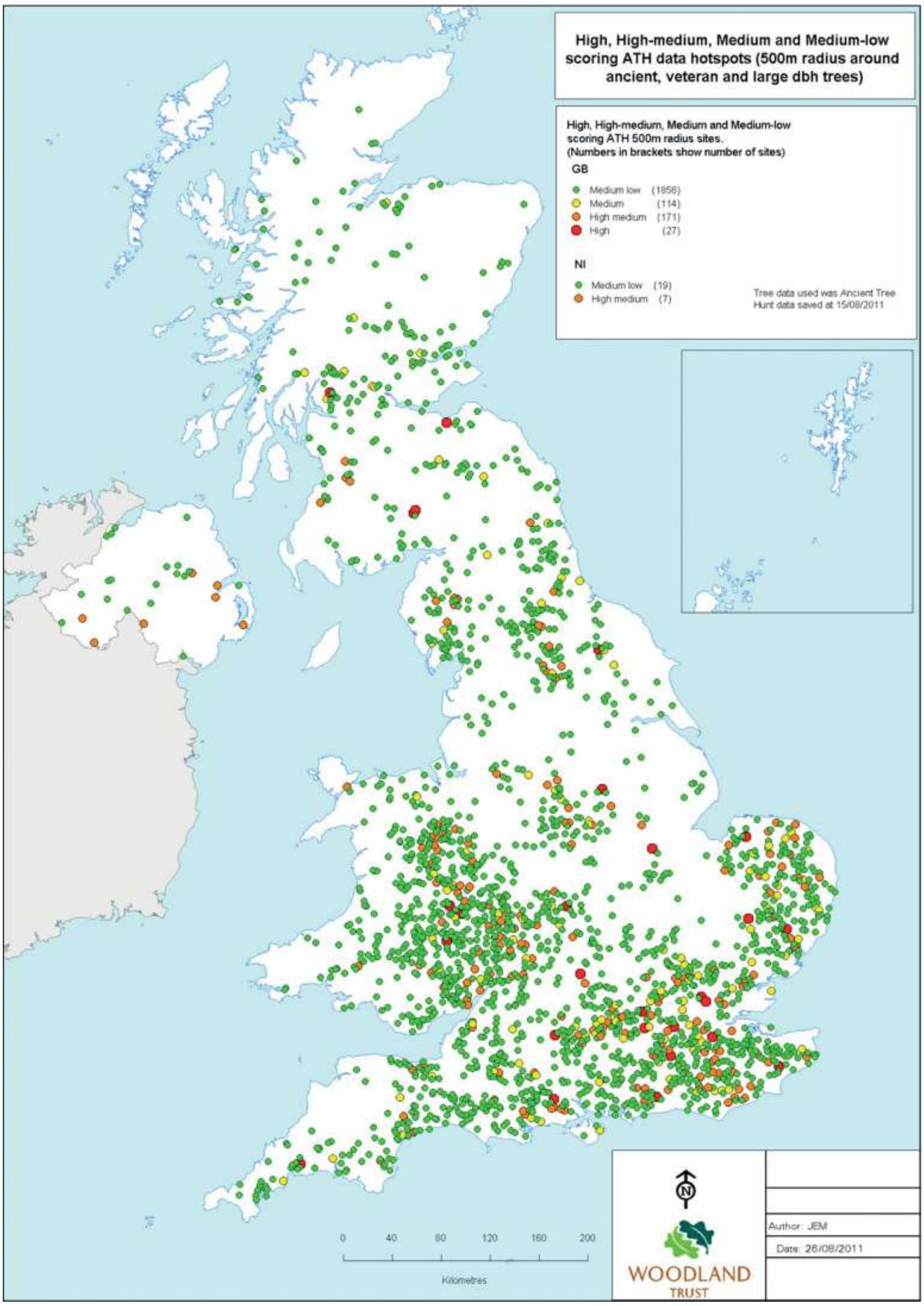
Conclusions

The quality of the tree records on the Ancient Tree Hunt is remarkable and demonstrates the value of citizen science projects. The majority of the trees recorded are completely new to the experts and some outstanding 'finds' have been captured. The project has mapped thousands of ancient trees - the most valuable trees in the UK landscape. These hand-picked trees go to show that the UK has landscapes rich in special trees that we should value above all others because of their age, size or condition. The UK benefits from this Natural Capital of fat, old and decaying trees.

Table 6.2 The numbers of ancient and veteran trees and trees with a dbh greater than 1.5m

	Area Quality Value		
Primary field measure	**High**	**Medium**	**Low**
No Ancient Trees	15+	1 to 14	0
No Veteran Trees	100+	11 to 99	3 to 10
No trees with dbh >1.5m	15+	6 to 14	2 to 5

Map showing locations of high to medium value, hotspot collections of trees in the UK **Figure 6.6**



Results from data analysis of 100,000 tree records August 2011.

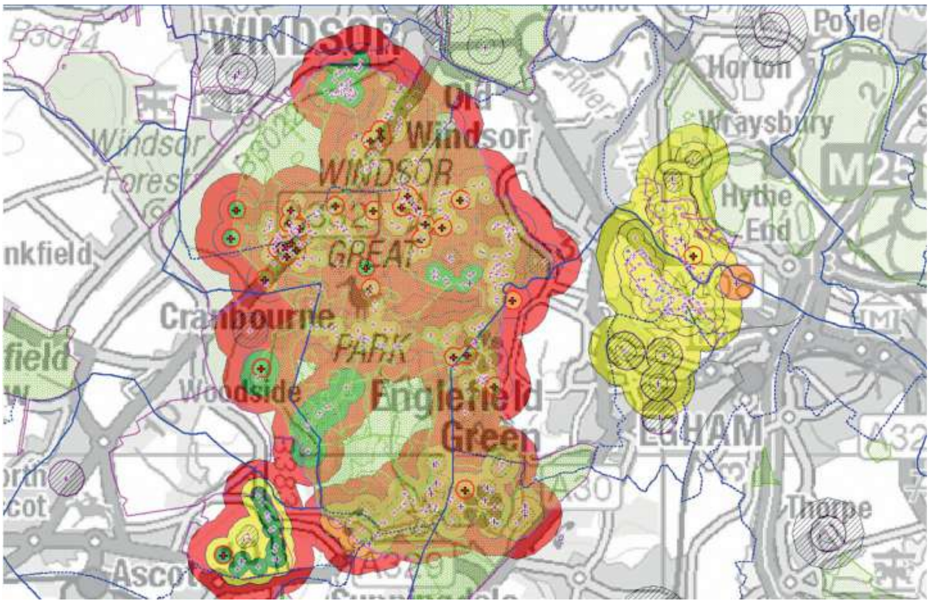
Finding and recording trees has helped them to be better recognised, as individuals, as hotspots and as part of landscapes. The process of collection has inspired owners, government agencies and authorities at national and local level, NGOs, communities and individuals to seek ways to safeguard their futures.

The analysis of the data indicates the places in the UK with some of the best old growth stands although absence of data is not evidence that no old growth is present – further tree record collection should be continued as it is of such biodiversity value. Other types of analysis should be considered such as kernel density analysis. This may better indicate the hottest locations and zones of value radiating from them.

The majority of TSIs in the UK face unprecedented threats similar to those across the world. Recent research provides shocking evidence of massive declines of some of the largest organisms on earth (Lindenmayer et al., 2012). Losses are primarily due to intentional removal, new pests and diseases, root compaction and

Spatial analysis of the data at a local level

Figure 6.7



Windsor Great Park and Runnymead Protection

damage especially from agricultural intensification, competition and removal due forestry intensification and fire. However the biggest danger is that the loss is iterative and cumulative – one tree here, another there, so it is remarkably difficult to see the overall picture until very late in the day. If such trees are lost and populations continue to collapse, as predicted, with them will also disappear the ecological, historic and landscape roles of these keystone structures that cannot be provided by younger trees.

The Woodland Trust and Ancient Tree Forum campaign for it to be a national priority to seek to safeguard their lives for as long as possible. It should also be a Europe wide aim for all countries to capture the records of old or giant or hollow trees and pollards and the habitats in which they occur with the aim of using the data to raise awareness of these large, very long-lived organisms and help to conserve global old growth biodiversity and history associated with them.

References

Bergman, K.-O., 2006. *Living coastal woodlands: conservation of biodiversity in Swedish archipeligos*. Swedish Forest Agency.

Butler, J.E., Rose, F. and Green, E.E., 2001. *Ancient Trees, icons of the most important wooded landscapes in Europe.* NACONEX.

Lindenmayer, D.B., Laurance, W.F. and Franklin, J. F., 2012. Global Decline in Large Old Trees. *Science*, 338: 1305-1306.

Lonsdale, D., 2013. *Ancient and other veteran trees: further guidance on management*. Tree Council.

Rackham, O., 2009. Foreword. In: Pollard, E., and Brawn, E., (eds.), The Great Trees of Dorset. The Dovecote Press.

Repton, H., 1803. O*bservations on the Theory and Practice of Landscape Gardening*, T. Bensley, Bolt Court for J. Taylor at the Architectural Library, High Holborn, London.

Vera, F.M.W. 2000. Grazing ecology and Forest History. CABI 528 pp.

Woodland Trust, 2008. What are ancient, veteran and other trees of special interest?, Ancient Tree Guide No:4, 7 pp.

Chapter 7
Worked Trees and Ecological Indicators in Wooded Landscapes

Ian D. Rotherham

Summary

A consequence of the long-standing traditional uses of trees in the woods and the long-term continuity and connectivity of uses through many centuries enables us to 'read' the landscape (Rotherham, 2011, 2013). The relationship between the natural conditions, and the history of uses of the woodland have led to numbers of species such as ground floor plants being useful as so-called 'indicators' and antiquity and continuity of a wooded landscape on the site (Hermy et al., 1999; Goldberg and Kirby, 2002/3; Crawford, 2006, 2009; Castle et al., 2008; Rose, 1999; Peterken, 1974, 2000).

Combining such indicators with an analysis and understanding of 'worked' trees can provide a very useful insight into woodland history, use and management. There are two main types of 'modified' trees through extraction of 'wood' and of 'timber', together with numerous other variants on the themes. These two forms of modified tree are pollards and coppices, and they can be related to basic types of woodland management or use (Jones, 2009; Rackham, 1986).

This chapter provides an introduction and overview to the approaches and the issues raised.

Coppices and wood pastures

In Britain, there are two broadly distinct 'ancient woodland' landscapes. Firstly, there are coppice woods, often managed since medieval times as simple coppice, or more frequently 'coppice-with-standards' (Rotherham, 2012, 2013). These have few obviously large trees, but strikingly rich and sometimes diverse ground floras (Photograph 1). Secondly, there are parklands, which may have historic links back medieval parks. These areas generally have poorer ground floras due to grazing livestock, and are characterised by massive and ancient trees, chiefly 'pollards'. In terms of wildlife conservation, it has been assumed that coppice woods were excellent habitat for woodland birds and flowers and parks for rare lichens and fungi growing on the trees, and insects or other invertebrates that depended on veteran tree dead wood habitat (Rotherham, 2007ab). Medieval parks were part of a suite of landscape types that mix trees and grazing or browsing mammals. These included wood-pasture, wooded commons, forests as relicts of a great wooded savanna across much of north-western Europe (Vera, 2000; Rotherham, 2013). Parks are 'pasture-woodland', related to forests, heaths, moors, and some commons, with grazing animals and variable tree cover. Aside from the obvious external enclosure, they were essentially unenclosed grazing lands. In the two centuries following the Norman Conquest, numbers of parks in England increased dramatically to perhaps three thousand or more, with possibly fifty in Wales, and eighty in Scotland. From the early 13th century, a royal licence was technically necessary to create a park in areas of royal forest; though in both England and Scotland baronial parks were created without licence. Where documents survive, they provide invaluable reference materials for a now vanished age, giving insight into landscape and ecology. The average English medieval park was around 100 acres though size varied considerably (Rotherham, 2007a, 2007b).

Parks are different from medieval coppice woods, which sit alongside them and sometimes, even within them; these enclosed landscapes are unique resources for conservation. They provide insights into ecological history and research has transformed understanding of the importance of parks for rare invertebrates. Until relatively recently, perhaps the 1990s, medieval parks were 'Cinderellas' of nature conservation not considered to be 'ancient woodland'. Parks have trees (usually but not always), and large (and sometimes smaller) grazing mammals, and to survive trees need protection. Some parkland trees are ornamental and others are managed 'working' trees, with differences in species and structures.

Parks share features with other unenclosed grazed landscapes with trees and woods: chases, forests, moors, heaths, commons and some fens. These wooded and 'treed' landscapes occurred almost everywhere and so too might their shadowy footprint today. Many parks 'took in' parts of earlier landscapes when they were enclosed from 'waste' or 'forest', and management may have allowed parts of this ancient ecology to survive. In other cases, parks include ecology and features from specific periods of active management (with specific ends and outcomes), from subsequent times of abandonment, or changed use. Each phase preserves, modifies, or removes earlier ecology; these working landscapes evolving over a thousand years or more (Rotherham, 2007ab).

The extensive medieval landscapes, which included parks, provided hunting, foodstuffs, and both wood and timber for building and fuel. Alongside their deer, medieval parks contained wild boar, hares, rabbits, game birds, fish in fishponds, and grazing for cattle and sheep. For some, such as Bradgate Park in Leicestershire, pannage (feeding pigs on acorns) from the oaks provided revenue in rents. Medieval parks generally had large areas of heath or grassland (called 'launds', the origin of modern-day 'lawns', or plains) dotted with trees, along with woods (called holts or coppices, and if for holly (*Ilex aquifolium*) hollins). The launds provided food for animals in summer, and the hollins, provided it through the winter. Parks may have held and maintained deer (fallow (*Dama dama*), and red deer (*Cervus elaphus*)) for the table and the hunt. In the latter case, this sometimes involved release beyond the park pale and into the chase beyond. Some parks extended over many miles with Woodstock in Oxfordshire having a perimeter of seven miles with hunting on a grand scale. Others were much smaller; some little more than deer paddocks.

Solitary trees in launds were 'pollarded' (high coppice) or 'shredded' (branches removed from the tall, main stem). The only new tree growth outside the woods was in protective thickets of hawthorn (*Crataegus monogyna*), holly, and bramble (*Rubus fruticosus* agg.). Special woods called holly hags or hollins had holly cut on rotation as winter deer-fodder. A boundary fence, called the park pale surrounded the park. This was cleft oak fencing, banking with cleft oak fencing, or a wall. The bank normally had an internal ditch and park pales had deer leaps to entice wild deer into the park. Buildings in these multi-functional parks included manor houses (from Tudor times), keepers' lodges, and banqueting houses. Turf and stone were extracted and mineral coal too. Arable crops such as cereals might be grown within the park pale. Deer were a priority but shared the landscape with other domestic stock such as cattle, horses, and even goats. Wharncliffe Chase near Sheffield even had North American Buffalo in the early 20th century. Many parks had warrens in or near and relict 'pillow mounds' now evidence these. Other parks had productive fishponds surviving today as ornamental features or abandoned.

Large oaks were grown for timber; in some cases trunks and boughs carefully nurtured to form particular shapes and sizes for specific functions in houses, halls, churches, barns and ships. Careful planning and management over many decades are key aspects of park historical ecology.

Photograph 1: An obvious ancient oak tree.

Most of the very old trees, often oak (*Quercus robur*), are specimens that have been actively managed for at least several centuries and then abandoned. The trees range from relative youngsters of 400 years, to veterans of 800 to 1,200 years; one of the most precious resources of former medieval parks. Large trees provided shelter for cattle and deer in winter and shade in summer. They produced herbage to feed the livestock, most deer and cattle preferring to browse on leaves and shoots than to graze grass. The trees were cut high, several metres above ground, keeping re-growth out of the reach of the grazing animals, until the parker cut it for fodder. This pollarding is effectively high coppice and means that leaf fodder or fuel wood and small wood, can be combined with grazing animals. Hollins and haggs ensured herbage throughout the winter. For several months of the year, longer during colder periods such as the so-called 'Little Ice Age' of the 1400s to 1800s, grass does not grow in Britain and livestock depended on stored hay and cut branches of evergreen holly. Pollarding extended the lifespan of trees and ensured supply and continuity of dead wood, a highly important wildlife habitat.

The coppice tradition

From the Middle Ages until the second part of the 19th century, ancient woods throughout much of Britain and Western Europe, were managed as coppices, either as simple coppice or as coppice-with-standards (Rotherham and Jones, 2000; Rotherham and Egan, 2005). In coppice woods the trees were periodically, (generally every 10-30 years, but as often as once a year), cut down to the ground to what is called a 'stool'. Then from the stool grew multiple stems, called coppice or underwood. The poles of wood were said to 'spring' from the stool, and hence the names of many coppice woods in England include the word 'spring'. Indeed, in many areas local people think a 'spring-wood' name is to do with the seasons or water; it is not, and it provides sure evidence of antiquity. In a coppice-with-standards, some trees were not coppiced but allowed to grow on to become mature single-stemmed trees and these were the standards. The standards were of various ages. The coppice provided 'wood' and the standard trees provided 'timber'. The timber trees, mainly oak, were mostly for building projects but their by-products of bark and 'lop and top', were of economic value too (Jones, 2009).

Coppice was long-used not only for making hurdles and for house building, but also for tools, and for ancient trackways such as those crossing prehistoric fenlands. One of the oldest, best-recorded and most important uses of coppice poles was for charcoal making. However, a vast number of other crafts and industries also depended on it. Coppice wood was also essential for domestic purposes as it provided firewood used for heating and cooking. Before the introduction of sweet chestnut coppice, ash, hornbeam and alder poles were used extensively in the hop industry in the south-east of England and in Herefordshire. These formed the frameworks up which the hop-bines could be trained.

Coppice woods were valuable and particularly, in the first few years after they were coppiced, were vulnerable to grazing damage. For this reason, they were surrounded by stock-proof barriers such as fences, banks with external ditches, stone walls, hedges, or a combination of these. Where these woodland boundary features survive, they are important archaeological remains that tell you much about your wood, its extent, and its management. The woods had also to be protected against human thieves and trespassers particularly in autumn, when berries and fruits were ripe, and in winter, when firewood supplies were low.

There were also special woods in some regions called 'hollings', 'hollins' or 'holly hags' where the holly was cut on rotation to feed the deer and other livestock in winter. These might be in a park (specifically to feed deer in winter) or in the wider wooded landscape. Today, former holly hags are often full of tall holly trees and spreading, coppiced holly clones (Jones, 2009).

One formerly widespread woodland type was the wooded common. These sites were unfenced areas where commoners had rights to graze animals and to take other products such as fuel and building materials. These commoners held land in the open fields, or were tenants of the manorial lord, the local monastic landowner, or the Crown estate. They had certain rights on the common land in the manor, and their rights were strictly regulated and administered; this was not a free-for-all. Commoners usually had the rights of cutting underwood, harvesting the wood from pollards, and taking dead wood, but not the right of felling the timber trees. These common rights were called estovers or botes (e.g. hedgebote wood for making fences, housebote for housebuilding, and cartbote for making farm vehicles).

The more common forms include a raised coppice called a 'stub' which is often found as a significant ancient boundary feature, perhaps at a woodland edge on an old parish boundary. Some coppices, especially from ancient

Photograph 2: Ancient hazel coppice, Derbyshire.

Photograph 3: Ancient small-leaved lime, Whitwell Wood.

hazels (Photograph 2), may mix different ages and sizes of re-growth on one stool (the base of the cut tree), whereas the most frequently found examples are with all the poles (the re-grown shoots), of the same age. In upland sites especially, and particularly growing in boulder clutter of rocky scree slopes, there are multi-stemmed 'medusoid' trees which probably result from a form of coppice use. Some trees like alder and lime also form coppice stools naturally by stem growth and fall with age, followed by re-growth, or because of grazing damage. Your worked or retired trees can provide remarkable insight into management of your wood from maybe a few decades ago, to centuries past. Some coppice lime trees are around 3,000 years old (Pigott, 1993) (Photograph 3).

Worked and working trees

Clues to past woodland uses are the rich resources of once managed, 'worked', or 'working' trees or what I describe as 'retired veterans' (Rotherham, 2012, 2013). This heritage is unique to ancient wooded or treed landscapes. Once vital to local and even national interests the trees were coppiced, pollarded, shredded, stubbed, or grown

The wood-wain by Myles Birket Foster) **Figure 7.1**

as maidens for timber. They also produced leaf fodder, bark, coppice wood for fuel and construction, acorns, nuts, and mast. Today, long-abandoned, these trees are iconic features rich in biodiversity; their shapes and forms provide unique archives through which we read the past. Woods and other wooded landscapes were at the very heart of pre-industrial society, providing fuel, food and building materials (Figure 7.1). They were essential for transport (such as shipbuilding and the first railway lines), and for making charcoal for heating, cooking, and especially for metal smelting and working. Very often, these lands were contested spaces with landowner and peasant or commoner at loggerheads over rights and usage. Similarly, local landowners, the major aristocracy, the church, and the Crown were in conflict over issues such as hunting rights and timbers uses. In some cases, national security was at stake, as for example when timber merchants required big trees for shipbuilding but ironmasters demanded charcoal for making armour, weapons and canon. Trees even produced pyroligneous acid (also known as wood vinegar; a dark liquid produced through carbonization, which occurs if wood is heated and the air supply is restricted such as during charcoal production), wood tar, and a plethora of volatile organic compounds for burning, for waterproofing, and as oils and paraffins. In a pre-petrochemical society, these were vital substances. Today, we depend almost entirely on mineral oil and coal to produce these materials.

Individual 'worked' trees, if 'ancient', bear the marks of centuries of human exploitation. This might be giant old pollards with massive heavy boughs, or great coppice stools with crowns of re-grown sprouts. When we examine these magnificent examples of living heritage, they have a story to tell of an interaction between them and local people over hundreds of years. The 19th-century clergyman and diarist, the Revd Francis Kilvert gives some idea of how special these trees are when he described the ancient oaks of Moccas Park, Herefordshire:

'…….grey, gnarled, low-browed, knock-kneed, bowed, bent, huge, strange, long-armed, deformed, hunchbacked, misshapen, oakmen with both feet in the grave yet tiring down and seeing out generation after generation.'

To understand the once-worked trees you need to appreciate a time when woodland and trees were at the centre of local and even national economies. To build you required big 'timbers' of the correct size, shape and dimensions, plus smaller 'wood' for in-filling and more modest construction work. The different tree species were selected for their properties: durability, hardness, water or rot resistance, flexibility, strength and more. Great trees might be forced to grow in particular ways and shapes over a period of a hundred or two hundred years, in order to provide the necessary materials for ships or buildings. Wood was at the heart of society in a way that it is not now, and probably will never be again.

The consequence of all these uses is a remarkable heritage of these trees, some tall and straight, others bent and bowed, or misshapen tangles of re-growth. These tell the story of woods and woodmen of times past. Huge pollards of wooded common, forest, or park are instantly recognisable and include many of our most iconic trees. Indeed, these wonderfully decrepit old giants are so obvious that you might imagine that in Britain at least, we know where they all are. Well we do not and certainly, twenty years ago we did not, until the advent of the Ancient Tree Forum and their Big Tree Hunt (Rotherham, 2013). This has been one of the most popular community-based surveys of our environment ever undertaken and has revolutionised our knowledge and understanding of ancient trees. You can be sure too, that the work of countless ordinary individuals across the country has helped to save the lives of many old trees that would otherwise have been 'lost'. The wonderful thing about this is that there is still much more to do, and anyone can take part by visiting the Ancient Tree Forum web site for guidance on how to survey and record his or her local area. Our team in Sheffield recently discovered a woodland of 1,000 to 2,000 previously unrecognised ancient veteran worked trees. All this is in woodland close to several major cities and in the heart of the Peak National Park; imagine what remains to be found elsewhere (Handley and Rotherham, 2013).

Old veterans still found and recorded, in hidden valleys, secret streamsides, and ancient hedgerows. Even more exciting is the recent recognition of massive old coppice trees, some many centuries in age. Alongside veteran smaller trees such as hawthorn, rowan, birch, holly, and hazel, these provide a rich resource for researchers. Many are much older than you might think, and as 'worked' trees now retired, they provide real insight into the lives and the landscapes of your local countryside (Handley and Rotherham, 2013).

Woodland archaeology and ecology: archaeology 'in' the woods and archaeology 'of' the woods

As we play detective in the woods, we are looking for clues to their pasts. The traces left by the woodland crafts and the workers and families include where they lived, the worked trees, the pits, platform, processing areas and trackways. These are the archaeology of the woods, and along with internal and external wood banks, ditches, walls and other evidence relate closely to the history of the wood and its existence over time (Rotherham and Ardron, 2006; Rotherham, 2007c). Other people living and working in woods, such as quarrymen and miners, also left evidence. This is the archaeology in the woods but not of the woods. In many sites, this is a huge part of the modern-day landscape and tells unique stories of human interaction with environmental resources. The story runs from prehistoric times, to the medieval and early industrial, right up to the present day. Throughout history, all the people using the woods, and living in and around them, left their mark (Figure 7.2). The changes in land-use in the wood can be identified in the various internal and external boundary features; so a mediaeval deer park may have large external banks and even walls, plus an internal ditch to keep the deer in. There might be earthworks within the wood that are the remains of deer management features. Converted from a park to a coppice wood the site may have internal banks and ditches to mark out the different coppice compartments, and a ditch outside the boundary bank in order to keep out grazing animals. In some regions such as North Derbyshire or South Yorkshire, traditional medieval coppices were replaced by intensive industrial coppice for iron and steel industries again leaving distinctive evidence. For many sites in Britain, the 19th and 20th centuries saw abandoned traditions and replacement by exotic 'high forest' of non-native tree species like European larch, Norway spruce, and Scots pine (not native outside the Highlands). Sycamore and beech were widely used. Many woods were converted to conifer or sycamore plantations. Others in urban areas became amenity woods, often with clinically tidy management and emphasis on access provision often at the expense of conservation.

Wooded environments provide ideal conditions for special plants and animals, often only found in woods and wooded landscapes. Excitingly, some of these are good 'indicators' of ancient woodlands and we can use them to help find, identify, and verify our ancient wood (Photograph 4-8). Reading the landscape mixes archaeological humps and bumps with identification of woodland plants and animals (Spencer, 1990; Rotherham et al., 2008; Rotherham and Wright, 2008, 2011).

Old Oaks on Wickham, Common Kent after painting by S. Johnson. Raphael Tuck & Sons, Oilette, 1920s to 1930s, unused final. **Figure 7.2**

Photograph 4: *Allium* sp. (Wild garlic) - an indicator of damp ancient woods.

Photograph 5: *Hyacinthoides* sp. (Bluebell).

Photograph 6: *Oxalis acetosella* (Wood sorrel) - an indicator of ancient woods and relicts and often in upland areas.

Looking for the indicators

Helpfully for the beginner, many of the woodland wildflowers are familiar, easy to identify, and usefully, along with trees can be read like a book, as long as you know the language.

Within this book, the marks on the pages are the archaeological features, the worked trees, and the plants and animals. These indicators, along with soils, can be a rich source of information on history and former management and both presence and unexpected absence of key species can provide clues to the past (Rose, 1999; Rackham, 1986; Rotherham, 2011, Wright et al., 2012).

Ancient woods have antiquity and continuity of woodland cover providing refuge for a great variety of plants and animals over the centuries. Whilst this is the case within the wood, there will have been major changes in the surrounding landscapes. Consequently, ancient woods are often very rich in wildlife, and have undisturbed soil profiles and natural water features. Ancient woodland can also provide a living record of past woodland management practices and the organisation of the landscape. This is through the presence of features such as wood-banks, old pollards and coppice stools, remnant charcoal pits, ore furnaces and kilns (Rotherham and Jones, 2000).

How ancient woodland botanical indicator species are used

When trying to identify ancient woodland sites it is useful to sum the number of ancient woodland indicators to enhance the level of confidence. It is also possible to weight the species according to their reliability as indicators. There is a general increase in confidence with an increase in the number of ancient woodland indicators (Rose, 1999; Rotherham, 2011). However, a number of authors have found that this approach potentially gives a false impression of antiquity or at least a lack of disturbance. This is for various reasons such as:

- **The size of the woodland:** A small ancient wood may contain for example fifteen ancient woodland indicator species, and a larger but younger recent wood might contain the same number. Site history and complexity are therefore important. In particular, larger woods may have 'acquire' fragments of older woodland but these are now incorporated into a generally younger wooded site. It is worthwhile looking in detail at the particular species and their reliability as indicators alongside the total number found. The context of the wood, spatial, geographical, historical and ecological, will also influence expectations. Therefore, in base-rich soil the expected numbers will be much higher than a species-poor acidic site though they may be equally ancient.
- **Internal environmental variations (habitat diversity):** Ancient woodlands without significant internal habitat variation may contain the same number of ancient woodland indicator species as younger woodland with greater internal variation. However,

Photograph 7: *Anemone nemorosa* (Wood anemone) - an excellent indicator of an old woodland.

Photograph 8: *Lamium galeobdolon* (Yellow archangel).

in the latter case the key indicator species of ancient woodland continuity will be absent.

- **Biogeographical variations in species status:** The potential range of species in woodland can vary across the country due to a mix of environmental and historical factors. Because of this, relatively fewer species are needed to assign 'ancient' status to a wood on the eastern side of Britain than the west. This is due to the western Atlantic influences that are conducive to many of the species concerned. (Glaves et al., 2009abc).

A typical, regional, botanical indicator list for ancient woodlands in England is given in Table 7.1 as an example.

Intelligent Interrogation

Part of the approach that we are adopting and developing is based around the idea of 'Intelligent Interrogation' of the lists. There is a danger that the use of indicators becomes too formulaic and users expect a definitive numerical answer to indicator occurrence and worth. Indeed, it may be useful for an overall assessment of woodland status generate some form of numeric index or gradation. However, the evidence must be considered on a wide front and the lists of botanical indicators require scrutiny and assessment at many levels (Rotherham, 2001; Wright et al., 2012). They need to be assessed in terms of site history, of map-based evidence of land-use, of archaeological evidence of human activity and plant cover, of other documentation or historical sources, and in terms of the core ecology of the plants themselves. There is much to take in, including soils and other sediments and the evidence they hold; of working and worked trees and the stories they tell; and the variation and patterns of landscape history through time and space. The system that is emerging will help draw together key evidence and it will then aid the interpretation and presentation of that evidence to the benefit of woods and woodland and tree practitioners (Table 7.2).

The grid is a first attempt to bring together all the varied sources of evidence and information on a wooded or forested landscape so that they can be interrogated in a simple and integrated way. The application of the weighting scores is an optional approach that places emphasis on the degree to which evidence is robust for this to have been a wooded landscape for a very long period i.e. five or more centuries. The approach we have adopted involved the collection and collation of objectively gathered data, but then its interpretation and interrogation of this information subjectively. This is what I describe as 'Intelligent Interrogation' (Rotherham, 2011). This system builds on the approaches described previously in the Woodland Heritage Manual (Rotherham et al., 2008), and it is unique so far in linking indicator species, woodland heritage features, and historically worked trees. The research considers ideas and evidence such as from Kirby (1988) and Goldberg and Kirby (2002/03), and develops them in the context of environmental indicators as described by Ellenberg (e.g. Hill et al., 1999) and by Grime and colleagues (Grime et al., 2007).

Table 7.1

An Example of Ancient Woodland Botanical Indicator Species for the English Peak District Gritstone Area

*Acer campestre**	*Gagea lutea*	*Pyrola minor*
Adoxa moschatellina	*Galium odoratum*	*Ranunculus auricomus*
Agropyron caninum	*Geranium sanguineum*	*Rhamnus catharticus*
Allium ursinum	*Geum rivale*	*Rosa arvensis*
Anemone nemorosa	*Helleborus viridis*	*Rubus caesius*
*Aquilegia vulgaris**	*Hordelymus europaeus*	*Rubus saxatilis*
Brachypodium sylvaticum	*Hyacinthoides non-scripta*	*Sanicula europaea*
Bromus ramosus	*Hypericum pulchrum*	*Scirpus sylvaticus*
Campanula latifolia	*Ilex aquifolium*	*Solidago virgaurea*
Campanula trachelium	*Lamiastrum galeobdolon*	*Sorbus torminalis*
Cardamine amara	*Lathraea squamaria*	*Stachys officinalis*
Cardamine impatiens	*Lathyrus montanus*	*Stellaria holostea*
Carex laevigata	*Lithospermum officinale*	*Stellaria neglecta*
Carex pallescens	*Lonicera periclymenum*	*Stellaria nemorum*
Carex digitata	*Luzula pilosa*	*Tamus communis*
Carex remota	*Luzula sylvatica*	*Taxus baccata* (where native)
Carex strigosa	*Lysimachia nemorum*	*Thelypteris oreopteris*
Carex sylvatica	*Melica uniflora*	*Tilia cordata* or *platyphyllos*
Chrysosplenium alternifolium	*Mercurialis perennis*	*Trollius europaeus*
Chrysosplenium oppositifolium	*Milium effusum*	*Ulmus glabra*
Circaea x intermedia	*Myosotis sylvatica*	*Veronica montana*
Cirsium heterophyllum	*Narcissus pseudonarcissus**	*Viburnum opulus**
Conopodium majus	*Orchis mascula*	*Vicia sepium*
*Convallaria majalis**	*Oxalis acetosella*	*Vicia sylvatica*
Corydalis claviculata	*Paris quadrifolia*	*Viola palustris*
Daphne laureola	*Phyllitis scolopendrium**	*Viola reichenbachiana*
Daphne mezereum	*Polygonatum multiflorum*	nw *Calamagrostis epigejos*
Dipsacus pilosus	*Polygonatum odoratum*	⚬ *Carex pendula*
Dryopteris carthusiana	*Polypodium vulgare (s. lato)*	⚬ *Carpinus betulus*
Dryopteris pseudomas	*Polystichum aculeatum*	⚬ *Malus sylvestris*
Epipactis helleborine	*Polystichum setiferum*	⚬ *Poa nemoralis*
Equisetum sylvaticum	*Potentilla sterilis*	nw *Platanthera chlorantha*
Equisetum telmateia	*Primula vulgaris**	x *Moehringia trinerva*
Festuca altissima	*Prunus padus*	nw *Sedum telephium*
Frangula alnus	*Prunus avium*	nw *Serragula tinctoria*

N.B. *Rhododendron ponticum, Prunus laurocerasus, Castanea sativa, Fagus sylvatica, Mahonia aquifolium, Hedera* sp., *Ilex* sp., *Pinus sylvestris, Larix decidua* are often indicative of Victorian high forest plantings;
x. Appears in plantations
nw. Not typically woodland
⚬ Not native of often introduced
* Only include these species if they occur well within the wood and do not appear to have been planted.

This list is based on one developed for the Peak National Park firstly by Penny Anderson, and then by subsequent peak park Ecologists. It has been applied in the South Pennines / South Yorkshire / North Derbyshire region by Ian Rotherham and colleagues and modified accordingly (Glaves et al., 2009a, 2009b, 2009c). The list can be used in a wider range of situations but subject to the provisos as given. To be applied with caution and in the context of the attached notes on regional and other variations.

Table 7.2

Evidence-based Ancient Woodland Status Grid (from Rotherham, 2011)

	Woodland	Old woodland	Ancient Woodland	Influence	Interpretation
	At least pre-1800 AD origin		Pre-1600 AD origin		
Evidence type	**Indication**	**Affirmation**	**Confirmation and continuity**		
Ecological	Indicator species Old trees Landscape context	Above threshold number of indicators Key species presence Community structure Worked trees Other	Key indicator species perhaps including rarities Saproxylic insect indicators Veteran worked trees: • stubbs • coppice • pollards Other ancient trees including veteran natural coppices	Association with woodland conditions Association with woodland continuity Association with absence of non-woodland use	1. + Perhaps evidence of continuity 2. Perhaps evidence of severance Weighted for biogeographical trends especially Atlantic influence Weighted for soil type and especially base status
	ECO Score 1	**ECO Score 2**	**ECO Score 3-5**		
Pedological	Absence of non-woodland soils	Woodland soils such as leached brown earths, podzols, acid brown earths etc	Woodland soil depth Sediment profiles and evidence of site continuity of woodland cover e.g. pollen C-dating of charcoal or of sediments	Association with woodland conditions Association with woodland continuity Association with absence of non-woodland use	1. + Perhaps evidence of continuity 2. - Perhaps evidence of severance
	PED Score 1	**PED Score 2**	**PED Score 3-5**		
Archaeological	Boundary features Old trackways Pits and platforms	Wood bank or other significant boundaries Woodland-related trackways Charcoal, whitecoal and other industries Old worked trees	Palimpsest of features indicating pre-1600 AD origins: • Ancient wood bank • Ancient park bank • Other ancient significant boundaries • Ancient woodland-related trackways • Dateable charcoal, whitecoal and other industries • Veteran worked trees	Evidence of woodland conditions Evidence of woodland continuity Lack of evidence of non-woodland use	1. + Perhaps evidence of continuity 2.. - Perhaps evidence of severance
	ARC Score 1	**ARC Score 2**	**ARC Score 3-5**		
Historical	Maps Place names Lane names Field names Location	First Edition Ordnance Survey presence Early estate maps Archival evidence of woodland use	Estate records pre-1600 AD Court rolls, evidence of disputes over woodland use or produce, bills of sales for woodland produce or rights, ownership and management documentation	Evidence of woodland conditions Evidence of woodland continuity Lack of evidence of non-woodland use	1.+ Perhaps evidence of continuity 2. - Perhaps evidence of severance
	HIST Score 1	**HIST Score 2**	**HIST Score 3-5**		
Other	?	?	?	Evidence of woodland conditions Evidence of woodland continuity Lack of evidence of non-woodland use	Woodland types: 1. Coppice 2. Park / Pasture Wood 3. Wooded Common 4. Linear remnant 5. Fragment
TOTAL EVIDENCE–BASED SCORE:	4 or less very weak	4-8 pre-1800 AD	9+ strong case pre-1600 AD		Described by woodland type or types and weighted by evidence-type

Conservation and conclusions

Many 'wooded' or ancient 'treed' landscapes exist today but largely over-looked or misidentified. The ghosts, shadows, or footprints of anciently wooded areas still survive, sometimes intact, and others barely clinging by their fingernails. Yet each has a unique story to tell in its own quiet history. Commons, heaths, fens, roadside verges, hedgerows, urban parks, and even gardens, all may have evidence of our woodland past. For the landscape detective this is a truly exciting prospect. However, often associated with 'cultural severance' many of these sites are in a sharp decline (Rotherham, 2008). An additional problem is that with severance follows intensification or abandonment, both potentially serious issues.

A real worry for our ancient woods and their unique heritage is that they can be lost ever so easily. Indeed, the current vogue in Britain of 'biofuel' extraction from wooded landscapes is on the one-hand laudable and a continuation of timeless traditions. On the other hand, such industrial and mechanised extraction should not be allowed in 'ancient woods'; to do so is tantamount to heresy. Generally when this type of use occurs there has been no meaningful survey of the woodland landscape and certainly not of veteran worked trees. One man, a large timber extraction machine and a few chainsaws can remove trees ranging in age from a few hundred years, to a thousand years or more in just a few hours. The track vehicles used, so-called low-impact machines, erase an ancient landscape and it banks, ditches, pits and platforms in just a few hours. I liken this to taking a felt-pen to scribble over the oil paint of the Mona Lisa; you still have a picture but it is not what it was. Currently, aside from a few dedicated local and regional groups across Britain, very few of our woodlands have been surveyed for their heritage interest; there is much to do (Rotherham et al., 2008). A final issue and again a growing problem for woodland conservation is that of recreational 'parkification'; in other words the conversion of a site to one primarily managed for leisure and urban-dwellers' recreation and not conservation. In Britain especially, there is much grant aid support for activities and use, but often not for effective survey, assessment and conservation management (Rotherham, 2012, 2013).

In terms of conservation significance, the ancient woods of Britain are hugely important for nature conservation and heritage reasons (Rackham, 1986, 2006). However, perhaps the special importance of an ancient wood is the feeling of walking in the footsteps of the ghosts of people that lived and worked our woods over thousands of years. These 'ghosts' have left their mark on the wooded landscape, on the soils, and even on the vegetation itself. As stewards of the environment, we have a responsibility to protect ancient, semi-natural woodlands for future generations. That some shadows of wooded landscapes remain today but beyond the 'wood', is a new concept and raises issues which are both exciting and challenging (Handley and Rotherham, 2013; Rotherham, 2012, 2013). The hunt for shadows and ghosts is now on, and this raises possibilities of a woodland lineage from lost, medieval coppices or even from earlier wood pastures and wooded commons. The recognition and identification of these remarkable survivals has come directly from the processes and ideas discussed above.

Bibliography and References

Castle, G., Latham, J., Mileto, R., 2008. *Identifying Ancient Woodland in Wales – The role of the Ancient Woodland Inventory, historical maps and indicator species*. Countryside Council for Wales. Contract Science Report No. 819.

Crawford, C.L., 2006. A *provisional ancient woodland indicator plant list for Scotland*. Native Woodlands Discussion Group Newsletter, 31 (2), Autumn 2006. [Downloadable from www.tnrc.co.uk]

Crawford, C.L., 2009. Ancient woodland indicator plants in Scotland. *Scottish Forestry*, 63(1): 6-19.

Glaves, P., Rotherham, I.D., Wright, B., Handley, C. and Birbeck, J., 2009. A Report to the Woodland Trust. *Field Surveys for Ancient Woodlands: Issues and Approaches*. Hallam Environmental Consultants Ltd., Biodiversity and Landscape History Research Institute, and Geography, Tourism and Environment Change Research Unit, Sheffield Hallam University, Sheffield.

Glaves, P., Rotherham, I.D., Wright, B., Handley, C. and Birbeck, J., 2009. *A Report to the Woodland Trust A Survey of the Coverage, Use and Application of Ancient Woodland Indicator Lists in the UK*. Hallam Environmental Consultants Ltd., Biodiversity and Landscape History Research Institute, and Geography, Tourism and Environment Change Research Unit, Sheffield Hallam University, Sheffield.

Goldberg, E. and Kirby, K., 2002/2003. *Ancient woodland: guidance material for local authorities*. English Nature, Peterborough.

Grime, J.P., Hodgson, J.G. and Hunt, R., 2007. *Comparative Plant Ecology. A Functional approach to common British species*. Second Edition. Castlepoint Press, Dalbeattie.

Handley, C. and Rotherham, I.D. (eds), 2013. S*hadow Woods and Ghosts: A Survey Guide*. Wildtrack Publishing, Sheffield, 63 p.

Hermy, M., Honnay, O., Firbank, L, Grashof-Bokdam, C. and Lawesson, J.E., 1999. An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation. *Biological Conservation*, 91: 9-22.

Hill, M.O., Mountford, J.O., Roy, D.B. and Bunce, R.G.H., 1999. *Ellenberg's indicator values for British Plants*. ECOFACT 2a Technical Annex. Centre for Ecology and Hydrology, Wallingford.

Kirby, K.J., 1988. *A Woodland Survey Handbook*. Nature Conservancy Council, Peterborough.

Peterken, G.F., 1974. A method for assessing woodland flora for conservation using indicator species. *Biological Conservation*, 6: 239-245.

Peterken, G.F., 2000. Identifying ancient woodland using vascular plant indicators. *British Wildlife*, 11: 153-158.

Pigott, C.D., 1993. The History and Ecology of Ancient Woodlands. *Landscape Archaeology and Ecology*, 1: 1-11.

Rackham, O., 1986. *The History of the Countryside*. Dent, London.

Rackham, O., 2006. *Woodlands*. Collins New Naturalist, London.

Rose, F., 1999. Indicators of Ancient Woodland: the Use of Vascular Plants in Evaluating Ancient Woods for Nature Conservation. *British Wildlife*, 10(4): 241-251.

Rotherham, I.D., 2007. T*he Historical Ecology of Medieval Deer Parks and the Implications for Conservation*. In: Liddiard, R. (ed.) The Medieval Deer Park: New Perspectives, Windgather Press, Macclesfield, 79-96.

Rotherham, I.D., 2007. The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: a UK case-study. *Forest Ecology and Management*, 249: 100-115.

Rotherham, I.D. (ed.), 2007. *The History, Ecology and Archaeology of Medieval Parks and Parklands*. Wildtrack Publishing, Sheffield.

Rotherham, I.D., 2008. *The Importance of Cultural Severance in Landscape Ecology Research*. In: Dupont, A., Jacobs, H. (eds) (2008) Landscape Ecology Research Trends. Nova Science Publishers Inc., New York, 71-87.

Rotherham, I.D., 2011. *A Landscape History Approach to the Assessment of Ancient Woodlands*. In: Wallace, E.B. (ed.) Woodlands: Ecology, Management and Conservation. Nova Science Publishers Inc., USA, 161-184.

Rotherham, I.D., 2012. *Traditional Woodland Management: the Implications of Cultural Severance and Knowledge Loss*. In: Rotherham, I.D., Jones, M. and Handley, C. (eds) (2012) Working and Walking in the Footsteps of Ghosts. Volume 1: the Wooded Landscape. Wildtrack Publishing, Sheffield, 223-264.

Rotherham, I.D., 2013. *Searching for Shadows and Ghosts*. In: Rotherham, I.D., Handley, C., Agnoletti, M. and Samoljik, T. (eds) (2013) Trees Beyond the Wood – an exploration of concepts of woods, forests and trees. Wildtrack Publishing, Sheffield, 1-16.

Rotherham, I.D. and Ardron, P.A., 2006. The Archaeology of Woodland Landscapes: Issues for Managers based on the Case-study of Sheffield, England and four thousand years of human impact. *Arboricultural Journal*, 29(4): 229-243.

Rotherham, I.D. and Egan, D., 2005. *The Economics of Fuel Wood, Charcoal and Coal: An Interpretation of Coppice Management of British Woodlands*. In: Agnoletti, M., Armiero, M., Barca, S., Corona, G. (eds), History and Sustainability. European Society for Environmental History, 100-104.

Rotherham, I.D. and Jones, M., 2000. Seeing the Woodman in the Trees – Some preliminary thoughts on Derbyshire's ancient coppice woods. *Peak District Journal of Natural History and Archaeology*, 2: 7-18.

Rotherham, I.D. and Jones, M., 2000. *The Impact of Economic, Social and Political Factors on the Ecology of Small English Woodlands: a Case Study of the Ancient Woods in South Yorkshire, England*. In: Forest History: International Studies in Socio-economic and Forest ecosystem change. Agnoletti, M., Anderson, S. (eds), CAB International, Wallingford, Oxford. 397-410.

Rotherham, I.D., and Wright, B., 2008. Searching for the Ghosts: how a forester reads the woodland landscape. *World of Trees*, 16: 40-41.

Rotherham, I.D. and Wight, B., 2011. Surveying and assessing vascular plants in hedgerows to inform historic interpretation, planning decisions and conservation strategies. *Aspects of Applied Biology*, 108: 123-131.

Rotherham, I.D., Jones, M., Smith, L. and Handley, C. (eds) 2008. The Woodland Heritage Manual: A Guide to Investigating Wooded Landscapes. Wildtrack Publishing, Sheffield.

Spencer, J., 1990. Indications of antiquity: some observations of the nature of plants associated with ancient woodland. *British Wildlife*, 2: 90–102.

Vera, F., 2000. *Grazing Ecology and Forest History*. CABI Publishing, Oxon, UK.

Wright, B., Rotherham, I.D., Darwin, N.M.A. and Hall, R. 2012. A new approach to practical survey and interpretation of hedgerows: an introduction to the "Hedgerow Ecological Description Grading and Evaluation System" (HEDGES). *Arboricultural Journal*, 34(3): 134-150.

Chapter 8
Ancient forests in Germany: distribution, importance for maintaining biodiversity, protection and threats

Monika Wulf

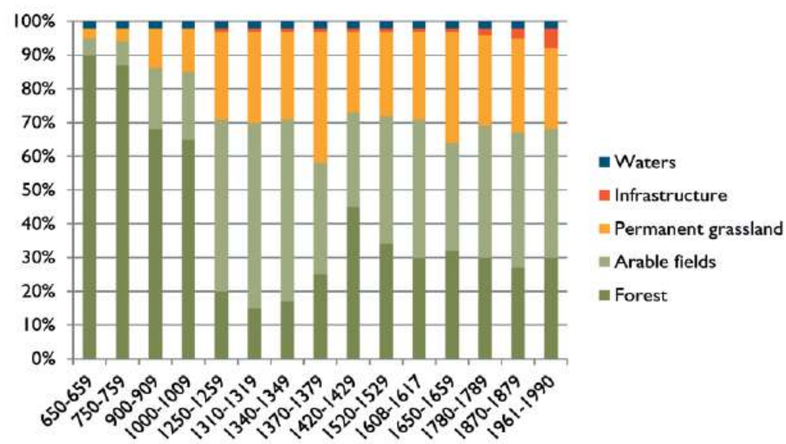
Introduction

Humans have tremendously altered the central European landscape for several centuries (Ellenberg and Leuschner, 2010). Thus, there is little virgin forest, and it is located on a few special sites that are not usable by humans, e.g., extremely steep slopes in mountainous areas. Despite early and extensive human impacts, central Europe was mainly covered with forests approximately 1,000 years ago, as shown on a small-scale map by Schlüter (1952, scale 1:500,000). The land-cover reconstruction by Schlüter (1952) was based on sources that vary greatly in quality and refer to the end of Antiquity until the beginning of the early Middle Ages, with a mean of approximately 900 A.D. At that time, clearing of the forests had already begun as well as the drainage of wet areas to acquire land for agricultural usage, but forests clearly prevailed. Forests were still semi-natural due to the marginal effects of humans (Walter and Straka, 1970; Ellenberg and Leuschner, 2010). According to Bork et al. (1998), forests in Germany covered slightly less than 70% of the land around 900 A.D.; but approximately 250 years before that time, they covered c. 90% (Figure 8.1).

Since 900 A.D., the human impact on the European landscape has led to extended clearing to acquire agricultural land for food production because of the growing human population. The peak of forest clearing in Germany is dated to the 12th and 13th centuries (late Middle Ages), in parallel with the increasing colonization of the landscape (Mantel, 1990). In the late Middle Ages, particularly in the 14th century, colonization was finished, clearing was stopped, and forest areas recovered (Figure 8.1). From the 16th to the 18th century, several episodes of clearing occurred again, particularly in Brandenburg (northeast Germany, Figure 8.2) and in the northernmost part of Germany (Schleswig-Holstein) because of the increasing number of inhabitants. At the beginning of the 19th century, a lot of clearing occurred again in all of Germany, mainly for receipts to fill the empty public treasury and war chest (Mantel, 1990). In the 19th and

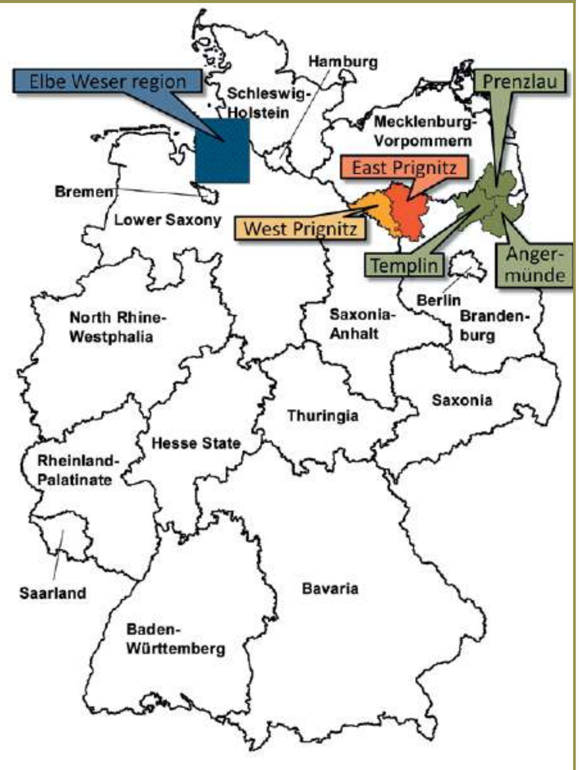
Development of land use in Germany

Figure 8.1



Development of land use in Germany (excluding the Alps) during the Middle Ages and in modern times according to Bork et al. (1998). Forests include shrubs outside forests. Arable fields include gardens and vineyards. Permanent grasslands include wasteland, grassland in urban areas and along roadsides. Infrastructure includes sealed areas near houses and roads.

Figure 8.2 Federal countries of Germany with some regions mentioned in the text



twentieth centuries, there was a slight overall increase in forest area, and the pattern of forest-open land distribution changed little. These statements are consistent with Figure 8.1 in Bork et al. (1998). The final period of forest clearing is characterized by extensive conversions of semi-natural deciduous and mixed stands into coniferous dominated stands (Hesmer, 1938; Mantel, 1990)

Thus, it is clear why semi-natural forests with long habitat continuity, the so-called ancient forests (habitat continuity >200 years), came into focus during a symposium held at the Norddeutsche Naturschutzakademie (NNA) in 1993. The results from this symposium were published one year later (NNA, 1994). The main results were a definition of ancient forests, overviews of activities for an inventory of ancient forests and proving the importance of ancient forests for maintaining biodiversity. Ten years later, all of the ancient and recent forests in Germany were inventoried (Glaser and Hauke, 2004).

Most of the studies on ancient forests were published in the German language and are therefore inaccessible for international readership. The main intention of this book chapter is to report (i) the status of ancient forest and recent forest inventories, (ii) the importance of maintaining the plant species diversity of ancient forests, and (iii) the protection of and the threats to ancient forests in Germany. First, an overview of the entire situation in Germany is given, and second, some case studies are used to elucidate a more detailed situation in the northern lowland of Germany where semi-natural ancient forests are particularly rare.

Distribution of ancient and recent forests

At the NNA symposium, ancient forests were defined as, "Forests that have continuously existed for at least two centuries as forests, according to historical maps, historical site descriptions or other indications" (NNA, 1994). Thus, an ancient forest site is independent of the actual age of the tree species; however, continuous land cover as a forest is essential. The threshold of at least 200 years was set because for many central European countries, the most reliable historical maps have been produced from the mid-18th century on. Glaser and Hauke (2004) have used several maps of different scales and dates of production. For some regions in Germany, only maps at a scale of 1:100,000 are available, so the overview of ancient and recent forests was produced at this scale.

At the end of 1992, forest areas in Germany covered approximately 104,536 km², or c. 29.3%, of the entire area (Table 8.1). Of these nearly 30% forested areas, 77% are ancient forests, and 23% are recent forests (Table 8.2). Ancient forest areas are remarkably larger in the southern part of Germany, particularly in the highlands. In the northern part of Germany, recent forests prevail, which results from the tremendous clearing in the Middle Ages to the 14th century and from the 16th to the 18th century in some regions (Mantel, 1990; Küster, 2008).

The percentage of deciduous tree species is higher in ancient than in recent forest sites (Table 8.2). In contrast, coniferous tree species are dominant in the recent forest areas. The percentage of mixed forests is similar for both forest types. More than half of the ancient forest

Table 8.1 Forest and non-forest area, deciduous, mixed and coniferous ancient and recent forests in Germany

CORINE landcover 1998	km ²	%
Germany	**356,778**	**100**
Forests	104,536	29.3
Ancient forests	80,493	22.6
Coniferous ancient forests	41,815	11.7
Mixed ancient forests	17,771	5.0
Deciduous ancient forests	20,907	5.9
Recent forests	24,043	6.7
Coniferous recent forests	15,680	4.4
Mixed recent forests	5,227	1.4
Deciduous recent forests	3,136	0.9
Non-forests	252,242	70.7

Table 8.2

Ancient and recent forests according to three forest classes

Forest classes according to CORINE landcover 1998	Ancient forests = 100%	Recent forests = 100%
Deciduous forests	26	13
Mixed forests	22	22
Coniferous forests	52	65

area is covered by coniferous tree species, whereas both deciduous and mixed stands cover more than 20%. Recent forests that are dominated by coniferous and deciduous stands cover slightly more than 10% (Table 8.2).

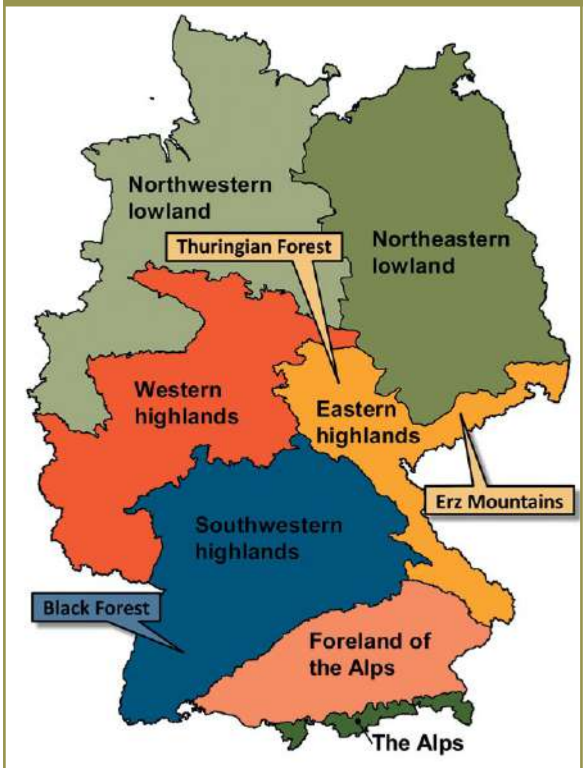
Deciduous ancient forests occur mainly in the highlands. The more or less continuous cover with forests and the dominance of specific tree species is strongly associated with ownership. The proportion of manorial and ecclesiastical forests was and is relatively high, and these are most often semi-natural deciduous stands. Such forests were mainly used for timber production and less for wood pasture. This is in contrast to the northern German lowlands, where forests have been intensively used for wood pasture and otherwise, e.g., pine stumps for tar production, litter raking and gaining of grass.

The recent forests that are stocked with coniferous tree species have faced intensive usage. They were exploited by timber production and litter raking, thus leading to the severe degradation of the soil sites. Those sites could be reforested only with coniferous tree species, mainly pine and spruce. This can be observed for example in the Thuringian Forest, Erz Mountains and the Black Forest (Figure 8.3).

At first, a large part of the recent forest areas was created by the systematic and extended afforestation of former agricultural land. Extended afforestations in the 19th century concentrated on the older and younger moraine landscape in northern Germany. In the late 19th and 20th centuries, new forest areas were established by afforestation or were developed by the small-scale, secondary succession of abandoned land on exceptional sites, e.g., military training areas and post-mining landscapes. The high percentage of coniferous tree species in recent forests indicates the extended afforestations with those species on potential deciduous or mixed forest sites within the last 200 years.

Figure 8.3

Biogeographic regions in Germany (according to Riecken et al., 1994)



Distribution with respect to biogeographic regions

Following the suggestion by Riecken et al. (1994), the landscape of Germany can be divided into seven large biogeographic regions (Figure 8.3). The biogeographic regions were pooled to conform to those of Meynen and Schmithüsen (1953-1962), and climatic factors, geomorphology, topography, soil types and hydrology were considered (Riecken et al., 1994).

These biogeographic regions vary in the proportion of ancient and recent forests, and there are also large differences in the proportions of deciduous and coniferous forests (Table 8.3). These differences occur because of the variation of environmental conditions and because of ownership structures in the regions.

Northwestern lowland

This landscape is characterized by having the smallest portion of forest area. In the southern area and the Westphalian lowland, this small area occurs because of dense human populations (e.g., Ruhr District) and large areas that are intensively used for agriculture. In the past, the northern area was covered by huge heathland areas. They were afforested to a large extent, which explains the very high proportion of recent forests.

Northeastern lowland

The portion of forest area in the northeastern lowland is very small, but ancient coniferous forests prevail. Relatively extensive beech stands in ancient forest sites are specific to the northern part of Brandenburg and some areas of Mecklenburg-Vorpommern. The proportion of

Table 8.3

Proportion of deciduous, mixed and coniferous ancient and recent forests in the seven biogeographic regions in Germany

	% forest area	Ancient forest total	Deciduous ancient forest	Mixed ancient forest	Coniferous ancient forest	Recent forest total	Deciduous recent forest	Mixed recent forest	Coniferous recent forest
NW lowland	10.8	28.8	18.0	3.0	7.8	71.2	14.1	8.6	48.4
NE lowland	23.8	62.0	17.1	7.3	37.6	38.0	10.8	4.5	22.8
W highlands	41.3	81.9	43.4	20.5	18.0	18.1	4.4	9.5	4.2
E highlands	38.5	92.5	8.9	9.9	73.6	7.5	0.7	1.5	5.4
SW highlands	41.6	85.9	25.5	28.3	32.0	14.1	1.9	7.0	5.2
Foreland of the Alps	24.3	85.0	5.0	13.0	67.1	15.0	1.0	4.3	9.7
The Alps	58.6	89.3	3.0	29.4	56.9	10.8	0.4	5.0	5.4
Mean	34.1	75.0	17.3	15.9	41.9	25.0	4.7	5.8	14.4

recent forests is high for two reasons. First, from the 18th until the 20th century, large areas of fen were cultivated with enormous effort. In particular, moist meadows were extensively used, and pastures were developed in Alnus-dominated stands by secondary succession. Second, either former military training areas or post-mining landscapes were afforested, or spontaneous reforestation took place. Altogether, secondary succession and spontaneous reforestation had led to an increase in the forest area, whereas the extension of rural areas has accounted for open land.

Western highlands

In this landscape, the forest area has remained more or less stable for the past 200 years, reflected by a very high proportion of ancient forests. A huge area of this landscape is characterized by relatively large differences in the relief, thus preventing profitable agricultural usage. Moreover, most of the forest areas are publicly or manorial owned and have been for a very long time, and these are the largest and most contiguous ancient forest sites.

Eastern highlands

In the eastern highlands, ancient forests is greatest, but the forests are dominated by coniferous tree species. Particularly, the Erz and Fichtel Gebirge, the Vogtland and parts of the Bavarian, Böhmer and Thuringia Forest are dominated by coniferous stands. The central part of the Thuringia Becken has been extremely poor in forests for several centuries.

Southwestern highlands

The proportion of ancient forests here is very high, and these are mainly coniferous stands. This is particularly true for the Black Forest and the Odenwald, the Spessart and parts of the Franconian Jura. There are also extended ancient forests on sandy soils around Nuremberg. Outstanding recent forests can be found in the Franconian and Swabian Jura.

Foreland of the Alps

This landscape is characterized by a large proportion of coniferous ancient forest, whereas deciduous forests on ancient forest sites are nearly restricted to the flood-plains of the larger streams.

The Alps

Because the proportion of forest area is the highest here among all of the biogeographic regions, this small mountain area has an exceptional position. The proportion of ancient forests is very high, and the high percentage of coniferous stands is because of site conditions prevailing at higher altitudes.

Distribution of ancient and recent forests, with particular focus on the northern lowland

From the facts shown above, it is obvious that semi-natural ancient forests are mainly threatened in the northern lowlands of Germany. Only small areas have remained as ancient forests, most of which have been converted into coniferous stands. Therefore, two case studies of the northeastern lowlands should give some detailed insights into the development of the forest-open field distribution at a scale of 1:50,000. Both regions, the Prignitz and the Uckermark, are located in the Federal state Brandenburg (Figure 8.2). The forest area in Brandenburg covers ca. 35%, and approximately 65% of the total forest area includes ancient forests (Wulf and Schmidt, 1996). Approximately 22% and 35% of the Prignitz and Uckermark regions, respectively, is covered by forests. According to Wulf (2004), not only ancient forests but also old forests (habitat continuity <100 years) have been identified in both regions using historical maps. The oldest is the Schmettau map from the 18th century (1767-1787, scale 1:50,000, Figure 8.4); for the 19th century, we used the Survey of the Prussian government (approximately 1880, scale 1:25,000, Figure 8.5). Various topographical maps (scale 1:50,000 and 1:25,000) were used as actual references.

According to Hesmer (1938), the Prignitz region comprises the two old rural districts West and East Prignitz, and the Uckermark region comprises the three old rural districts Angermünde, Prenzlau and Templin. In all but one district, coniferous forests, mainly Scots Pine, already prevailed ca. 150 years ago (Table 8.4). Even in the deciduous forest rich district, Prenzlau coniferous forests increased to ca. 20% within 50 years. Nevertheless, in that district, the proportion of deciduous stands remains the highest because of large areas with high relief that are impossible to use for profitable agriculture. The higher percentage of coniferous stands in East compared to West Prignitz is related to the higher proportion of sandy soils in the eastern part (Müller, 1941).

The Prignitz region

Nearly 10% of all forests are ancient forest sites, and nearly 7% are old forests with a habitat continuity of at least 100 years (Table 8.5). Within the last five decades, several new forests have been established. The afforestation has mainly occurred on moist grasslands that have failed to be drained well enough for profitable use as grassland or meadow.

The historical maps do not provide much information on the tree species in the forest areas, except for tree species names from relatively few locations. However, on the maps from the 1780s, ± closed or open forests and forests on moist or wet lowlands can be distinguished. On the maps from the 1880s, pure deciduous or coniferous and mixed stands were clearly indicated by boundaries of small dotted lines. A study by Wulf and Rujner (2011) indicates that the historical forest vegetation in ca. 1780 was dominated by deciduous stands. Taking this into account, the data in Table 8.6 show that mainly ± closed forests have been converted to coniferous forests only within one century. Large areas of forest on moist or

Section of the Schmettau map
(1767-1787, original scale 1:50,000; sheet no. 36 Oranienburg)

Figure 8.4

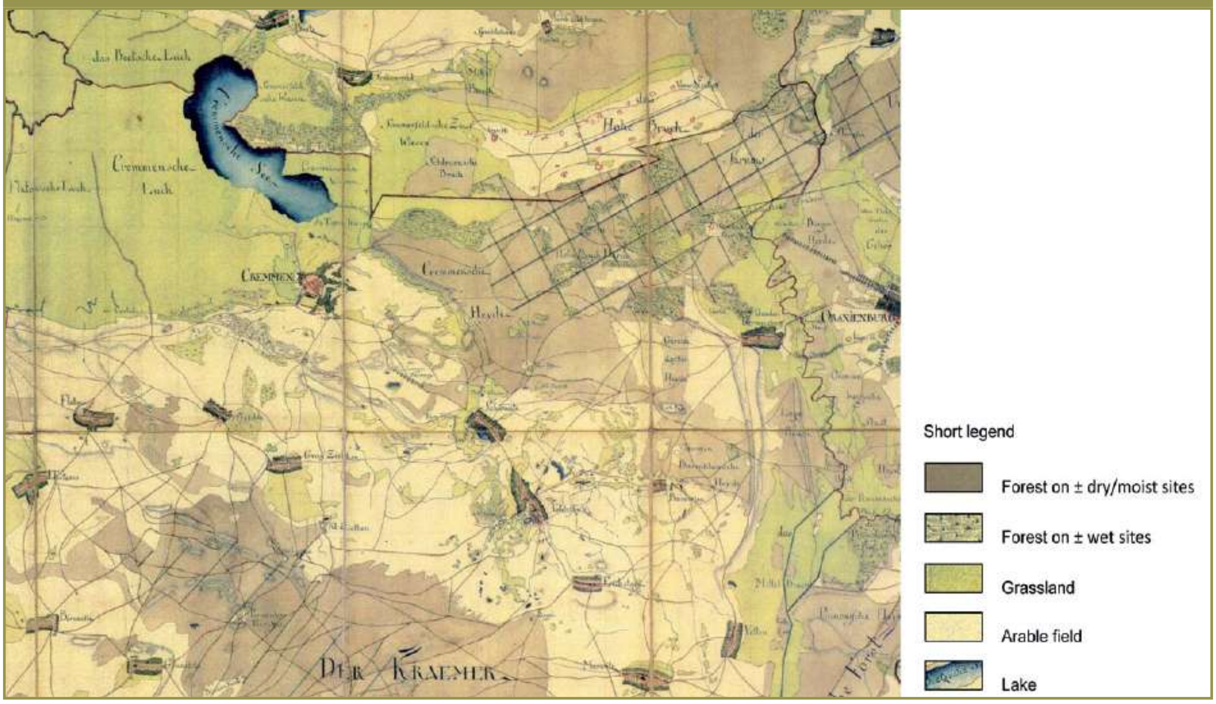


Figure 8.5

Section of the maps of the Prussian government
(c. 1880, original scale: 1:25,000; sheet no. 3143 Wustrau, 3144 Loewenberg, 3145 Nassenheide, 3243 Linum, 3244 Kremmen, 3245 Oranienburg, 3343 Nauen, 3344 Boetzow and 3345 Hennigsdorf)

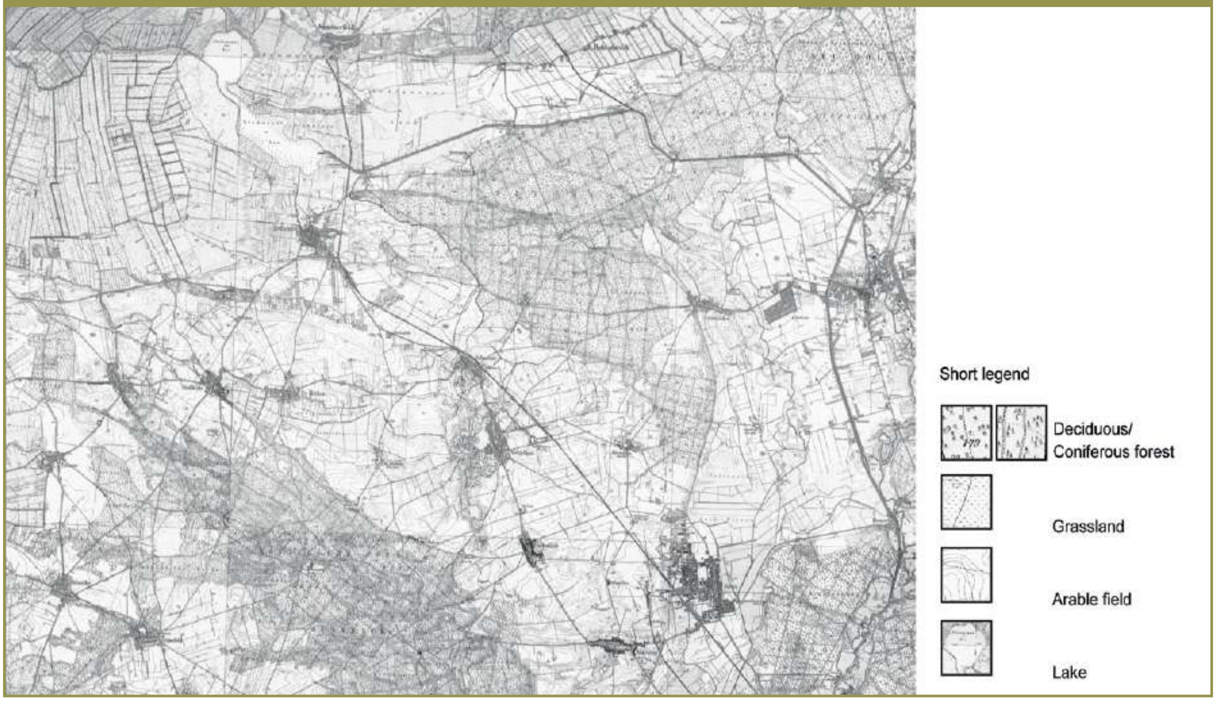


Table 8.4

Forest area, proportion of coniferous stands and proportion of dominant tree species in the Prignitz and Uckermark region in the year 1927 according to Hesmer (1938)

	Prignitz region		Uckermark region		
[%]	West Prignitz	East Prignitz	Prenzlau	Templin	Angermünde
Forest area	20 – 30	20 – 30	5.0 – 10	30 – 40	15 – 20
Of the total forest area					
Coniferous forests	80 – 90	90 – 95	50 – 60	80 – 90	70 – 80
Pine forests	80 – 90	90 – 95	40 – 50	80 – 90	70 – 80
Spruce forests	1.0 – 2.5	<1.0	2.5 – 5.0	1.0 – 2.5	<1.0
Beech forests	<0.1	2.5 – 5.0	20 – 25	5.0 – 10	10 – 15
Oak forests	2.5 - 5.0	1.0 – 2.5	10 – 15	2.5 – 5.0	10 – 15
Birch and elder	5.0 – 7.5	2.5 – 5.0	7.5 -10	2.5 – 5.0	2.5 – 5.0

Table 8.5

Overview of ancient, old and recent forest area in the Prignitz region

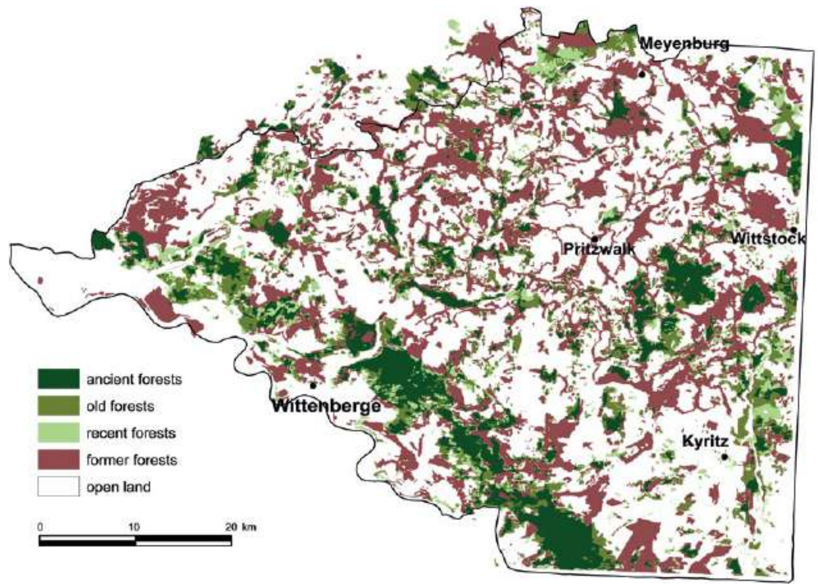
Forest type with regard to habitat continuity	Explanations	Area [ha]	% of the total area [ha]
Ancient forest	Continuously forest area since at least ca. 1780	30.659	9.7
„Old“ forest	Continuously forest area since at least ca. 1880	21.839	6.9
Recent forest 1	Forest area on the 1780 map, but arable field or grassland on the 1880 map, and again forest area on the 1980 map	6.572	2.1
Recent forest 2	Forest area only on the 1980 map	10.602	3.4
Sum		69.672	22.1

The total area of the region is 314,823 ha.

wet lowlands were cleared between 1780 and 1880. The proportion of ± open forests was not high, but most of them were also converted to coniferous stands.

The actual distribution of forest and open land in the Prignitz region has remained nearly stable for a century (Figure 8.6). There has been no severe decrease in oak and beech stands during this time, whereas many alder stands have been converted to grasslands (Hilf, 1928). Although nearly all of the deciduous and mixed stands have remained from 1880 until today, stands with old trees are rare, and larger areas of pure deciduous stands are rare. The Gadower Forest is a 3,000 ha forest near the Elbe River: of this forest, 65% is covered by deciduous stands, whereas the rest is predominantly covered by Scots Pine (Müller, 1941).

Forest-open land distribution in the Prignitz region — Figure 8.6



Reconstructed with the Schmettau map (ca. 1780), the maps of the Prussian government (ca. 1880), and actual topographical maps (ca. 1980).

Proportion of combined forest types from the historical maps in the Prignitz region — Table 8.6

Forest type on the 1780 map	Forest type on the 1880 map	Total area [ha]	% of the total area	% of the forest area [69,672 ha]
± closed forest	Deciduous forest	1.691	0.5	2.4
± closed forest	Mixed forest	2.087	0.7	3.0
± closed forest	Coniferous forest	22.440	7.1	32.2
± closed forest	No forest	4.325	1.4	6.2
Forest on moist/wet lowlands	Deciduous forest	739	0.2	1.1
Forest on moist/wet lowlands	Mixed forest	936	0.3	1.3
Forest on moist/wet lowlands	Coniferous forest	1.702	0.5	2.4
Forest on moist/wet lowlands	No forest	2.005	0.6	2.9
± open forests	Deciduous forest	43	0	0.1
± open forests	Mixed forest	52	0	0.1
± open forests	Coniferous forest	969	0.3	1.4
± open forest	No forest	242	0.1	0.3
No forest	Deciduous forest	1.167	0.4	1.7
No forest	Mixed forest	1.656	0.5	2.4
No forest	Coniferous forest	19.016	6.0	27.3
No forest	No forest	10.602	3.4	15.2
Other areas		245.151	77.8	
Sum		314.823	100	100

The Uckermark region

As in the Prignitz region, ancient and old forests cover 20% and ca. 8% of the Uckermark region, respectively, the highest proportion of the total area (Table 8.7). Approximately 18,000 ha have been afforested within the last ca. 50 years.

Also comparable to the Prignitz region, mainly ± closed forests have been converted to coniferous stands, but 5% of the ± closed forests have been converted to mixed stands. Other forest types are negligible in the Uckermark region (Table 8.8).

The Uckermark region is characterized by extended arable fields in the northeastern part where only a few small forests are embedded in the non-forest matrix (Figure 8.7). Here, the nutrient level of the soils is relatively high, and agricultural use is thus a very old tradition, dating back more than 200 years (Wulf and Schmidt, 1996). In contrast, in the southern and southwestern part, large forest areas have survived because they have been manorial or publicly owned for a long time. Most of the ancient forests were coniferous stands, but there are also extended areas of deciduous forest, mainly beech stands. One of them is the famous "Grumsiner Forest" (UNESCO world heritage site since June 2011).

Overview of ancient, old and recent forest area in the Uckermark region — Table 8.7

Forest type with regard to habitat continuity	Explanations	Area [ha]	% of the total area [ha]
Ancient forest	Continuously forest area since at least ca. 1780	79.520	20.0
„Old" forest	Continuously forest area since at least ca. 1880	33.040	8.3
Recent forest 1	Forest area on the 1780 map, but arable field or grassland on the 1880 map, and again forest area on the 1980 map	8.713	2.2
Recent forest 2	Forest area only on the 1980 map	17.770	4.5
Sum		139.043	35.0

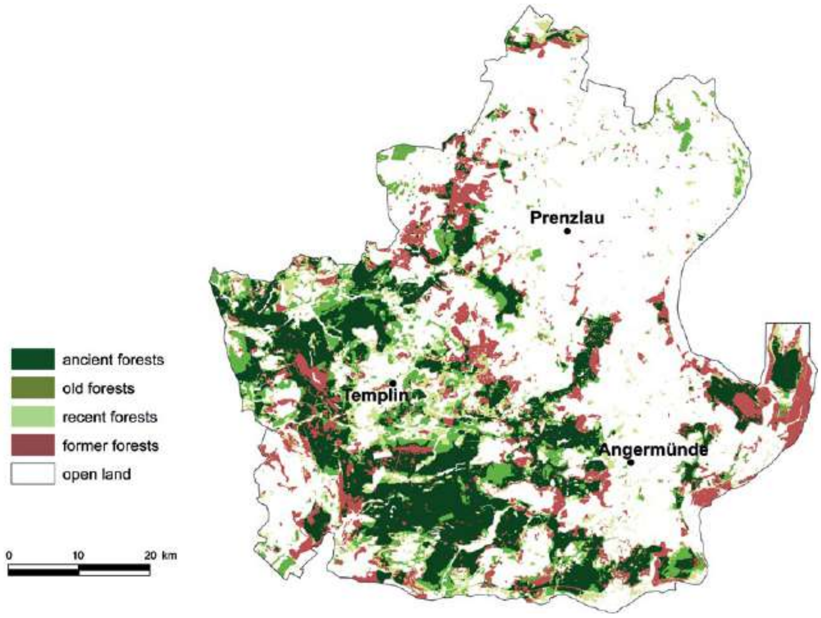
The total area of the region is 398.405 ha.

Proportion of combined forest types of the historical maps in the Uckermark region — Table 8.8

Forest type on the 1780 map	Forest type on the 1880 map	Total area [ha]	% of the total area	% of the forest area [69,672 ha]
± closed forest	Deciduous forest	12,933	3.2	9.3
± closed forest	Mixed forest	18,658	4.7	13.4
± closed forest	Coniferous forest	44,930	11.3	32.4
± closed forest	No forest	7,275	1.8	5.4
Forest on moist/wet lowlands	Deciduous forest	852	0.2	0.6
Forest on moist/wet lowlands	Mixed forest	263	0.1	0.2
Forest on moist/wet lowlands	Coniferous forest	643	0.2	0.5
Forest on moist/wet lowlands	No forest	767	0.2	0.6
Pastured forests	Deciduous forest	45	0	0
Pastured forests	Mixed forest	43	0	0
Pastured forests	Coniferous forest	1,153	0.3	0.9
Pastured forest	No forest	241	0.1	0.2
No forest	Deciduous forest	4,164	1.0	3.0
No forest	Mixed forest	5,167	1.3	3.7
No forest	Coniferous forest	23,709	6.0	17.1
No forest	No forest	17,770	4.5	12.8
Other areas		259,791	65.1	
Sum		398,405	100	100

Forest-open land distribution in the Uckermark region

Figure 8.7



Reconstructed with the Schmettau map (ca. 1780), the maps of the Prussian government (ca. 1880), and actual topographical maps (ca. 1980).

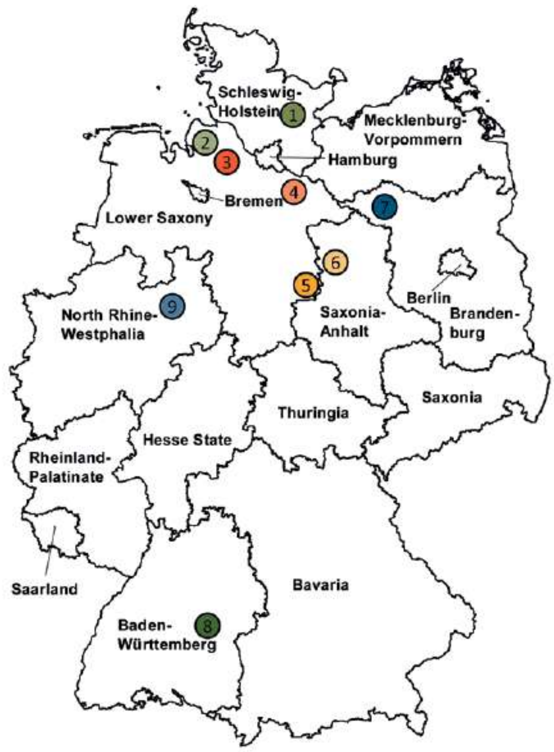
Importance for maintaining biodiversity

Several publications on ancient forests indicate their particular importance for maintaining animal and plant species diversity in the temperate forests of Europe (e.g., Peterken, 1981, 1993; Peterken and Game, 1984; Hermy et al.,1999, Sroka and Finch, 2006) and of North America (e.g., Matlack, 1994). No review is likely to give a complete overview of all of the studies conducted in Germany, although it has been attempted, focusing on vascular plant species and considering only published studies. From Figure 8.8, it is obvious that most of the research has been performed in northern Germany. These studies were used to extract a list of 20 selected indicator plant species for ancient forests (Table 8.9). It must be noted that the list is not valid for all of Germany because it is well known that the associations of plant species with ancient forests vary among regions (Wulf and Kelm, 1994). Nevertheless, many of the species in Table 8.9 were mentioned as central European ancient forest plant species by Hermy et al. (1999).

Unfortunately, there is no standardized definition of ancient forest indicators, and the identification of indicators has only rarely involved statistical tests (Wulf, 1997). However, the large number of studies on plant species that are associated with ancient forests from several European countries (cf. Hermy et al., 1999) is convincing, and there are even several plant species that are restricted to ancient forests (e.g., Wulf, 2004). Among the plant species in Table 8.9, there are several on the Red List of the Federal State Lower Saxony (Wulf and Kelm, 1994) and Brandenburg (Wulf, 2004). This is mainly because of the restricted area of deciduous ancient forests, which are the usual habitats of these plant species.

Published studies of ancient forest indicator plant species in Germany

Figure 8.8



1: Härdtle & Westphal (1998); 2: Wulf & Kelm (1994); 3: Wulf (1997); 4: Heinken (1998); 5: Zacharias (1994); 6: Otte (1996); 7: Wulf (2003b); 8: Schneider & Poschlod (1999); 9: Kühn (2000).

Table 8.9 Twenty selected indicator plant species for ancient forests in Germany

Author number	1	2	3	4	5	6	7	8	9
Adoxa moschatellina			×		×	×			
Anemone nemorosa					×	×	×	×	×
Carex sylvatica		×	×		×	×	×		
Equisetum sylvaticum		×	×		×		×		
Galium odoratum		×	×		×	×	×		
Hepatica nobilis	×		×		×	×			
Lamium galeobdolon		×	×		×		×	×	
Listera ovata		×			×		×		
Lysimachia nemorum		×	×						
Luzula pilosa				×			×		×
Melica uniflora		×	×		×	×	×		
Mercurialis perennis		×	×		×		×		
Milium effusum				×	×		×		
Oxalis acetosella		×	×		×		×		×
Paris quadrifolia		×	×		×	×	×	×	
Phyteuma nigrum/spicatum			×		×		×		
Primula elatior		×	×		×				×
Pulmonaria obscura/officinalis		×			×				×
Sanicula europaea		×	×		×	×	×		
Viola reichenbachiana/riviniana		×	×		×	×	×	×	

For author numbers see Figure 8.8

Protection of ancient forests

From Heiss (1987), one may get the impression that ancient forests have been an international focus since the 1980s and that this may have had an effect on the German policy of forest protection. Additionally, the Nature Protection Academy of Lower Saxony published the results of a symposium on ancient forests in 1994, suggesting that ancient forests are at least a national focus. However, even the Federal inventory of ancient forests in Germany initiated by the Federal Agency for Nature Conservation (Glaser and Hauke, 2004) did not lead to obligatory laws or regulations protecting ancient forests. Nevertheless, it can be stated that there are several instruments in place to protect forest areas, and they should be mentioned here because they are potential bases for the protection of ancient forests in the future. There are also some different approaches to consider.

The Federal policy of forest protection in Germany is integrated in two main global processes based on the UNCED (United Nations Conference on Environment and Development) 1992;

- the global forest policy that is based on the "forest declaration" of UNCED 1992 and
- the global biodiversity policy that is based on the convention on biodiversity (CBD) 1992.

The "forest declaration" is a "declaration on principles" and is not related to the law of nations. However, all efforts to set the global forest policy on a foundation related to the law of nations with an international convention have failed. The CBD is an obligatory agreement (Winkel, 2006; Mann, 2012).

In the context of the global forest policy, the "Helsinki"-process at the Pan-European level was important. A definition of "sustainable forest management (SFM)" that was based on six criteria and 27 indicators was acquired, and the resolution L2 "Pan-European Criteria, Indicators and Guidelines for Sustainable Forest Management on Operational Level" was adopted (MCPFE, 2000). The Pan-European Criterion no. 4, with seven indicators, concerns the maintenance, conservation and enhancement of biological diversity in forest ecosystems. The first indicator refers to the changes in the natural and ancient semi-natural forest types (Puumalainen et al., 2003; Wulf, 2003a). According to the title of a publication by Heiss (1987), these forests have been inventoried for the European council memberstates and Finland. Unfortunately, a figure in Heiss (1987) shows in very rough 100,000 ha steps the estimated area of designated and potential woodland reserves. From that figure, it appears that approximately 100,000 ha of woodland were already designated as reserves with and without management and that the largest part of these areas are

Table 8.10

Forest area and protected forest area of the EU member state Germany
(according to Parviainen et al., 2000a and Bücking, 2007)

EU member state	Germany (FRG)
Area of forest	10,700,000 ha = 107,000 km²
Forest cover as % of total forest area	30
Total area of protected forests (ha)	400,000
Total area of protected forest area as % of forest cover	4.0
Area of strict forest reserves (ha)	24,976
Area of strict forest reserves as % of forest cover	0.23

potential woodland reserves.

Unfortunately, Heiss (1987) did not provide a definition of ancient woodland, but his introduction indicates that this term was synonymous with "virgin" forests. Thus, ancient forests in the sense of forests with a habitat continuity of at least 200 years were not inventoried at that time. However, several impulses for the Federal policy were revealed by the European Union (EU). Most important are the bird protection guidelines (from 1979) and the guideline for Flora-Fauna-Habitat (FFH) (from 1992), which both aspire to realize a European net of protected areas (Natura 2000). Despite the recommendations of the EU superior counselor (EU Ministerrat) from 1988, ancient forests have not been included in appendix I of the FFH guidelines from 1992 (Stegink-Hinrichs, 1994). Thus, it is not clear how many of the strict forest reserves mentioned by Parviainen et al. (2000a,b) occur on ancient forest sites (Table 8.10, see also Wulf, 2003a)

In the framework of the FFH, Germany has claimed to have a very high proportion of forest areas (Winkel, 2006). Though 17% of the total forest area includes FFH areas (unpublished data), it is not clear how many of the FFH areas are ancient forests. The same is true for the strict forest reserves (SFR), which have been designated within the last 100 years (Table 8.11). In the new "recommendations for the establishment and care of strict forest reserves" (Projektgruppe Naturwaldreservate 1993), the consideration of "ancient forest sites" is recommended for the selection of suitable areas. Meyer et al. (2007) mentioned that 716 SFRs existed in 2007, covering 31,176 ha in total (0.29% of the total forest area), but no information is given about whether ancient forests have been considered starting in 1993. Because particularly semi-natural stands were selected to be designated as SFRs, it can be assumed that these are ancient forests because those stands have usually survived on ancient forest sites. The data in Table 8.11 show some inconsistencies because of the different sources used. For completeness, the table is presented here as it was originally published by Meyer et al. (2007).

Recently, Germany took international responsibility to protect beech forests in an interlinked network (BfN, 2008). In the report commissioned by Greenpeace in April 2011, it mentioned that besides other sources, the Federal inventory of "ancient forests" by Glaser and Hauke (2004) has been considered the expert opinion (Panek 2011). In this context, the "Grumsiner Forest" (Brandenburg, NE Germany) attains world heritage status as part of the "Ancient Beech Forests of Germany" by UNESCO in 2011 (Geisel et al., 2012). The Grumsiner Forest is 1,291 km² and was shown to have been a beech-dominated forest for c. 400 years (Luthardt et al., 2004).

Table 8.11

Development of the designation of SFRs
(according to Meyer et al., 2007)

Year	Number of SFR	Area [ha]	Source(s)
1968*	150	2.100	Bauer (1968); Trautmann (1969)
1976**	472	10,880	Trautmann (1976)
1980**	472	10,315	Anonymous (1980)
1989	570	12,827	Bohn & Wolf (1989)
1991	564	16,443	Wolf & Bohn (1991)
1993	no data	44,650	BML (1994)
1994	637	19,380	Anonymous (1994)
1995	635	20,503	Bundesamt für Naturschutz (1997)
1997	651	21,795	Bücking (1997)
1998	678	25,016	Bundesamt für Naturschutz (1999)
2000	679	24,976	Bücking (2000); Parviainen et al. (2000a)
2001	629	23,718	Bundesamt für Naturschutz (2002)
2001	781	28,205	Bücking (2003)
2004	824	30,587	Bundesamt für Naturschutz (2004)
2007	716	31,176	Query by Meyer

*Only data for the former GDR (East Germany), no data for the former FRG (West Germany).
**Data for the former FRG, data from 1968 of the former GDR are added.

The inventory of German ancient forests was conducted in the framework of the research project "Analysis of the distribution of endangered biotopes in Germany with a European wide importance" from 1999 to 2001 (Verbreitungsanalyse gefährdeter Biotoptypen von europäischer Bedeutung in Deutschland (FKZ-Nr. 8988515)). In the foreword of the study by Glaser and Hauke (2004), the president of the Federal Agency for Nature Protection (Bundesamt für Naturschutz = BfN) mentioned that the results can be used as a basis for political decisions and plannings on the federal and state level. Nevertheless, on the national level, neither the Federal Forest Act (Bundeswaldgesetz) nor the Federal Law on Nature Conservation (Bundesnaturschutzgesetz) considered the protection of ancient forests (Stegink-Hinrichs, 1994). All German states have enacted their own State Forest Laws. They reflect the basic structure and the main provisions of the Federal Forest Act but differ "in terms of, e.g., (i) the legal definition of sustainable forest management (SFM) and minimum requirements for forest operations, (ii) safeguards for protective and social forest functions and environmental impact assessment (EIA) requirements, (iii) provisions regarding protected forest areas, (iv) structural set-up, mandates, and responsibilities of forest sector administrations and state forest enterprises, (v) public support to the forest sector, and (vi) penal provisions." (Mann, 2012, p. 22). Among these 16 State Forest Laws, no one considered "ancient forests" to be particularly in need of protection.

At least Lower Saxony considered ancient forests in the long-term ecological forestry planning of 1994, the so-called LÖWEN (Langfristige, ökologische Waldbauplanung für die Niedersächsischen Landesforsten, ML, 1994). In the LÖWEN, it is assured that, "On sites where soils were not degraded or severely disturbed by human impacts, disturbing or altering the naturally developed structure of the organic and mineral layer is not allowed" (LÖWEN, p. 11). Furthermore, "a sufficient representativeness of semi-natural forest communities should be achieved. This is particularly true for forest communities occurring on old, not otherwise used sites and on forest soils sites" (LÖWEN, p. 24). Lower Saxony has therefore put some efforts into creating maps of the historical land use derived from old maps (Ostmann, 1994). However, these maps are available for only 25% of Lower Saxony.

Despite these activities, Germany still lacks laws or guidelines that specifically address the protection of ancient forests.

Threats to ancient forests

In general, there is no threat that solely affects ancient forests. Direct and indirect human impacts, e.g., forest management, atmospheric depositions and climate change, potentially affect all forests. For European forests, this is comprehensively demonstrated by Ellenberg and Leuschner (2010). One example is enhanced N deposition for more than 100 years (Ulrich and Meyer, 1987) that has resulted in an increase of the N content in forest soils and changes in the humus quality (Ellenberg and Leuschner 2010). As a result, changes in the vegetation toward an increase of nitrogen indicator plant species are observed (Zerbe, 1992).

However, one threat may particularly affect the plant species diversity of ancient forests: "extinction debt" (Tilmann et al., 1994), in which evidence of the process takes decades or even longer to appear. It is well known that forest herbs can live in a habitat for several decades or longer (Inghe and Tamm, 1985; Gilliam, 2007), even if the habitat conditions have become unfavorable. This delayed response to habitat alterations has been termed extinction debt (Paltto et al., 2006; Vellend et al., 2006; Lindborg et al., 2011). For instance, Paltto et al. (2006) found a delayed response of vascular forest plants to habitat loss and fragmentation during the past 120 years. Because recent forests may not exist for as long as is required for evidence of extinction debt to become apparent, it is likely that this effect is more relevant for plant populations in ancient forests.

As mentioned above, 77% of all forests in Germany are ancient forests. Most of these forests have become fragmented in the past. Fragmentation is defined as the conversion of a former extended habitat into smaller, isolated habitats embedded in a matrix that is usually uninhabitable for species of the original habitats (Valladares et al., 2006). The process of fragmentation comprises two facts: loss of habitats and dissection of habitats (Köhler and Eggers, 2012). Around 1800, the proportion of deciduous and mixed stands was still relatively high, but this proportion has changed dramatically within decades. Mainly for economic reasons, these stands were converted to coniferous-dominated stands (Mantel 1990), and these have remained until today (Glaser and Hauke, 2004). It is likely that the animal and plant species that are adapted to semi-natural ancient forests are threatened simply because large parts of those stands have been converted to pure or prevailing coniferous stands in the past.

For example, Figures 8.9 and 8.10 demonstrate the dramatic changes in the dominant tree species from c. 1800 until today for the Prignitz region (northeast Germany) (Wulf and Rujner, 2011). Two hundred years ago, oak and alder forests covered 44% and 37% of the total forest area, respectively. Approximately 6% was covered by oak-hornbeam forests. Only 100 years later, most of the deciduous stands were converted to Scots Pine stands (Hesmer, 1938). An actual map of forest vegetation illustrated that pine stands still prevail, whereas oak and beech dominated stands cover only 7.6% and 3.4%, respectively (Wulf and Rujner, 2011).

Figure 8.9 **Historical forest vegetation in the Prignitz region around 1800**
(according to Wulf & Rujner, 2011)

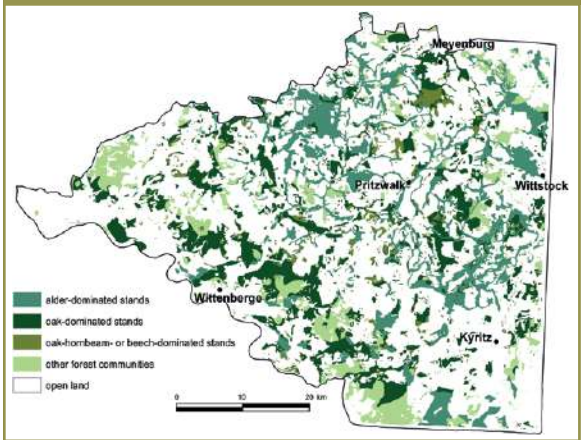
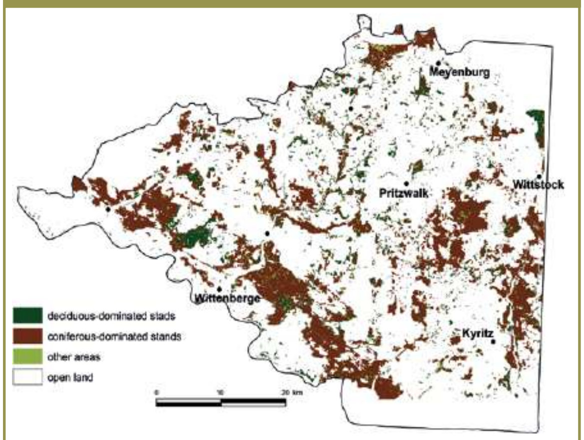


Figure 8.10 **Actual forest vegetation in the Prignitz region around 2000**
(according to Wulf & Rujner, 2011)



A case study from northwest Germany

A study on semi-permanent plots in a northwestern German region (Naaf 2011) showed that environmental changes may have effects on the vegetation of ancient forests within only two decades. In the Elbe-Weser-Region (Figure 8.2), 415 vegetation plots in ash- and oak-dominated stands on moist and base rich sites were surveyed from 1986 to 1989 (Wulf, 1992). Of the 415 total plots, 175 relocated plots were selected (excluding the effects of spatial autocorrelation) and resurveyed in 2008 and 2009 by Naaf (2011). Several plant species show a significant negative or positive average change in their abundance, i.e., the so-called 'loser' or 'winner' species. Among the losers are many forest specialists (species closely tied to forests), including several ancient forest indicators, e.g., *Hepatica nobilis, Paris quadrifolia* and *Sanicula europaea* (Wulf, 1997; Naaf and Wulf, 2011).

Two decades ago, not all environmental factors that could be potential drivers of these changes had been measured or were available. Therefore, plant species' traits have been used that attempt to detect the drivers behind these changes in forest vegetation. Of 115 species tested, 31 were winner species and 30 were loser species (Naaf and Wulf, 2011). Among six traits, oceanic distribution is one of the important traits in discriminating between winner and loser species. The proportion of plant species with an oceanic distribution is 40% for the winner species compared to 3.3% for the loser species. Higher performance of species with an oceanic distribution (e.g., *Hedera helix* and *Ilex aquifolium*) can be interpreted as a response to the increasingly warmer winters (Naaf, 2011). This assumption is supported by a few empirical studies that "have observed shifts in local abundance of temperate forest plants in response to climate change. In a resurvey of 103 British woods after 30 years, Kirby et al. (2005) observed changes in mean cover that were related to an increase in the duration of the growing season for 17 species. However, decreases or increases in cover were not associated with a northern, southern, continental or oceanic distribution of the species (Kirby et al., 2005). Our study suggests that species with certain distributions may already show responses to climate warming over a short time period of two decades" (Naaf, 2011, p. 73).

Summary and concluding remarks

- A map at scale 1:100,000 provide an overview on the distribution of deciduous, mixed and coniferous ancient and recent forests in Germany (Glaser and Hauke, 2004).
- Several publications have shown that semi-natural ancient forests are important for the maintenance of plant species' diversity and that several plant species can be designated as ancient forest indicator species (e.g., Wulf, 2003b).
- Despite several political instruments to protect forests in the European Union (e.g., the forest declaration of the UNCED 1992) and at the Federal and State level in Germany (e.g., guidelines for Flora-Fauna-Habitat (FFH)), there are no laws or regulations to protect ancient forests (cf. Stegink-Hinrichs, 1994).
- Several strict forest reserves have been established since 1968. Today, these reserves comprise an area of c. 31,200 ha, which is only 0.3% of the entire forest area in Germany.
- Recently, Germany took international responsibility to protect beech forests in an interlinked network. Some "Ancient Beech Forests of Germany" were designated as world heritage sites by UNESCO in 2011 (e.g., Geisel et al., 2012).
- An example from northwest Germany revealed that forest plant species of ancient forest sites have been obviously affected by climatic changes within the last two decades. The average abundance of plant species with an oceanic distribution (e.g., *Hedera helix* and

Ilex aquifolium) has increased from 1988 to 2008 and can be interpreted as a response to increasingly warmer winters (Naaf, 2011).

- From the study in northwest Germany, it is obvious that there are several ancient forest indicator species among the 'loser', defined as plant species with a significant negative average change in their abundance (Naaf and Wulf, 2011).

Despite the growing interest in ancient forests and their doubtless importance for maintaining biodiversity, there is no published overview on protected ancient forest areas in Germany. This is in clear contrast to the attention given to them by many scientific studies, whose results show that the forests are potential "hot spots" of biodiversity in central Europe (e.g., Ray et al., 2004). As in other European countries, there is a lack of digital large-scale maps (scale at least 1:50,000) in Germany (but see Wulf and Schmidt, 1996; Wulf, 2004). This may be because of the time-consuming work to produce such a map and the restricted funding possibilities. Nevertheless, these maps are necessary for further scientific studies to be conducted at a small scale, e.g., estimation of the carbon sequestration potential of forest stands on ancient and recent forest sites (Ellenberg and Leuschner, 2010). This is one argument to follow the recommendation of Rackham (2008), who stated that "There is a need to maintain archives of the present or recent state of woodland as a basis against which to measure future changes" (Rackham, 2008, p. 583).

Acknowledgement

This research was funded by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and the Ministry for Science, Research and Culture of the State of Brandenburg (MWFK). Hearty thanks are given to K. Meier and U. Jahn for their technical assistance.

References

Anonymous, 1980. Berichte aus den Bundesländern zur Auswahl, Einrichtung und Bestandserfassung der Naturwaldreservate. *Natur und Landschaft*, 55: 134-143.

Anonymous, 1994. Naturwaldreservate in den Bundesländern. *Allgemeine Forstzeitung*, 49: 564-570.

Bauer, L., 1968. Die Naturschutzgebiete der Deutschen Demokratischen Republik nach Typen und Größenklassen. *Archiv für Naturschutz und Landschaftsforschung*, 8: 241-247.

Bohn, U. and Wolf, G., 1989. Ergebnisse des Kolloquiums über Naturwaldreservate1989. *Natur und Landschaft*, 64: 587-591.

Bork, H.R., Bork, H. Dalchow, C., Faust, B., Piorr, H.-P. and Schatz, T., 1998. *Landschaftsentwicklung in Mitteleuropa*. Klett-Perthes, Gotha, 328 p.

Bücking, W., 1997. Naturwald, Naturwaldreservate, Wildnis in Deutschland und Europa. *Forst und Holz*, 52: 515-522.

Bücking, W., 2000. *Naturwaldreservate, Bannwälder, Schonwälder.* In: Konold, W., Böcker, R., Hampicke, U. (Eds.): Handbuch Naturschutz und Landschaftspflege, 2. Erg. Lfg. 7/00 III-2.2, Landsberg, 1-16.

Bücking, W., 2003. *Naturwaldreservate - "Urwald" in Deutschland.* Aid infodienst, 1473: 1-66.

Bücking, W. 2007: Naturwaldreservate in Europa. Forstarchiv, 78: 180-187.

Bundesamt für Naturschutz (BfN) (ed.), 1997. *Daten zur Natur 1996*. Landwirtschaftsverlag, Münster, 170 p.

Bundesamt für Naturschutz (BfN) (ed.), 1999. *Daten zur Natur 1999*. Landwirtschaftsverlag, Münster, 266 p.

Bundesamt für Naturschutz (BfN) (ed.), 2002. *Daten zur Natur 2002*. Landwirtschaftsverlag, Münster, 284 p.

Bundesamt für Naturschutz (BfN) (ed.), 2004. *Daten zur Natur 2004*. Landwirtschaftsverlag, Münster, 474 p.

Bundesamt für Naturschutz (BfN), 2008. *Beech Forests - a German contribution to the global forest bioidversity*. Selbstverlag, Bonn, 86 p.

Bundesministerium für Ernährung, Landwirtschaft und Forsten (BML), 1994. *Nationaler Waldbericht der Bundesrepublik Deutschland.* Selbstverlag, Bonn, 100 p.

Ellenberg, H. and Leuschner, Chr., 2010. *Vegetation Mitteleuropas mit den Alpen*. 6. Aufl., UTB Ulmer, Stuttgart, 1334 p.

Geisel, T., Luthardt, M. E. and Schulz, R., 2012. *Der Grumsin. UNESCO-Weltnaturerbe „Alte Buchenwälder Deutschlands"*, (In German and English). Verlagsbuchhandlung Ehm Welk, Angermünde, 184 p.

Gilliam, F.S., 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. *BioScience*, 57(10): 845-858.

Glaser, F.F. and Hauke, U., 2004. Historisch alte Waldstandorte und Hudewälder in Deutschland. *Angewandte Landschaftsökologie*, 61: 1-193.

Härdtle, W. and Westphal, Chr., 1998. Zur ökologischen Bedeutung von Altwäldern in der Kulturlandschaft Schleswig-Holsteins. *Braunschweiger Geobotanische Arbeiten*, 5: 127-138.

Heinken, Th. 1998. Zum Einfluss des Alters von Waldstandorten auf die Vegetation in bodensauren Laubwäldern des niedersächsischen Tieflandes. *Archiv für Naturschutz und Landschaftsforschung*, 37: 201-232.

Heiss, G. 1987. Situation of natural and ancient, seminatural woodlands within the Council of Europe's member States and Finland. Council of Europe. *Environmental Encounters Series*, 3: 51–64.

Hermy, M., Honnay, O., Firbank, L., Grashof-Bokdam, C. and Lawesson, J.E., 1999. An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation. *Biological Conservation*, 91: 9-22.

Hesmer, H., 1938. *Die heutige Bewaldung Deutschlands*. Paul Parey, Berlin, 57 p.

Hilf, R.B., 1928. Zur Forst- und Bestandesgeschichte der Mittelmark. *Bericht über die Winterversammlung des Märkischen Forstvereins zu Berlin*, 1928: 5-17.

Inghe, O. and Tamm, C.O., 1985. Survival and flowering of perennial herbs. IV. The behaviour of *Hepatica nobilis* and *Sanicula europaea* on permanent plots during 1943-1981. *Oikos*, 45: 400-420.

Kirby, K.J., Smart, S.M., Black, H.I.J., Bunce, R.G.H., Corney, P.M. and Smithers, R.J., 2005. Long term ecological change in British woodlands (1971-2001). *English Nature Research Report*, 653: 1-139.

Köhler, R. and Eggers, B., 2012. *Waldfragmentierung und Artenschutz. Analyse der Auswirkungen der Fragmentierung von Waldökosystemen auf Indikatorarten unter Berücksichtigung von Landschaftsstrukturindizes. Landbauforschung*. Sonderheft 363: 1-83.

Kühn, I., 2000. *Ökologisch-numerische Untersuchungen an Wäldern der Westfälischen Bucht*. Archiv naturwissenschaftlicher Dissertationen, 12: 1-192.

Küster, H.-J., 2008. *Geschichte des Waldes. Von der Urzeit bis zur Gegenwart*. 2. Aufl., Beck Verlag, München, 267 p.

Lindborg, R., Helm, A., Bommarco, R., Heikkinen, R.K., Kühn, I., Pykälä, J. and Pärtel, M., 2011. Effect of habitat area and isolation on plant trait distribution in European forests and grasslands. *Ecography*, 35(4): 356-363.

Luthardt, M.E., Schulz, R. and Wulf, M. 2004. *Ein Buchenwald im Wandel der Zeit : 300 Jahre Nutzungsgeschichte im Grumsiner Forst, Natur und Text*. Rangsdorf, 102 p.

Mann, S., 2012. *Forest Protection and Sustainable Forest Management in Germany and the P.R. China. A Comparative Assessment*. BfN-Skripten, 311: 1-118.

Matlack, G.R., 1994. Plant species migration in a mixed-history forest landscape in eastern north America. *Ecology*, 75(5): 1491-1502.

MCPFE, 2000. *General Declarations and Resolutions Adopted at the Ministerial Conferences on the Protection of Forests in Europe Strasbourg 1990 - Helsinki 1993 - Lisbon 1998.* MCPFE Liaison Unit Vienna.

Meyer, P., Bücking, W., Gehlhar, U. and Steffens, R., 2007. Das Netz der Naturwaldreservate in Deutschland: Flächenumfang, Repräsentativität und Schutzstatus im Jahr 2007. *Forstarchiv*, 78: 188-196.

Meynen, E. and Schmithüsen, J., 1953-1962. *Handbuch der naturräumlichen Gliederung Deutschlands*. Selbstverlag, Remagen, 1339 p.

Ministerium für Landwirtschaft und Forsten (ML) des Landes Niedersachsen, 1994. *Langfristige, ökologische Waldbauplanung für die Niedersächsischen Landesforsten, Runderlass vom 05.05.1994*, 38 p.

Müller, W., 1941. Vom Wald unserer Prignitz. *Prignitzer Heimatjahrbuch* (Nebentitel: Das Jahrbuch der Prignitz), 1941: 113-123.

Naaf, T., 2011. *Floristic homogenization and impoverishment - herb layer changes over two decades in deciduous forest patches oft he Weser-Elbe region (NW Germany)*. PhD Thesis University of Potsdam, 135 p. [http://opus.kobv.de/ubp/volltexte/2011/5244]

Naaf, T. and Wulf, M., 2011. Traits of winner and loser species indicate drivers of herb layer changes over two decades in forests of NW Germany. *Journal of Vegetation Science*, 22: 516-527.

Norddeutsche Naturschutzakademie (NNA) (ed.), 1994. *Bedeutung historisch alter Wälder für den Naturschutz*. NNA-Berichte, 7(3): 1-159.

Ostmann, U., 1994. *Die Landnutzungsarten in topographischen Karten des 18. und 19. Jahrhunderts als standortkundliche Beiträge zum Naturschutz*. NNA-Berichte, 7/3: 60-68.

Otte, V., 1996. Das Alter des Waldes als Ursache floristischer Unterschiede in Forsten des Alvensleber Hügellandes. *Hercynia*, 30: 53-68.

Paltto, H., Nordén, B. Götmark, F. and Franc, N., 2006. At which spatial and temporal scales does landscape context affect local density of Red Data Book and indicator species? *Biological Conservation*, 133: 442-454.

Panek, N., 2011. *Deutschlands internationale Verantwortung: Rotbuchenwälder im Verbund schützen.* (unpubl.) Gutachten im Auftrag von Greenpeace e. V. Hamburg, 71 p.

Parviainen, J., Kassioumis, K., Bücking, W., Hochbichler, W., Päivinen, R. and Little, D., 2000a. *COST Action E4: Forest Reserves Research Network. Mission, Goals, Linkages, Recommendations and Partners, Final Report.* Joensuu, Finland, 28 p.

Parviainen, J., Kassioumis, K., Bücking, W., Hochbichler, E., Päivinen, R. and Little, D., 2000b. *Final report summary: mission, goals, outputs, linkages, recommendations and partners.* In: European Commission. COST Action E4 - Forest reserves research network, Office for Official Publications of the European Communities EUR 19550, Luxembourg, 9-37.

Peterken, G.F., 1977. Habitat conservation priorities in British and European woodlands. *Biological Conservation*, 11: 223-236.

Projektgruppe Naturwaldreservate des Arbeitskreises Standortkartierung in der AG Forsteinrichtung, 1993. Empfehlungen für die Einrichtung und Betreuung von Naturwaldreservaten in Deutschland. *Forstarchiv*, 64: 122-126.

Puumalainen, J., 2001. *Structural, compositional and functional aspects of forest biodiversity in Europe*. Joint FAO/UNECE and JCR Paper, Geneva Timber and Forest Discussion Papers, United Nations, New York and Geneva, ECE/TIM/DP22, 87 p.

Puumalainen, J., Kennedy, P. and Folving, S., 2003. Monitoring forest biodiversity: a European perspective with reference to temperate and boreal forest zone. *Journal of Environmental Management*, 67(1): 5-14.

Rackham, O. 2008. Ancient woodland: modern threats. *New Phytologist*, 180: 571-586.

Ray, D., Hope, J. and Watts, K. 2004. *Development of a forest habitat network strategy in west Lothian*. Report No. AB(LJ15)0304118 to Scottish Natural Heritage, Final Report 29 March 2004, 29 p.

Riecken, U., Ries, U. and Ssymank, A., 1994. *Rote Liste der gefährdeten Biotoptypen der Bundesrepublik Deutschland*. Kilda Verlag, Greven, 184 p.

Schlüter, O., 1952. Die Siedlungsräume Mitteleuropas in frühgeschichtlicher Zeit. 1. Teil. Einführung in die Methodik der Altlandschaftsforschung. *Forschungen zur deutschen Landeskunde*, 63: 1-47.

Schneider, C. and Poschlod, P., 1999. Die Waldvegetation ausgewählter Flächen der Schwäbischen Alb in Abhängigkeit von der Nutzungsgeschichte. *Zeitschrift für Ökologie und Naturschutz*, 8: 135-146.

Sroka, K. and Finch, O.-D., 2006. Ground beetle diversity in ancient woodland remnants in north-western Germany (Coleoptera, Carabidae). *Journal of Insect Conservation*, 10: 335-350.

Stegink-Hinrichs, L., 1994. Historisch alte Wälder – ihre Berücksichtigung in Konzepten und Programmen. *NNA-Berichte*, 7(3): 152-159.

Tilman, D., May, R.M., Lehman, C.L. and Nowak, M.A., 1994. Habitat destruction and the extinction debt. *Nature*, 371: 65-66.

Trautmann, W., 1969. Zur Einrichtung von Naturwaldreservaten in der Bundesrepublik Deutschland. *Natur und Landschaft*, 44: 88-89.

Trautmann, W., 1976. Stand der Auswahl und Einrichtung von Naturwaldreservaten in der Bundesrepublik Deutschland. *Natur und Landschaft*, 51: 67-72.

Ulrich, B. and Meyer, H., 1987. *Chemischer Bodenzustand der Waldböden Deutschlands zwischen 1920 und 1960. Ursachen und Tendenzen seiner Veränderung*. Berichte des Forschungszentrums für Waldökosysteme Universität Göttingen, B 6: 1-133.

Vellend, M., Verheyen, K., Jacquemyn, H., Kolb, A., van Calster, H., Peterken, G. and Hermy, M., 2006. Extinction debt of forest plants persists for more than a century following habitat fragmentation. *Ecology*, 87: 542-548.

Walter, H. and Straka, H., 1970. *Arealkunde. Floristisch-historische Geobotanik*. 2. Aufl., Ulmer, Stuttgart, 478 p.

Winkel, G., 2006. *Waldnaturschutzpolitik in Deutschland Bestandsaufnahme, Analysen und Entwurf einer Story-Line.* Unpublished Inaugural-Dissertation, 562 p. [http://www.freidok.uni-freiburg.de/volltexte/2851/pdf/Dissertation_G_Winkel_final.pdf]

Wolf, G. and Bohn, U., 1991. Naturwaldreservate in der Bundesrepublik Deutschland und Vorschläge zu einer bundesweiten Grunddatenerfassung. *Schriftenreihe für Vegetationskunde*, 21: 9-19.

Wulf, M., 1992. *Vegetationskundliche und ökologische Untersuchungen zum Vorkommen gefährdeter Pflanzenarten in Feuchtwäldern Nordwestdeutschlands*. Dissertationes Botanicae, 185: 1-246.

Wulf, M., 1994. Überblick zur Bedeutung des Alters von Lebensgemeinschaften, dargestellt am Beispiel „historisch alter Wälder". *NNA-Berichte*, 7(3): 3-14.

Wulf, M., 1997. Plant species as ancient woodland indicators in northwestern Germany. *Journal of Vegetation Science*, 8(5): 635-642.

Wulf, M., 2003a. Forest policy in the EU and its influence on the plant diversity of woodlands. *Journal of Environmental Management*, 67(1): 15-25.

Wulf, M., 2003b. Preference of plant species for woodlands with differing habitat continuities. *Flora*, 198: 444-460.

Wulf, M., 2004. *Auswirkungen des Landschaftswandels auf die Verbreitungsmuster von Waldpflanzen. Konsequenzen für den Naturschutz.* Dissertationes Botanicae, 392: 1-306.

Wulf, M. and Kelm, H.-J., 1994. Überblick zur Bedeutung „historisch alter Wälder" für den Naturschutz - Untersuchungen naturnaher Wälder im Elbe-Weser-Dreieck. *NNA-Berichte*, 7(3): 15-50.

Wulf, M. and Rujner, H., 2011. A GIS-based method for the reconstruction of the late eighteenth century forest vegetation in the Prignitz region (NE Germany). *Landscape Ecology*, 26: 153-168.

Wulf, M. and Schmidt, R., 1996. Die Entwicklung der Waldverteilung in Brandenburg in Beziehung zu den naturräumlichen Bedingungen. *Beiträge für Forstwirtschaft und Landschaftsökologie*, 30(3): 125-131.

Zacharias, D., 1994. Bindung von Gefäßpflanzen an Wälder alter Waldstandorte im nördlichen Harzvorland Niedersachsens. *NNA-Berichte*, 7(3): 76-88.

Zerbe, S., 1992. *Fichtenforste als Ersatzgesellschaften von Hainsimsen-Buchenwäldern. Vegetationsveränderungen eines Forstökosystems.* Berichte des Forschungszentrums für Waldökosysteme Universität Göttingen, A 100: 1-173.

Chapter 9

Tree abundance, density and age structure: the key factors which determine species-richness in saproxylic invertebrates

Keith N.A. Alexander

Introduction

Conservation should be based on practical observation rather than unstable theory (Rackham, 2006). This is a critically important point - far too much woodland conservation is currently based on an unproven hypothesis of the structure of the forests which spread across Europe following the last Ice Age - the high forest hypothesis. This is especially the case with our most precious sites, the Special Areas of Conservation (SACs), where practical observation would suggest that current approaches to 'minimum intervention' management will inevitably lead to decreasing species richness as a result of decreased sun penetration and increased shading. This chapter will focus on the specialist invertebrates which depend upon the natural decay and degradation of the dead woody tissues produced by trees and shrubs as they develop and age. It will discuss the importance of the age structure of the tree population, the spacing between trees, and the total numbers of trees, as well as the importance of connectivity across the landscape. A basic understanding of the key aspects of tree biology and tree ecology - the aging and decay processes of trees as well as tree form and tree habitats - is an essential tool for people involved in the conservation management of wood-decay invertebrates. A good appreciation of tree terminology is also essential in order to successfully achieve conservation of tree-dependent wildlife

The secret of successful conservation of these wood-decay invertebrates is to think landscape scale - the largest sites support the greatest range of species (Alexander, 2004a, b). It is also important to appreciate that the widest variety of wood-decay habitats is produced by an open-grown tree, where the tree has space to develop its full potential of form and structure (Alexander, 2007; Green, 2010) (Photograph 1 and 2). Only an open-grown tree has good lateral branch development and the potential to support the full range of wood-decay fungi and invertebrates which need decaying wood in the lower crown (Alexander, 2002) (Photograph 3, 4 and 5). Only an open-grown tree can survive into old age, as natural crown retrenchment with age results in a reduced crown height and leaves the tree very vulnerable to over-shading by neighbouring younger trees. Retrenched trees are referred to as 'ancient trees' and support many of Europe's rarest wood-decay invertebrates. The term 'veteran tree' refers to trees which have substantial development of decaying woody tissues resulting either from natural ageing processes or from physical damage - an 'ancient tree' is a type of 'veteran tree' but not all 'veteran trees' are ancient (Ancient Tree Guide No.4) .

Photograph 1: Open-grown oak showing full lateral branch development. Glengarriff Woods, Ireland (K. Alexander).

If conservation of wood-decay communities is an objective of site management then it is vital to consider the long-term production of suitable deadwood habitats from the living trees. It is especially important to base conservation action on the trees, rather than on such abstract concepts as 'woodland' or 'forest'. Trees are real, but terms such as 'woodland' and 'forest' mean different things to different people (Alexander, 2008).

Photograph 2: Open-grown oak, Calke Park, England (K. Alexander).

Photograph 3: This line of trees was planted about 100 years ago; one of the middle trees has been felled; the left hand oak tree now clearly shows an open-grown lateral branch development while the right side has high forest form structure; the tree on the right also has high forest form structure with poor lateral branch development. Heavitree Pleasure Ground, Exeter, England (K. Alexander).

Photograph 4: An old oak tree growing in a more natural situation, but also showing open-grown form on the left side and high forest form on the right side where there is competition from neighbouring trees. Wye Gorge, Wales (K. Alexander).

Photograph 5: Open-grown oak, one on left with history of shredding, the one on the right typical natural open-grown form, the difference in lateral branch size is very clear, Bodfach Park, Wales (K. Alexander).

Wood-decay invertebrates – how many species are there and why are they important?

Few countries have carried out full inventories of their native wood-decay invertebrates. Britain and Ireland may be the only European countries able to quote simple statistics. Alexander (2002) provides a full listing together with basic information on their known ecology, distribution and conservation status: at that time Britain was believed to be supporting 1792 different wood-decay invertebrate species and Ireland 615 species. The figures are somewhat different today as knowledge of the ecology of the species has grown, but essentially Britain is currently believed to have about 2000 native species of wood-decay invertebrate. The best studied group is the Coleoptera (beetles), with 700 species. 54% of these beetle species have been assessed as being rare, and 23% feature on Britain's Red Data Book (Hyman and Parsons, 1992). Other European countries are much richer in species but the proportion of Threatened species and species of conservation interest generally is probably similar to that of Britain. There is abundant evidence that this fauna is of great importance to conservation across Europe – the IUCN European Red List of Saproxylic Beetles (Nieto and Alexander, 2010) has shown that, at a continental scale, 11% of saproxylic beetles are threatened. This compares with 9% of butterflies, 13% of birds and 15% of mammals. Almost 14% of the assessed beetles are thought to have significantly declining populations. The drivers for those declines are mostly still in place – habitat degradation and loss poses the main threat, either in relation to forestry practices or due to a general decline in veteran trees throughout the landscape.

These species are much more than features of conservation interest however, as they are part of the natural decomposition processes of deadwood, they are instrumental in the release of the nutrients which are locked up in wood, and part of natural recycling of nutrients (Stokland et al., 2012). They enrich the soil and facilitate the return of nutrients to the trees. Many are active predators and parasites of pest species, which would otherwise have a more serious impact on the economics of human exploitation of timber. Others are important in the pollination of flowering plants. The benefits of these obscure invertebrates to human populations are actually manifold and discussion of these aspects alone would occupy an entire book.

The importance of age structure of the tree population, the spacing between trees, and the total numbers of trees

Although conservationists tend to get over-occupied with quantifying the volumes of deadwood available in particular areas, there are actually four key factors which determine the species-richness for wood-decay invertebrates (Alexander, 2008) and volumes of deadwood do not feature:

- Total number of trees which make up the population
- Age structure of those trees
- Density of those trees
- Connectivity in the landscape

The first three will be discussed further in this section, with connectivity discussed separately in the following section. The first three relate to physical structure, but the fourth is as much about connectivity in time as in space and is best considered separately. Analysis of the tree population – the living trees – is much more important to wood-decay conservation than trying to quantify the volumes of deadwood. It is the living trees which generate the deadwood and it is by understanding the population dynamics of the living trees that conservationists can conserve the wood-decay fauna most effectively.

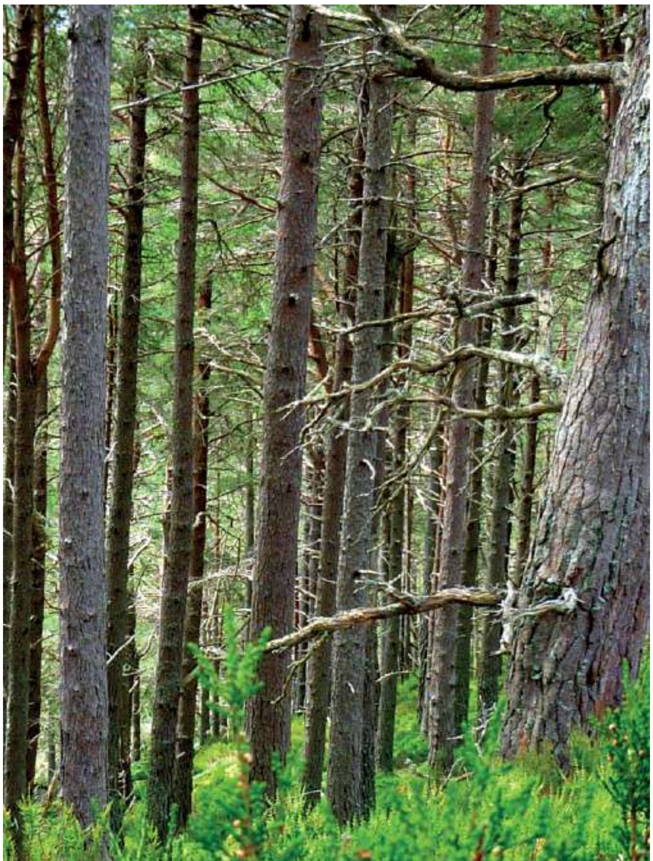
How many trees are needed to maintain population viability for the dependent wildlife? There have been attempts at answering this question for a very few species, notably Hermit Beetle *Osmoderma eremita* (Bergman, 2006; Ranius, 2006) but the question is really too all-encompassing to be completely answerable. What is very clear, however, is that the larger sites, the sites with the largest populations of trees, are the most species-rich. The obvious implication is that the more trees that are accessible the better.

It should be very obvious that sustainable conservation of decaying deadwood habitats requires the continual input of freshly dead woody material. This is only feasible where there is a diverse age structure of the trees. Young trees only generate small quantities of small dead branch and root material, but the production of a wider variety of dead woody tissues increases with age. As an individual tree matures it begins to accumulate an increasing volume of dead heartwood tissues as well as producing the occasional dead branch and/or root. As the volume of dead heartwood tissues increases with age it will eventually be colonised by specialist heartwood-decay fungi which are able to exploit the situation and start the recycling process. While it is at this later stage that the value of the tree is greatest to wood-decay wildlife, there is a continual need for new generations of trees developing in order to provide future replacements for the older trees as they eventually die and decay. This requires a diverse age structure. Little or no research has however been carried out on the complexity of tree population age structure that is required to ensure long-term viability of the various decay stages.

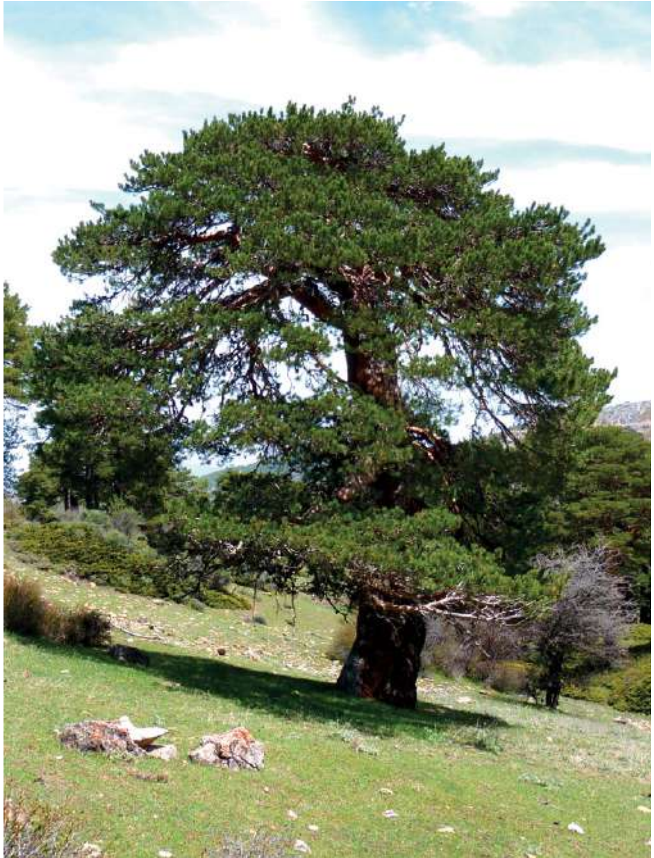
Tree density is another very important aspect. It has already been pointed out that only an open-grown tree has the potential of developing the full range of wood-decay situations, especially from the point of view of the important lateral branch habitat and the heartwood decay process that requires the retrenched ancient stage to complete the process. In the case of a *Quercus robur* tree, the lateral branch spread may extend up to 15m from the trunk centre, which means that a similar-sized neighbouring tree should be no closer than 30m, from trunk centre to trunk centre. This has enormous implications in tree planting programmes as very wide spacing is required if the desired end product is an ancient oak. Typically tree-planting schemes in forestry and landscaped developments employ commercial forestry planting densities, often at 2 to 4m spacing. Such plantings will never achieve significant wood-decay conservation, even where the expressed intention is to thin the trees as they grow (Ancient Tree Guide No.7). Experience has shown that thinning is all too often never carried out or carried out after the form of the new trees have already been damaged by the too dense planting and establishment stages – open-grown form lateral branch development in particular can be lost by overcrowded planting (Photograph 6). The need to rescue ancient oaks from competing growth has been demonstrated by Ranius and Jansson (2000); this has become standard practice in British forests (Alexander et al., 2010, 2011).

While open-grown trees are very important to the conservation of wood-decay wildlife, there are species which benefit from the decaying wood being situated in the moister conditions provided by shade. Shade is of course available beneath the canopy of open-grown trees, but this situation tends to be more exposed to drying winds and the desiccation caused by winter cold. There are undoubtedly wood-decay species which require relatively close-grown groups of trees, and this is especially the case with some invertebrates which favour stands of *Fagus sylvatica*, for example. 'Relatively' needs to be emphasised however, as the close-planting used by commercial forestry is often too close to favour these species as the trees tend to grow up relatively tall and thin and to have shortened life-spans as a result.

Trees vary considerably in their optimal requirements for light while developing. *Quercus robur* and *Pinus sylvestris* are examples of light-demanding trees while *Fagus sylvatica* and *Carpinus betulus* are examples



Photograph 6: Overcrowded pine, Feshiebridge, Scotland (K. Alexander).



Photograph 7: Open-grown pine in wood pasture, Sierra de Baza, Andalucia, Spain (K. Alexander).

of shade-tolerant trees. Open-grown conditions are therefore much more important for the light-demanding species, while the shade-tolerant species grow well under both light and shade conditions. The relationship of certain shade-preferring wood-decay invertebrates with *Fagus sylvatica* is therefore partly related to the ability of this tree to develop under conditions of relatively heavy shade.

In a given area there is clearly an optimal tree population which covers maximal tree numbers, optimal age structure, and variable tree density. What is lacking at present are models which can determine this optimal population for a unit area. Tree species of course adds a further dimension, as the same is equally true for each tree species (Alexander et al., 2006).

The importance of connectivity in the landscape

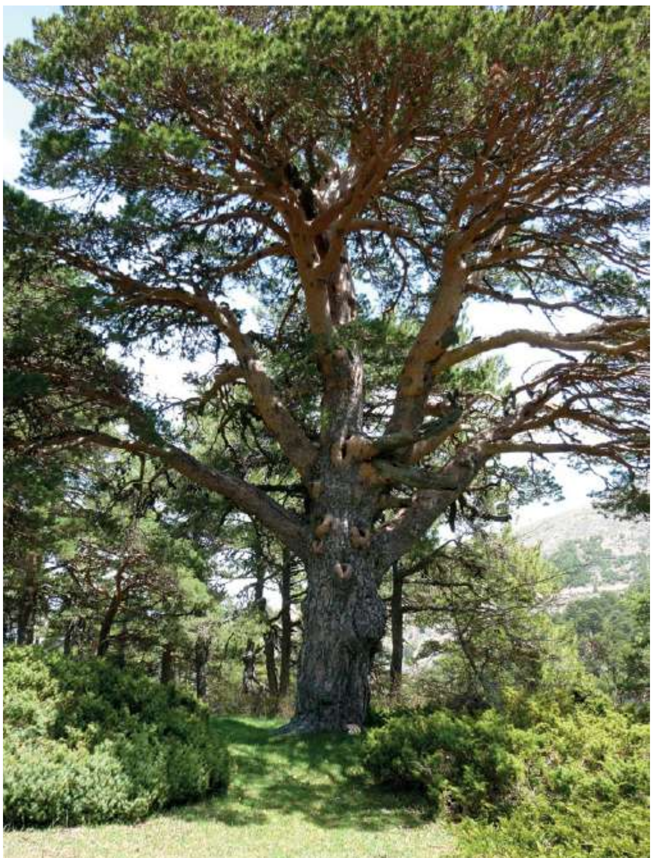
Each species of wood decay invertebrate potentially exhibits its own mobility characteristics, its ability to penetrate the landscape. This aspect has been little studied however. It is assumed that common and widespread species are highly mobile and able to cross relatively large distances of inhospitable habitat, ie areas lacking suitable trees. These are not species that require much conservation attention, if any at all. The rarest species appear to be the least mobile, which appear only able to move from one suitable tree to another if the intervening distance is relatively low and where there is good shelter and appropriate weather conditions for flight activity, ie the air is relatively warm, humid and calm. Between these two extremes is a full spectrum of variation between species. Conservation action becomes increasingly important as mobility decreases.

The basic principle of connectivity conservation is the provision of suitable trees throughout the landscape, which then may act as stepping stones between the relatively species-rich hot-spots. The richest sites tend to be those with the longest history of containing suitable tree populations – the oldest and largest forests and wood pastures (Alexander, 1998; Alexander and Butler, 2004) (Photograph 7). In the long-established cultural landscapes of Europe the rarest species are not necessarily confined to relatively undisturbed forests – these often remaining today as common wood pastures (Photograph 8). The species may have had time to colonise other situations such as tree-lined watercourses, some of which may actually be remnant old forest. Many historic forests have become mosaic landscapes, as the better agricultural land has become exploited by people, often leaving the old forest trees on the poorer land or retaining strips as field boundaries. Other situations which can be colonised by the rarer wood-decay invertebrates include traditional orchards and sweet chestnut groves, where fruit and nut harvesting is optimised by using concentrations of long-established open-grown trees. Where such cultural landscapes have developed alongside or close to old forest then the invertebrate are readily able to spread out into the cultural landscape. This is well-recognised in England where the Noble Chafer *Gnorimus nobilis* is largely confined to the traditional orchard landscapes alongside the medieval Forests of Dean and Wyre (Alexander and Bower, 2011).

With low mobility, connectivity in time is as important as connectivity in space – the rarer species become trapped in relict old forest areas through their inability to colonise new sites beyond the forest boundaries. Such species provide useful markers or indicators of old forest conditions (Alexander, 1998, 2003, 2004a). The primary conservation action for such species is to maintain habitat quality in the known sites, and encouragement of increased mobility through restoring habitat linkages should be a secondary action.

The special conditions provided by lateral branches on open-grown trees

Lateral branches in the lower crown of open-grown trees gradually die as they are shaded out from the developing crown above. They are a feature of relatively young and maturing trees rather than ancient trees. Their position is what makes them unique as wood-decay habitat – aerial dead branches sheltered and buffered from the wind by the crown above. These dead branches remain relatively humid, in contrast to dead branches high in the crown of the tree which are exposed to the full rigours of the local climate – sun in summer, frost in winter, and exposed to the drying air at all times. These aerial dead branches in the lower crown are colonised by specialist wood-decay fungi and this provides a unique habitat for wood-decay invertebrates. Such branches are however very vulnerable to the activities of people – in full view and so a subject for concern over public safety, and readily cut and removed from farm vehicles which can then get closer to the trunk for agricultural activities such as fertilising the pasture or ploughing, all with consequent damage to tree roots and tree health.



Photograph 8: Open-grown pine showing lateral branch development, Sierra de Baza, Andalucia, Spain (K. Alexander).

Heartwood decay and the rarest invertebrates

The heartwood decay succession is the latest of the broad types of woody decay to be found in trees. As a tree grows new annual rings of woody tissues are laid down beneath the bark and the tree gradually expands in girth. Only the outer annual rings remain alive and functional, the inner ones gradually die and form what is known as the heartwood of the tree. In the case of oak it is known that annual rings die after 25-30 years and so any oak tree that is say 100 years old will contain a core of dead annual rings – heartwood – of 70-75 years growth, and a tree 200 years old will contain a heartwood of 170-175 years growth. These dead woody tissues are not accessible to the living tree; before they die the tree extracts the more mobile nutrients present and deposits unwanted materials, as well as - in some cases – complex organic chemicals which will slow down any subsequent decay. Where these decay-resistant chemicals are laid down the dead woody tissues are referred to as durable heartwood – this is the case with oak (*Quercus*) for example but not beech (*Fagus*). In beech the death of the inner annual rings appears not to be so precisely genetically controlled as in oak, and sections of rings appear to die asynchronously, and without any decay-resistant chemicals being laid down; this type of death of the tissues is referred to as ripewood.

Eventually the dead woody tissues in the centre of the tree become colonised by specialist wood-decay fungi which break down the cellulose and – in some cases – also the lignin content. Different fungi may cause different types of decay, eg *Laetiporus sulphureus* typically specialises in durable heartwood and breaks down the cellulose, leaving the lignin behind as brown-rot (also known as red-rot) – hard and dry material which is brittle - whereas *Ganoderma australe* breaks down the lignin and then the cellulose, not quite simultaneously, causing what is referred to as a white-rot by leaving soft and moist cellulose towards the end of the process. Whichever type of heartwood decay takes place, the

Photograph 9: Overcrowded secondary woodland on former open wood pasture, Goehrde, Germany (K. Alexander).

Photograph 10: Overcrowded young oaks, Hamilton High Parks, Scotland (K. Alexander).

trunk is eventually hollowed and the base accumulates debris which composts to form a black soil-like material generally referred to as wood mould. The whole process may continue while the tree is alive and healthy, and the tree actually benefits from the process through the nutrients previously locked up in the dead woody tissues being released through the process of fungal decay – aerial roots may be produced by the tree and grow down into the wood mould to extract nutrients.

The process of decay of these woody tissues provides a wide range of niches for invertebrates to exploit. These invertebrates live inside the hollowing tree and are protected from extremes of weather outside. Invertebrate colonisation usually follows the death of the fungal mycelium within the tissues, with a whole succession of species specialising on the different stages of the process – some feeding on the fungal mycelium itself, others on the products of the decay, some favouring brown-rot others white-rot, and eventually at the end of the process are invertebrates which live in the wood mould in the base of the cavities created by the fungi. Given that wood mould is the end product of the decay of the woody annual rings, the host trees are generally old for the tree species by the time this stage is reached. As the habitat takes a long time to develop it is naturally the rarest of the wood-decay habitat types and one which few individual trees will reach during their lifetimes.

Wood-decay beetles informing hypotheses of natural forest structure

The rationale for minimum intervention management is that the original forests which developed after the last Ice Age and before people began to have a significant impact on forest structure were of a continuous closed-canopy 'high forest' nature. This hypothetical forest structure is based both on an interpretation of pollen assemblages preserved in peat and other dateable deposits, and the observation that when people abandon an area of land it is gradually colonised by trees and shrubs and eventually forms a closed canopy. However, the modern landscape can hardly be considered 'natural' - by the definition of the supporters of this hypothesis - the truly 'natural' processes that would have operated in the distant past are no longer the natural processes which will occur today Photograph 9 and 10). A key factor is that wild large herbivore assemblages are no longer present within the landscape. Where deer are present – natural or naturalised – this succession may not actually occur, as evidenced by the current fashion for deer eradication due to their observed impacts on woodland structure. 'Minimum intervention' management is a peculiar approach in that it is rarely properly defined, if ever. The best definition that the author has heard is 'the minimum needed to protect, maintain and enhance the intrinsic values' (John Deakin, Head Forester, The Crown Estate at Windsor, UK). Where an intrinsic value is forest structure and where that structure is becoming increasingly uniform under the natural processes that are currently operating, then intervention is justifiable in order to conserve the special associated interests.

There are actually two alternative hypotheses about the structure of the original forest cover of Europe: the closed canopy hypothesis (as promoted in the final quarter of the 20th century by Peterken, 1993, 1996, and others) and the wood pasture hypothesis (Vera, 2000, 2013). Advocates of the former, earlier story, have manipulated data on sub-fossil beetle assemblages to support their case. Although a full and detailed analysis has not yet been carried out, a strong case has been made (Alexander, 2012) that, in reality, the sub-fossil beetle assemblages are completely at variance with the closed canopy hypothesis, but more or less consistent with the wood pasture hypothesis. The sub-fossil beetle record does demonstrate that the original forest contained widespread open-grown and ancient trees.

In a fully natural ecosystem with trees – as in the hypothetical original postglacial forest – it seems reasonable to expect the full suite of native wood-decay invertebrates, including those of open-grown trees. As people began to have an impact on the natural undisturbed tree cover then they would have initiated shifts in the representation of the wood-decay invertebrates – favouring some species while pushing others in the direction of rarity and even extinction. After thousands of years of people activity, Britain has 700 native wood-decay beetle species (Alexander, 2002). It is not known how many had colonised Britain before people began to have a significant impact but sub-fossil evidence has been found for just 18 species which are no longer found there (Buckland and Dinnin, 1993). This is a remarkably low percentage – 2.6% extinction – considering the stories of large-scale forest clearance that have been promulgated by the paleo-ecologists. The extinct species are a more or less equal mix of shade-loving species and species requiring open-grown trees (Alexander, 2003). Sub-fossil studies are relatively new, however, and so the figure of 18 is almost certainly an under-estimate of the losses; nonetheless, this really does not sound like a major shift in species-richness. Clearly habitat representation has not changed a great deal – the vast majority of saproxylic beetles are still able to live in the modern cultural landscape. It should however also be acknowledged that a large number are on the verge of extinction due to declining habitat availability through modern development pressure – 54% currently are of sufficiently restricted occurrence to have conservation status.

So, if the overall species-richness of wood-decay beetles has changed little since postglacial forest times, what changes have studies of the sub-fossil fauna demonstrated? The weevil *Dryophthorus corticalis* provides an instructive case study. It lives within moist brown-rotten heartwood inside exceptionally large old examples of open-grown oak trees. It is present within the modern British landscape at just one site, a very special site - Windsor Forest and Great Park - with the most extensive landscape of open-grown ancient oaks in the country. There appears to be a requirement for large concentrations of suitable host trees; the species has particularly low mobility under modern conditions. And yet the sub-fossil record demonstrates that this weevil was actually much more widespread in the postglacial forest period, and present at a site 250km to the north. This is strong evidence that open-grown conditions, suitable for the development of ancient oak trees, were not only widespread at this time but also sufficiently linked across the landscape, enabling the species to move freely from tree to tree (Photograph 11 and 12). The sub-fossil discoveries include many such species requiring open-grown conditions – *Prostomis mandibularis, Teredus cylindricus, Hypulus quercinus, Batrisodes venustus, Gastrallus immarginatus*, etc. The ecology of these beetles clearly demonstrates that open forest conditions were the norm, not exceptional, in the natural forests of Britain. The beetle assemblages demonstrate the very widespread occurrence of large, almost certainly open-grown trees, reaching ages that are not feasible under closed-canopy conditions. Heartwood decay is a strong feature of these trees, as is wood mould in hollow trunks, and even lateral branching allowing the development of rot-holes in the trunk. Basically the palaeo-entomological work on sub-fossil beetles has never before been examined objectively, separate from the closed forest hypothesis. W.G. Hoskins (1966) was thinking of industrial archaeology when he said: 'There are profoundly important discoveries to be made by those who have learnt to use their eyes intelligently. Most of us are visually illiterate, and our education has helped to make us so.' Unfortunately most scientists are blinded as part of their training'.

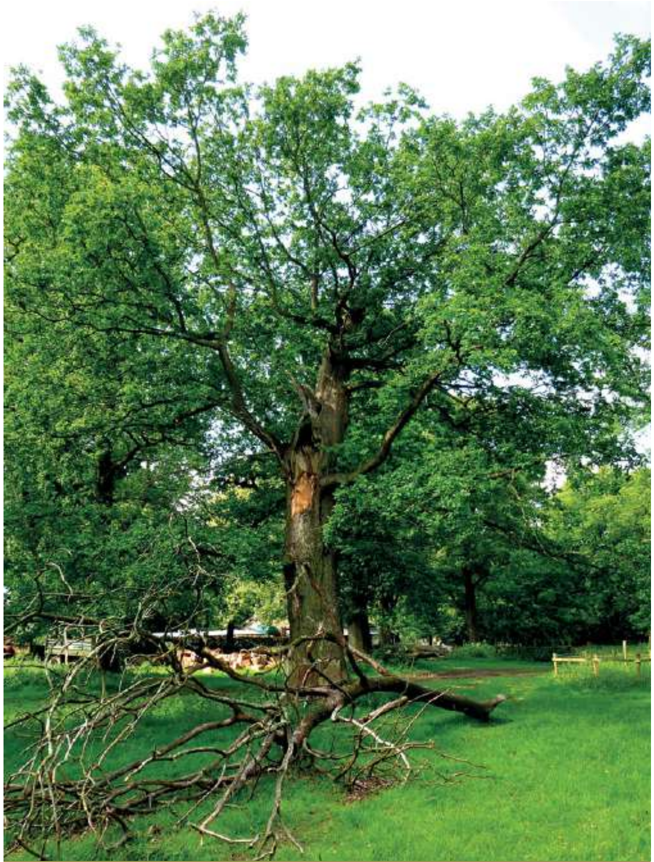
Photograph 11: Good spacing of trees, Calke Park, England (K. Alexander).

Photograph 12: Ancient oak, fully retrenched crown, Calke Park, England (K. Alexander).

The consequences of minimum intervention management that excludes large herbivore grazing

It has been shown by Vera (2000) that large herbivores have a very significant impact on forest structure. Native forests have evolved alongside wild large herbivore populations; one without the other is an artificial and man-made situation. Wood-decay invertebrates have evolved to exploit the wide variety of decaying wood situations which develop under the relationships between trees and

Photograph 13: Death by non-intervention management - veteran oak killed by over-shading secondary woodland in former wood pasture, Hasbruch, Germany (K. Alexander).



Photograph 14: Veteran oak, crown collapsed through wind damage rather than retrenchment, Levens Park, England (K. Alexander).

large herbivores. The removal of large herbivores from a forest creates an imbalance that is disadvantageous to a high proportion of wood-decay invertebrates and is especially damaging to those species which require advanced development of heartwood decay, the development of lateral branching and the availability of trees retrenching naturally through old age (Photograph 14). In cultural landscapes, domestic livestock may have replaced the wild large herbivores and maintained suitable conditions for long periods of human history, and tree exploitation such as shredding and pollarding may have extended the lifespan of trees and kept them free of competing woody growth.

In the absence of large herbivores it becomes necessary to consider direct and active management of forest in order to conserve wood-decay beetles. Working methods need to be devised to enable trees to have sufficient space and to develop into large open-grown form trees. Removal of the suppression of seedlings and saplings will inevitably lead to the development of thickets of young growth (Photograph 15). Cutting management becomes highly advisable – coppice!

There are a few examples available where long-term minimum intervention can be seen to be causing this damage. The Forêt de Fontainebleau in northern France had domestic livestock removed over a hundred years ago and - without browsing animals to provide a selective advantage to oak over beech – ancient oaks have now largely been eliminated by crown competition with beech and any new oaks developing are overcrowded and developing as high forest form trees. The specialist wood-decay fauna of old oaks is now under severe threat here. Similar problems are evident elsewhere eg the Hasbruch in Lower Saxony, where old oaks are in severe decline through minimum intervention management (Photograph 13). The decline in oaks has been explained as a ‘natural process’ and part of ‘natural cycling’ by Peterken (1996) who advocates leaving management to natural processes, but these are no longer natural systems, they are cultural modifications. There is no evidence that beech dominance will return naturally to oak dominance in due course, as Peterken says. In reality this is the dominance of shade-tolerant species over light-demanding species in the absence of large herbivores, as explained by Vera (2000). The hypothetical cycling of Peterken is leading to the extinction of many rare and threatened invertebrates. He has provided no reliable evidence in support of his hypothesis. In contrast, the Vera process is well-established in ecology and can be seen in action at many sites, eg the New Forest and other sites in England. At Ashton Court Park, Bristol, removal of large herbivore browsing and grazing has resulted in ancient oaks becoming engulfed in ash and sycamore woodland – tree species which are very palatable to large herbivores and

Photograph 15: Dense secondary growth in former wood pasture at Bialowieza Forest, Poland (Photo: K. Alexander).

which would have been suppressed by them (Alexander, 2013). Active cutting has now been carried out and plans expressed for restoring deer to the area with the ancient oaks in order to conserve them.

Approaches to conserving dead wood

Conventionally, invertebrate specialists tend to emphasise the importance of leaving dead wood to decay naturally in situ, largely ignoring the population of living trees which generate that dead wood. It is much more important – in the author's opinion – to focus first on managing the tree populations and ensuring that they can provide sustainable quantities of deadwood and in the full variety that an open-grown tree can generate; quality of decaying wood is very important, and in many ways more so than quantity. Measuring gross volumes of deadwood that are available is a very coarse way of assessing site value for wood-decay invertebrates, but it may be better than nothing. Ideally those gross volumes should be broken down by type of deadwood and stage in the decay process. By type of deadwood I mean reflecting the full suite of dead wood habitats, incorporating whole trunks, branches, twigs, stumps, and roots, and considering broad girth ranges. The more that can be left and the greater the variety then the conservation effort will be more worthwhile. Speight and Good (2003) have demonstrated that maintenance of quantities of coarse woody debris in European forests is largely irrelevant to the maintenance of biodiversity in wood-decay hoverflies (Diptera: Syrphidae) as many of these develop in rot-holes in living trees, and so the wood-decay conservation effort needs to focus much more on those living trees.

Within commercial forestry operations, there is clearly a need to retain whole living trees with space to grow on into old age and to continue the process of generating wood-decay habitats (Humphrey et al., 2004). Ideally these should be retained throughout the forest rather than be concentrated and thereby isolated from other such groups of trees. But scattered trees would be very vulnerable to incidental damage during forestry operations. The best option is probably to retain groups of such conservation trees as identified stands or compartments, away from the main centres of commercial activity, but also in sufficient quantity to provide a network of stepping stones across the forest.

Guides to good management of old tree populations have been produced (Read, 2000; Lonsdale, 2013). While these are written in English, versions in other European languages are currently being developed.

Conclusions

Conservation should be based on practical observation rather than unstable theory (Rackham, 2006). If landscape planners and forest managers desire to conserve wood-decay invertebrates as part of their operations then they need to rely on knowledge of tree biology and tree ecology rather than hypothetical woodland ecology. The four key factors which determine the species-richness for wood-decay invertebrates are:

- Total number of trees which make up the population – the more trees the better, but not at the expense of individual space;
- Age structure of those trees, with not only old trees with their important full suite of wood-decay situations, but also cohorts of new generations to provide continuity over time;
- Density of those trees, ensuring that trees with an open-grown form – lateral branches well developed - are as well-represented as closer grown trees with more of a high forest form;
- Connectivity in the landscape, enabling movement of the invertebrates, with scattered trees providing the essential stepping stones.

The range of tree species adds a further complication as each tree species that forms part of the local landscape needs to be considered in the same way. It goes without saying really that the dead woody tissues that these trees produce should be retained to decay naturally, preferably in situ, but at the very least displaced only the minimum required to maintain access, ensure public safety, etc. It is important that the conservation of decaying wood habitats should be treated seriously and sustainably, and not be treated as tokens.

References

Alexander, K.N.A., 1998. *The links between forest history and biodiversity: the invertebrate fauna of ancient pasture-woodlands in Britain and its conservation*. In: Kirby, K.J. and Watkins, C. (eds) The Ecological History of European Forests, CABI Publ., Wallingford, UK, 73-80.

Alexander, K.N.A., 2002. *The invertebrates of living and decaying timber in Britain and Ireland - a provisional annotated checklist.* English Nature Research Reports, No. 467, 142 p.

Alexander, K.N.A., 2003. Wood decay, insects, palaeoecology and woodland conservation policy and practice – breaking the halter. *Antenna* (Royal Entomological Society, London), 29: 171-178.

Alexander, K.N.A., 2004a. *Revision of the Index of Ecological Continuity as used for saproxylic beetles*. English Nature Research Reports, No. 574, 60 p.

Alexander, K.N.A., 2004b. *Landscapes with ancient trees: invertebrate mobility and population viability*. In: Smithers, R. (ed.) Landscape ecology of trees and forests, Proceedings of the 12th IALE (UK) conference, 107-114.

Alexander, K.N.A., 2007. *Old growth: ageing and decaying processes in trees.* In: Rotherham, I.D. (ed). The history, ecology and archaeology of medieval parks and parklands. *Landscape Archaeology and Ecology*, 6: 8-12.

Alexander, K.N.A., 2008. Tree biology and saproxylic Coleoptera – issues of definitions and conservation language. *Revue d'Ecologie* (La Terre et la Vie) Suppl. 10: 9-13.

Alexander, K.N.A., 2012. *What do saproxylic (wood-decay) beetles really want? Conservation should be based on practical observation rather than unstable theory*. In Rotherham, I.D., Handley, C., Agnoletti, M., Samojlik, T. (eds) Trees Beyond the Wood Conference Proceedings, Wildtrack Publishing, Sheffield, 41-59.

Alexander, K.N.A., 2013. *Ancient trees, grazing landscapes and the conservation of deadwood and wood decay invertebrates*. In: Rotherham, I.D. (ed). Trees, Forested Landscapes and Grazing Animals. A European Perspective on Woodlands and Grazed Treescapes, Routledge, London, 330-338.

Alexander, K.N.A. and Bower, L., 2011. The Noble Chafer and Traditional Orchards - an old-growth species in the English cultural landscape. *British Wildlife,* 23: 17-22.

Alexander, K.N.A. and Butler, J.E., 2004. *Is the US concept of "Old Growth" relevant to the cultural landscapes of Europe? A UK perspective.* In: Honnay, O., Verheyen, K., and Bossuyt, B. (eds.) Forest Biodiversity: Lessons from History for Conservation. IUFRO Research Series, 10, 233-246.

Alexander, K.N.A., Butler, J.E. and Green, T., 2006. The value of different tree and shrub species to wildlife. *British Wildlife*, 18: 18-28.

Alexander, K.N.A., Stickler, D. and Green, T. 2010. Is the practice of haloing successful in promoting extended life? - a preliminary investigation of the response of veteran oak and beech trees to increased light levels in Windsor Forest. *Quarterly Journal of Forestry*, 104(4): 257-265.

Alexander, K.N.A., Stickler, D. and Green, T., 2011. Rescuing veteran trees from canopy competition: is the practice of haloing successful in promoting extended life? *Countryside Land Management* 9(1): 12-16.

Ancient Tree Guide no.4. *What are Ancient, Veteran and other Trees of Special Interest?* Woodland Trust and Ancient Tree Forum, Grantham, UK. [http://frontpage.woodland-trust.org.uk/ancient-tree-forum/atfnews/news04/guides.htm]

Ancient Tree Guide no.7. *Trees for the Future.* Woodland Trust and Ancient Tree Forum, Grantham, UK.

Bergman, K.O., 2006. *Living coastal woodlands - conservation of biodiversity in Swedish Archipelagos.* Report to EU LIFE – Coastal Woodlands project, 46p. [http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFileandrep=fileandfil=Coastal_Woodlands_Report_biodiversity.pdf]

Buckland, P.C. and Dinnin, M.H., 1993. *Holocene woodlands, the fossil insect evidence*. In: Kirby, K.J. and Drake, C.M. (eds) Dead wood matters: the ecology and conservation of saproxylic invertebrates in Britain. English Nature Science No. 7, 6-20.

Green, T., 2010. The importance of open-grown trees. From acorn to ancient. *British Wildlife,* 21: 334-338.

Hoskins, W.G., 1966. *Old Devon*. David and Charles, Newton Abbot.

Humphrey, J.W., Sippola, A.-L., Lempérière, G., Dodelin, B., Alexander, K.N.A. and Butler, J.E., 2004. *Deadwood as an indicator of biodiversity in European forests: from theory to operational guidance.* In: Marchetti, M. (ed) Monitoring and indicators of forest biodiversity in Europe - from ideas to operationality. Proceedings of the EFI/IUFRO Conference 12-15 November 2003, Florence, Italy. EFI Proceedings 51. European Forest Institute: IUFRO, Joennsu, 193-206p.

Hyman, P.S. and Parsons, M.S., 1992. *A review of the scarce and threatened Coleoptera of Great Britain*. Part 1. UK Nature Conservation No 3. Joint Nature Conservation Committee, Peterborough.

Lonsdale, D., 2013. *Ancient and other veteran trees: further guidance on management.* Ancient Tree Forum and Woodland Trust, Grantham, UK.

Nieto, A. and Alexander, K.N.A., 2010. *European Red List of Saproxylic Beetles.* Luxembourg: Publications Office of the European Union.

Peterken, G.F., 1993. *Woodland Conservation and Management.* Chapman and Hall, London.

Peterken, G.F., 1996. *Natural Woodlands: ecology and conservation in north temperate regions.* Cambridge University Press.

Rackham, O., 2006. *Woodlands*. Harper Collins, London.

Ranius, T., 2006. Measuring the dispersal of saproxylic insects: a key characteristic for their conservation. *Population Ecology*, 48: 177-188.

Ranius, T. and Jansson, N. 2000: The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. *Biological Conservation*, 95, 85-94.

Read, H.J. (ed), 2000. *Veteran Trees: A guide to good management.* English Nature, Peterborough.

Speight, M.C.D., 1989. S*aproxylic invertebrates and their conservation.* Nature and Environment Series No. 42. Strasbourg: Council of Europe.

Speight, M.C.D. and Goog, J.A., 2003. *Development of eco-friendly forestry practices in Europe and the maintenance of saproxylic biodiversity.* In: Mason, F., Nardi, G. and Tisato, M. (eds) Proceedings of the International Symposium 'Dead-wood: a key to biodiversity', Mantova, May 29th – 31st 2003. Sherwood 95, Suppl.2, 73-77.

Stokland, J.N., Siitonen, J. and Jonsson, B.G., 2012. *Biodiversity in Dead Wood*. Cambridge University Press, UK.

Vera, F.W.M., 2000. *Grazing ecology and forest history.* CABI Publ., Wallingford, UK, 506 p.

Vera, F.W.M., 2013. *Can't see the trees for the forest.* In: Rotherham, I.D. (ed). Trees, Forested Landscapes and Grazing Animals. A European Perspective on Woodlands and Grazed Treescapes, Routledge, London, 99-126.

Chapter 10
Old growth and dead wood as key factors for nature conservation in managed forests. Basics and practice

Harald Schaich, Thomas A.M. Kaphegyi, Rudolf Lühl, Nicole Schmalfuß, Mattias Rupp, Thomas Waldenspuhl, Werner Konold

Introduction

Globally, forest biodiversity conservation is concentrated on the halting of primary forest harvesting and degradation by enlarging the area of undisturbed natural forest ecosystems in protected areas (FAO, 2011). At present, the Convention on Biological Diversity (CBD) aims at incorporating at least 17% of the terrestrial surface worldwide – including the most representative forest biomes – into a network of protected areas (Convention on Biological Diversity, 2010). In Europe however, forests have been shaped by humans for centuries and in most regions almost no remnants of primary forests remain. Consequently, the form and intensity of forest management is – in addition to other parameters – one of the prime factors threatening the conservation of forest habitats and species in Europe (Brunet et al., 2010). At the same time, certain traditional forest management practices, e.g. woodland grazing or coppicing, have created structurally rich forest stands, which could also be very valuable for biodiversity conservation and the provisioning of forest ecosystem services (Gross and Konold, 2010; Plieninger et al., 2011).

In this context, setting aside semi-natural forests in strictly protected areas to allow for natural dynamics in forest development is only one measure to conserve forest biodiversity in Europe. Protected areas should be complemented by other approaches, which focus on the incorporation of biodiversity requirements into forest management (Bauhus et al., 2009; Schaich and Konold, 2012), on the reestablishment or mimicking of traditional forest management systems (Rotherham, 2013; Suchomel et al., 2013), and on the restoration of structural complexity and site-adapted species in non-natural secondary forests like conifer plantations (Zerbe, 2002). In Germany, the goals of the CBD have been taken up in the federal government's National Strategy on Biological Diversity (BMU, 2007). It aims to protect 5% of the total forest area in strict protected areas, but also strives to foster an ambitious guideline strategy for close-to-nature forest management in public forests, to revive traditional forest management systems and to implement payment schemes for nature conservation management in 10% of the privately owned forests by 2020.

Close-to-nature approaches to forest management emerged in European public forests in the second half of the twentieth century as a response to the ecological and economic problems created by the prevailing even-aged, pure and relatively young forest stands (Schütz, 1999). Close-to-nature forestry generally comprises management approaches to enhance continuous forest cover, stands with site-adapted and mixed tree species, uneven-aged stand structures, selective harvesting and the use of natural tree regeneration (Larsen and Nielsen, 2007). Beyond classical close-to-nature management approaches, further objectives of nature conservation have to be considered if managed forests are to host a high level of biodiversity and provide a broad array of ecosystem services. Such additional objectives are the conservation of largely undissected forest areas on ancient woodland sites, the avoidance of mechanical disturbance and chemical pollution of forest soils, the development of ecologically valuable forest edges, the enhancement of more open forest stands and traditional forest management practices, the augmentation of late successional phases and old growth features, and the fostering of a semi-natural amount of dead wood (Schaich and Konold, 2005).

In fact, one of the most pressing problems for forest biodiversity conservation in managed forests is the scarcity of late successional phases and old growth as well as the lack of dead wood in the form of coarse woody debris and snags (Lindenmayer et al., 2006; Nilsson et al., 2003). In primary forests, very old trees and dead wood have been ubiquitous (Keddy and Drummond, 1996). Although amounts of old growth and dead wood vary constantly according to the successional phase of forest development, there has hardly been a primary forest without old trees and dead wood (Nilsson et al., 2003). In managed forests, trees are harvested as long as they can be sold as valuable timber, which is long before they develop structures of maturity, such as dead branches in the crown or wood decay or others. In times of rising energy prices worldwide, timber of minimal quality as well as wood and branches of small dimensions are increasingly extracted from managed forests for the bioenergy sector in Europe (Plieninger et al., 2009).

Old growth and dead wood offer a larger spectrum of habitats such as stem holes, wood in varying degrees of decay, as well as dead branches in the crown or bark hollows (Photograph 1). As such, a huge number of species depend on these resources, for instance hollow-nesting birds or saproxylic beetles (Müller et al., 2007), but also mammals like bats or dormice, amphibians, fungi and mosses (Chambers, 2002; Raabe et al., 2010). Many of the species that are dependent on old growth and dead wood structures are legally protected via Annex II and Annex IV of the EU Habitats-Directive or national laws. As a consequence, many researchers have been working on threshold values, which have to be considered in order to conserve dead wood dependent species guilds in managed forests located in different biogeographic regions (Keddy and Drummond, 1996; Lonsdale et al., 2008; Müller and Bütler, 2010). However, over the past years the amount of old growth and dead wood resources has only been marginally affected by close-to-nature management approaches (Schaich and Plieninger, 2013). As a consequence, managed forests in Germany often do not fully comply with the demands concerning structural complexity that are formulated in the German and European Union biodiversity strategies (BMU, 2007; European Commission, 2011). New practical guidelines and incentives, particularly for the enhancement of old growth and dead wood resources in public and private forests, are therefore needed. Building on empirical evidence from research projects and on a strategy for practical forest management, this chapter aims to enhance knowledge on basic interactions between old growth features, dead wood, forest management, and forest biodiversity as well as to explore practical approaches to foster such habitat resources in managed forest ecosystems. Taking the regional perspective of southwestern Germany (federal state of Baden-Württemberg), the chapter presents: basic attributes by which to classify old growth and dead wood features in forest ecosystems; outlines the actual status of regional old growth and dead wood resources in Baden-Württemberg in relation to spatial and institutional aspects; highlights the role of traditional forest uses such as woodland pasturing for the conservation of old growth features; analyses the importance of habitat trees for biodiversity and especially hollow-nesting birds; and introduces an operational strategy to foster the quantity and quality of habitat trees and dead wood in managed state-owned forests. In a brief synthesis, we derive practical and policy recommendations on how to foster old growth and dead wood features in complex, human-shaped forest landscapes and how to synchronize this important issue with other goals of ecosystem services provisioning in European forests.

Photograph 1: A decaying old growth oak offers plenty of habitat structures (H. Schaich).

The role and attributes of old growth and dead wood in forest ecosystems

Numerous scientific studies have demonstrated the vital role of old growth and dead wood as habitats for fauna and flora of temperate forest ecosystems. Estimates based on empirical case studies suggest that 20% of all fauna in Central Europe rely on old growth and dead wood features and every fourth native beetle species is dependent on dead wood (Schiegg, 1998; Similä et al., 2002). Consequently, there is a close relationship between the amount of old growth and dead wood features in managed forests and species richness as well as abundance of certain threatened species in forest ecosystems (Scherzinger, 1996). In addition, old growth and dead wood is also important for the functioning of forest ecosystems and the provisioning of different ecosystem services such as nutrient cycling, soil development, water storage and regulation of the local climate (McComb and Lindenmayer, 1999). In mountainous regions, dead wood also helps to prevent erosion and facilitates natural regeneration via seedling establishment on and around downed logs (Scherzinger, 1996).

To assess their contribution to biodiversity conservation objectives and ecosystem service provisioning in forests, it is necessary to consider different attributes of old growth and dead wood features. In this respect, the total amount of old growth and dead wood is a central attribute, but it is also important to have information on their quality and their spatial distribution and temporal dynamics (Schaich and Konold, 2005).

Amount of old growth and dead wood

Differences in the amount of old growth and dead wood in primary forests depend on the natural forest type, the age of the forest, the relative area of the different age classes and successional phases, site productivity and likeliness of natural disturbances (e.g. windthrow) (Keddy and Drummond, 1996). In his studies of primary forests in Slovakia, Korpel (1997) detected in beech forests on productive sites a mean value of 200 m^3 ha^{-1} of dead wood, however, the total amounts in single stands ranged from 50 m^3 ha^{-1} (during the optimal phase of forest development) to 310 m^3 ha^{-1} during the decay phase. In their analyses of European primary forests, Nilsson et al. (2003) found a mean number of 50-100 old trees with diameters at breast height (DBH) over 40cm including all forest types and different sites. Excluding the factors of extreme events and single late successional phases, there is a direct correlation between the amount of old growth trees and dead wood features and the site productivity in primary forest ecosystems (Korpel, 1997; Nilsson et al., 2003). Taking into account the demands of old growth and dead wood colonizing species guilds, several authors consider a proportion of 10% of the mean dead wood volume of the respective primary forest on the specific sites as the minimum amount for a managed forest stand to make a contribution to forest biodiversity conservation; a proportion of 50% is regarded as an optimum contribution (Keddy and Drummond, 1996; Korpel, 1997). This is in accordance with recent research results and recommendations that demand thresholds of >20-50 m^3 ha^{-1} (Müller and Bütler, 2010) and 5-10 habitat trees ha^{-1} (with DBH > 40 cm) (Flade et al., 2004; Reif et al., 2001) as minimum values to conserve threatened species that are dependent on old growth and dead wood features in lowland beech forest types.


Photograph 2: Coarse woody debris of different sizes in a mixed beech stand (W. Konold).


Photograph 3: Standing dead willow log offering lots of habitat structures (W. Konold).

Quality of old growth and dead wood

The usability of old growth and dead wood features for specialized species and the respective value for biodiversity conservation also depend strongly on qualitative factors. Here, decisive factors include the dimension, form, tree species, and degree of decay as well as the exposition and microclimate of the respective dead wood or old growth feature (Schaich and Konold, 2005). Many species of insect and bird fauna depend on relatively thick old and dead trees. Therefore 20-25 cm DBH is regarded as the minimum dimension of dead wood stems that could be valuable for biodiversity conservation. However, several beetle species as well as hollow-nesting birds can only use old and dead trees starting from a DBH of between 40-60 cm (Köhler, 1999; Nilsson et al., 2003). The abundance of additional microstructure like dead branches also increases proportionally with larger dimensions (Michel and Winter, 2009). As such, it is also very important to have a suitable number of large old growth trees with > 70 cm DBH within the stand. Nilsson et al. (2003) found the typical number of 10-20 old growth trees with > 70 cm DBH per ha in European primary forests and even up to

30 individuals in primary beech forests. Regarding dead wood, the form as standing dead wood (snag) or fallen log (coarse woody debris) (Photograph 2) is also essential to ensure habitat usability for different species. Snags of large dimensions are a particularly important structural element for saproxylic beetles and hollow-nesting birds and mammals (Photograph 3), however, these are largely absent in managed forests (Scherzinger, 1996). Different fauna species are adapted to colonise specific species of old and dead wood and even a specific degree of decay (McComb and Lindenmayer, 1999). The degree of decay and the special habitat niche is again significantly influenced by the exposition and microclimate of the respective old growth and dead wood individual. In this respect, central recommendations are to provide a species proportion of old growth and dead wood according to the proportion of prevalent tree species within the respective forest stand, and to provide a huge range of different degrees of decay in dead wood features to maximise the colonization potential for different species groups.

Photograph 4: Calcareous beech forests dominating on the Jurassic sediments of the Swabian Alb (low mountain range of south-western Germany) (H. Schaich).

Dynamics of old growth and dead wood supply

The supply of old growth and dead wood features in an undisturbed forest stand depends on the successional phase of forest development as well as on the intensity and frequency of external disturbances (Korpel, 1997; Nilsson et al., 2003). In undisturbed forested landscapes of a significant size there is continuous, though spatially dynamic, supply of large old growth and dead wood resources that guarantees the typical structural diversity of a certain forest type. However, in managed forests, the spatial distribution of old growth and dead wood elements must be recognized to enable permeability and mobility of dependent species on a stand and a landscape scale (Reif et al., 2001; Schiegg, 1998).

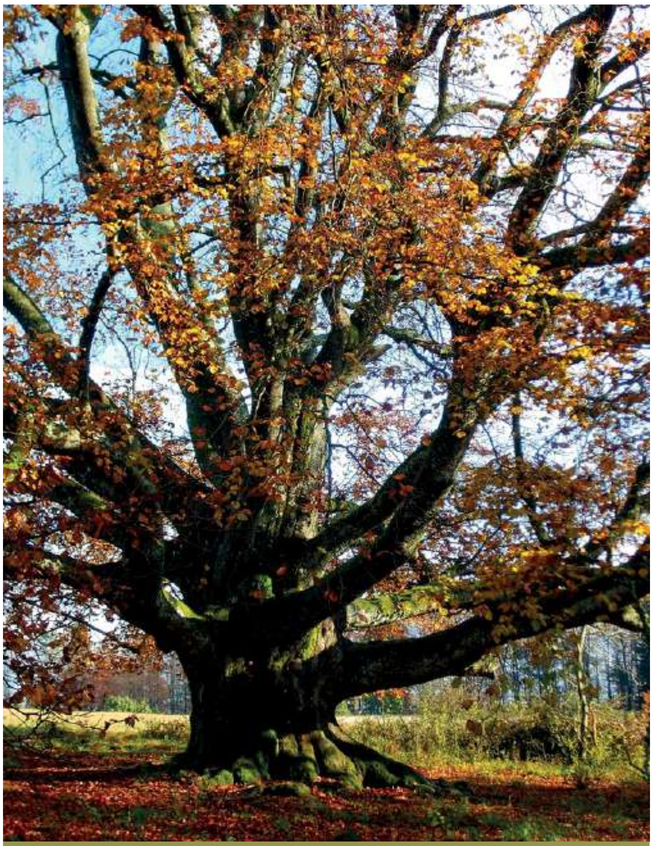
Forest area, ancient woodlands, old growth and dead wood in Baden-Württemberg (southwestern Germany)

The federal state of Baden-Württemberg is well-forested with a forest area of 39% compared to 31% in Germany as a whole. Large forest areas are in the low mountain ranges of the Black Forest (forest area: 71%), the Odenwald (62%), the Swabian Alb (44%) as well as in the Swabian Keuper region (41%) and the glacially formed foothills of the Alps (27%) (Glaser and Hauke, 2004). Dominant tree species vary according to the respective biogeographic region. The Black Forest, the Odenwald and the southwestern foothills of the Alps are mainly stocked by coniferous forest stands with spruce, fir and pines; regionally, e.g. along the edges of the Black Forest to the Upper Rhine Valley, mixed forest stands with deciduous trees and beech forests are also found. The Swabian Alb as well as the Swabian Keuper region are dominated by calcareous beech forests (Photograph 4) as well as mixed forest stands with maple and ash, and to a lesser degree by oaks as complementary species. In Baden-Württemberg, roughly 40% of the forest area is owned by municipalities and other public bodies (like churches or trusts), 36% is privately owned and 24% is owned by the federal state. Most private forests are small in size: 39% are <5 ha, 31% are between 5-200 ha, and only 30% are >200 ha (Kändler et al., 2005). However, forest ownership distribution varies quite strongly across the region, e.g. in the northern Black Forest one can find a high percentage of state forests while in the southern part private forests of small to medium sizes are prevalent.

Ancient woodlands in Germany can be defined as forest stands which have been stocked continuously with trees over a period of approximately 200 years (Glaser and Hauke, 2004). Despite the definitions of Rackham (1980) and Peterken (1993), who regard woodlands as ancient if they have existed continuously over a period of 300 and 400 years, in many parts of Germany, area-wide historical maps and archive sources for the spatial identification of woodlands have only been available since approximately 1750-1800 (Wulf, 1997). In the Germany-wide study by Felix and Hauke (2004) – drawing on the year 1800 as reference date and on CORINE Land Cover data from the year 1998 – 92% of the forest area of Baden-Württemberg was classified as ancient woodlands, which is considerably higher than 77% for the whole forest area in Germany. The proportion of ancient woodlands is presumably overestimated in the study of Felix and Hauke (2004) as a large scale was applied and small forest patches were only covered starting at a certain size. However, the study was able to compare the relative differences in ancient woodland coverage across Germany. Ancient woodlands are very frequent in the Black Forest (96%) and in the Odenwald (97%), whereas in the Swabian Alb (84%) the proportion is comparably low as – according to Bieling et al. (2013) – many formerly extensively used calcareous grasslands have been afforested with spruce during the last century. The large proportion of ancient woodlands in southwestern Germany means that most of the forests have potentially experienced a relative continuity of basic site characteristics and nutrient and water balances. Concerning biodiversity, this habitat continuity could be a decisive factor in the conservation of several typical and often threatened woodland plant species, which are slow colonizers due to their dispersal traits (Wulf, 1997). However, the classification as an ancient woodland refers only to the continuity of forest cover and does not necessarily mean that all of those stands host large amounts of old growth or dead wood (Peterken, 1993).

According to the results of the Germany-wide forest inventory conducted in 2002, the volume of large trees with >50 cm DBH was 119 Mio m³ (24% of the growing stock) and the volume of large old growth trees with > 70cm DBH was only 20.5 Mio m³ (4% of the total growing stock) in the federal state of Baden-Württemberg (Kändler et al., 2005). When age classes are considered, 89,000 ha of the forest stands have a mean age of >140 years and only 20,500 ha are >160 years, which is equivalent to 6.7% and 1.6% of the whole forest area, respectively. The most important tree species with regards to volume of old growth forest stands of >160 years are oaks (42%) and beech (21%), followed by fir (14%), pine (10%), spruce (10%) and other deciduous tree species (2%). Over all forest stands in the federal state a total volume of dead wood of 12.4 m³ per ha was reported, consisting of 9.4 m³ per ha coarse woody debris – which was recorded with a minimum length of 1m – and only 3 m³ per ha standing dead wood (Kändler et al., 2004). If stands with heavy storm impacts from 1999 are excluded, the total amount of dead wood in the managed forest of Baden-Württemberg decreases to 8.5 m³ per ha (6.3 m³ coarse wood debris and 2.2 m³ per ha), which is clearly below the thresholds that are expected to protect species that are dependent on these resources (e.g. Müller and Bütler, 2010).

In regularly managed forest areas, the silvicultural system, the rotation period and the management intensity are decisive direct influencing factors on the amount of old growth and dead wood remaining in forest stands (Brunet et al., 2010). Forest ownership and the related attitudes and interests of the specific owners were identified as relevant indirect factors influencing the availability of old growth and dead wood (Schaich and Plieninger, 2013). If the mean forest area of Baden-Württemberg is considered, state forests have a higher amount of dead wood (approx. 16 m³ per ha) and a higher proportion of old growth with > 70cm DBH (4.5%) than small-scale private forests (approx. 11 m³ per ha, 3.4%) according to the data of the Germany-wide forest inventory (Kändler et al., 2005). To a greater extent than other factors, this could be related to the high amount of "recent" forests originating from afforestations of former farm lands in private ownership. However, the situation can differ significantly across the region. A case study of deciduous forest stands on ancient woodland sites in the Swabian Alb revealed a significantly higher amount of dead wood in small-scale private forests (22 m³ per ha) compared to state-owned forests (9 m³ per ha) (Schaich and Plieninger, 2013). Growing stock of small-scale private forests was also significantly higher than in state forest in this case study, which was related to a higher tree density as well as to a higher proportion of old growth trees in extensively managed small-scale private forests in the Swabian Alb.



Photograph 5: Old growth beech ('Weidbuche') on a former pasture site in the Swabian Alb region (W. Konold).

Old growth in Baden-Württemberg can actually be found more frequently in remnants of historical forest management systems, in hunting estates, and in protected areas – all of which are also ancient woodlands – rather than in regularly managed forests. Composite forests of coppice and standards in the Upper Rhine Valley as well as overgrown coppices in the Black Forest or the Swabian Alb often host old growth oaks as well as other deciduous tree species (Konold, 2006). Wood pastures and common pasture systems with dispersed trees are also regionally important for the conservation of old growth (see Photograph 5 and the following chapter). Former hunting estates and landscape parks with alley trees could be locally valuable for the protection of old growth trees (Bund Heimat und Umwelt, 2012). Strictly protected forest areas (referred to in Baden-Württemberg as 'Bannwald', as well as in core areas of UNESCO Biosphere Reserves e.g. the Biosphere Reserve Swabian

Photograph 6: Strictly protected forest area ('Waldschutzgebiet' or 'Bannwald') in Baden-Württemberg (H. Schaich).

Alb) and forest stands without regular management (referred to in German as 'arB-Wald', e.g. on steep slopes) also add to the stock of old growth and dead wood in the forest landscapes of Baden-Württemberg (Photograph 6). However, with a proportion of 0.6% of the total forest area and a clustered spatial distribution, the contribution of strictly protected forest areas to the enhancement of old growth and dead wood features is still limited in terms of quantity and ecological functionality.

Wood pastures, old growth features and biodiversity in southwestern Germany

In the context of traditional forest uses and their impacts on forest stands, livestock can influence the growth, distribution and diversity of woody species directly through browsing and trampling, as well as by acting as vector for diaspores. Depending on the age of the tree and the intensity of livestock impacts, morphological and physiological changes can occur. If affected woody plants are left to age, pasture-specific and highly irregular shapes can develop (Photograph 7). Adult trees react to browsing on their wooden parts with sap and resin efflux and later by coating the area that has been bitten with extra tissue. These old growth trees, usually equipped with massive crowns, crooked stems and branches, offer multiple structures on their surfaces that serve as habitats for epiphytes, fungi and small animals. They are therefore valuable resources for nature conservation in European forests (Rotherham, 2013).

If livestock grazing is too intensive and combined with wood extraction, it can potentially have a devastating impact. For this reason, forestry laws in southwestern Germany have, since the early 19th century, separated agricultural from forestry use and forbidden non-

Photograph 7: Livestock impacted, multi-stemmed beech trees in the Black Forest region (W. Konold).

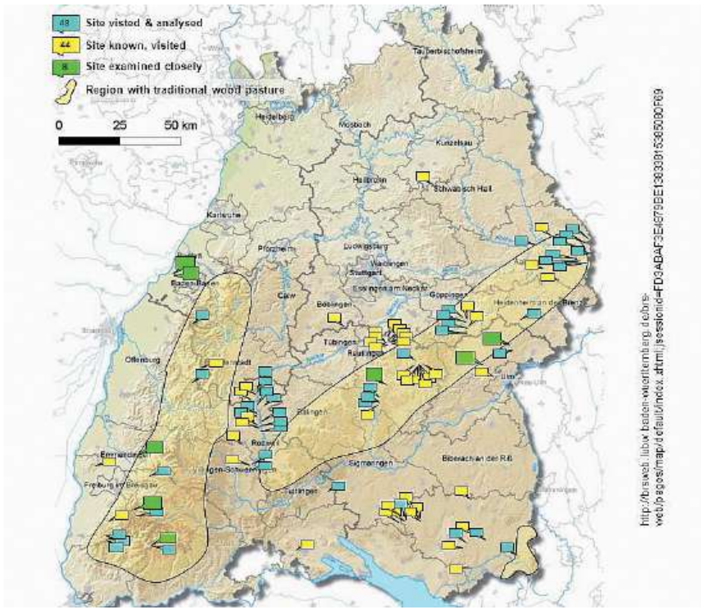
authorized livestock grazing and herding in forests (Müller, 2005).

The wood pasture research project: aims, sites and results

Despite the legal prohibition, wood pastures have persisted or have been newly established on small-scale, mostly rural areas in southwestern Germany. A research project on wood pastures aimed to identify currently active pasture woodlands in order to: (a) study land owners' motivations to practice an "illegal" land use as well as their general attitudes in relation to this issue, and (b) to characterize structural and floristic composition of wood pastures compared with adjacent managed forests (Rupp, 2013a). During the three year research project, a total of 100 wood pastures were identified using a pyramid scheme; eight of them were examined in detail with regards to structure and vegetation (Figure 10.1) (Rupp, 2013b). The amount of active wood pastures is surprisingly high in view of their problematic legal status. However, they are usually small with areas varying between 2 and 12 ha. They are situated predominantly in regions with disadvantageous climatic conditions and soil quality, e.g. in the low mountain ranges (see also

Distribution of wood pastures in Baden-Württemberg

Figure 10.1



Distribution of wood pastures in Baden-Württemberg as identified in the respective research project. The green icons show the closely examined sites and the yellow areas indicate the location of the low-mountain ranges with traditional wood pasturing (on the left hand side: the Black Forest; on the right hand side: the Swabian Alb (Map source: http://brsweb.lubw.baden-wuerttemberg.de, Data source: Rupp 2013a).

Figure 10.1). The livestock used are different breeds of sheep, goats, cattle, and horses, and in one case ibex (Capra ibex). The findings of the study show that this land use was kept alive in some areas in accordance with traditional practice. In other areas, modern nature conservation projects have been the driving force for the reactivation of formerly traditional pasture woodlands.

New wood pastures have often been created in nature conservation areas, in which a former pasture use has been documented. However, in most of the 100 wood pastures identified, old growth trees were cleared during the last two centuries after pasturing was banned and forest areas were managed for timber and fire wood (Härdtle et al., 2004). Most of the trees in the studied wood pastures – predominantly conifers or beech – are roughly 100 years old. However, in some of the wood pastures – with a more or less continuous pasture history – trees that are older than 200 years exist. In interviews, the land owners stated that they would leave the old growth trees because they consider them as something special due to their age, huge dimensions, ecological and cultural value and their unique presence in the landscape. The old growth trees with big crowns were considered to enrich the local scenery and embody a sense of place.

Livestock influences on tree regeneration

Structural analyses were undertaken regarding the influence of livestock on woody species such as trampling and particularly browsing. The affected trees can develop into richly structured adult specimen typical of wood pastures, which are rarely found in other woodland biotopes. Tree layer canopy covers between 10 to 50% of the ground. The understorey layer contains only few trees as many have been browsed by livestock or mechanically thinned out to stimulate herb layer productivity. However, in comparison to adjacent managed forest stands, the wood pastures generally contain more woody species and up to three times more individuals of woody species in the herb as well as in the shrub layer. Due to their semi-open structure, wood pastures receive high quantities of sunlight and therefore offer more habitat niches than closed managed forests. This also allows a wide range of tree species to germinate and to grow up into the tree layer. For example, the tree layer of a reactivated wood pasture on the eastern Swabian Alb contains 15 different tree species with many individuals, whereas the adjacent managed forest hosts only nine species. Noticeable is also the mixture of different light-demanding pioneers (e. g. *Salix caprea, Cerasus avium, Populus tremula, Sorbus aucuparia*) and competitor species (e. g. *Quercus robur, Fagus sylvatica, Ulmus glabra, Tilia platyphyllos*) in wood pasture sites. The spatial distribution of trees in wood pastures is also distinctive: Trees germinate preliminarily in the ecotones between denser and more open areas or at the edges of glades.

In wood pastures, livestock acts more intensely than game species, and nearly all woody species are browsed. In the adjacent managed forest stands, only moderate game browsing was found and this was basically concentrated on deciduous tree species and fir (*Abies alba*). Repeated browsing of apical shoots forces the tree to substitute the loss of stems with the growth of multiple branches that replace the apical shoot. During ongoing browsing on wooded pastures, the netting of branches widens a tree's diameter until the livestock can no longer reach the shoots in the middle. In this so called 'Kuhbusch' stage of tree development (Bergmaier et al., 2010), some shoots in

Photograph 8: A central shoot of *Fagus sylvatica* develops out of a browsed Kuhbusch' stage in the Black Forest (Feldberg region) (M. Rupp).

Photograph 9: Hornbeam (*Carpinus betulus*) in a ring-shaped growth form (diameter: about 3 m) due to browsing on the Swabian Alb (M. Rupp).

the middle of the tree complex that are out of reach of the livestock are able to grow tall (Photograph 8). In the case study wood pastures, such forms were mainly observed in beech (*Fagus sylvatica*), but also in juniper (*Juniperus communis*), lime (*Tilia platyphyllos*) and hornbeam (*Carpinus betulus*). Hornbeam occasionally grows in a ring-shape with diameters of up to 3 m or more, and forms unique trees when aged (Photograph 9).

In wood pastures, tree species that are favored by livestock and are thus less-competitive in regenerating can nevertheless grow up when sheltered by protective species with thorns or prickles (Morgan, 1991). Such trees eventually overgrow the sheltering species and block their sunlight. Interactions were found in wood pastures on the Swabian Alb mainly between *Fraxinus excelsior*, *Acer*- and *Tilia*-species in the shelter of *Rosa*- and *Crataegus*-species, *Prunus spinosa, Juniperus communis* or *Cornus sanguinea.* In the Black Forest wood pastures, dense stands of spruce or holly serve as shelter for *Sorbus aucuparia*.

Old growth features in wood pastures

Trees with DBH from anywhere between 50 cm to more than 130 cm were found in the studied wood pastures. The managed forests adjacent to the wood pasture sites contain forest stands with homogeneous tree ages, dominated by coniferous tree species (spruce and douglas fir), with tree diameters of between 12 and 60 cm and a closed canopy layer. Main factors that influence the tree species composition in the tree layer of the wood pastures are the natural site conditions as well as the respective land use history of the site. Specific interests of the land owners play a central role in determining how sites are managed. On a site in the central Black Forest, huge pines (*Pinus sylvestris*) serve as shelter for the livestock and ash (*Fraxinus excelsior*) provides leaf fodder. In addition, old *Castanea sativa, Cerasus avium* and *Prunus domestica* subsp. *prisca* offer tree crops for livestock and land owners. Land owners of wood pastures in the Swabian Alb mentioned that the naturally growing *Fagus sylvatica* was supplemented by lime (*Tilia* spec.), presumably for fodder and honey production, as well as *Fraxinus excelsior* and *Ulmus glabra* for leaves and timber production.

The comparative study showed that managed forests form mainly closed stands with trees building perpendicular crowns high above the ground, while wood pastures frequently showed park-like structures with trees forming huge elliptical crowns with a browsing line on the underside. The study also revealed the strong presence of zoochorous woody species in the herb and shrub layer in wood pastures, an example of which was found on a site on the eastern Swabian Alb in Figure 10.2. With regards to diaspore distribution, two processes were observed on the project sites: firstly, livestock carries the seeds endogenously and drops them with their excrements, as with *Malus sylvestris* or *Lonicera xylosteum*. Secondly, birds and small mammals are attracted by the semi-open structures in the wood pastures and thereby distribute tree species such as *Cerasus avium, Ilex aquifolium, Crataegus* spec., and *Quercus robur.*

Old pasture trees on the eastern Swabian Alb offer

Figure 10.2

Chory-types of woody species in wood pastures and adjacent managed forests on the Swabian Alb.

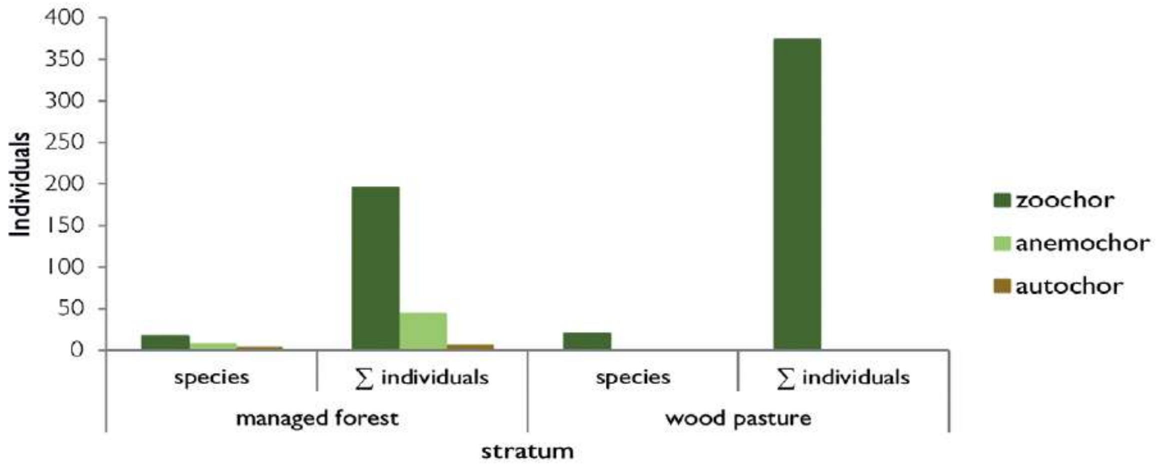


Table 10.1

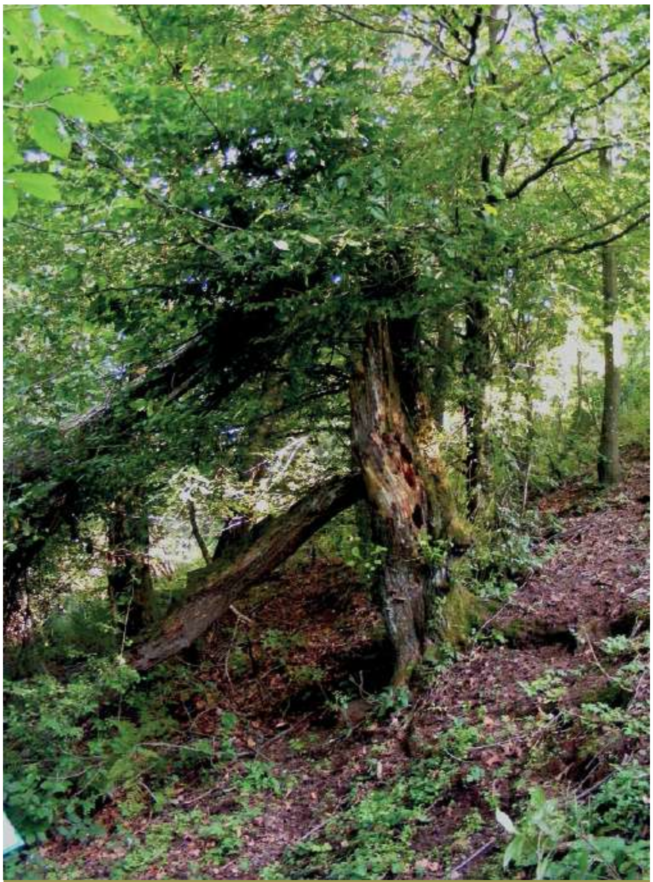
Structures found on the surface of old trees in a wood pasture in a Hutewald on the Swabian Alb (n=475).

Structure	Individuals and percentage [%]
Coating by extra tissue	415 (87,4 %)
Crown hollows	265 (55,8 %)
Mull pockets	86 (18,1 %)
Ulcerations	83 (17,5 %)
Dying parts of bark, branches and stem	195 (41,1 %)

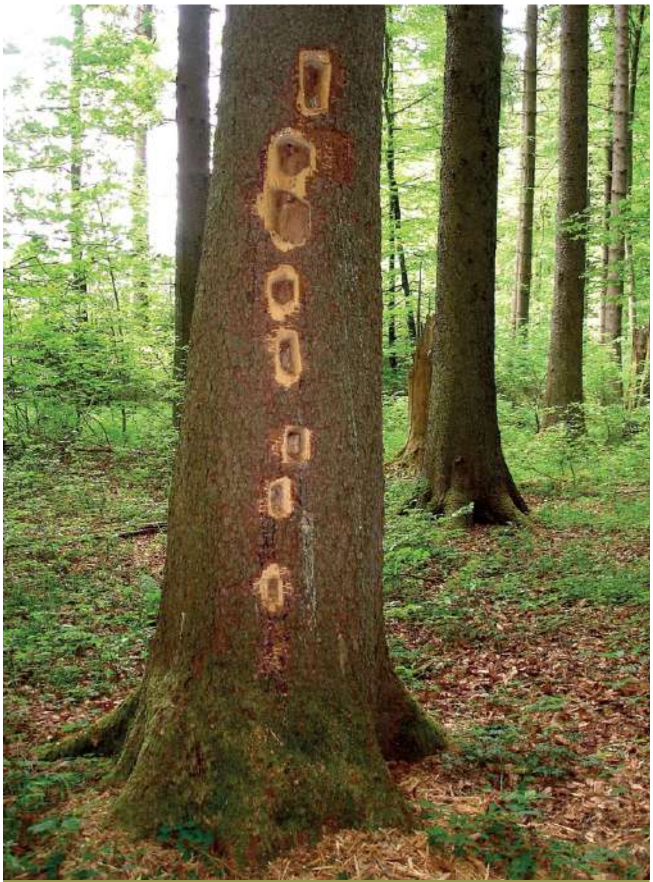
Photograph 10: Several stems of one *Fagus sylvatica* individual have lifted up a stone. Around the bases of the trunks, different milieus of moisture and light, holes and hollows can be found (M. Rupp).

manifold structures on their surfaces (see Table 10.1), such as cracks in the barks, all grades of dying wood, crutches, wounds, hollows and caves, mull pockets, small water basins, ulcerations and overgrowth of former wounds or objects e.g. stones (Photograph 10). Most of these features are dependent on the above mentioned livestock influences during the trees' youth and are rarely found in managed forests. The high surface area of the big crowns of wood pasture trees also offers a realm for epiphyta. In the Upper Rhine Valley, the Swabian Alb and the Black Forest, every old tree we examined was settled by moss and lichens on stems and crowns. On the Alb site, 475 old trees carried mosses, 464 were covered by lichens, 306 bore algae, 50 hosted fungi, and 31 were settled by higher spermatophyta.

Adult pioneer trees – like *Betula pendula, Salix caprea, Populus* spec. and others – appear in higher quantities in wood pastures than in managed forests and can spend their whole life cycle in pasture woodlands without being subject to selective cutting. For instance, in a managed forest stand in the Black Forest, four pioneer tree species were found, whereas in the adjacent wood pasture, ten pioneer tree species were detected in the tree layer. Pioneer trees die earlier than competitor tree species, thereby offering sap and resin as well as softer dead wood, which is essential for many species such as xylobiontic beetles or woodpeckers (Photograph 11). When pioneer trees collapse, they create light islands which attract grazing animals who manage to keep the small glade open for a period of time. Thus, old growth can be seen as an important driver for the spatial dynamics of herbivory: Xylobiontic insects and woodpeckers dig in the wood, various insects feed on the sap, and broken-off rotten branches host small mammals. The examined managed forests offer larger quantities of small to medium sized dead wood (7-50 cm in diameter) than the adjacent wood pasture. However, wood pastures have the potential to enrich forest landscapes with large-sized dead wood when old pasture trees with large crowns decay (Photograph 12).



Photograph 11: Senescent pioneer tree (*Salix caprea*) about to decay completely and used by woodpeckers and insects (M. Rupp).



Photograph 13: Remnant holes of black woodpecker foraging on xylophagous insects in an old growth spruce tree (H. Schaich).

Photograph 12: Toppled oak is left to decay naturally in a wood pasture in the Rhine Valley (M. Rupp).

Conclusion and perspectives

Obviously wood pastures offer a realm for old growth trees, which is rarely present in managed forests. Interviewed land owners, farmers, and nature conservationists appreciate the multiple functions provided by old growth trees to plants, wildlife, farm animals as well as in terms of landscape beauty. The future of wood pastures and old pasture trees is dependent on the existence of farms with extensive livestock management. Their survival is in turn strongly dependent on agricultural and forestry laws and the will of societies to support financially such traditional forest uses. Modern forestry laws with less restriction on the application of wood pasture in nature conservation projects would support the conservation of wood pastures and their respective old growth features. To foster this valuable land use management, initiatives have been developed in Baden-Württemberg to integrate wood pasturing in nature conservation strategies (Schmalfuß and Aldinger, 2012) and to extend funding for land owners via regular agricultural payment programs or payment schemes for nature conservation measures. These initiatives view wood pasture as an important forest use system which unites the conservation of biodiversity, of old livestock breeds as well as of cultural heritage and recreation services.

Old growth as a resource for hollow-nesting birds in the Schönberg region

With a case study in the Schönberg region near Freiburg, we focus on the availability of bigger tree hollows as an indicator of old growth forest components. A range of animal species spanning from insects over small mammals to diverse birds are known to utilise the hollows of bigger trees (Johnsson et al., 1993). As such, the spectrum of the occurring hollow-dwelling species may be used to draw conclusions concerning the ecological status of a forest ecosystem (Wesolowski, 2007). However, exploring the full range of species in question is complex. For this reason the study concentrated on species that are considered to provide adequate insight into processes relevant for the availability of old growth trees: Building hollows for nesting and to use as hides at nighttime, the black woodpecker (Dryocopus martius) can be taken as an indicator in relation to the provisioning of a certain number of bigger tree hollows for so-called secondary hollow users. The black woodpecker is a territorial, insectivorous bird species. Woodpecker territories are known to vary in area between 300 to 600 ha. Territories have to provide a sufficient amount of forage, mainly ants and xylophagous insects and their larvae (Photograph 13) (Gorman, 2011). As such, the presence of the woodpecker is an indicator of the availability of a range of habitat requisites, e.g. old growth and dead wood of different ages and dimensions. Moreover, because of its spatial requirements, this species can serve as an indicator of environmental conditions beyond the spatial extension of single forests stands. Black woodpeckers preferably build their hollows in living trees. Hollows are mostly found in beech (*Fagus sylvatica*) and common pine (*Pinus sylvestris*). In order to avoid predators, the holes are located at a considerable distance from the ground, and they must provide sufficient room for the bird. Thus, in order to be suitable for woodpeckers, forested areas must contain trees of sufficient height and dimensions. Woodpeckers use tree holes for nesting and for hiding during the night and they defend their hollows efficiently against interspecific competitors. Hollows can be in use for years, depending on the inner climatic condition of the tree hole. Moisture and gradual rotting eventually force the woodpecker to abandon a hollow, thereby making it available for other species, e.g. the stock dove (Gorman, 2011).

The stock dove (*Columba oenas*) is a bird species that depends on the presence of bigger hollows and hollow-like structures for breeding. A lack of breeding habitats is assumed to be a main factor restricting the population development of this species. Suitable breeding habitat is characterised by a mosaic of meadows and forest edges, where the birds forage on seeds, fruits and green leaves, as well as forests with a sufficient number of tree hollows (Glutz von Blotzheim and Bauer, 1980; Murton and Westwood, 1974). Ranging distances of the dove vary between 1 to 4 km during the breeding period. As the dove is not capable of creating hollows or niches by itself, it relies on the presence of suitable nesting conditions. Breeding stock doves have been observed in rocks, buildings and even underground in rabbit holes. However, in southwestern Germany, broods of this dove species are almost exclusively sighted in tree hollows that have been built by the black woodpecker (Hölzinger and Mahler, 2001). Given that they are assumed to rank at the lower end of the interspecific competition for tree hollows, the presence of successfully breeding doves may indicate that the availability of hollows is sufficient for the existence of a range of more competitive hollow dwelling species.

Photograph 14: Breeding stock dove detected in a former black woodpecker cave by using an endoscopic camera system (T. Kaphegyi).

The study site

The study site is located at the Schönberg (47° 58’-47° 56’ N, 7° 46’-7° 48’ E) near the city of Freiburg, southwestern Germany, in the foothills between the Black Forest Lower Mountain Range and the Upper Rhine Valley. The absolute altitude is 645 m with an annual average mean temperature of 9 °C. The climate is characterised by relatively high summer temperatures and mild winter conditions. In-situ rock is mainly limestone. At higher elevations, soil conditions are unsuitable for agricultural use. Forest cover consists of deciduous mixed forest, where beech is prevalent. The Schönberg area extends over about 2,400 ha and incorporates forests, pastures, and vine cultivation. About 340 ha are covered by forests, of which 88 ha are beech forest stands older than 100 years (Bogenrieder, 2006).

Study procedure and results

The case study was concentrated on the availability and use of bigger tree hollows with a minimum entrance width of 6 cm in vertical and horizontal dimensions (Johnsson et al., 1993). During the winter season 2007 to 2008, the 88 ha of beech stands of >100 years distributed over the Schönberg area were completely explored for black woodpecker hollows and for hollow-like structures that originate from natural processes such as breaking-off of branches or rotting etc. The leafless period made it possible to search the forest stands efficiently for tree hollows (Stojanovic et al., 2012; Wesolowski, 2001). Trees with hollows were recorded and the diameter, height, and distance of the hollow-structure from the ground were measured. We climbed every tree with potential hollows in order to obtain parameters by which to characterize

Photograph 15: Ring marking of black woodpecker nestlings (C. Harms).

the hollow structure. In this context, we measured the horizontal and vertical diameters of the hollow entrances and of the inner cave, and we assessed climatic conditions and rotting processes within the hollows.

Within the 88 ha of the studied beech stands we found 22 black woodpecker hollows and 90 hollow-like structures in total. During 2008, 2009 and 2010, the use of the hollows by hollow-dwelling animals was explored each spring using an endoscopic camera (Photograph 14). The hollows were used by stock dove, black woodpecker (Photograph 15), green woodpecker (*Picus viridis*), tawny owl (*Strix aluco*), and diverse smaller bird species such as nuthatch (*Sitta europaea*), great tit (*Parus major*), and blue tit (*Parus caeruleus*). In addition to the bird species, different mammals including Eurasian squirrel (*Sciurus vulgaris*), fat dormouse (*Glis glis*), greater mouse-eared bat (*Myotis myotis*), and insects such as the hornet (*Vespa crabro*) inhabited the hollows. On some occasions, successive utilization of the same hollow by different species was identified, however, simultaneous usage was not found. In 2008, about 3% of the available hollow structures and 91% of existing black woodpecker caves were inhabited. In 2009, we found that 8% of the hollow structures were inhabited and 50% of the existing woodpecker caves were in use. The respective proportions in 2010 were 14% for the hollow structures and 64% for black woodpecker hollows. In the Schönberg area, stock doves exclusively bred in hollows formerly built by the black woodpecker. The stock dove preference for black woodpecker hollows has also been confirmed by other research (Kosinski et al., 2010). Other hollow-dwelling species also clearly preferred black woodpecker hollows over other hollow structures ($\chi^2 = 16.432$; df = 1; $p < 0.001$). Some researchers describe dry climate conditions inside the hollow and a maximum of 30 cm depth as important characteristics if the hollow is to be suitable for the stock dove (e.g. Möckel, 1988). In contrast, we found that even very wet conditions and greater depths (e.g. 125 cm) did not prevent the dove from selecting and successfully breeding in hollows.

The population dynamics of the stock dove were monitored from 2008 until 2012 in total. Over the five breeding seasons, the number of breeding pairs in our study area varied between five and nine per season (average: 7.6 a^{-1}). Clutches of the stock dove typically consist of two eggs, and feeding the nestlings with secretion produced in skin folds of the craw allows multiple overlapping breeding per season. Over the five years of the study, the average number of clutches per breeding pair was 1.84 (min.: 1.38; max.: 2.25; SD: 0.35).

Conclusions and discussion: Interspecific relation reveals the importance of old growth forests

The breeding population of the stock dove seems to have been stable during the five year period of the case study. Compared with other research which e.g. identified 1.9 breeding pairs per km^2 in Thuringia (Kühlke, 1985), the density of breeding stock doves ranging from 5 to 9 pairs within the 88 ha of old growth beech stands in the study was considerably high. However, comparing the abundance of breeding pairs, clutches or hollows between different studies is not reasonable in cases where the availability of suitable breeding habitat is not clearly defined for the area where the data in question were collected.

The stock doves in the Schönberg region exclusively used hollows formerly built by black woodpeckers. During the five years of the study, the doves used the same hollows every season, although some hollows provided non-optimal conditions in terms of wet hollow climates and hollow morphology. In a nearby study area, a breeding pair did not abandon the cave even despite a massive woodpecker impact on the individual reproduction success. We observed a black woodpecker destroying the nestlings of nearly all successive clutches in the respective cave during two subsequent seasons. It appears that once stock doves have selected a hollow they adhere to it strongly.

The case study revealed a considerable proportion of non-inhabited hollow-like structures in the old growth beech forests at the Schönberg. This finding may suggest that factors other than the supply of nesting possibilities restrict the population of the stock dove in the area. However, our surveillance did not indicate that predation restricted the dynamics of the dove population nor did the habitat structure suggest that food availability is a minimum requirement for the dove in the case study area. In light of these findings, the case study seems to underline the importance of black woodpecker hollows for a range of forest dwelling species and therefore for forest ecology. This is particularly true since one has to take into account that hollows are used for functions other than breeding, e.g. resting places and night hides, which cannot be readily quantified and therefore may be underestimated in our research. Trees with appropriate dimensions are a prerequisite for black woodpecker hollows. Recent research provides evidence of the black woodpecker preferring beeches affected by heart rot (Zahner et al., 2012). In addition to tree dimensions, the relevance of heart rot for primary hollow dwellers further emphasizes the importance of old growth trees for the ecology and biodiversity of managed forests.

The old growth and dead wood strategy of the federal state Baden-Württemberg

The low amount of old growth and dead wood in state-owned forests together with a growing societal demand with regard to biodiversity conservation (BMU, 2007) led to the development of the old growth and dead wood strategy (ODS – referred to in German as 'Alt- und Totholzkonzept') for state-owned forests in the federal state of Baden-Württemberg (ForstBW, 2010). Given that societal acceptance of forest management is crucial for the legitimacy of the state-forest agency ('ForstBW'), the advancement of the established close-to-nature management approach in regard to old growth and dead wood has been necessary in Baden-Württemberg (MLR, 1993). In addition to this societal development and the basic knowledge that old growth and dead wood resources are lacking, several factors and a special constellation of protagonists and stakeholders opened up a 'window of opportunity' for the implementation of the ODS in Baden-Württemberg's state-owned forests (Waldenspuhl et al., 2011). These included:

- development of a concept of strategic sustainability management for state-owned forests (Waldenspuhl and Hartard, 2010);
- increasing knowledge around the definition of operational threshold values concerning old growth and dead wood for habitat and species conservation (Müller and Bütler, 2010; Schaber-Schoor, 2010);
- a new political constellation of different stakeholders and administrations;
- increased legal requirements regarding the protection of species in forests as well as societal requirements as expressed in the National Strategy on Biological Diversity (BMU, 2007); and
- affirmative guidelines for forestry practice.

Probably the most decisive factor for the establishment of the strategy was the politically motivated restructuring of the competences of federal ministries and administrations in Baden-Württemberg in 2005. Through the consolidation of conservation and forestry administrations into a single department under one directive, the cooperation and the coherence between the respective actions, instruments as well as targets were strengthened.

The legal requirements regarding the protection of forest species have also increased significantly within recent years (Lorho, 2010) and have been a strong driver for the development of the strategy. In 2007, the requirements of the Habitats and Birds directive of the European Union were formulated in an operational guideline for a strict protection system for species and habitats of joint interest of the European Commission (KOM guideline) as well as for the jurisdiction of the European court of justice (Lorho, 2010). According to these new European guidelines and their translation into national and state conservation laws, forest owners had to implement coherent and primarily preventive measures in order to meet European and national legal targets and to guarantee the ecological conditions in the resulting Natura 2000 network of protected areas. The legal proclamation in national and state forest laws that state-owned forests should serve the public welfare in particular (Ruppert-Winkel and Winkel, 2011), was an additional driving force behind the Baden-Württemberg state forest agency's development of a strategy on old growth and dead wood. It also facilitated compliance with the new legal conservation requirements.

The ODS was collectively developed by the forest and nature conservation administrations with the purpose of complying with the new legal regulations on species and habitat protection as well as to guarantee sustainable forest management in the future. Through implementation of the strategy, the preservation and restoration of favourable conditions for species inside and outside the Natura 2000 areas are being accomplished and it is possible to avoid an individual case-by-case review of every forest management and economic measure.

Objectives and strategy development

The forest agency of Baden-Württemberg decided to develop a concept for the conservation of old growth trees and dead wood in 2008, which has implemented in state-owned forests since 2010 (ForstBW, 2010). The major objective was to increase significantly the numbers of old growth trees and the amount of dead wood in managed state forests of Baden-Württemberg. In detail, the old growth and dead wood strategy (ODS) was intended to achieve and to comply with the following objectives and requirements, respectively:

- fulfill the requirements for a favourable preservation status for Annex I forest habitats of the EU Habitats Directive;
- fulfill the conservation requirements of certain Annex

Photograph 16: Old growth beech with a cavitiy and a peculiar proliferation structure (H. Schaich).

II and Annex IV species of the EU Habitats Directive;

- comply with the demands of harvesting safety;
- can be integrated in standard forest management measures; and
- can be re-adjusted according to monitoring results (controlling).

Given that some of the objectives or requirements were partially contradictory, it was necessary for the elaboration of the strategy to engage an interdisciplinary work group consisting of several experts from both the nature conservation and forestry sectors, e.g. experts on species, silviculture, conservation law, harvesting safety, and economics. Experts on species – including birds, beetles, bats, mosses – added their knowledge about species ecology and habitat requirements. Experts on harvesting safety checked which alternative strategy offered the best solutions with regards to forest workers' safety. Forest economists calculated the costs of setting aside old growth and habitat trees and the loss of valuable timber and fire wood resources.

The three components of the strategy

The ODS consists of three basic components of old growth and dead wood conservation:

- Single habitat trees with crucial structures such as large woodpecker holes, aeries or other known essential breeding sites of protected species are marked, reserved from harvesting and protected over the long term.
- Groups of around 15 habitat trees are identified, marked, mapped and set-aside from management and harvesting. As such, they grow large and old, and develop a whole range of old growth features such as crown breaks or wood decay and finally become dead wood. These 'habitat tree groups' are identified in all older stands with an average of one group per three ha.
- Additionally, small forest stands, the so-called forest refugia (in German 'Waldrefugium'), of high protection value are set-aside completely so that they can develop without direct human interference and can decay naturally.

Among the old growth features of highest conservation value were trees with large hollows (Photograph 16), especially when filled with duff, oaks nursing generations of beetle larvae of e.g. *Osmoderma eremit*, and aerie trees as these are often occupied for many years by nesting birds. Trees with these structures should primarily be set-aside from harvesting and should be conserved as single habitat trees.

Although it is often single trees that have a rare structure and are therefore of high value for biodiversity, such trees and their structures are best protected when set-aside together with surrounding trees. For example, beeches with black woodpecker hollows are very rare in managed forests (see chapter above) and should therefore be included in the ODS. When such hollow-trees are left isolated following the harvesting of the surrounding trees, they very often become sunburnt and die quickly, thereby losing their habitat function e.g. as a breeding site for woodpeckers and secondary hollow nesters. If such a hollow tree is integrated into a habitat tree group of beeches, the surrounding trees provide shade and shelter to the hollow tree and act as a buffer against external impacts. Hence, the group of trees will conserve old growth features for a potentially longer period than a single tree. By choosing groups of habitat trees and allowing them to develop naturally until they die and decay, both the number of old growth features and the amount of dead wood increases.

According to the ODS, one group of 10 to 15 trees is chosen per three ha as a habitat tree group. The group is not chosen systematically with regard to spatial distributions but rather according to known breeding sites, existing structures and old growth features as well as concentrations of trees with low timber quality. If possible, forest harvesting requirements are also taken into consideration and habitat tree groups located at a sufficient distance from skid trails and in areas where they are likely to have only few negative impacts on future harvesting operations are designated.

As a third protection component of the ODS, forest refugia with an area of more than one ha are set-aside for strict protection. These are preferably forest stands with old growth trees of huge dimensions on ancient woodland sites with habitat continuity. Other suitable sites are forest stands of a certain age with known habitats of rare, protected, or forest relic species, of low timber quality, low growth rates or unfavourable harvesting conditions. The forest refugia represent small protected forest areas where old growth and dead wood accumulates up to an amount far higher than in the surrounding managed forest stands.

The ODS aims to create a diverse network of old growth and dead wood in managed forests that interconnects functionally with the existing strictly protected forest areas of larger size ('Bannwald', 'arB' stands). Additionally, it is intended to complement and improve the established close-to-nature forest management concept in the state-owned forests of Baden-Württemberg.

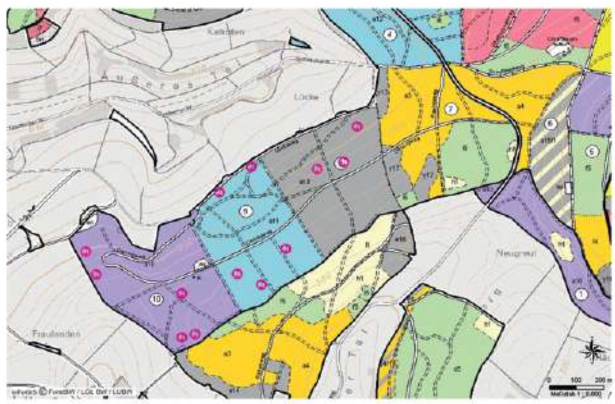
Implementation of the concepts in state-owned forests

Since 2010, the ODS with its three protection components has been implemented across Baden-Württemberg's state-owned forests, within and outside Special Areas of Conservation (SACs) designated under the EU Habitats directive. Prior to any harvesting operation in forest stands older than 80-100 years or with trees with >50 cm DBH, the district forester who chooses the trees for harvesting is also obliged to designate single habitat trees or groups of habitat trees. Thus, habitat trees and habitat tree groups remain, while the rest of the forest stand slowly reaches harvest maturity and is harvested. Where there are known breeding sites or groups of old growth trees or other trees with valuable structures for biodiversity conservation, they can be designated as habitat tree groups before a harvesting operation and also be selected within forest stands that are younger than 80 years.

As the habitat trees grow older, their stems and crowns become more and more destabilized and are eventually bound to break down. As they are designated and protected within forest stands that continue to be harvested, they become a partly unpredictable source of danger for forest workers. When located next to forest roads or footpaths, they might also become dangerous for forest visitors. The latter risk can be minimized by selecting habitat tree groups located at least a tree length distance from roads, paths and zones with a high visitor frequency.

To improve the long-term protection of the single habitat trees or the habitat tree groups as well as to ensure work safety, the designated trees are permanently marked. A combination of color marking in the field and spatial data detection was field-tested and approved: For the safety of forest workers during future harvesting operations, it is very important that the group of habitat trees is clearly recognizable in the field. Therefore at least all border trees of the group are marked with a white wavy line (Photograph 17). Geographic coordinates of every designated ODS component were measured and recorded in an electronic database, which enabled the production of forest maps that display all habitat tree groups for every operation in the respective forest district (Photograph 18). These maps again add to harvesting safety because possible dangerous zones can be identified prior to harvesting operations. The map also provides an overview of the number and spatial distribution of the single habitat trees and habitat tree groups and the electronic data helps to manage the implementation of the ODS.

Photograph 17: Old growth beech within a habitat tree group marked with a wavy white line (N. Schmalfuß).



Photograph 18: Forest map with habitat group trees (red circles).

The set-aside forest refugia are chosen in the course of the ten-yearly forest management planning process. During forest management planning, the relevant criteria are best considered in the field. Nature conservation and species experts are involved in the planning process and in the final choice of forest refugia. The set-aside areas are also marked in the field and displayed with their edges of extension within the forest maps.

Training campaign and information on the strategy

Prior to and during the implementation, foresters and forest workers were trained to implement the ODS. This training included topics such as the ecological basis and necessity for the protection of old growth and dead wood, specific knowledge on the ecology and habitat requirements of certain species, the juridical background of species protection, implementation measures and techniques, and the silvicultural operations for the conservation of ODS components in different forest types. The campaign was started with training workshops for more than 200 extension officers who were designated the task of conducting further training within their forest district. However, it became obvious that the foresters and forest workers wanted further support. Thus different types of training and workshops were designed, concentrating on the implementation in different forest types and focusing on specific groups of species.

In addition to the training campaign and the on-going implementation, a range of information material was published. As well as a detailed booklet on the strategy implementation, this included brochures on silvicultural aspects of the implementation in specific forest types, and further information on tree structures, marking and measuring in practice as well as a first report on the status of implementation (Photograph 19).

Status of implementation and perspectives

In the context of the strategic sustainability management of the state-owned forest in Baden-Württemberg, the annual implementation figures for habitat tree groups and forest refugia were published on the state agency's website. This transparency regarding the implementation status of the strategy is very important for the acceptance of all stakeholders and the public.

Until the end of 2011 – two years after the beginning of the ODS implementation – 5,185 habitat tree groups with a total of c. 61,000 individual trees have been designated, marked and documented in the state-owned forests. A habitat tree group comprises a mean of 12 trees. The target value for the designation of habitat tree groups in 2011, which was defined at 3,525 habitat tree groups according to the managed forest area, was thus surpassed by about 50%. This positive development was fostered by a foresighted designation of habitat trees in stands where no management or harvest operation was planned. Moreover, structurally rich or old growth stands

Photograph 19: Available information material for the implementation of the old and dead wood strategy in state-owned forest of Baden-Württemberg.

in a pre-use phase as well as old growth trees over young cultures or young forest stands were very soon designated as habitat tree groups to protect them against clear-away cuttings. At the end of 2011, the implementation of the forest refugia amounted to a total of 642 refugia and a total area of 2,017 ha in the state-owned forests. As planned within the ODS, they are designated within the regular forest planning process. The designated refugia have a mean area of 3.1 ha, which is considerably larger than the defined minimum size for forest refugia of >1.0 ha.

While the implementation of the old growth and dead wood strategy in state-owned forests is making good progress, the desired transfer of the strategies and their principles to municipal and private-owned forests is proceeding slowly. Some forest owners – especially municipalities – implement the concept because of a personal commitment to fostering nature conservation in their forests as well as to comply with demands articulated by stakeholders in the municipalities. So far, no direct financial incentives are provided to private or municipal forest owners for the designation of habitat tree groups or forest refugia even though these would be likely to make compliance with the principles of the strategy more attractive. However, forest owners have been able to credit the implementation of forest refugia as compensatory measures for construction works inside and outside of forests that have had impacts on ecosystems or characteristic landscapes (e.g. construction of new settlements or streets). As habitat banking systems gain importance in the context of the intervention regulation in the federal law for nature conservation and given the increasing importance of publicly financed payment schemes for nature conservation (Schaich and Konold, 2012), the ODS could also serve as a useful tool for safeguarding and developing old growth and dead wood resources in municipal and private forests in the future.

Conclusions

Over recent decades, forests have been increasingly used for timber harvesting as well as for biomass extraction in the federal state of Baden-Württemberg as in almost all regions of Europe (Berger et al., 2013). Economically efficient forest management has consistently strived to avoid successional stages of forest development that are less productive (old growth) or not productive at all (dead wood) and has also sought to abandon traditional supplementary forest uses, e.g. wood pasturing. This leads to a considerable decline particularly of those species that are dependent on old growth and collapsing phases of forest development as well as on light-demanding species in pioneering stages and semi-open forest stands (Bunnell and Houde, 2010; Gustafsson and Perhans, 2010). In 1992, the federal state of Baden-Württemberg introduced a close-to-nature management approach for its state-owned forest area (MLR, 1993), which was successful in enhancing natural regeneration and site-adapted, semi-natural tree composition. However, this did not achieve the necessary increase in old growth and dead wood resources for the conservation of the specific species and habitats and it did not comply with national biodiversity goals and European legislation in southwestern Germany.

In this context, the development and implementation of the old growth and dead wood strategy was a consequent and pragmatic step forward to increase the amount of old growth and dead wood in the overly managed forest landscapes of Baden-Württemberg. Although the strategy has only been implemented for a short time and the ecological effects of this scheme are therefore still largely unclear, the first results of the implementation and the acceptance of the strategy within the forestry and conservation administrations as well as amongst the broader public are quite promising. The old growth and dead wood strategy could therefore serve as a blueprint for other regions in Europe facing the same challenges in forest conservation. However, still deeper insights into the mechanisms of usage and dispersion of resources and requisites provided by old growth forests is crucial in order to refine such strategies and to derive operational targets on quantitative and qualitative parameters for the provisioning of old growth and dead wood resources. According to the current state of knowledge, thresholds for key resources like basic parameters for such strategies refer mostly to the spatial unit of the respective forest stand (e.g. Müller and Bütler, 2010). The availability and distribution of old growth and dead wood features on a landscape level , which is very decisive for the conservation of populations of threatened species that are dependent on these resources, is largely neglected in the standards of such strategies. Here, research must generate more specific knowledge so that a spatially and temporally dynamic network of old growth and dead wood features can be established via operational standards on a landscape level.

Additionally, the case study on wood pastures in southwestern Germany revealed that such traditional, multifunctional land use systems can contribute significantly to enhance structural diversity and especially the amount of old growth resources in forest landscapes. Traditional forest uses, e.g. forest pasturing or composite and coppice forest systems, should therefore be integrated into forest conservation and old growth strategies. Priority should be given to sustaining actively managed, traditional systems and to re-establishing them on sites where such land use systems have been persistent in the past and habitat continuity has not been interrupted for a long time (Schaich and Konold, 2005). Forest laws have to be modified in this sense and state-financed payment programs should be offered to increase the attractiveness for farmers and private forest owners of establishing such traditional land use systems.

With regard to key mechanisms like ecological functionality and habitat connectivity, the implementation of a conservation strategy to enhance old growth and dead wood at a landscape scale in European forests should be taken into account. Herewith, the diverse and regionally varying land ownership structure is an important factor with regards to availability and distribution of old growth elements. In state-owned forests, close-to-nature forestry approaches have to be complemented by the implementation of strategies and management standards to foster old growth and dead wood. In this context, the implementation of sound scientific evaluation as an inherent component of the strategies is required. The development of payment schemes becomes even more important as in times of rising energy prices several countries in Europe are exploring potentials to intensify the harvesting of woody resources for the bioenergy sector from all forest ownership classes and especially from regionally prevalent, old growth-rich, small-scale private forests. Therefore, instruments like payment schemes for old growth and dead wood as well as the implementation of traditional forest land use systems are needed for different forest owners to counter initiatives aimed at extracting more woody resources and to achieve the objectives of the biodiversity strategies for European forests on a landscape scale.

References

Bauhus, J., Puettmann, K. and Messier, C., 2009. Silviculture for old-growth attributes. *Forest Ecology and Management,* 258: 525-537.

Berger, A.L., Palik, B., D'Amato, A.W., Fraver, S., Bradford, J. B., Nislow, K., King, D. and Brooks, R.T., 2013. Ecological Impacts of Energy-Wood Harvests: Lessons from Whole-Tree Harvesting and Natural Disturbance. *Journal of Forestry*, 111: 139-153.

Bergmaier, E., Petermann, J. and Schroeder, E., 2010. Geobotanical survey of wood pasture habitats in Europe: diversity, threats and conservation. *Biodiversity and Conservation*, 19: 2995-3014.

Bieling, C., Plieninger, T. and Schaich, H., 2013. Patterns and causes of land change: Empirical results and conceptual considerations derived from a case study in the Swabian Alb, Germany. *Land Use Policy*, 35: 192-203.

BMU (Ed.), 2007. *National Strategy on Biological Diversity.* Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Berlin.

Bogenrieder, A., 2006. *Die Vegetation des Schönbergs*. In: Körner, H. (Ed.) Der Schönberg. Natur- und Kulturgeschichte eines Schwarzwald-Vorberges, Lavori Verlag, Freiburg, 55-100.

Brunet, J., Fritz, Ö. and Richnau, G. 2010. Biodiversity in European beech forests - a review with recommendations for sustainable forest management. *Ecological Bulletins*, 53: 77-94.

Bund Heimat und Umwelt (Ed.), 2012. *Jagdparks und Tiergärten: Naturschutzbedeutung historisch genutzter Wälder.* Bund Heimat und Umwelt in Deutschland (BHU), Bonn.

Bunnell, F.L. and Houde, I., 2010. Down wood and biodiversity - implications to forest practices. *Environmental Reviews*, 18: 397-421.

Chambers, C.L., 2002. Forest management and the dead wood resource in Ponderosa Pine forests: effects on small mammals. *USDA Forest Service Gen. Tech. Rep.* 181: 679-693.

Convention on Biological Diversity, 2010. *Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets.* CBD, Nagoya.

European Commission, 2011. *Our Life Insurance, our Natural Capital: An EU Biodiversity Strategy to 2020.* European Union, Brussels.

FAO, 2011. *State of the World's Forests, Food and Agricultural Organization of the United Nations.* Rome.

Flade, M., Möller, G., Schumacher, H. and Winter, S., 2004. Naturschutzstandards für die Bewirtschaftung von Buchenwäldern im nordostdeutschen Tiefland. *Der Dauerwald,* 29: 15-28.

ForstBW (Ed.), 2010. *Alt- und Totholzkonzept Baden-Württemberg.* Landesbetrieb ForstBW, Stuttgart.

Glaser, F.F. and Hauke, U., 2004. *Historisch alte Waldstandorte und Hudewälder in Deutschland.* Angewandte Landschaftsökologie, Heft 61, Bundesamt für Naturschutz, Bonn-Bad Godeberg.

Glutz von Blotzheim, U.N. and Bauer, K.M., 1980. *Columba oenas (Linnaeus 1758) - Hohltaube*. In: Handbuch der Vögel Mitteleuropas. Band 9, Akademische Verlagsgesellschaft, Wiesbaden, 42-63.

Gorman, G., 2011. *The black woodpecker. A monograph on Dryocopus martius*. 184 p..

Gross, P. and Konold, W., 2010. The "Mittelwald" - an agroforestry system between rigid sustainability and creative options. A historical study. *Allgemeine Forst Und Jagdzeitung* 181: 64-71.

Gustafsson, L. and Perhans, K., 2010. Biodiversity Conservation in Swedish Forests: Ways Forward for a 30-Year-Old Multi-Scaled Approach. *Ambio*, 39: 546-554.

Härdtle, W., Ewald, J. and Hölzel, N., 2004. *Wälder des Tieflandes und der Mittelgebirge.* Ulmer, Stuttgart.

Hölzinger, J. and Mahler, U., 2001. *Columba oenas (Linnaeus 1758) - Hohltaube.* In: Die Vögel Baden-Württembergs. Band 2.3: Nicht-Singvögel 3, Verlag Eugen Ulmer, Stuttgart, 25-36.

Johnsson, K., Nilsson, S. G. and Tjernberg, M., 1993. Characteristics and utilization of old Black-Woodpecker Dryocopus martius holes by hole-nesting species. *Ibis,* 135: 416.

Kändler, G., Schmidt, M. and Breidenbach, J., 2005. *Der Wald in Baden-Württemberg - Ergebnisse der Bundeswaldinventur 2.* - Forest Research Institute Baden-Württemberg. [http://www.fva-bw.de/forschung/bui/bwi.html]

Kändler, G., Schmidt, M. and Breitenbach, J., 2004. *Die wichtigsten Ergebnisse der zweiten Bundeswaldinventur.* FVA-Einblick, 8: 1-5.

Keddy, P.A. and Drummond, C.G., 1996. Ecological properties for the evaluation, management, and restoration of temperate deciduous forest ecosystems. *Ecological Applications,* 6: 748-762.

Köhler, F., 1999. *Totholzkäfer und Naturwaldreservate in Deutschland - ein aktueller Überblick.* In:Natur- und Umweltschutzakademie des Landes Nordrhein-Westfalen (Ed.), Buchennaturwald-Reservate - unsere Urwälder von morgen, NUA Seminarbericht, Recklinghausen, 165-173.

Konold, W., 2006. *Wälder im Waldland aus landespflegerischer Sicht.* In: Tanner, K. M., Bürgi, M. and Coch, T. (Eds.), Landschaftsqualitäten, Haupt, Bern, 293-317.

Korpel, S., 1997. Totholz in Naturwäldern und Konsequenzen für Naturschutz und Forstwirtschaft. *Forst und Holz*, 52: 619-624.

Kosinski, Z., Bilinska, E., Derezinski, J., Jelen, J. and Kempa, M., 2010. The Black Woodpecker *Dryocopus martius* and the European Beech *Fagus sylvatica* as keystone species for the Stock Dove Columba oenas in western Poland. *Ornis Polonica,* 51: 1-13.

Kühlke, D., 1985: Höhlenangebot und Siedlungsdichte von Schwarzspecht (*Dryocopus martius*), Rauhfußkauz (*Aegolius funereus*) und Hohltaube (*Columba oenas*). *Die Vogelwelt*, 106: 81-93.

Larsen, J.B. and Nielsen, A.B., 2007. Nature-based forest management - where are we going? Elaborating forest development types in and with practice. *Forest Ecology and Management,* 238: 107-117.

Lindenmayer, D.B., Franklin, J.F. and Fischer, J., 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biological Conservation*, 131: 433-445.

Lonsdale, D., Pautasso, M. and Holdenrieder, O., 2008. Wood-decaying fungi in the forest: conservation needs and management options. *European Journal of Forest Research,* 127: 1-22.

Lorho, 2010. Rechtliche Anforderungen an den Artenschutz im Wald. *AFZ-Der Wald*, 65:6-7.

McComb, W. and Lindenmayer, D., 1999. *Dying, dead, and down trees.* In: Hunter, M. L. (Ed.) Maintaining Biodiversity in Forest Ecosystems, University Press, Cambridge, 335-372.

Michel, A.K. and Winter, S., 2009. Tree microhabitat structures as indicators of biodiversity in Douglas-fir forests of different stand ages and management histories in the Pacific Northwest, USA. *Forest Ecology and Management,* 257: 1453-1464.

MLR (Ed.), 1993. *Wald, Ökologie und Naturschutz - Leistungsbilanz und Ökologieprogramm der Landesforstverwaltung Baden-Württemberg.* Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Forsten Baden-Württemberg, Stuttgart.

Möckel, R.,1988. *Die Hohltaube (Columba oenas), Die neue Brehm-Bücherei.* A Ziemsen Verlag, Wittenberg Lutherstadt. 199 p.

Morgan, R., 1991. The role of protective understorey in the regeneration of a heavely browsed woodland. *Vegetatio*, 92: 119-132.

Müller, J., 2005. *Landschaftselemente aus Menschenhand*. Biotope und Strukturen als Ergebnis extensiver Nutzung, Elsevier, München.

Müller, J. and Bütler, R., 2010. A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. *European Journal of Forest Research,* 129: 981-992.

Müller, J., Hothorn, T. and Pretzsch, H., 2007. Long-term effects of logging intensity on structures, birds, saproxylic beetles and wood-inhabiting fungi in stands of European beech Fagus sylvatica L. *Forest Ecology and Management,* 242: 297-305.

Murton, R.K. and Westwood and N.J. 1974. Some effects of agricultural change on the English avifaune. *British Birds,* 67: 41-69.

Nilsson, S.G., Niklasson, M., Hedin, J., Aronsson, G., Gutowski, J. M., Linder, P., Ljungberg, H., Mikusinski, G. and Ranius, T., 2003. Densities of large living and dead trees in old-growth temperate and boreal forests. *Forest Ecology and Management,* 178: 355-370.

Peterken, G.F., 1993. *Woodland Conservation and Management*, London, Chapman & Hall.

Plieninger, T., Schaich, H. and Kizos, T., 2011. Land-use legacies in the forest structure of silvopastoral oak woodlands in the Eastern Mediterranean. *Regional Environmental Change*, 11: 603-615.

Plieninger, T., Thiel, A., Bens, O. and Hüttl, R.F., 2009. Pathways and pitfalls of implementing the use of woodfuels in Germany's bioenergy sector. *Biomass and Bioenergy*, 33: 384-392.

Raabe, S., Muller, J., Manthey, M., Durhammer, O., Teuber, U., Gottlein, A., Forster, B., Brandl, R. and Bassler, C., 2010. Drivers of bryophyte diversity allow implications for forest management with a focus on climate change. *Forest Ecology and Management*, 260: 1956-1964.

Rackham, O.,1980. *Ancient Woodland, its History, Vegetation and Uses in England.* Arnold, London.

Reif, A., Coch, T., Knoerzer, D. and Suchant, R., 2001. *Landschaftspflege in verschiedenen Lebensräumen - Wald*. In: Konold, W., Böcker, R. and Hampicke, U. (Eds.), Handbuch Naturschutz und Landschaftspflege, ecomed, Landsberg, XIII-7.1.

Rotherham, I.D. (Ed.), 2013. *Trees, Forested Landscapes and Grazing Animals. A European Perspective on Woodlands and Grazed Treescape Earthscan.* Oxford.

Rupp, M., 2013a. *Beweidete lichte Wälder in Baden-Württemberg: Genese, Vegetation, Struktur, Management.* Dissertation an der Professur für Landespflege der Albert-Ludwigs-Universität Freiburg i. Br., Albert-Ludwigs-Universität Freiburg Freiburg.

Rupp, M., 2013b. *Creation of open woodlands through pasture: Genesis, relevance as biotopes, value in the landscape and in nature conservation in Southwest-Germany.* In: Rotherham, I. D. (Ed.) Trees, Forested Landscapes and Grazing Animals – A European Perspective on Woodlands and Grazed Treescapes, Earthscan, Oxford, 301-316.

Ruppert-Winkel, C. and Winkel, G., 2011. Hidden in the woods? Meaning, determining, and practicing of 'common welfare' in the case of the German public forests. *European Journal of Forest Research,* 130: 421-434.

Schaber-Schoor, G., 2010. Alt- und Totholzkonzepte der Bundesländer - Fachliche Anforderungen, Ziele und Handlungsansätze. *AFZ-Der Wald*, 65: 8-9.

Schaich, H. and Konold, W. 2005. *Naturschutzfachliche Grundlagen und Möglichkeiten der Operationalisierung eines Honorierungssystems ökologischer Leistungen im Wald.* In: Winkel, G., Schaich, H., Konold, W., & Volz, K. R. (Eds.), Naturschutz und Forstwirtschaft: Bausteine einer Naturschutzstrategie im Wald, Bundesamt für Naturschutz, Bonn-Bad Godesberg, 222-304.

Schaich, H., and Konold, W., 2012. Remuneration of ecological services in forestry - new options for compensation measures in forests? *Naturschutz und Landschaftsplanung*, 44:5-13.

Schaich, H., Plieninger, T., 2013. Land ownership drives stand structure and carbon storage of deciduous temperate forests. *Forest Ecology and Management,* 305: 146-157.

Scherzinger, W., 1996. Naturschutz im Wald - Qualitätsziele einer dynamischen Waldentwicklung, Ulmer, Stuttgart.

Schiegg, K., 1998. Totholz bringt Leben in den Wirtschaftswald. *Schweizerische Zeitschrift für Forstwesen,* 149: 784-794.

Schmalfuß, N. and Aldinger, E., 2012. Lichte Wälder - Warum sind sie uns wichtig? *FVA-einblick*, 16: 6-9.

Schütz, J.-P., 1999. Close-to-nature silviculture: is this concept compatible with species diversity? *Forestry*, 72: 359-366.

Similä, M., Kouki, J., Martikainen, P. and Uotila, A., 2002. Conservation of beetles in boreal pine forests: the effect of forest age and naturelness on species assemblages. *Biological Conservation,* 106: 19-27.

Stojanovic, D., Webb, M., Roshier, D., Saunders, D. and Heinsohn, R., 2012. Ground-based survey methods both overestimate and underestimate the abundance of suitable tree-cavities for the endangered Swift Parrot. *Emu*,112: 350-356.

Suchomel, C., Helfrich, T. and Konold, W., 2013. *Niederwald*. In: Konold, W., Böcker, R., & Hampicke, U. (Eds.), Handbuch Naturschutz und Landschaftspflege, Wiley-VCH, Weinheim, 1-24.

Waldenspuhl, T. and Hartard, B., 2010. Strategisches Nachhaltigkeitsmanagement für den Landesbetrieb ForstBW. *AFZ-Der Wald,* 15: 18-20.

Waldenspuhl, T., Schmalfuss, N. and Schaber-Schoor, G., 2011. *Vernunft/Zwang versus ethische Normen im Waldnaturschutz am Beispiel des Alt- und Totholzkonzeptes für den Staatswald Baden-Württemberg*. In: Akademie für Umwelt und Naturschutz Baden-Württemberg (ed.) Klimawandel: Wie sieht die Zukunft unserer Wälder aus? Auf dem Weg zu stabilen Waldökosystemen, AUN Baden-Württemberg, Stuttgart, 53-63.

Wesolowski, T., 2001. Ground checks - an efficient and reliable method to monitor holes`fate. *Ornis Fennica,* 78: 197.

Wesolowski, T., 2007. Lessons from long-term hole-nester studies in a primerval temperate forest. *Journal of Ornithology,* 148: 395-405.

Wulf, M., 1997. Plant species as indicators of ancient woodland in northwestern Germany. *Journal of Vegetation Science,* 8: 635-642.

Zahner, V., Sikora, L. and Pasinelli, G., 2012. Heart rot as a key factor for cavity tree selection in the black woodpecker. *Forest Ecology and Management*, 271: 98-103.

Zerbe, S., 2002. Restoration of natural broad-leaved woodland in Central Europe on sites with coniferous forest plantations. *Forest Ecology and Management*, 167: 27-42.

Chapter 11
The diversity of ancient woodlands in Austria: Historical developments and contemporary social importance

Elisabeth Johann

Abstract

Austrian landscapes range from plains at approximately 100 metres above sea-level to the Alps with peaks at almost 4,000 m. With a share of 47% the forest surface is an important element. One can assume that forests have been used intensively in the course of time and have been impacted by an increasing industry and population, but also by climate change. In some areas the utilization caused the modification of forest stands in particular with regard to the density, composition of tree species and age structure and reduced the extent of the forest area. However, despite these long-term interventions in the forest ecosystem the forests have never been cleared totally and about 30% of the territory remained wooded even in times of heavy exploitation. This is the reason why the share of natural forests is still relatively high. Today, some of these forests now form important assets of the Austrian network of protected forest areas. In this study I want to highlight the socioeconomic and ecological factors in the past which were responsible for this development. It will be illustrated by two case studies from different geographical regions. This examination can contribute to improving the knowledge base for decision making at the internodes of energy, biodiversity and forest policy as well as in forest resource management.

Introduction

A lot of European forests have been used as agricultural land in the past, but others, even if they are no virgin but managed forests, have not. Ancient forests are extremely valuable for the conservation of forest species and serve as reference for comparison with recent afforestations. They also form a valuable field laboratory for studying fundamental ecological processes. Often they form the last resort for the protection of archaeological and geomorphological heritage in a modern landscape. The importance for forest conservation has been accepted widely and particularly studied in Great Britain and Flanders, where the extent and distribution of the ancient forest resource is well known (Metaforum Leuven, 2011).

In the past twenty years there has been an increased interest in the management and fate of the remaining forest lands. However, there is a lack of understanding or agreement on what is meant by various terms that describe the condition of a forest. On occasion of the International Scientific Conference on The World's Natural Forests and Their Role in Global Processes Lund (2012) revised the definitions of old growth, pristine, climax, ancient forests, degradation, desertification, forest fragmentation, and similar terms. Having a common understanding of what constitutes a "forest" and its derivatives (such as old growth, pristine, native, secondary forest) is fundamental for a discussion of assessment methods, ecosystem status, and sustainability. However, there is considerable variation nationally and globally in the definition and use of these terms.

According to the Forestry Commission (Natural England, 2013) "Ancient wood (woodlands)" is a classification for woodland which has been in continuous existence from before AD 1600 in England, Wales and N. Ireland and from before AD 1750 in Scotland. It may be: Ancient Semi-natural woodland - Ancient woodland sites that have retained the native tree and shrub cover that has not been planted, although it may have been managed by coppicing or felling and allowed to regenerate naturally (Spencer and Kirby, 1992). Generally "Ancient Forests (Woodlands)" are defined as forests that have existed since at least a number of centuries, compared to recent forests which are much younger in origin. Most of them have been traditionally managed. Ancient forests do have a specific group of plant species only occurring in these forests (Metaforum Leuven, 2011).

Forests are the product of human intervention in natural processes and have always been dependent on the most relevant socio-economic evolution. There were two factors which influenced the natural composition of tree species: natural factors such as climate, topography, geology, exposure, and anthropogenic factors such as landscape management, population growth, ownership structures and legal bindings. The management of forest landscapes is intensely dependent on the local demands of the rural population, political power structures and external demands such as mining and timber trade.

With a forest share of approximately 47% of its territory Austria is one of the most densely forested countries in Europe. Therefore forests rank among the most significant elements of Austria's cultivated landscapes. However, Austrian forests in their present form are the product of centuries of utilization, but also management. One can assume that forests have been used intensively in the course of time and have been impacted by an increasing industry and population, but also by climate change. In some areas the utilization caused the modification of forest stands in particular with regard to the density, composition of tree species and age structure. In some areas the impact affected the extent of the forest area and resulted in the diminution of the forest area by permanent or temporary clearings (Kral, 1988, 1991).

Despite these long-term interventions in the forest ecosystem the forests have never been cleared totally and about 30% of the territory remained wooded even in times of heavy exploitation in the first half of the 19th century. This is the reason why according to international conventions (FFH-guidelines of EU) the share of natural forests is still relatively high in Austria. More than two thirds of the forest surface contain elements of the natural vegetation (25% natural and semi natural forests). The existence of numerous habitats and species is directly linked to the sustainable management of forests, which has a long tradition in Austria. This is also illustrated by the fact that about 43% of the Natura 2000 areas reported by Austria are forest areas.

However, Austria's forests are not evenly distributed over the federal territory. A high percentage of forests are located on the steep slopes of the Alpine regions and the lower mountain ranges. Areas with low forest cover are situated in the summerwarm east (Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, 2010) (Figure 11.1).

Today some of these forests now form important assets of the Austrian network of protected forest areas. What were the reasons why some forest areas were not overused and thus were able to maintain more or less undestroyed natural ecosystems, which are able to contribute remarkably to the present-day biodiversity? In this study I want to highlight the socioeconomic and ecological factors in the past which were responsible for this development. It will be illustrated by two case studies from different geographical regions. By analyzing the most important driving forces some conclusions can be drawn with regard to the solving of the societal discourse concerning the designation of forest protected areas and the responsibility and participation of the local population in this process at present.

Figure 11.1 **Forest area of communities in Austria (%)**
(Bundesforschungs- und Ausbildungszentrum für Wald, 2010)

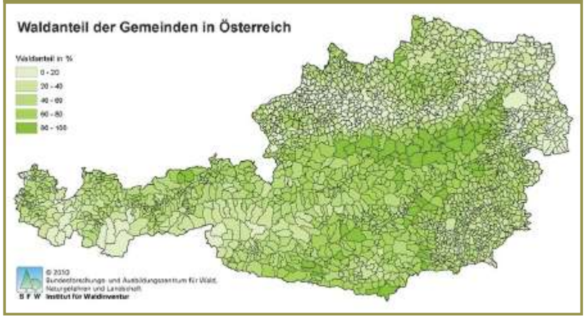
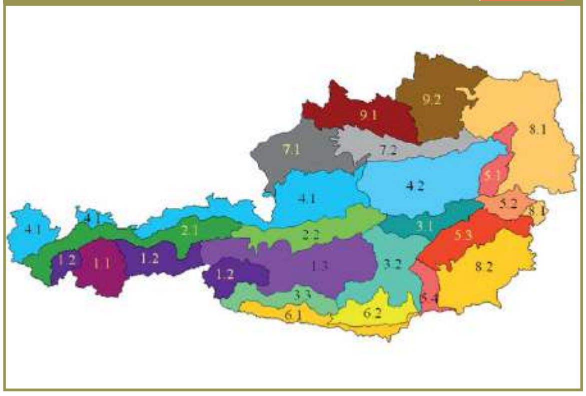


Figure 11.2 **Forest ecoregions in Austria**
(Kilian et al., 1994)



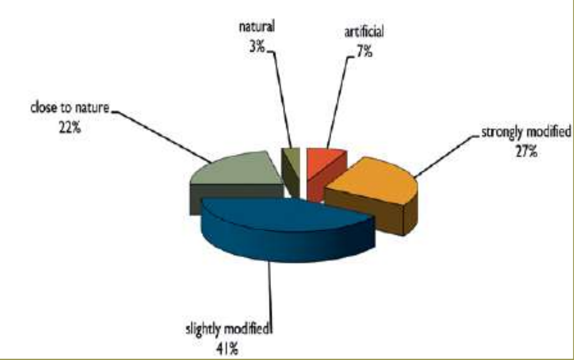
Study area

In Austria 22 forest ecoregions have been distinguished, with special regard to the regional climate and to the woodland communities that prevail due to these climatic conditions and combined to form nine principal ecoregions (Figure 11.2).

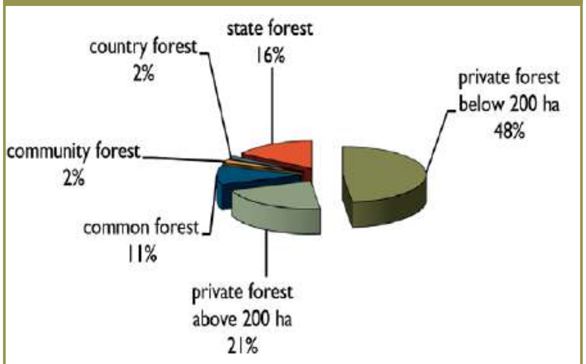
Austria's forest cover but also its distribution pattern with regard to the range of naturalness of ecosystems is distributed quite diverse due to the topographical site, climate conditions, altitudinal zones, and natural woodland communities. Thus the percentage of forests is the highest in Styria and Carinthia (60%) in contrast to the lowland in the northeast of Austria (Lower Austria, Burgenland), where the forest area is very much fragmented and the percentage is below 40 and therefore also below the Austrian average of 47% (Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, 2002). Federal provinces with a high share of mountain forests and a high amount of traditionally shaped farm forests show the highest proportion of natural forest ecosystems (Vorarlberg, Tyrol, Salzburg, Carinthia) with a share of more than 40% of natural or semi-natural forests (Grabherr et al., 1998) (Figure 11.3).

Natural or seminatural forests are situated in the

Naturalness of the Austrian forest area **Figure 11.3**



Distribution of forest ownership in Austria **Figure 11.4**



montane and submontane altitudinal zones of the Alpine range particularly in the northern and southern limestone alps, while the submontane and foothill colline forests of the Alpine foothills and the planar zone in the summerwarm east have been moderately altered. They are forests which have been exploited but retained some residual elements of the potential natural vegetation. Some of them are also strongly altered forests (Frank, 2009).

Most of the forests are high forests. 85% are privately owned; about 70% are managed by small scale farming (Figure 11.4).

Material and Method

The study is based on unpublished archive material (primary sources) and spezialized literature. Primary sources related to forest ownerhip rights and management practises are stored in archives in Vienna (Hofkammerarchiv Wien), concerning coppice forests of the lowlands in St. Pölten (Niederösterreichisches Landesarchiv, Archiv der Niederösterreichischen Agrarbezirksbehörde), concerning high forests of the Alpine region in Klagenfurt (Kärntner Landesarchiv). Information about legal bindings concerning the management of commons, starting from the late Medieval period till the early modern period of modern history have been gathered by the publications of the Imperial academy of sciences having collected and published them in 1881 (Kaiserliche Akademie der Wissenschaften, 1881) and by Winter (1886, 1896, 1909, 1913). Forest laws concerning the 18th/19th century were published by Kropatschek (1789). The present status of the forests situated in the investigated region have been analyzed and published by several institutions particularly of the University of Applied Life Sciences (Hochbichler, 2008) and the Austrian research centre Mariabrunn in Vienna (Kilian et al., 1994) as well as Senitza (1996). The study also takes into account the outcome of previous research of the author (Johann, 1993, 2004).

Forest management in Europe and globally is currently experiencing a paradigm shift from sustainable timber production towards a multi-dimensional understanding of sustainable forest management (MCPFE 1993, 1998). However, the increasing demand for bio-based products and bioenergy will probably increase pressure on forest ecosystems, which are a key component in maintaining biodiversity. Global change, whether generated by climate change, land use change, social or economic pressures increases the need to understand socio-ecological processes in forest resource management (Hochbichler, 2008). It is worthwhile to analyze the historical development of forests having been exposed to the multiple uses in the past and why some former societies where able to balance the often converging interests in the different forest products and why some societies failed. This examination can contribute to improving the knowledge base for decision making at the internodes of energy, biodiversity and forest policy as well as in forest resource management.

In this study I focus on forests with a long tradition in forest management. They have been and still are owned by commons or farmers. Despite the long tradition of forest utilization the investigated forest sites have one thing in common: that they are ancient forests because they have never been cleared and turned into fields or pastures. Therefore the natural composition of species is still present to a considerable high extent. This is the reason why some of these forests have become part of Austria's nature protection network. To Figure out the most important driving forces for the development two regions were selected, which show great differences with regard to the geographical situation, topography and vegetation. They are located in the summerwarm east (Weinviertel, Lower Austria) and in the mountain region of the Central Alps (Hohe Tauern, Carinthia). Thus a colline landscape with a low share of forests and fertile fields has been compared with a montane/subalpine zone with a high share of forests and a low percentage of arable land. Both ecoregions have experienced different historical developments but are presently characterized by rural structures.

The historical development, ownership structures and forest management have been analyzed. Also the present importance with regard to its ecological value has been studied. In comparing the results I wanted to point out some of the driving forces which were relevant in the course of time to maintain the high naturalness of the forest stands apart the high demands for utilization.

Results

Austria is situated in the temperate climatic zone and a great share of its land consists of mountains. Austrian landscapes range from plains at approximately 100 m above sea-level to the Alps with peaks at almost 4,000 m. The influence of the mountainous topography produces a diversity of climatic conditions and different forms of land use. The vegetation is determined by latitude (the southern part is warm, north is cold), altitude (higher is colder), distance to the Atlantic Ocean (west is oceanic, east is continental), and the alpine elevation which influences precipitation patterns (central Alps and summerwarm east – arid, peripheral – humid). Another factor determining natural vegetation and possible forms of land use is the geological ground: A mixture of various crystalline and sedimentary rocks provides different possibilities for cultivation. In general, there are well-developed soils which are resistant to erosion, but there are also sites which are prone to erosive processes (steep slopes at high altitudes, lime stone sites – karst, loess – wind erosion).

During the glacial period (ice-age) with its last peak about 18,000 years ago, the Alpine region was completely covered with glaciers of up to 1,700 m strength. Forests started to grow again about 13,000 years ago from retreat areas in south-east Europe. In the stone-age the area was almost completely covered with forests. Only the high peaks of the Alps and bogs were spared. From the stone-age on (Neolithic: 4,000 years B.C.) settlers started to clear woodlands for agricultural use. Arable land was cleared while the forest remained untouched on steep and stony sites (Pregernig and Weiss, 1998). However, the impact on the woodland was not remarkable because the settlers moved to another place from time to time and therefore trees overgrew the open spaces. Even the clearings which came into being during the period of the Roman Empire where rejuvenated with trees in the time of the Big Migration of Nations. It was not before the Middle-Ages when settlements started again. The growing population cleared forests for farming and for pastures, thus lowering the timberline in the Alps and reducing the forest area in regions well suited for agricultural activities. At present, about 47 % of Austria's territory is covered with forests. Most of the forests are located in mountainous regions. In the planar zones forests often cover less than 20% of the land.

Case study I

Coppice forests in the lowlands (northeast of Lower Austria)

In Austria the share of floodplain and coppice forests is very small and comprises only 2.4% of the whole territory. 73% of these forests are managed as coppice forests; nearly half of them (43 %) have small scale structures. They are managed as coppice forests or coppice with standards with a varying number of standards in the overstory. Coppice forests have presently the highest extension in the Federal province Burgenland and Lower Austria. In these regions coppicing in the mixed oak stands of the colline and submontane sites of the pannonian east has a long tradition and is still an important asset to the cultural landscape (Hochbichler, 2008).

Landscape

With a share of 13% to 15% forests the region addressed in this case study belongs to the most deforested areas in Austria. It comprises mainly Tertiary downs and gravel terraces. Both elements of the landscape are partly covered with Loess and limestone-free Flyings. The climate is pannonian-subcontinental, arid-warm with moderate cold winters with little snowcover. Summery dry periods are frequent. The annual precipitation does not exceed 450 mm to 700 mm and is the lowest in Austria; the maximum appears during the summer season (Harlfinger and Knees, 1999).

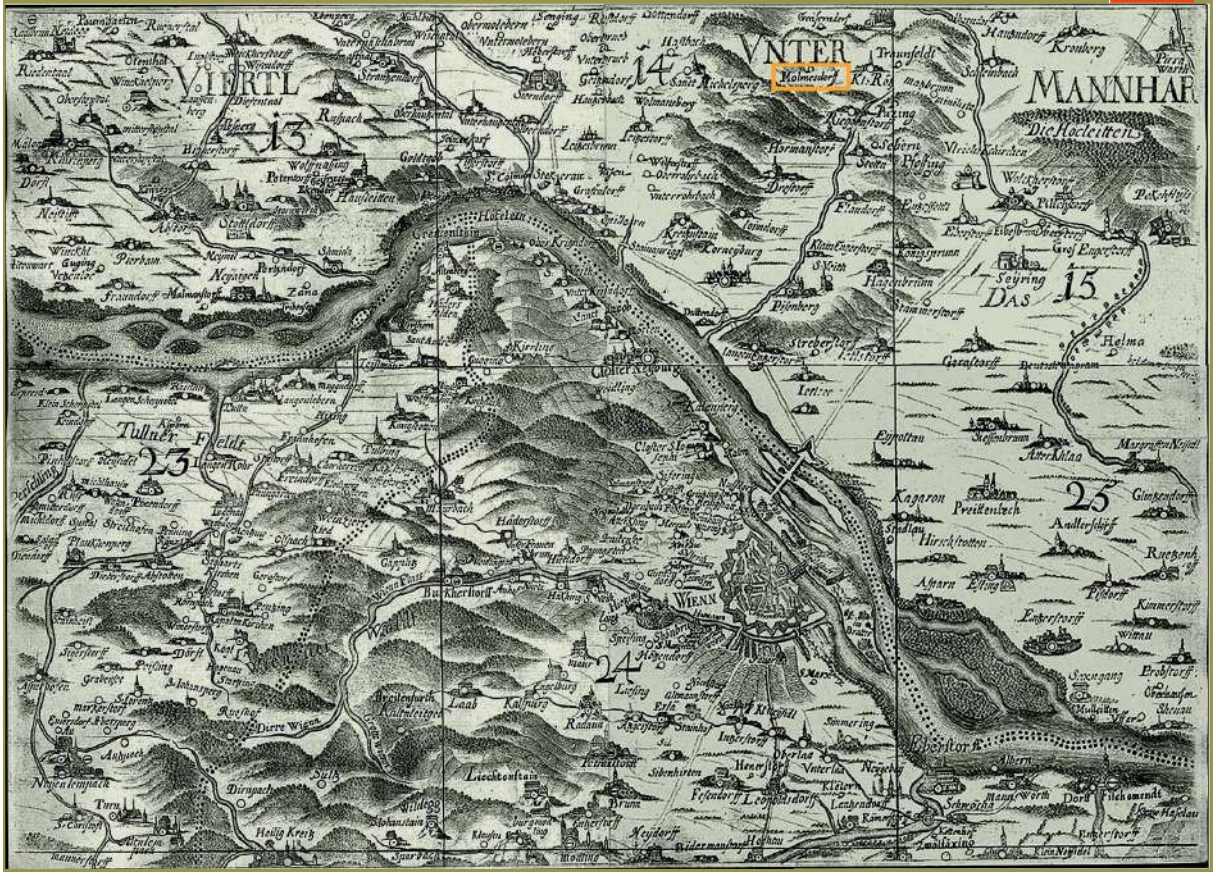
The region is situated in the ecoregion summerwarm east in the woodland community of the „Pannonian lowland and hilly region" (Kilian et al., 1994). At the colline altitudinal zone *Quercus robur* (pendulate oak) and *Carpinus betulus* (common hornbeam) forests are growing, at lower altitudinal zones mixed forests of *Quercus cerris* (Turkey oak) and *Quercus petraea* (European oak) are dominating On sunny and arid sites as well as limestone-rich sites *Quercus pubescens* (Pubescent Oak) is present. Coppice forests are dominating. Assessing the potential natural vegetation some problems occur due to the impact of former utilization practices such as coppicing, pasturing and litter harvesting on the composition of species (Starlinger, 1997).

The ecoregion (ecoregion 8.1 see Figure 11.2) is very well suited for growing crops and therefore agricultural activities are dominating. Something special are the productive floodplain forest and woodlands along the rivers Danube, March and Thaya. These floodplain forests are not in the focus of this study. Some of the cleared land with marginal yield such as moving sand dunes (Marchfeld), but well suited to grow forests have been afforested to a considerable extent with *Pinus nigra* (black pine) and *Robinia pseudoacacia* (common acacia) more than hundred years ago (Kilian et al.,1994).

In this study I am investigating the coppice forests (with and without standards) growing in the hilly region of the „Weinviertel“ situated in the northeast of Lower Austria (altitude 150 m - 350 m) und the gravel terraces

Figure 11.5

Common Molmannsdorf (Mollmersdorf) 1697 (Vischer, 1697)



of the Marchfeld (altitude 140 m - 150 m). They have been and still are in the ownership of commons and jointly managed in the traditional way for centuries. Two of the largest commons Mollmannsdorf (community of Harmannsdorf) with a forest area of 120.25 ha and Niedersulz (135.78 ha) will be taken as examples for the development in view of the fact that their history and management is documented since the 15th century (Figure 11.5).

Historical development: Settlement – ownership structures

The still existing commons in Lower Austria have historically two different starting points. One is connected with the first settlements and has a more than 5400 year old history. The second is the result of a fight concerning the participation in utilization rights which could be solved in the middle of the 19th century.

Already before Slavic tribes settled in the woodland-free areas extended villages existed in the region between Danube and Moravia (Marchtal, Mistelbach, Leiser Berge) in the 5th and 6th century. The management of the surrounding agricultural land was planned and organized jointly.

Under the leadership of Charlemagne or Charles the Great the cultivation of the conquered land in the eastern part of his Empire started in the 9th century. In its first beginning the unplugged land of the conquered territories belonged to the king or duke but could be utilized simultaneously by the settlers. The king donated extended uncultivated land to noblemen, monasteries and commons. Because of the rather late colonization land also was given to free settlers. The woodland and forests surrounding the villages were jointly used and called "Gmain" (common land). Simultaneously the cultivated land was in the restricted ownership of distinct farmers. The sum of parcels often scattered in the landscape together with the right of utilization of the common wood land and joint pasture was called bovate. A bovate also included the participation in the management of the community because the laws and orders given by the administration referred to the utilization of the common land, the common pastures and of running waters (Schiff, 1899).

In the region of the "Weinviertel" large commons developed during the Medieval period. They often comprised more than 60 to 70 farmsteads (Photograph 1). A considerable number of documents have been maintained verifying the kind of management and claimed duties. The amount of duties which had to be paid for the utilization of the land depended on the frequency of utilization, the size of the common land and also the size of the existing available woodland.

Photograph 1: Zwerchhof Niedersulz. This type of farmstead was very common in the south and southeast of Austria (P. Lauppert).

Photograph 2: Coppice forest in the northeast of Lower Austria (J. Kiessling).

Multiple uses of forests and management

Till the 19th century the existence of forests was essential for the rural population of Lower Austria. However, the size of these forests was only partly extended. Additionally important were the small and scattered farm forests, the floodplain forests and the jointly used coppice forests with and without standards. Nevertheless, for many farmers in this region wood was not the main use. More important were other forest uses such as pasture, slash and burn activities, litter harvesting, and tar and resin. Often the success of agriculture and livestock breeding was dependent on these kinds of uses.

From the very first beginning forest utilization and management of the coppice forests owned by the commons was regulated by common laws which based on the agreement of the members of the commons. These orders ("Weistümer") were developed by an open dialogue between the farmers entitled to forest rights. It was a law orally transferred from generation to generation. From the late medieval and early modern period onwards till the end of the 18th century this law was written down for several reasons. One of the most important motives to lay it down in writing was the fear to loose these rights to the surrounding manors wanting to patronize the commons. Another motive was to maintain the recourses of the commons in a sustainable way by preventing the forest utilization and pasturing against the demand of new settlers having moved into the village (Photograph 2).

The sustainable management of the commonly owned coppice forests was secured by the following measures: (1) distribution of the entire forest area in annual utilizable blocks. The size of these blocks depended on the given forest area and the number of members entitled to utilization rights, (2) restriction of the allowable amount of harvested wood according to the demand of the specific farmstead, (3) ban of young stands and cleared areas, (4) limitation of the time of harvesting and timber transport, (5) sparse use of wood, (6) constraint of the sale of wood within and prohibition of the sale of wood outside the boundaries of the village (Winter, 1909). Also pasturing was regulated by common laws. Thus forest grazing which had been allowed in former times was restricted to areas without young stands. Also the number of cattle which were allowed to stay in the forest was limited (Johann, 1979).

Thus the former unlimited utilization of common forests became reduced by and by. These restrictions included the amount of wood and the quality which was allowed to harvest. Also the former right to use the forest free of charge was abolished locally. While in many common forests fuelwood could be harvested without limitations the use of construction timber was often controlled by a forester or another person engaged by the members of the common. However, from the 16th century at the latest also the annual amount of fuel wood each farmstead was entitled to became as well reduced. Extended forest uses were not allowed any more by the old settlers to avoid the devastation of the forest land (Winter, 1886, 1896, 1909, 1913).

Conflicts – external interests

Although commonly practiced utilization and the sustainable management were supervised by foresters and judges who were recruited from the villagers, the State and the manors increased the control concerning the commonly owned forests exercised during the 16th century. The argument used as a pretext to justify this control was the necessity of forest protection against the devastation practiced by the farmers. In fact, the multiple use of forests by farmers with regard to pasture, litter and fodder, tar and limestone burning and the harvesting of fuel wood contradicted to the interest of the State, the manors and the increasing industry considering the production of valuable timer to be of highest priority. The forest law from 1766 and the order from 1768 valid for the entire Crownland Lower Austria considered the following management practices to act against these laws and to be responsible for the destruction of the forests: forest grazing of goats, forest grazing of cattle in clearcuts and young stands, forest grazing of sheep and pigs, the construction of fences, uncontrolled gathering of resin (Kropatschek, 1789).

In many cases farmers were forced to overutilize the forest land and to inhibit the reforestation of cleared land. This was due to the fact that according to the Forest Law from 1766 clearcuts which became naturally forested should be treated like forest land and were no more available for pasturing. However, despite these restrictions forest management for the provision of the multiple uses of the farmsteads was preserved during centuries. The maintenance of self determination of a common or the partly or total loss of this self determination to the surrounding manors or the State was depending on the functioning of the society within the village, the degree of competence of the involved mayor and the representatives of the village, but also on the availability of old documents proving the traditional village rights. If the self governance was weakened by disagreements within the community, the common frequently lost its rights or had to accept their reduction. In some cases the manor gained the full ownership over the former common woodland. These social factors were the reason why the development differed from common to common.

One example proving that the fight of a common against the manor could be successful is the common Mollmannsdorf (Figure 11.5). After a heavy dispute with the neighbouring manor in the 16th century this community was able to keep the ownership of their forest till the present day. This forest with a size of 120.25 hectares can be regarded to be one of the most compact and not scattered forest areas in this region (Niederösterreichische Agrarbezirksbehörde unpubl. data 1581) (Photograph 3, 4, 5, 6 and Figure 11.6).

The multiple use of farmsteads favoured mixed forests with a high percentage of understory. In commonly managed farm forests radical impacts were rather rare, the transition of forest land due to changing demands happened relatively slowly.

The typical forms of forest management systems (coppice forests with and without standards, floodplain woodland) were relatively stable and secured the

Photograph 3: Meadow in the coppice forest Rohrwald (Naoag).

Photograph 4: Old boundary stone (monastery Klosterneuburg) in Rohrwald, district Korneuburg, Lower Austria (S. Laefner).

Photograph 5: Mollmannsdorf: late-Gothic shrine in the community of Harmannsdorf (Naoag)

maintenance of the quality of soil. Even forest grazing could contribute to the quality of the soil in case it was regulated in an adequate way.

Till the 19th century the so-called “by products“ or “minor utilization“ were the most important uses in common woodlands. However since the beginning of the modern period they were increasingly condemned by modern forestry. Caused by global changes with regard to industry and technical development (construction of railroads, replacement of charcoal by mineral fuels) the market for wood and timber changed dramatically in the 19th century. The demand for timber of high value increased and the demand for fuel wood decreased.

Photograph 6: View to the church and the coppice forest (Rückersdorf-Harmannsdorf) (S. Laefner).

Besides, reforms in the field of agriculture also influenced forest management such as forest pasturing which lost its importance in the 18th/19th century. The maintenance of the forest land was also secured by the Imperial Forest Law from 1852 which for the first time was valid in the entire Austro-Hungarian Monarchy. According to this law it was not allowed any more to turn forest land into something else. “Forest land has to be maintained as forest land“. Clearcuts had to be reforested within five years (Fischer et al., 1917).

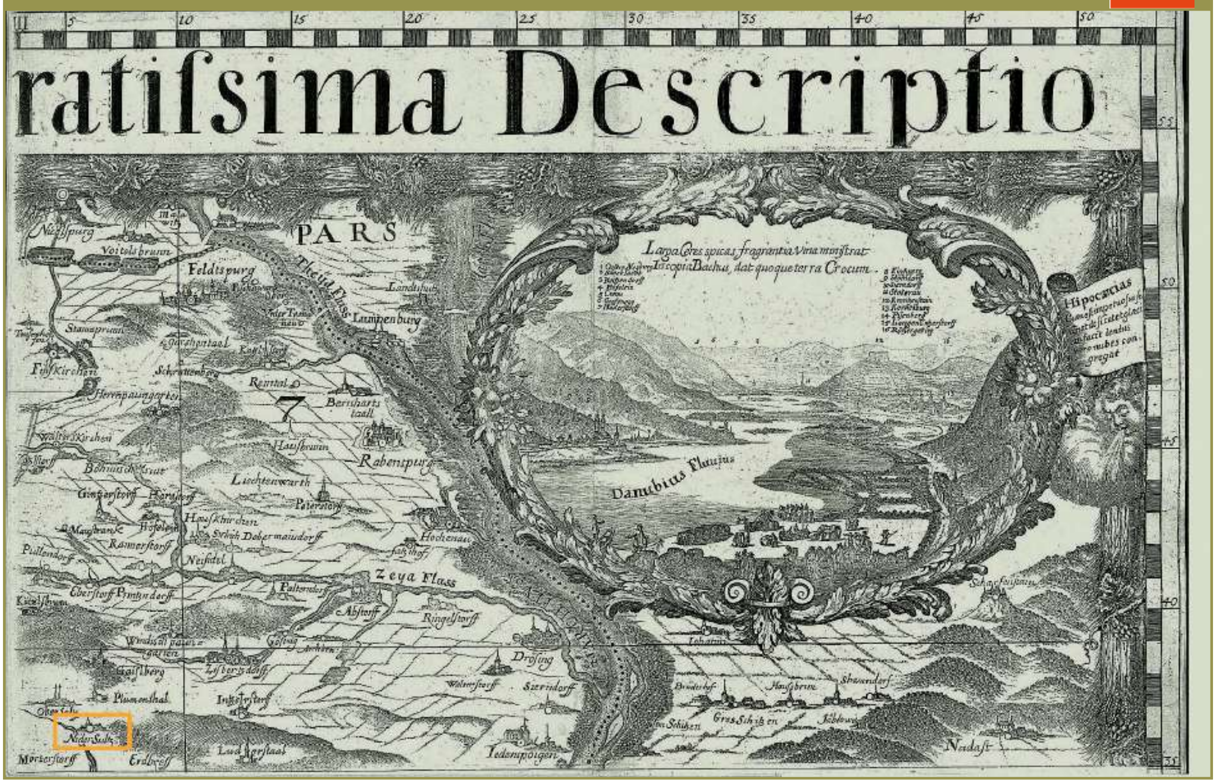
The protection of woodland – balance of utilization interests

Referring to the time of the end of the 19th century no detailed information are available concerning the economical situation of common forests. The Austrian Forest Congress 1882 as well as several contemporary witnesses from this time complained the bad condition of these “unregulated and wild common forests” overused by farmers. The neglecting of the existing statutes and the often not defined amount of wood the farmstead was entitled to receive as well as controversial ownership rights were considered to be the main reason for the bad condition of the forest stands. However, several laws published in the 1880s (Teilungs- und Regulierungsgesetz July 7th 1883 and June 3rd 1886) provided the basis to regulate the utilization rights and thus improve the yield and the culture of the commonly owned and utilized forests (Schiff, 1899).

Forest culture should be implemented by specialized consulting. Thus also the condition of the forest should be improved. However, till the end of the 20th century the production of timber of high value was in the focus of interest of the forest authority involved in this activities and the so-called by-products were set aside. This focus has changed since the demand for biomass increased again.

To illustrate the development I choose the common woodland of Niedersulz as an example (Niederösterreichische Agrarbezirksbehörde unpubl. data 1751-1908).

Map of part of Lower Austria including the common Niedersulz (Vischer, 1697) **Figure 11.6**



Example: ancient forest Niedersulz

Its development can be regarded as representative for a considerable number of commons in the northeast of Lower Austria. This common was able to preserve and maintain its forest area of more than 130 hectares till present day (Figure 11.6).

The concerned forest was mentioned first in a groundbook of the monastery Heiligenkreuz in 1435. It was described as a forest situated across the river Danube where the members of the common had utilization rights for which they had to pay taxes. 1638 and 1675 the management of the woodland and pastures was written down. The maintenance of this woodland is proved by several documents (certificates) describing ownership rights and wood harvesting in detail. Each full sized farmstead was allowed to utilize four coupes (Lose) of the forest, each half sized farmstead two coupes. The amount of taxes the farmers had to pay to the manor Niederleis on Saint Martin's day corresponded to the size of the farmstead. The common considered this forest to be its ownership and managed and used the forest in the traditional way at all times. Thus conflicts arouse between the monastery Heiligenkreuz as the manor and the common which were solved by a compromise in 1797. This agreement preserved the utilization rights of the common but forced them to pay for these rights. Besides, the common was obliged to deliver the wood harvested on 12 coupes to the parsonage. This agreement had to be renewed every ten years (Photograph 7).

The villagers had to cultivate the forest area according to the existing forest laws and to maintain its good growth. The administration of the manor claimed the right to control the management of the common land by foresters. However, it was still the exclusive responsibility of the common to figure out and mark the suitable places for the annual clear cut. Not all villagers could participate in the utilization. The right was attached to 63 farmsteads whereas there were already 81 houses in this village at this time.

According to the Imperial Law from July 1st 1813 the forest area was mapped, the growing stock and calculated yield estimated and allotted to annual felling areas. The forest survey of the "common oak forest Niedersulz" included the report of the geographical location and boundaries of the property, the growing stock and the direction of the planned conduct of felling. The forest stand contained oak trees mixed with some rather well growing pine (Pinus sylvestris) and European Aspen (*Populus tremula*). The calculated rotation period amounted to 18 years. Within this period the dimension of the harvested fuelwood was expected to have grown to a diameter of a man's arm, and because of the fertile soil would have reached the age of cutting. The final age of the overstory and standards was determined with 80 years (Niederösterreichische Agrarbezirksbehörde unpublished data 1751-1908).

In course of time the common administration bought some neighbouring forests. This purchase was financed by its own resources. The common also paid further expenses such as taxes, the employment of a forest warden and reforestation activities. 63 farmers were allowed to participate in the utilization of the forest of about 100 ha. The annual logging unit was divided into sections. Each farmstead entitled to utilization rights was allowed to harvest two sections per year. This kind of management neglecting the demands of the remaining members of the village excluded from the utilization caused permanent disagreements within the community. The excluded members protested and made complaints several times (1834, 1644, 1847, 1862, and 1868) and at last made an application for the regulation and separation of the commonly owned forest area according to the law from July 3rd 1886 valid for the entire Crownland Lower Austria (Schiff, 1899). It took a long time to work out an agreement acceptable for all participants. 1903 at last the ownership of the forest was dedicated to the forest-cooperative Niedersulz (Waldgenossenschaft Niedersulz), the parish and 62 peasant families. Despite the long lasting disagreements the common Niedersulz was able to maintain the forest area in its extension and also to go on with the management as a coppice forest with standards.

Photograph 7: Parsonage of Niedersulz (late 18th century) (P. Lauppert).

The prolongation of the composite forest system resulted in the structure of the oak coppice forests with standards characteristic for the summerwarm east (Weinviertel). Proved by field research Frank (1937) confirmed that this kind of regulated forest management system has been practiced since more than 400 years. In addition, Kral (1985) proved a remarkable increase of the portion of oak during this period due to human intervention by pollen analysis.

Present structures – the cultural landscape as a witness of former forest uses

The long lasting utilization of forests and woodland and the experience gathered from this traditional forest management can be described as composite forest system. This system has a wide variation depending on site conditions. Coppice forests with a low number of standards were growing on sites where the quality class was low. Sites of medium or high quality class were stocked with coppice forests with a rich overstory and a high number of standards. Coppice forests without standards were restricted to unfavourable and unfertile sites (Eckhart, 1975).

The planned management of coppice forests with standards can be considered as one of the first examples of sustainable forest management (Schütz, 2001). The principle relies on the sustainable distribution of age classes (diameter classes) in the overstory containing a sufficient number of staddles in the understory. The number of staddles available for the rejuvenation of the overstory is important for the sustainable safeguarding of the regrowth for the overstory (Hochbichler, 2008). Due to this kind of management a suffiecient supply with timber and fuelwood for the own demand of the members of commons could be secured. In a similar way also forests owned by bigger enterprises were managed for centuries apart from the rotation period of the fuel wood which – compared to the peasant's forests - was extended to 25 to 30 years (Hagen 2005). Thus the sustainable utilization of valuable timer and the supply with fuel wood of the sourrounding peasants and communities was secured. In Lower Austria according to the forest survey from 1961/70 the share of coppice forests amounted 20%, coppice forests with standards 30% and coppice with some hold-over trees 50% (Eckhart, 1975).

Changing goals in the management of composite forest systems with standards have created varying types of forests in course of time. Historically coppice forests were mainly managed in order to cover the local demand of the communities for energy, i.e. fuel wood. They can be regarded as the forerunners of today's short rotation energy plantations. Caused by market changes and the decline of the importance of fuel wood (coal and oil became available for energy use) also the value of coppice forests with and without standards decreased. Large parts of former coppice forests were substituted by afforestation with other tree species, or converted to high forests by postponing their harvest, and managing them in longer rotations. Anyway, this reduced the area of coppice forests considerably. Within the past decades discussions concerning the best composition of the overstory and improvements of the performance of the site by conversion or transition of composite forest systems into high broadleaved and coniferous forests were put at the forefront (Krissl and Müller, 1989). Traditional silvicultural planning processes concerning oak-dominated standard coppices are also questioned because of the increasing loss of vitality of oaks since the 1960s (Tiefenbacher, 1996).

However, since the end of the 20th century the interest in composite forest systems received a renewal caused by a high demand for valuable broadleaved timber and biomass. Since renewable resources are advocated and even financially supported, because of their almost neutral CO_2 balance, managing coppice forests could experience a revival. At least this development could encourage forest owners to take up again managing their coppice forests. This could be an important contribution to rural development, because the management and sustainable use of coppice forests could forestall the drainage of added value from the respective region, and could revive typical economic communities, like the commons ("Agrargemeinschaften").

Photograph 8: Coppice forest Niederweiden (Lower Austria) (J. Kiessling).

Nature protection aspects value for today's society

Only recently these traditional management systems have become once again important in the frame of nature protection and landscape conservation (Freist and Klüssendorf, 1991; Buckley, 1992) by sustaining a type of cultural landscape of special species diversity (Institut für Waldwachstum und Zentrum für Umwelt und Naturschutz, 2008). It can also promote the further development of broadleaved-management systems (Schütz and Rotach, 1993) (Photograph 8).

Today in this region a broad spectrum of tree species is characteristic for coppice forests with standards and composite forests. Pendulate oak (*Quercus robur*) and European oak (*Quercus petrea*) are dominating with a share of 60% in the overstory. The oak species are mixed with common ash (*Fraxinus excelsior*), common maple (*Acer pseudoplatanus*), Norway maple (*Acer platanoides*), wild service tree (*Sorbus torminalis*), service tree (*Sorbus domestica*), wild cherry (*Prunus avium*) and European wild pear (*Pyrus communis* subsp. *pyraster*) (Schöfberger, 1990). These existing broadleaved species in the overstory are considered as valuable hardwood mixture for the future and receive particular tending operations (silvicultural measures). In the understory hornbeam (*Carpinus betulus*), field maple (*Acer campestre*), field elm (*Ulmus minor*), small-leaved lime (*Tilia cordata*) and several other tree species as well as common hazel (*Corylus avellana*) are growing. Most frequent are cornelian cherry (*Cornus mas*), common privet (*Ligustrum vulgare*), spindle tree (*Euonymus* *europaeus*), black elder (*Sambucus nigra*) and other shrubs (Hagen, 2005).

The management of coppice forests with standards has a high importance for xerotherm (light and warm temperature loving) organism. A high biodiversity on small spaces occurs due to the temporal follow-up of structural varying kinds of vegetation within a short temporal period and also by the bordering of clear cut areas and young stands of differing ages.

Caused by the traditional management systems practiced for hundred of years a specific biocoenosis could develop adapted to the rhythm of regular disturbance due to utilization and following period of regeneration. This dynamic provides the living space for a high number of plant and animal species and safeguards them because the traditional management of coppice forests offers different phases of development (open spaces, shrubb-phase, phase of closed canopy) side by side (Treiber, 2002). In fact coppice forests and composite forests belong to forest ecosystems with the highest number of species in Europe (Ellenberg, 1996). Their importance for the safeguarding of endangered species, in particular for thermophile insects and birds is proved in many cases (Buckley, 1992; Rossmann, 1996, Treiber, 2002). Nowadays the pannonian oak and hornbeam forests managed as coppice forests belong to the habitat type (91G0) (Pannonian subcontinental oak-hornbeam forests) of the European wide network Nature 2000 which is considered to be endangered (Petersen et al., 1998). Its favorable shape can only be safeguarded by adequate utilization and adapted management systems (Ellmauer, 2005). Thus wood harvesting and the protection of species and the biotope can be combined (Institut für Waldwachstum und Zentrum für Umwelt und Naturschutz, 2008). Further measurements can promote the safeguarding of important and valuable structures of these forests such as the increase of the amount of dead wood and the support of regeneration to ensure the aimed composition of species in protected habitat types.

Case study 2

Farm Forests in the mountain region (Central Eastern Alps - today's National Park Hohe Tauern, Carinthia)

In Austria two third of the territory belongs to mountainous regions which is characterized by particular features such as small structures and vulnerability.

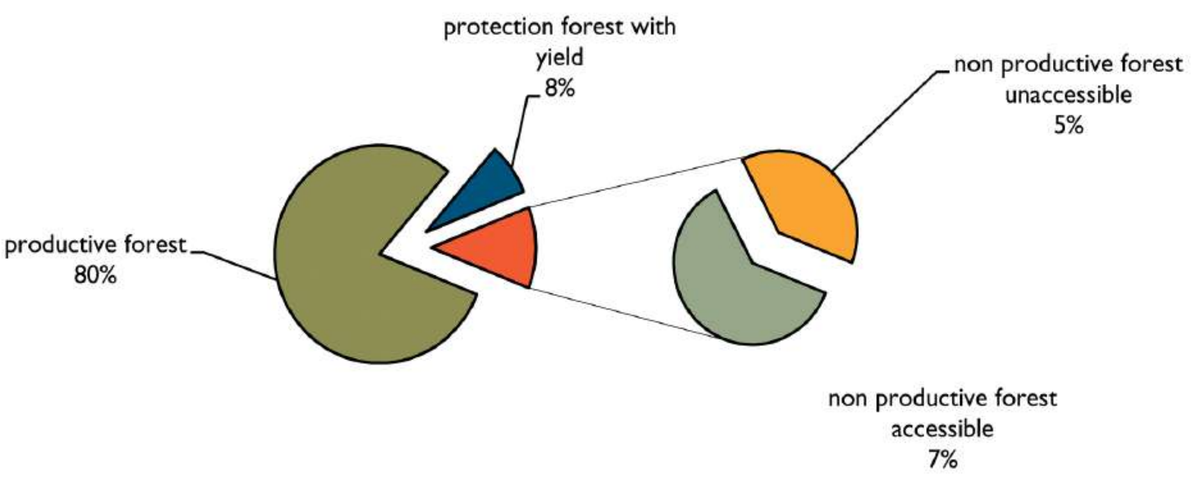
19.5% of the total Austrian forest area is classified as protection forest. Among this category 7.6% are protection forests with yield, 11.9% non-productive protection forests. 7.3% of the non-productive protection forests are accessible and 4.6 % are inaccessible (Figure 11.7). According to the results of the Austrian Forest Inventory (Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, 2002) there is a need for regeneration (two third of the area in the productive and one quarter in the non-productive protection forest). The inhibiting factors that obstruct an adequate regeneration are i.e. too dense ground vegetation, erosion, and forest pasturing.

The "Hohe Tauern" or High Tauern which are addressed in this case study are a mountain range of the main chain of the Central Eastern Alps. The range includes Austria's highest peak, the Grossglockner. It is situated between the Federal provinces of Salzburg, Carinthia and East Tyrol (Photograph 9).

Today along 100 kilometres of the main chain stretches the High Tauern National Park (Nationalpark Hohe Tauern), to which a private owner and three Federal Provinces (Carinthia, Salzburg and Tyrol) have contributed territory (Figure 11.8 and Figure 11.9). With an area of about 1,834 square kilometres (708 sq mi), it is by far the largest of Austria's six national parks as well as the largest nature reserve in the Alps. The protected area of today includes glaciers, rocks, alpine pasture and forests.

A peculiarity of the national park "Hohe Tauern" is

Share of productive and non-productive forests in Austria — Figure 11.7



Photograph 9: Hohe Tauern with the highest peak Großglockner (E. Johann).

the fact that the protected area does not only include undisturbed natural sites but also cultural landscapes shaped by the management of farmers for centuries. The high diversity with regard to animals and plants, but also a high abundance of the cultural heritage (farmsteads, churches, castles, ruins) are the result of a long-lasting symbiosis between wild nature and cultural landscape. The first people arrived already 5000 years ago. The motivation to settle in this harsh and challenging region was the search for gold, but also the strategic position of the place along the traffic connection between the Mediterranean region and Central Europe.

Landscape

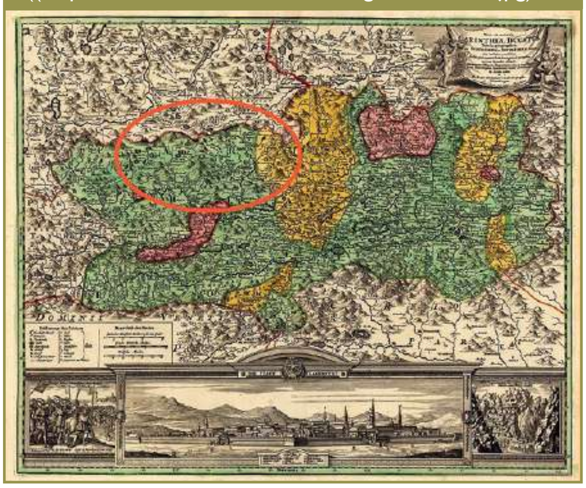
The forests of the present national park in its entirety represented a modest colonized living space for centuries. However, an increasing population caused the decrease of the forest area by clearings and utilization also on steep slopes, particularly on the sunny side of the valley, already at the end of the Middle Ages (Figure 11.10).

Today the unfragmented forest belt merely starts just above the highest farmsteads (Photograph 10). Its extent and density depends on its exposure and therefore also on the natural upper border for settlements. Often the cultivated area on sunny slopes is separated from the lower alpine pastures just by a small and understocked strip of forest land.

The shady slopes exposed to the north are not suited for settlements. Therefore they never have been cleared and the forests are not scattered, but fully stocked, reaching from the bottom of the valley up to the timber line at an altitude of about 2000 m. Thus the percentage of forest land of the specific communities differs remarkably and is mainly determined by its topographical location. It varies between 30% to 50% of the productive, and between 15% to 40% of the entire area of a definite community (Johann, 2004) (Figure 11.11).

In general the upper timber line expands to an altitude of about 2000 m to 2200 m, the upper timber line of the forest with yield to 1700 m to 1800 m. The possibility of growing barley and rye is limited to 1700 m, for corn to 1200 m above sea level. The upper boundary for alpine

Map of Carinthia 1730-1740 Figure 11.8
(Homann, 1730-1740)
((http://www.altelandkarten.de/images/19594-01.jpg)



Map of the Hohe Tauern Nationalpark in Austria 1992 Figure 11.9
(drawn by Anita Graser 2008) (https://commons.wikimedia.org/wiki/File:Nationalpark_hohe_tauern.png)

Settlements Grosskirchhaim and Sagritz and protection forest 1688 Figure 11.10
(Valvasor, 1688; reprint 1882)

Photograph 10: The Möltal – valley near Winklern (E. Johann).

Photograph 11: Mallnitz-valley - Cleared slopes on the sunny side of the valley, the shady side is forested around 1910 (Österr. Nationalbilbiothek Wien: Bildarchiv, Nr. 131.449).

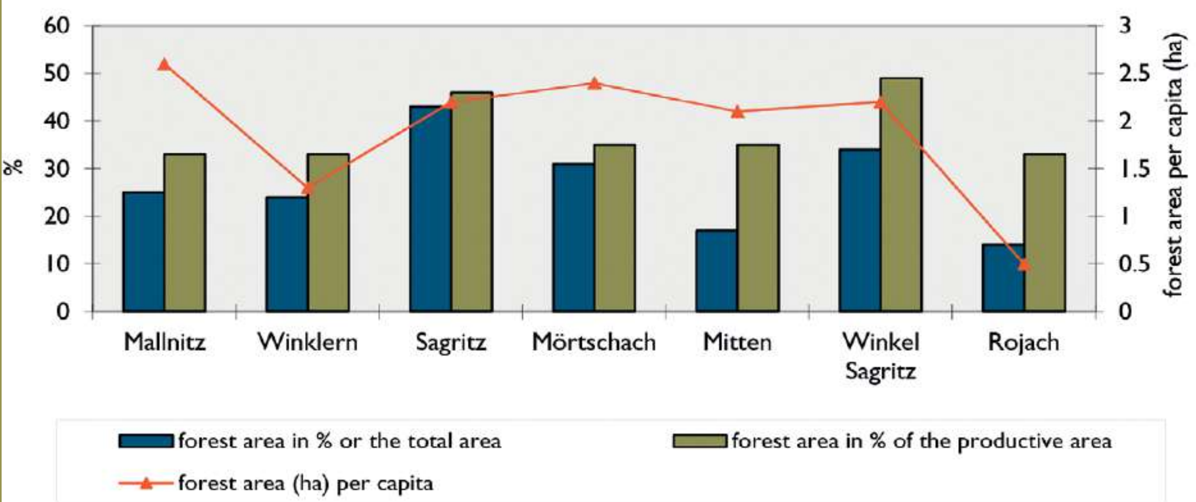
pasturing can be considered at an altitude of 2600 m (Photograph 11).

The main natural forest communities comprise spruce-fir forests (*Picea abies – Abies alba*) and spruce forests (see Figure 2 forest habitat 1.3). They occur at an altitude between 750 m to 1650 m. Caused by locally influenced climatic conditions such as frost or specific stands (i.e. moisture) also montane spruce forests without the occurrence of fir are natural. Locally beech (*Fagus silvatica*) can be part of the natural vegetation, pine (*Pinus sylvestris*) occurs only on sunny poor sites on a small scale. Grey alder (*Alnetum incanae*) is growing in riparian forests and on wet slopes (i.e. originating from avalanches and soil erosion). On fresh-wet slopes locally also mixed forests of sycamore maple (*Acer pseudoplatanus*), Scots elm (*Ulmus glabra*), and common ash (*Fraxinus excelsior*) are growing. Montane spruce forests (particularly Larici-piceetum) (1650 m – 1900 m) and subalpine larch (*Larix*) - arolla pine forests (Larici-pinetum cembrae) are well developed at an altitude of 1900 m to 2100 m. Sub-alpine shrubbs of green alder (*Alnetum viridis*) are growing on wet stands with a rich snow-cover. At the subalpine altitude (1400 m – 2100 m) shrubbs of mountain pine with rusty-leaved alpenrose (Rhododendro ferruginei-pinetum prostratae) are well developed (Winter et al., 2005).

At the bottom of the valleys a continental inner-alpine climate is dominating, characterized by very warm summers and cold winters with relatively low precipitation. The precipitation permanently increases correspondingly with the altitude up to the mountain range. At high altitudes a frosty climate with Atlantic influence is dominating. The annual sum of precipitation amounts between 800 mm and 900 mm in the valley and between 900 mm to 1250 mm in the montane and subalpine region. The precipitation reaches its maximum in summer time (Winter et al., 2005).

Silicate rocks with components of rocks poor of base (gneiss, granite, slate, quartzphyllit) and rich of base (limestone-schists, volcanics) are dominating.

Distribution of the forest area in the Mölltal-valley around 1830 — Figure 11.11



Photograph 12: Upper Mölltal-valley farm house around 1920 (Österr. Nationalbilbiothek Wien: Heiligenblut, Kärnten: Aufnahme 1922 XII 28, Nr. 128.508).

Photograph 13: Forests with protective functions in the Upper Mölltal (1998) (Photo: E. Johann).

Locally also marble and limestone are present. The most frequent type of soil is semipodsol (more than 50%). Caused by climatic influence also podsol and ranker are broadly spread. Base-rich cambisol (brunic arenosols) and cambisols on limestone are relatively wide spread at higher altitudes (more than 20%). Less important are cambisols on moraine and gravel, gleysols and bogs.

Generally the living conditions in this high mountain region are extreme (Photograph 12). The living space is permanently threatened by natural impacts such as flooding, avalanches and soil erosion. In the course of time, natural (avalanches erosion) as well as human interventions have remarkably contributed to the evolution of the cultural landscape. Apart from anthropogenic influences changes in the natural conditions (climate, vegetation) have plaid an important role. Thus climate change in the course of history had an impact on the social environment of the rural population. The time of the first settlements corresponds with the period of the medieval climatic optimum lasting from the 8th to the 15th century. The climatic conditions of this time were convenient for the expansion of settlements but also for mining activities at high altitudes (up to 2000 m above sea level). The following little ice age had a dramatic effect on the entire cultural landscape.

My study focuses on the farm forests of the mountain region Hohe Tauern situated in the Federal province Carinthia, in particular on the protection forests of the Mölltal-valley. These protection forests have always been managed as high forests and have been valued by the local population because of their protective functions with regard to the safeguarding of the living space since the medieval period. This was the reason why they have never been cleared totally. Thus they can be described as ancient forests, even in some cases they can be regarded as pioneer forests due to natural dynamics such as erosion and avalanches (Photograph 13).

The share of protection forests in the individual communities was high, making up half of the forest area in most cases (Figure 11.12). Proved also by the results of pollen analysis the dominating tree species of the forests with yield was Norway spruce, either alone or associated with larch. Its portion varied from a small percent in some communities (Mallnitz, Lassach, Winklern, Winkelsagritz, Lainach, Gössnitz, Tresdorf, Stall) up to 30% (Sagritz, Rojach,), sometimes exceeding 50% (Stranach), particularly on steep slopes. The area of protection forest was already mapped in the cadastre (Franziszeischer Kataster) in the first decades of the 19th century (1820-1827). In the protocols attached to the cadastre also the occurrence of fir mixed with some larch is noticed. Broadleaved trees were not recorded in the high forests (Figure 11.12) (Kärntner Landesarchiv unpubl. data 1820-1827).

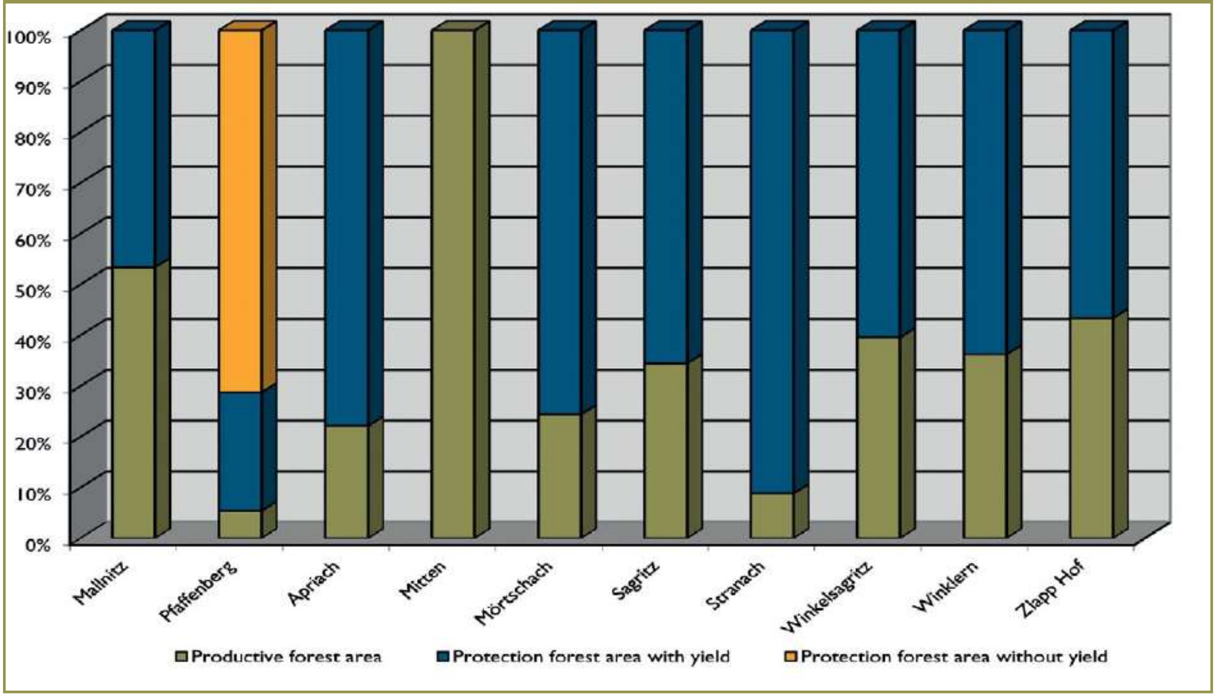
Historical development

The already mentioned traffic route across the mountain range which was constructed during the Roman Empire in the 1st century BC and joined two economic important regions – the Mediterranean in the south and Central Europe in the north, was one of the most important factors for people to settle in this area. Another factor was a considerable abundance of gold. Gold mining activities had been carried out already by Celtic tribes and were continued without interruption till the beginning of Modern times (Moosleitner, 1976).

In the 14th and 15th centuries the mountains Hohen Tauern comprised the biggest gold mine in Europe whith 10% of the global gold production. These mining activities were characterized by extreme climatic and

Proportion of the productive forest area, protection forest area with yield and protection forest area without yield in selected communities of the upper Mölltal-valley arround 1830 (Johann 2004)

Figure 11.12



environmental conditions, because the gold deposits were situated at an altitude up to 2700 m above sea level. Thus the location of the mines belonged to the highest in Europe. As they were in operation during the whole year mining was a high challenge for the miners considering that even approaching the most yieldable mine named "Goldzeche" required nine hours of walking (Figure 11.13). The path was in places exposed to extreme climate and dangerous terrain such as avalanche gears. During the high time of gold mining activities the consumption of wood and charcoal for the smelting process was high and caused the cutting of the mountain forests also at high altitudes (Johann, 2004).

„Goldzeche" gold mining activities above the timber line
(Landesmuseum für Kärnten, Klagenfurt)

Figure 11.13

Even if gold mining activities had started earlier the evolution of forests was influenced primarily by climatic factors till about 800 AD. Only locally anthropogenic impacts were noticeable before the 11th century, when the number of settlements increased. Clearings were not longer restricted to the edges of the forest but broke through the forest belt. However, they remained within the forest area and did not reach the upper tree line. During the 12th and 13th century extended clearing activities due to new settlements established for the production of cheese locally impacted this upper tree line (Meirer, 1973). In the 15th/16th century the flowering time of gold mining caused once more the decrease of the forest area which was locally continued till the 17th/18th century. This decrease also rooted in the changing climatic conditions due to the influence of the little ice age on agricultural activities (cold summers, early snowfall, and long lasting winters). At this time large clear cut areas for the supply of the mines (gold, copper, and iron) extended from the bottom of the valley till the upper tree line. They were legally permitted by the so-called "Montanforestreservat" giving the sovereign the right to prioritize mining activities and unlimited timber harvesting for the supply of the mines and attached smelting processes also in forests not owned by the sovereign (Johann, 1994).

Ownership structures

From the very beginning each farmstead was equipped with its own forest land in the vicinity of the house. The use of this forest was at the free disposal of the farmer.

Photograph 14: Mixed farm forests (spruce, larch) on steep slopes (E. Johann).

Photograph 15: Wooded landscapes in the Mölltal valley (E. Johann).

Besides, forest land, grassland and alpine pastures were often attached to the entire village and thus formed the common land with joint utilization structures. Moreover extended utilization rights in the neighbouring manorial or State-owned forests were attached to the respective farmstead (Photograph 14).

These rights covered the demand of the farmstead with regard to fuel wood, construction timber, wood for fences, water pipes and other agricultural uses, but also included the right for litter harvesting (soil and branch litter), forest grazing and alpine pasturing. Often also miners and peasants owning only a small piece of land were equipped with parts of such forest utilization rights for the purpose "to keep the peace in the village". Therefore forest land could be in the ownership of free or subservant farmers, of commons (called "Gemain"), of manors or the State. Utilization rights existed in state-owned, manorial and commonly owned forests. A particular feature of this region is the high amount of free farmers dating back to the time of first settlements. Their property was written down in the so-called "Landtafel" thus securing them certain undisputed rights (Johann, 2004).

When mining activities started, forests gained higher importance in the view of the sovereign as well as the mining industry. The high demand for firewood, poles and charcoal forced the sovereign on the one hand to claim the right of forest utilization ("Montanforstreservat"), on the other hand to influence the kind of farm forest management prioritizing wood harvesting and restricting traditional farm forest uses.

Forest management

The forest was mainly managed as high forest, one part as selection forest with a calculated rotation period of 120 years, one part as compartment system (Photograph 15). Only a very small part was managed as coppice with a short rotation period of 10 to 20 years.

The aspiration to protect the forest stands against overutilization and to safeguard the sustainability of the forest yield date back to the 16th/17th century. The first step was to describe the forest stands in detail, to estimate the yield as well as to make plans for harvesting and rejuvenation. The second step was to write down the measures which were considered suitable to fulfill the plans best. The third step was to publish the main important issues in form of so-called "Waldordnungen" (forest orders). Some of these descriptions are still stored in the Kärntner Landesarchiv Klagenfurt and prove the efforts of former generations to maintain the given resources for the following generations (Johann, 2004). To illustrate these actions I give some examples: Several descriptions of some forest stands in the Mölltal valley 1522, 1543, 1556, and of the entire valley 1650, forest descriptions of the manors Sommeregg 1651 and Gmünd 1652 and 1700 including a forest order from 1640. A general order published by Emperor Ferdinand in 1632 gave order to visit and assess all forests reserved for the supply of the mines to maintain the good quality of the stands and to avoid misuse (Kärntner Landesarchiv unpubl. data).

The first step toward a sustainable planning was the division of forest stands into annual coupes. This was particularly necessary when they were dedicated to the supply of the mining industry. Due to this planning the continual and permanent supply as well as the safeguarding of the forest stands could be preserved. The planning period often stretched out for a hundred years.

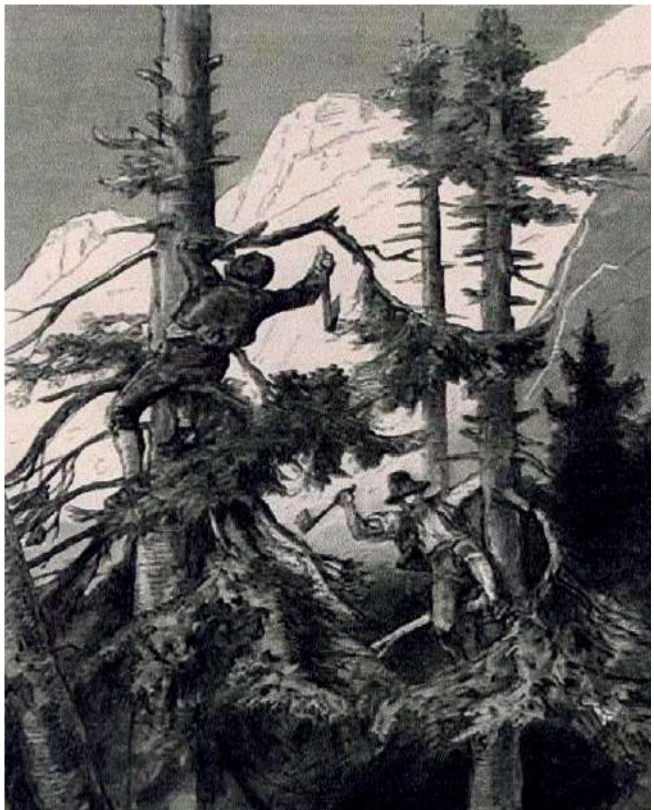
The maintenance of the forest cover had high priority in regions which were important for the energy-supply of the mining industry. This was the reason why temporal or permanent clearings carried out by farmers were restricted or forbidden. The amount of wood which was allowed to be cut should be adapted to the expected yield (increment). Frequent visitations and assessment were considered to be the best basis for an adaptive forest management. Therefore they were increasingly carried out and arranged by public and private foresters since the 18th century (i.e. 1766, 1785) (Kropatschek, 1785). The frequency of assessments increased in the first half of the 19th century (Guttenberg, 1898). Because these assessments and inventories focused on each stand exist they witness the occurrence of these forests for centuries. The assessments provided the basic elements for forest harvesting and have a long tradition also in the Mölltal-valley. These reports inform in detail about the condition of the respective forest stand and the planned and carried out utilization. Thus an assessment from 1837 gives notice about the extent of each forest stand, the composition of tree species and the expected yield. The existence of clearcuts caused by the harvesting of the mining industry for the production of charcoal are recorded as well. Until the second half of the 19th century the rejuvenation of these clearcuts was mainly left to nature (leaving of seed trees, ban of forest grazing). This assessment gives also record about the understocking of many forest stands situated on the sunny slopes. However, informs also about the overstocking of forest stands growing on sites hardly accessible. They showed a high amount of dead wood and had a high age. They had not been used for a long time or had never been used at all (Johann, 2004).

Information about the existing forest areas, the tree species and the growing stock as well as the expected yield, the distribution of fields, pastures, gardens and woodland in the landscape as well as ownership structures can be gathered also by the protocols and detailed maps of the cadastre (Kärntner Landesarchiv 1820-1827) from the 1820s (Figure 11.14).

Controversially to the management for the supply of the mining industry farmers practiced selective cutting to cover the various demands of the farmstead. For the production of construction timber, boards, fences, fuel wood, water pipes and other products needed for the running of the farm different diameters were necessary. Depending on site conditions farmers calculated the final age of trees between 90 to 150 years. The rejuvenation in the forest stand was left to nature. Everywhere forest grazing was quite common from springtime till late autumn. In summertime the livestock stayed at the alpine pastures except the cattle which was needed for the daily supply. This cattle grazed in the surrounding forests the whole day also in summertime. In the entire Mölltal valley because of the lack of broadleaved trees branch litter from spruce provided the necessary manure for the fields. Also this right to litter was legally secured

Figure 11.14

Map of the region Mallnitz (Mölltal valley) (Kärntner Landesarchiv unpul. data 1820-1827)



Photograph 16: Branch litter harvesting for the supply of the farmstead (19th century) (Rosegger et al., around 1900).

(Photograph 16).

Farm forest management was for a long time carried out to cover the own demand of the farmstead only. However, caused by the increase of the urban population, the development of industry and traffic but also tourism a remarkable increase of the demand for utilizable timber came into being in the second half of the 19th century. Therefore timber prices increased which had been very low before. Thus the aimed goal also of farm forest management activities basically changed from fuelwood and charcoal production to the production of the most valuable timber.

Within the last hundred years the importance of the various forest uses (agriculture – timber production) have undergone dramatic changes particularly at high altitudes. Within the last decade the forest area increased due to the abandonment of unfertile agrarian sites in context of the extensification of agriculture. Today the maintaining of the social and protective functions is one of the most important tasks the forests have to fulfill in the Tauern-region.

Protection forests against avalanches

Until the second half of the 19th century the rural population had only very few possibilities to protect themselves against the threatening by natural hazards such as avalanches. On the one hand it was the choice of the place of settlement conducted by traditional

Photograph 17a: Forest with protective functions (upper Mölltal valley) 1929 (Johann, 2004) (Österr. Natonalbibliothek Wien: Bildarchiv, Nr. 232.324).

Photograph 17b: Forest with protective functions (upper Mölltal valley) 1999 (E. Johann).

knowledge concerning nature and the environment. On the other hand it was the maintaining of the forest area situated above the farmsteads and along the traffic routes in a sufficient extent and good stand quality (Photograph 17a and 17b). However, the traditional knowledge particularly with regard to avalanches and flooding only developed slowly from generation to generation and had to be reassessed several times (Bundesministerium für Land- und Forstwirtschaft, 1989).

Since the early modern period several activities carried out by the commons as well as the manors aimed at the protection of settlements as well as traffic routes. The most important measure was the ban of the forest area which was considered to fulfill protective functions. In some regions the maintenance of the protective function was more important than wood production and was a strong impulse to achieve sustainable forest management in its entirety.

Farmers had always been aware of the necessity of safeguarding protective forests. This was the reason why the forest stand situated above the respective farmstead usually was allocated to it in order to fulfill protective functions. The only person who was allowed to use this area was the farmer himself. Wood harvesting in form of clearcuts for the supply of the mining industry was not allowed. Thus people and their exposed assets seemed protected in a sufficient way. In the Mölltal-valley there are several examples proving the ban of forests and exclusion from wood harvesting apart from the owner of this piece of land. One of the very old documents proving the protection of a forest stand in favor of some villages dates back to 1518 (protection of a forest called "Rannachwald" situated in the community "Winklsagritz" in favor of the inhabitants of the villages "Krass", "Griess" and "Ranach") (Johann 598-612) (Figure 11.15).

The concerned forest was managed as storeyed high forest surrounded by meadows, pastures, and forests. After a court-session and a following inspection of the site the district court made the judgment that the affected forest stand should be sheltered as protection forest because of the imminent danger of avalanches. Thus litter harvesting with threatening rakes was forbidden as well as temporal clearings. The arguments for this decision pointed out the fact that avalanches had destroyed people and their assets in the surrounding villages not only the current year but also in the past. The local farmers having gone to court referred on the old law ("Landrecht"). It regulated the management of forests with protective functions and prohibited the cutting of wood in areas endangered by avalanches and above roads as well as clearings. These protection forests should be free of use.

In addition to this the council decided the ban of further forest stands with regard to the protection against soil and stone erosion. Apart from the farmer who had historical rights of forest grazing and harvesting a certain

Figure 11.15

Protection forest Rannach situated in the community Winklsgritz. Map from 1828
(Kärntner Landesarchiv unpuibl. data 1820-1827)

Figure 11.16

Common forest Stappitz map from 1828
(Kärntner Landesarchiv unpubl. data 1820-1827)

amount of construction timer and timber for fences nobody was allowed to cut wood or to make clearings. The judgment came into being after a complaint of the members of the common. In 1688 the forest stand was put under protection once more because of the impact of an avalanche which had once more damaged the livestock and people and their assets tremendously.

The so-called "Waldverteilungsvergleich" (agreement for the distribution of forests), completed in 1620 in the manor "Oberfalkenstein", may serve as another example for taking into account the protective functions of forest stands (Figure 11.16). The concerned forest area was located in the Mallnitz-valley and was in the ownership of a common called "Stappitz", comprising 33 farmsteads. When the originally common forest became divided into parcels among the villagers, 40% of them were equipped with a protection forest. This forest area was in any case situated just above the respective farmstead. Due to this kind of division the farmer and his assets were considered to be protected against avalanches. The borders of the plots were marked to avoid conflicts. The avalanche gear as well as the plot of land used for the transport of timber and branch litter remained common land. It is remarkable, that on the occasion of this division not only farmers but also peasants and miners owning only a small piece of land or even no land at all were provided with a proportion of forest.

Decades later the view of the forest authority changed and the protection of the farmstead was considered to be secured best by the responsibility of the entire society. In the context of the division of the common forests of "Mallnitz", a common located just below the mountain range, it was pointed out by the district court that the distribution of protective forests was strictly forbidden. Protection forest should be left free to safeguard houses, fields and farmers and their assets. In protection forests nobody should be allowed to cut wood or branch litter any more.

Protection forests were also addressed by forest assessment protocols initiated and carried out by the government in 1766. (Johann, 1968) These detailed records ("Waldbereitungsprotokolle") also comprised the description of the entire protection forests of this region and described the individual stands. There was a high abundance of those protection forests being either in the ownership of commons or of individual farmsteads. In some commons even each farmstead had its own protection forest. Because of the danger of flooding, soil erosion and avalanches wood harvesting was strictly forbidden apart the extraction of dead wood. Farmers having old utilization rights were allowed to exercise their rights, but also in this case these rights were restricted. Among these protection forests also the common Stappitz cited above was mentioned with four forest stands within its common boundary (Hofkammerarchiv Wien, 1751-1770).

In case of emergency, when avalanches threatened the main traffic route across the mountain range and thus endangered the life of travelers and miners, farmers had to give up their traditional right of forest use (ius lignandi) although they had possessed this right for a very long time. Only the permission to collect dead wood remained. There was only one farmer in the surrounding area who was allowed to continue with wood cutting, however only at places where the stand structure was very dense. He derived this right from an explicit decree given to him by the Governor of Carinthia in 1694.

Conflicts – external interests

Summarizing the development one can conclude that despite the strict rules and orders concerning the management of protection forests, these forests were repeatedly damaged, thus affecting their protective function. In case public goods such as roads or the safety of travelers were endangered, the authorities prohibited the utilization of the forest stands entirely or allowed only single tree systems of management.

In case private good was threatened the authorities estimated the expected danger of avalanches less seriously. The forest authority itself gave permission for utilization or also marked trees for felling even when farmers protested against wood cutting in their protection forests. However, because of the sometimes long lasting period between the occurrences of the individual avalanches it was sometimes difficult for the actors to estimate the risk in each concrete case. Particularly from the beginning of the 19th century onwards the dispute concerning the protection forest and its management was obviously also driven by the motive to claim ownership rights both by the farmers and the mining authority. Predominantly

Overutilized forest stands Döllach caused by conflicting demands (mining industry – common) (Wagner, around 1850)

Figure 11.17

those forest stands were concerned which could be harvested easily and whose timber could be transported to the consumer without great efforts (Figure 11.17). Thus a multitude of conflicts originated between the mining authority and the farmers from the beginning of the 19th century onwards. Repeatedly the farmers pointed out the expected threats caused by avalanches, particularly when clear cutting systems were carried out, while the mining authority appeased the danger.

The protection of woodland – balance of utilization interests

Legal prescriptions to safeguard the protection forest were already part of the forest laws of the 16th century (i.e. forest law of the manor Gmünd 1640). The restriction of utilization was one of the tools to reach this goal (Johann, 1994).

From 1808 onwards the forest authority was demanded by experts such as Freiherr v. Aretin to enact legal binding regulations concerning the utilization of forest and fields on sites endangered by erosion. He disregarded the arising opinion to cover the expenses for the removal of damages by tax revenue. Instead he proposed the idea to ask the person/common/industry being responsible for the damage for financial compensation (Aretin, 1808). In fact such restrictions came into being not before the Austrian Imperial Forest Law was brought into force on December 3rd 1852. It provided the possibility to distinguish between productive forests and protection forests (Schreckenthal, 1949). Thus forests situated on steep slopes or wind exposed sites or places near the timber line, where soil erosion and flooding could be expected, were approved as protection forests which had to receive a particular forest management. Forests which were necessary to prevent the impact of natural hazards such as avalanches, rock fall, erosion, landslide, debris flow or flooding on persons and their asset could also be banned. In these cases the demanded forest treatment was prescribed by the forest authority (Schindler, 1866).

Present structures – the cultural landscape a witness of former forest uses

In the 1990s the mountain forests situated in the national park region Mallnitz/Hohen Tauern have been investigated and assessed by Senitza (1996). He examined in situ the anthropogenic factors having influenced the development of the forests in the course of centuries. The results of his study match largely with the results gained by the analysis of the historical archive material. The remnants of former forest use such as root stocks and grassland species are still clearly visible in the present-day cultural landscape (Photograph 18 and 19).

The investigations carried out in nature prove that parts of the mountain forests of this region have been shaped and changed remarkably by intensive forest use, regionally lasting till the 1950s. In the present day national

Photograph 18: Pollarding at present day (E. Johann).

Photograph 19: Seebach-valley remnants of former grazing and moving activities (E. Johann).

park-region Mallnitz the anthropogenic impact included selective cutting of larch for construction timber and of spruce to gain fuel wood as well as the mowing of grass on temporal cleared extreme steep slopes. These plots can be recognized in nature by the present succession comprising green alder and birch, respective mountain pine. Particularly alpine pasturing at high altitude, which was carried out much more intensively compared to present day, has left visible tracks in the landscape.

The heavy impact of clearcuts carried out by the high industrial demand for charcoal of the forges and furnaces (copper, iron) are still visible in some forest stands, such as forests situated in the Mallnitz valley. However, clearcuts carried out for the supply of the gold mining industry during the 16th to the 18th century can not be noticed any more. Here the vegetation can for the most part be considered not affected by human intervention. These natural forests comprise more than half of the forest area.

The investigations also confirm that farm forest

Photograph 20: Old growth protection forest (1998) (E. Johann).

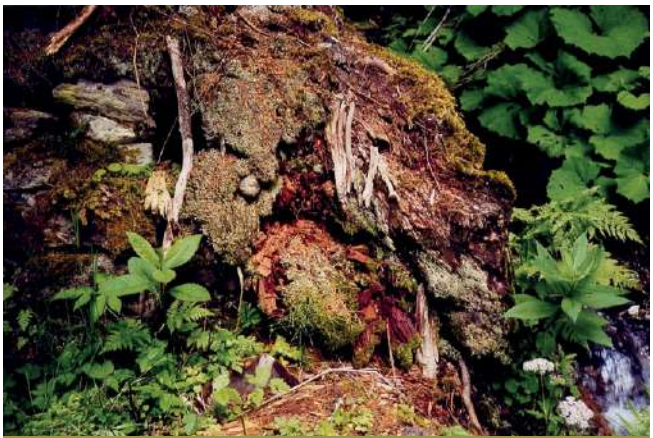
management preferred selection logging and the irregular cutting of single trees, adapted to the respective demand. It could be proved on 20% of the forest area. However, the degree of the decomposition of the rhizomes also confirms that the time of utilization dates back to the 1960s. The harvesting took place mainly at the final stage of tree growth. Strip selection cutting took place rather seldom. Clearcuts were carried out only on 6% of the area and rejuvenated till present day.. Traces of extensive pasturing in the past can be observed on about 12% of the forest area. Some forests in the valley are still grazed (grey alder forests and understocked larch forests with an open canopy) (Senitza, 1996). Forests growing at the bottom of the valley usually show a higher degree of human impact (Egger, 1994).

The traces of the frequent natural hazards having impacted the region in course of time and which were repeatedly mentioned in historic documents are still visible in today's landscape. They form the important element of the forest vegetation in this extreme high mountain landscape. Areas occasionally or periodically shaped by avalanches are covered with grey alder or mountain pine shrub forests or high perennials or grassland (54% in the Mallnitz valley). In areas were avalanches appear only episodically relative short succession cycles develop.

Nature protection aspects value for today's society

Today the forest growing in the investigated region comprises on the one hand side vegetation which is close to nature, on the other side vegetation which has been influenced by anthropogenic impact and therefore differs from the natural vegetation with regard to ecology, species composition and shape (Photograph 20).

However, the protection forests with their rather small anthropogenic impact can be considered as forests whose vegetation is close to nature also today (Photograph 21). The main part of the forest area belongs to the high mountain climax tree species, where natural subalpine Norway spruce forest communities are dominating



Photograph 21: Protection forests habitat (deadwood) (E. Johann).

Photograph 23: Biodiversity of mountain forests due to frequent natural disturbances by avalanches (E. Johann).

Photograph 22: Old spruce tree around 1920 (National Park) (Österreichische Nationalbibliothek Wien, Bildarchiv. BS 282: Partie bei Mallnitz)

(Photograph 22). Extended areas comprise continuous forest communities whereas the development of vegetation is inhibited by soil erosion or natural impacts, thus remaining more or less in an early stage. External disturbances such as frequent avalanches also contribute periodically in the short term to a regress to this early phase (Photograph 23). These communities of species show no anthropogenic influence and are therefore largely natural. This holds also true for the stands of green alder in gorges and mountain pine forest stands on steep slopes exposed to periodic avalanches (Senitza, 1996) (Photograph 23).

When the Großglockner, with a height of 3,798 metres above the Adriatic, the highest peak of Austria and the highest mountain of the Eastern Alps, was ascended for the first time by the archbishop of Gurk Franz Xaver von Salm Reifferscheid, who was accompanied by a huge group of interested scientists, the Tauernregion became internationally well known as a place for tourism but also as an scientifically interesting region from 1800 onwards (Jabornegg, 1875). Thus the specific and peculiar fauna and flora were already well known when Austria generally started its efforts to protect natural landscapes, in order to maintain their originality as well as endangered species in the second part of the 19th century. In nature reserves no human beings should be in the foreground of interest, but the nature respective the landscape in its naturalness and originality,having been relatively little changed by human intervention. The basis for the foundation of the present national park Hohe Tauern was laid by the donation of 4100 hectares to the German-Austrian-Alpine society by a private forest owner and businessman in 1918. He joined the donation with the explicit dedication that this mountain area should be preserved as a nature protection park for ever.

Situated on the border between Carinthia, Salzburg and Tyrol the Hohe Tauern National Park as a whole comprises an area of 183.600 hectares today. The first beginning was 1981. It is home to 10.000 animal and 1.800 plant species. The reserve spreads over wide alpine landscapes such as glaciers, cliffs, lawn and mountain farming culture and alpine landscapes. In addition to its function as a recreational area for man and nature the national park Hohe Tauern is still very important for scientific research, particularly in the context of climate change.

Parts of the cultural landscape, now situated in the national park, were used for many centuries. Despite this long human intervention unique and often very species-rich habitats were able to evolve. However, as the IUCN interference-free nature reserve zone has not to be below 75% negotiations between all stakeholders (Federal countries, landowners, communities, beneficiaries) and long-lasting public discussions were necessary. Thus the establishment of the national park required several years but is well accepted by the local population at present day.

Discussion – what do these two case studies have in common?

In the course of time farm forest management caused the development of a variety of forest types depending on the geographical site and the shape of landscape. In Austria they comprise coppice forests with and without standards in the summerwarm east as well as selection forests in the high alpine region, mixed broadleaved forests or dense monocultures of Norway spruce in the Alpine foothills, even age or multiple storied stands. They developed due to the multiple products these forests offered to the rural population such as wood, pasture, alpine pasture, litter harvesting, and the production of manure by soil or branch litter harvesting. All these different kinds of management occurred either as ecologically well balanced arrangement or as a product of unplanned and often extensive utilization. The multiple reasons for overutilization have often the same roots. At the first beginning of settlement each farmstead was equipped with the same amount of forest resources (own forest land, utilization rights). Caused by population growth, inheritance, selling and buying this fairness got lost from the 14th century onwards. In addition new settlers immigrated into the village such as miners and craftsmen who demanded to participate in the utilization of the common land even they did not own a farmstead with entitled utilization rights.

Since the 13th century the members of the commons took over responsibility for the shaping of the living space and the safeguarding of the given resources by participation in the administration as well as the management of the common woodland. The self-governance practiced at the beginning by the commons concerned the forest management as well as the regulation of pasturing and litter harvesting, but also the maintaining of wells, roads, fences, and bridges. In case commons (major, village-representatives) made efforts to give the land-less population a part or full access to the multiple forest products, balanced structures within the community were maintained. This modus operandi was often articulated by the wording “we give them access for the sake of piece”. As a result the common was able to preserve the self governance against the interest and pressure from outside, such as from the manor or the State. In case of serious disagreements within the community of villagers the commons often lost their former rights partly or even totally.

In the course of time the increasing interest of the sovereign in the forest resources as well as societal suspensions with regard to forest uses within the community caused tremendous conflicts. Not later than in early Modern times the power of forest authority developed also in those forests not being in the ownership of manors or the State. Common forests became banned by the sovereign to serve as a hunting place or for the sake of the supply of the mining industry. Thus the forest area became the object of claims for power, the sovereignty of commons was restricted, and the free ownership of farmers jeopardized. The basic elements the forest authorities relied on were (1) the right of noblemen to protect their property, (2) the right and duty of the manor to control the economic handling of the subservants, (3) the right of the authority to control the common property and (4) the right to control the forests which were reserved for the supply of the mines (Johann, 1983, 112).

The dominance was remarkable and comprised prescriptions concerning the rotation period as well as the extent of utilization and the location of harvesting (Johann, 1993, 213-223). The authority justified the supervision with the claim to protect the forest and to avoid forest destruction carried out by farmers. Seen with the eyes of the forest authority the multiple uses of forests such as forest grazing, litter harvesting and tar and limestone burning were generally overutilization and misuse. These uses were considered to be minor utilizations and received increasingly pressure by legal restrictions. However, certain consent among the farmers being entitled to these rights was able to avoid the extended uses and was the precondition for a sustainable forest management. Without this consent the ecological balance of the respective forest stand was endangered.

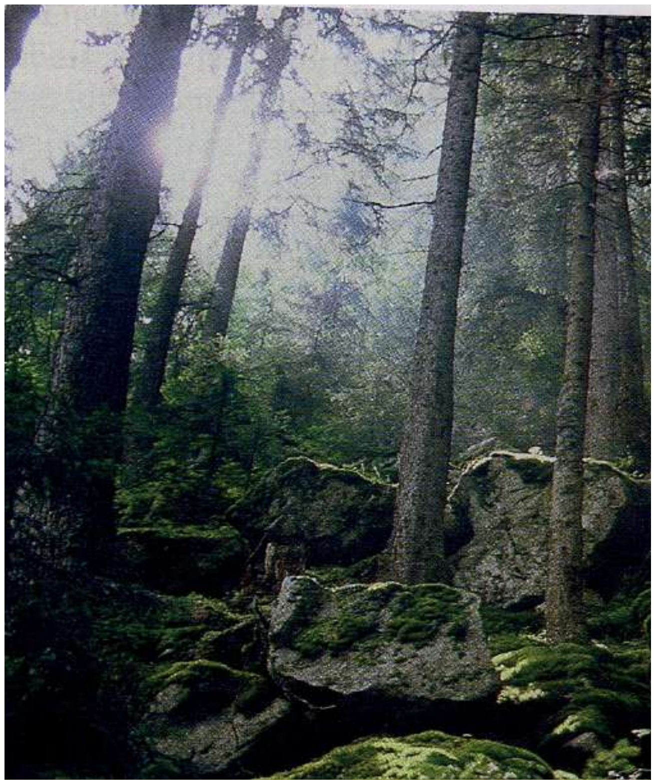
On the social level the arrangement between forestry and rural interests in any case were important factors. When ownership and utilization rights were secured on a long-term basis, the interest of the rural population in the sustainable management as well as the protection of forests was strong. The elements of rural economy (self supply, multiple forest use, selection forest management, coppicing) resulted in the maintenance of some kind of ecological balance in the forest. Far-reaching utilization in common forests as well as in farm forests was rather unusual. Also the transition or transformation of the forest stands caused by changing demands and new management methods as well as global market conditions came into being rather slowly.

Effects of management and forest use

Today wood and forest economy are the most important economic branches in Austria and regularly generate a high trade surplus. The intensity of forest management in Austria has been and still is very much shaped by the conditions of the site such as the inclination of the slopes and the seclusion. The construction of forest roads and the increasing technical progress also with regard to wood harvesting and transport offer new possibilities for wood harvesting, thus having a direct impact on the ecological structure of forest stands and their affinity to nature. In addition, global developments such as population and economic growth, trade liberalization and new markets have a remarkable influence.

Despite of the intensive management lasting for centuries the Austrian forests still represent rather predominately natural ecosystems compared to the strongly anthropogenic shaped European cultural landscape. The present high biodiversity is based among other factors on the ecological frame conditions such as climate, pattern of the natural landscape, geology as well as forest communities which also are the outcome of these natural site factors. According to the demand of society it has to be in the focus of forest management to maintain the site adapted to a relatively high biodiversity, still existing in a considerable part of the Austrian forests, particularly in the context of the global retreat of natural forests (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2004).

Beside the sustainable production of wood the society looks forward to a variety of other benefits the forest should make available all the time, such as the protection against natural hazards (avalanches, mudflow and rockfall), the regulation of waterbalance and climate, the deployment of water resources and recreation areas as well as the compensation of environmental impacts. In a typically alpine country like Austria ensuring and enhancing the protective effect is particularly important. Thus the social and environmental functions of the forests are crucial for the quality of life of the entire population. However, the performance of the forest ecosystem depends on ecological stability. A site-adapted biodiversity is considered to provide the basic precondition. It contributes in a substantial way to the optimization of the overall benefits of the forest land.



Photograph 24: Close to nature forest stand in the Mallnitz-valley. Since the 17th century it protected the people and their asset against avalanches. Wood cutting was not allowed. Therefore the natural composition of tree species maintained till present day (NPV Kärnten).

Benefit for today's society

In Austria biodiversity has mostly increased in the course of cultural history due to extensive management. However, starting from the time of industrialization and intensified during the recent fifty years a dramatic loss of this diversity came about also in Austrian. Here biodiversity is endangered by the fragmentation of the landscape and habitats caused by the construction of roads and new buildings, the abandonment of traditional land use systems, the impact of pollution and additional nutrients, and climate change (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2009).

Maintaining this diversity represents a special responsibility. Since 1994 Austria has been one of the states being contracting parties to the Convention on Biological Diversity (CBD). Six National Parks with a total of 235.000 hectares, several Nature parks and Nature protected areas often embedded in lovely landscapes, one Biosphere reserve located partly in and around the city of Vienna and a considerable number of protected areas due to the Austrian Natural Forest Reserve Programme constitute last areas of retreat for animal and plant communities which, without appropriate protection measures, would be threatened by extinction. In addition 14.7% of Austria's territory is nominated as Natura 2000 - the pan-European ecological network of special areas of conservation for the protection of rare habitats and species. Lower Austria is on the second range with 23% (Umweltbundesamt, 2013).

Parts of the forest area addressed in the two case studies were included in one of these protected areas within the last twenty years, such as parts of the coppice forests in the Lowlands, which are now integrated in the pan-European network Natura 2000. Particular management plans have been worked out to maintain the present status. In the high mountains protection forests maintained by farm forest management for centuries were put out of production and became part of the first Austrian national park (Photograph 24). It is the merit of our ancestors that the use and management of these cultural landscapes, particularly the forests, was able to preserve the biodiversity of plants and animals our society in longing for in present times.

Conclusion

Because the local people heavily depended on the natural given resources they were forced to develop sustainable management systems to secure the living space. As long as the communities had the sovereignty with regard to the shaping of the cultural landscape and were self responsible for the sharing out of the various forest products among the villagers, the traditional forest management was able to reach this goal. The cooperative coppice forest management carried out in Lower Austria centuries ago and still continuing in present days, or the joint responsibility of commons of the mountain regions with regard to the maintaining of the protection forests may serve as good examples of the functioning of the mutual traditional practice.

Today, caused by supra-regional and global concerns relating to the destruction of nature and its biodiversity protected areas are proclaimed, often banned, and in case of need also management plans are developed and implemented. However, what we can learn from history is the fact that the implementation of these plans will only be successful in the future if it takes into account the local demands, and if utilization conflicts can be solved reasonably. Thus the acceptance and participation of the local population in the shaping of the cultural and natural landscape are important tools which should not be neglected.

References

Aretin, G., 1808. *Über Bergfälle und die Mittel, denselben vorzubeugen, oder wenigstens ihre Schädlichkeit zu verhindern. Mit vorzüglicher Rücksicht auf Tirol*. Innsbruck: 22, 24, 33.

Buckley, G.P. (ed.), 1992. *Ecology and Management of Coppice Woodlands.* Chapman & Hall. London, 336 p.

Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (ed.), 2002. *Österreichische Waldinventur 2002.* BFW, Wien.

Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (ed.), 2010. *Österreichische Waldinventur 2010*. BFW, Wien.

Bundesministerium für Land- und Forstwirtschaft, 1989. *Lawinen in Österreich.* Lawinengefahren und Lawinenschutz, Bundesministerium für Land- und Forstwirtschaft, Wien: 8-9, 17-18.

Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (ed.), 2004. *Biodiversität in Österreich.* AV+Astoria Druckzentrum, Wien: 28 p.

Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (ed.), 2009. *Der Österreichische Wald (The Austrian Forest).* Vienna, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien 41 p.

Eckhart, G., 1975. Der Ausschlagwald und der "Staudenwald" in Österreich. *Österreichische Forstzeitung*, 4: 109-112.

Egger, G., 1994. *Almen, Mensch und Nationalpark im Tauerntal.* In: Wissenschaft im Nationalpark Hohe Tauern Kärnten, Kärntner Nationalparkschriften Bd. 8, Karte 1 und 5.

Ellenberg, H., 1996. *Die Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht.* Eugen Ulmer, Stuttgart. 1096 p.

Ellmauer, T. (ed.), 2005. *Entwicklung von Kriterien, Indikatoren und Schwellenwerten zur Beurteilung des Erhaltungszustandes der Natura 2000-Schutzgüter*. Vol. 3, Lebensraumtypen des Anhangs I der Fauna-Flora-Habitat-Richtlinie, im Auftrag der neun österreichischen Bundesländer, des BM f. Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, und der Umweltbundesamt GmbH, Wien, 616 p.

Fischer, R., Stronstorff, A. and Hirsch, E., 1917. *Das österreichische Reichsforstgesetz mit Erläuterungen zu seiner Handhabung.* R. Fischer u. A. Hirsch, Wien.

Frank, G., 2009. *Naturwaldreservate in Österreich – von persönlichen Initiativen zu einem systematischen Programm*. Mitt. Ver. Forstl. Standortskunde u. Forstpflanzenzüchtung 46.

Frank, J., 1937. *Der Hochleithenwald, Einführung in die Wälderschau des Niederösterreichischen Forstvereins 1937 in das Rudolf Graf von Abensberg und Traunsche Forstrevier Wolkersdorf.* Selbstverlag des NÖ. Forstvereins, Wien: 19 p.

Freist, H. and Klüssendorf, J., 1991. Vertragsnaturschutz zum Erhalten historischer Waldformen an einem Beispiel in Niedersachsen. *Forst und Holz*, 46: 86-88.

Grabherr, G., Koch, G., Kirchmeir, H. and Reiter, K., 1998. *Hemerobie Österreichischer Waldökosysteme*. Österr. Akademie der Wissenschaften (Hg.), Veröffentlichungen des Österreichischen MaB-Programmes Bd. 17, Universitätsverlag, Innsbruck.

Guttenberg, A., 1898. *Die Entwicklung des forstlichen Betriebes und seiner Einrichtung.* In: Geschichte der Österreichischen Land- und Forstwirtschaft und ihrer Industrien. Moritz Perles, Wien. 5 Bde., Vol. 4.

Hagen, R., 2005. Verjüngung, Nährstoffsituation und Wildeinflüsse auf Eichenmittelwaldschlägen des Weinviertels unter besonderer Berücksichtigung von Vereschungstendenzen, Diss. Univ. f. Bodenkultur, Wien, 323 p.

Harlfinger, O. and Knees, G., 1999. *Klimahandbuch der Österreichischen Bodenschätzung.* Klimatographie Teil 1, Innsbruck.

Hochbichler, E., 2008. Fallstudien zur Struktur, Produktion und Bewirtschaftung von Mittelwäldern im Osten Österreichs (Weinviertel). Österr. Ges. f. Waldökosystemforschung und experimentelle Baumforschung Universität für Bodenkultur (Ed.) *Forstliche Schriftenreihe Universität für Bodenkultur Wien*, 20: 11-12.

Hofkammerarchiv Wien (unpubl. data) Aktenbestand, 1751-1770. *General- Wald-, Berait-, Berain- und Schätzungskommission für das Herzogtum Kärnten*.

Homann, J. B. (unpubl. Data), 1730-40. *Nova et accurata Carinthiae Ducatus Tabula geographica, in Superiorem et Inferiorem divisa.* Nürnberg.

Institut für Waldwachstum und Zentrum für Umwelt und Naturschutz, 2008. G*rundlagen zur Behandlung von Niederwäldern in Österreich, Abschlussbericht*. Department für Wald- und Bodenwissenschaften and Department für Integrative Biologie und Biodiversitätsforschung, University of Bodenkultur, Vienna, 25 p.

Jabornegg, Frh. v., 1873. *Die Alpenwirtschaft in Kärnten, 1. Teil*. Kärntner Landwirtschafts-Gesellschaft (Ed.) Verlag Ferd. Kleinmayer, Klagenfurt, 15 p.

Johann, E., 1994. *Regelung zur Walderhaltung und Waldbewirtschaftung*. In: Autorengemeinschaft Österreichs Wald (Eds.) Österreichs Wald. vom Urwald zur Waldwirtschaft, Eigenverlag Wien, 153-200.

Johann, E., 1968. *Geschichte der Waldnutzung in Kärnten unter dem Einfluss der Berg-, Hütten- und Hammerwerke.* Klagenfurt, Verlag des Geschichtsvereins für Kärnten, 248 p.

Johann, E., 1979. Die Bewirtschaftung des gemeinschaftlichen bäuerlichen Waldbesitzes in Niederösterreich vom 14. bis ins 18. Jh. *Österr. Allgem. Forstzeitung,* Wien, 4.

Johann, E., 1983. *Die Geschichte des Gemeindewaldes in Österreich bis zum Ende des 19. Jahrhunderts*. In: Forst- und Jagdgeschichte Mitteleuropas. Mitteilungen der Forstlichen Bundesversuchsanstalt Wien, 151: 75-85.

Johann, E., 1993. *Die Bewirtschaftung des gemeinschaftlichen bäuerlichen Waldbesitzes in Niederösterreich vom 14. bis ins 19. Jahrhundert.* In: Brandl, H. (Ed.) Geschichte der Kleinprivatwaldwirtschaft - Geschichte des Bauernwaldes, Mitteilungen der Forstlichen Versuchs- und Forschungsanstalt Baden-Württemberg. Freiburg, 175: 213-223.

Johann, E., 2004. *Wald und Mensch. Die Nationalparkregion Hohe Tauern (Kärnten)*. Verlag des Kärntner Landesarchivs, Klagenfurt, 812 p.

Kaiserliche Akademie der Wissenschaften, 1881. *Steirische und Kärnthnerische Taidinge*. Ferdinand Bischoff und Anton Schönbach (Hg.), Verlag Braumüller, Wien: Bd. 6 Kärnten.

Kärntner Landesarchiv Klagenfurt (unpubl. data), Finanzdirektion Klagenfurt, Rechnungsdepartement, Mappe 4. *Verzeichnis deren im oberen Kreis Kärntens sich befindlichen landesfürstlichen Waldungen, wie solche aus denen Akten und alten Vergleich-Protokollen extrahiert worden, 1. Hälfte 19. Jahrhundert*. Finanzprokuratur, C Akten, Fasz. 300; Lodronsches Archiv Gmünd, L 321/162; 1820-1827. Franziszeischer Kataster, Protokolle und Skizzen der Katastral-Waldschätzungs-Elaborate, Schätzungsdistrikt I Villacher Kreis.

Kilian, W., Müller, F. and Starlinger, F., 1994. *Die forstlichen Wuchsgebiete Österreichs.* Eine Naturraumgliederung nach waldökologischen Gesichtspunkten. FBVA-Berichte 82: 1-60.

Kral, F., 1985. Zur natürlichen Bewaldung im Nordosten Österreichs mit Berücksichtigung der Eichenmistel. *Zentralblatt für das gesamte Forstwesen,* 102(4): 215-234.

Kral, F., 1988. *Pollenanalytische Ergebnisse zu waldgeschichtlichen Fragen in den Hohen Tauern*. Sauteria 4, Salzburg.

Kral, F., 1991. *Die Anwendung der Pollenanalyse im Rahmen forstlicher Fragestellungen*. Institut für Waldbau an der Universität für Bodenkultur, Wien.

Krissl, W. and Müller, F., 1989. *Waldbauliche Bewirtschaftungsrichtlinien für das Eichenmischwaldgebiet Österreichs*. FBVA Berichte Wien Nr. 40.

Kropatschek, F., 1789. *Vollständige Sammlung aller im politischen Cameral- und Justizfache unter der Regierung seiner k.k. Maj. Kaiser Ferdinand I in den k.k. Staaten erlassenen Gesetze und Verordnungen, Franz X. Pichl*, Wien.

Lund, H. G., 2012. *Definitions of old growth, pristine, climax, ancient forests, degradation, desertification, forest fragmentation, and similar terms*. Gainesville, VA: Forest Information Services. Misc. pagination. [http://home.comcast.net/~gyde/pristine.htm; last updated 03. 2013]

MCPFE-Ministerial Conference on the Protection of Forests in Europe, 1993. *Documents of the Second Ministerial Conference on the Protection of Forests in Europe*. 16-17 June 1993 in Helsinki, Finland.

MCPFE-Ministerial Conference on the Protection of Forests in Europe,1998. *Documents of the Third Ministerial Conference on the Protection of Forests in Europe*. 2-4 June 1998 in Lisbon, Portugal.

Meirer, K., 1973. *Beiträge zur Forstgeschichte Osttirols*. Diss. Univ. f. Bodenkultur, Wien.

Metaforum Leuven, 2011. *Conservation and management of forests for sustainable development: where science meet policy.* Katholieke Universiteit Leuven. Position paper working group Metaforum Leuven presented at the Forests2011 symposium of 24. November 2011. Metaforum paper 5. [https://ees.kuleuven.be/forests2011/PositionPaperForests.pdf; last updated 03.2013]

Moosleitner, F., 1976. Z*ur Geschichte des Tauernweges von der Bronzezeit bis zum 6. Jahrhundert n. Chr.* In: Tauernautobahn. Bd. 1, Salzburg.

Natural England, 2013. *Ancient Woodland Inventory (Provisional) for England - Digital Boundaries*. [http://www.gis.naturalengland.org.uk/pubs/gis/tech_aw.htm, last update 03. 2013]

Niederösterreichische Agrarbezirksbhörde (unpubl. data 1581) Gemeindearchiv Mollmannsdorf, Urkunde von 1581; (unpubl. data 1751-1908) Gemeindearchiv Niedersulz. Waldakten 1751-1905.

Petersen, B., Ssymank, A. and Hauke, U., 1998. Natura 2000 – die nationale Gebietsbewertung gemäß der Fauna–Flora-Habitat Richtlinie am Beispiel der alpinen biogeographischen Region in Deutschland. *Zeitschr. F. Naturschutz, Landschaftspflege und Umweltschutz.* 73: 393-403.

Pregernig, M. and Weiss, G. 1998. F*orest Policy in Austria: Policy Making by the Sector for the Sector.* Paper presented at the European Regional Meeting on "The Underlying Causes of Deforestation and Forest Degradation in Europe" 28-29 October, Bonn, Germany. Institute of Forest Sector Policy and Economics, Universität für Bodenkultur Wien (University of Agricultural Sciences Vienna). [http://www.boku.ac.at/sfh/Documents/Preg/uc-aut.pdf, last updated 08. 2012]

Rosegger P.K., Pichler F. and Rauschenfels A., around 1900. *Wanderungen durch Steiermark und Kärnten*. Gebrüder Körner, Stuttgart, 242 p.

Rossmann, D., 1996. *Lebensraumtyp Nieder- und Mittelwälder. –* Landschaftspflegekonzept Bayern, Band II.13 (Alpeninstitut GmbH, Bremen), Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen und Bayerische Akademie für Naturschutz und Landschaftspflege, München, 302 p.

Schiff, W., 1899. *Die Gesetzgebung über agrarische Gemeinschaften*. In: Geschichte der österreichischen Land- und Forstwirtschaft und ihrer Industrien. 1848-1899. vol 1 and 4, Moritz Perles, Wien, 1028 p.

Schindler, K. (ed.), 1866. *Forst- und Jagdgesetze der Österreichischen Monarchie*. Verlag Braumüller, Wien: 19-22.

Schöpfberger, H., 1990. Die Förderung von Edellaubhölzern im Weinviertel. *ÖFZ*,12: 31.

Schreckenthal, P., 1949. *Das Forstgesetz vom 3. Dezember 1852* *samt einschlägigen Gesetzen, Verordnungen und Erlässen unter Berücksichtigung der Rechtssprechung*. Manz´sche Verlags- und Universitätsbuchhandlung, Wien.

Schütz J.P.H. and Rotach, P., 1993. *Mittelwaldbetrieb* - Nostalgische Illusion oder zukunftsträchtiges Waldbaukonzept? *Wald und Holz*, 7: 9-12.

Schütz, J.P.H., 2001. *Der Plenterwald und weitere Formen strukturierter und gemischter Wälder*. Berlin, Parey, 207 p.

Senitza, E., 1996. *Der Bergwald in der Nationalparkregion Mallnitz/Hochalmspitze. Vegetationskartierung und Leitfunktionen als Planungsgrundlage.* In: Wissenschaft im Nationalpark Hohe Tauern Kärnten, Kärntner Nationalparkschriften Bd. 8: 78-79.

Spencer J.W. and Kirby, K.J., 1992. An inventory of ancient woodland for England and Wales. *Biological Conservation*, 62: 77-93.

Starlinger, F., 1997. *Natürliche Waldgesellschaften im "sommerwarmen" Osten Österreichs*. In: Waldbau an der unteren Waldgrenze (Müller, F. ed.), FBVA Berichte 95, Wien.

Tiefenbacher, H., 1996. Waldbau-Strategie angesichts eines "Eichensterbens". *Zentralblatt für das gesamte Forstwesen*, 113(2): 83-96.

Treiber, R., 2002. Mittelwaldnutzung-Grundlage der Vegetationsdynamik und Artenvielfalt in Wäldern der südelsässischen Hardt. *Zeitschrift füt angewandte Ökologie*, 34: 334-345.

Umweltbundesamt. *Natura-2000-Gebiete* http://www.umweltbundesamt.at/umweltsituation/naturschutz/sg/n2000/ last update 03. 2013.

Valvasor, J.W., 1688. *Das Herzogtum Kärndten*. Laibach-Nürnberg, 2. unv. Auflage, Rudolfswert 1882.

Vischer, G. M. 1697. *Archiducatus Austriae inferioris geographica et noviter emendata accuratissima descriptio.* Wien. Landebibliothek St. Pölten NÖLB AV 227/1697.

Wagner J. (s.d.) Döllach around 1850: Album für Kärnten, Heft 26.

Winter, F., Starlinger, F. and Herzberger, E., 2005. *Die forstlichen Wuchsgebiete Österreichs*, (BFW ed.). [http://bfw.ac.at/rz/bfwcms.web?dok=1144, last updated 2013-02-07]

Winter, G., 1886, 1896, 1909, 1913. *Niederösterreichische Weistümer.* 4 vol, Österreichische Akademie der Wissenschaften, Wien.

Chapter 12
The wood-pasture; for food, wood and biodiversity

Frans Vera

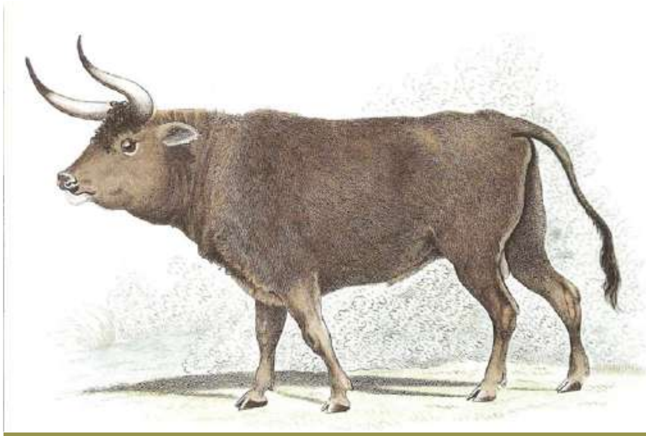
Introduction

This chapter is about the wood-pasture. It is based on research in Western and Central Europe (Vera, 2000; 2007; 2013). The wood-pasture is a park-like landscape, consisting of a mosaic of grasslands, bushes, thickets, solitary trees and groves (Flower, 1977; Pott and Hüppe, 1991; Rackham, 1980; 2003; Vera, 2000). It has an enormous variation in types of vegetation and an enormous variation in combination of these (Photograph 1). Because of that the wood pasture is very rich in wild plant and animal species (Alexander, 1998, 2001 and 2005; Alexander et al., 2006; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Ranius et al., 2005; 2008; Schuffenhauer, 2011; Schulze-Hagen, 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009). Being an agricultural system of pasturing livestock, the wood-pasture in Western and Central Europe goes back to the beginning of history and back to the introduction of agriculture between 7,000 and 5,550 years BP (Bogucky, 1988). It once covered large parts of the European continent (Pott and Hüppe, 1991; Rackham, 1980; 2003; Vera, 2000). It is the result of the wilderness taken into use by mankind in order to provide what was needed to fulfil the needs of its household, which consisted of grazing livestock, collecting of hay and honey, extraction of firewood and timber, and hunting of wild animals. This section describes how the wood-pasture as system works, how it provided mankind his living and how it is related to the originally present wilderness.

Photograph 1: A wood-pasture still in practice in Transylvania, Romania (F. Vera).

The wood-pasture

The wood-pasture is a park-like landscape grazed by livestock such as cattle (*Bos taurus*), horse (*Equus caballus*), sheep (*Ovis aries*), goat (*Capra hircus*) and pig (*Sus domestica*) and if present, by wild indigenous herbivores such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). Up to historic times also vanishes or almost vanished indigenous wild ungulates such as aurochs (*Bos primigenius*), tarpan (*Equus przewalksi gmelini*), elk (*Alces alces*) and European bison (*Bison bonasus*) roamed in wood pastures up to historic times (Brincken, 1826; Szafer, 1960; Vera, 2000). In the course of centuries loss of habitat, hunting and poaching made all wild herbivores decrease in numbers and density and disappear from large parts of their natural range. Two species even became extinct; the aurochs, the wild ancestor of cattle in 1627 (Szafer, 1960) (Photograph 2) and the tarpan, the wild ancestor of domestic horse in 1887 (Wrześniowski, 1878; Pruski, 1963). The European bison became extinct in the wild in 1921. The last specimen was killed in the former wood-pasture the forest of Białowieża by a poacher. However, 12 specimens survived in zoos, which became the founders of the population of about 3,000 specimens living in zoos and in areas in Europe where they have been reintroduced. This includes the forest of Białowieża



Photograph 2: The aurochs (*Bos primigenius*), the wild ancestor of our domestic cattle. The aurochs became extinct in 1627 in Poland. Besides prehistoric cave paintings, this is the only one left. It is a lithograph from 1862 after a painting from the 16th century that got lost.

where it was released in 1952 (Krasińska and Krasiński, 2007). The wild boar (*Sus scrofa*), the wild ancestor of the pig, still lives throughout Europe. So, livestock such as cattle, horse and pig in wood-pastures are indigenous species in Western and Central Europe. The wild ancestor of cattle and horse, aurochs and tarpan lived in Western and Central Europe up to historical times side by side with their domestic counterparts, while wild boar still does. Sheep and goat are non-indigenous in Western and Central Europe. They originate from where the domestication of all livestock species occurred, namely in what nowadays are Turkey, Syria and Ukraine (Clutton-Brock, 1989; Larson et al., 2005; Hongo et al., 2009; Outram et al., 2009; Ludwig et al., 2009; Ottoni, 2013; Felius et al., 2014).

The social context of the wood-pasture

The wood-pasture was uncultivated common land that lay beyond the cultivated that bordered the farms that formed settlements. The cultivated land consisted of fields with crops and hay lands. Beyond it was the uncultivated wilderness. "Germanic" people in Western and Central adopted an ancient system of law passed down by word of mouth for the use of the surrounding wilderness (Vera, 2000). The wilderness outside the farm and the cultivated land, the fields and the hay lands, could be used by any member of the local community to meet their needs (Meyer, 1931; Mantel, 1990). This included grazing and collecting fodder (from wild grass, trees and shrubs) for livestock, collecting firewood and timber for building and collecting honey. The customary law was passed on by word of mouth every year at the so-called commoners' meeting (Grossmann, 1927; Trier, 1963; Buis, 1985). The measure of common use was what necessary was for the livelihood of the household, the so-called "own" needs ("eigenen notdurft", "zur notturfft", "des Hauses Notdurft") (Endres, 1888; Grossmann, 1927: Hilf, 1938; Kaspers, 1957; Rubner, 1960; Hesmer and Schroeder, 1963; Buis, 1985; Tack et al., 1993). The concept of need was inextricably linked to the way in which the medieval economy was organized; that is mainly based on local self-sufficiency (autarchy). This meant self-subsistence of meat, milk, skins, wood and manure for the fields where they cultivated cereals. Equality with regard to meeting the people's needs was the starting point of the common land (Endres, 1888). Therefore a local community had to have access to the natural resources that could deliver these. There were also neighbouring communities which also had to meet their needs from the uncultivated wilderness (Endres, 1888). As a result of the increasing pressure by a growing population the individual local communities eventually made boundaries in the wilderness to indicate which area was considered as the common being for their exclusive usage. This gave rise to so-called "marken", derived from the word "marca" that means border. The earliest mention in the Netherlands goes back to a charter of 792/793 (Buis, 1985). Other words which more reflect the common usage in Western and Central Europe are: "gemeynte", "meente", "Gemeinde" or "Allmend" (from German: "für Allen gemein") (Hilf, 1938; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Mantel, 1990). In addition to rights, also duties of the individual commoners were laid down in regulations that were imposed on the use of the common (Hesmer and Schroeder, 1963; Buis, 1985). In charters written in Latin the uncultivated wilderness, among it the wood-pastures were named: "forestis", from which in German "Forst", in French "fôret", in Dutch "foreest" or "forest" and in English "Forest" was derived. In the common Germanic languages the uncultivated was named: "woud", "wald", "wold" and "weald" (Vera, 2000).

As mentioned above, equality with regard to meeting the people's needs was the starting point of the common land (Endres, 1888). This meant that a wood-pasture had to remain closed. Trading in livestock or food for livestock was forbidden, or subject to strict restrictions (Endres, 1888; Weimann, 1911; Hilf, 1938; Hesmer and Schroeder, 1963; Buis, 1985; Vera, 2000). Nothing could be traded from the common, such as wood, fodder or livestock. Any advantage to one member, e.g., if he sold products from the common, was seen as disadvantaging the other members of the community (Endres, 1888). If someone wanted to graze animals on the wood-pasture, he had to breed them himself and feed them in winter on fodder collected in the wood-pasture he as a commoner was privileged to use (Hausrath, 1898; Endres, 1888; Kaspers, 1957; Mantel, 1980; Vera, 2000). The animals of commoners from a particular common were branded, so that it was possible to establish whether there were any "foreign" animals in the common (Sloet, 1913; Ten Cate, 1972). As regards the grazing of livestock, it was therefore not possible to graze more animals than there was food produced by the common. This automatically led to a sort of ceiling on the number of livestock that could be kept (Endres, 1888; Vera, 2000), namely the number of animals which common land could provide with fodder all year round. This number included the livestock consumed by the commoners. Therefore, this system based on autarchy was very sensitive to fluctuations in the availability of food for livestock by weather conditions, resulting in fluctuations in the number of livestock. Fluctuations in the numbers of ungulates will also have been the consequence of diseases like rinderpest and anthrax. These diseases were widespread and until vaccination against them became possible in the 20th century a plague that locally could kill more than 80% of domestic ungulates and up to 95% of the wild ungulates (Sinclair, 1979; Prins and van der Jeugd 1993; Huygelen, 1997; Sternbach, 2003).

The feeding strategies of the ungulates in the wood-pasture

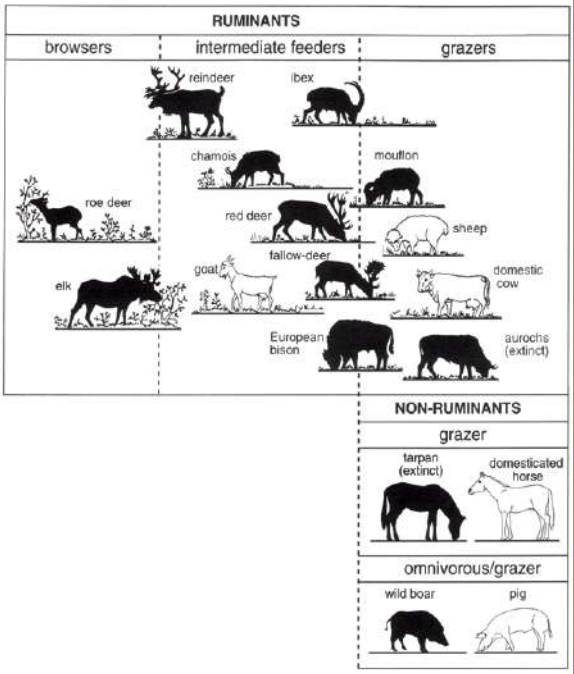
In wood-pastures domestic and wild ungulates exert by grazing, pruning and debarking an effect on the vegetation. What the effect is depends on their food preference and in turn on their digestive physiology in combination with their densities. The animals can be divided in two groups, the ruminants and the non-ruminants. Ruminants have a rumen in front of the intestinal tract. They are characterized as foregut fermenters. In fact it is the bacteria inside the rumen of the animals that digest cellulose by fermentation. Cattle, sheep, goat, European bison, red deer, roe deer and moose are ruminants (Van Soest, 1982). Non-ruminants have the bacteria in their intestinal tract, especially in the large cecum. There are called hindgut fermenters. Horse is a hindgut fermenter, as well as pig (Van Soest, 1982) (Figure 12.1).

Because of their diet and digestive physiology cattle and horse are specialized grass-eaters, so-called grazers. They mainly graze the grasslands in the wood-pastures. They can cope with a broad spectrum of quality of the grasses, ranging from young with relatively low levels of poorly digestible cellulose in the cell wall to the aged (and because of that yellow coloured) grass that has a relatively high proportion of the poor digestible cellulose in the cell wall. They are therefore characterized as roughage feeders (Van Soest, 1982). Sheep is like cattle a ruminant and a grass-eater, but less capable to digest cellulose of the cell wall. It is therefore selects more on the quality of grasses, in a sense that compared to cattle and horse it selects on for a higher digestibility due to a lower content of cellulose in the cell wall. Old grass, still grazed by cattle and horses is ignored by sheep. The diet of sheep contains more leaves, twigs and bark of trees and shrubs, than these. Therefore sheep has also been characterized as an intermediate feeder (Van Soest, 1982). This category of ruminants is with its diet and feeding strategy intermediate between grazers, such as cattle and browsers, such as roe deer and elk. Browsers feed almost exclusively on leaves, twigs and bark of trees and shrubs (Van Soest, 1982; Hofmann, 1989; 2007). Of livestock, goat is an intermediate feeder (Van Soest, 1982). It selects the whole year on average on the highest digestibility in its food. For grasses this means selection on a low level of the poorly digestible cell wall material cellulose, which means selection of the highest possible level of the highly digestible cell content. With the aging of grass, goat will switch from grasses to leaves, twigs and bark of shrubs and trees, which then have the relatively highest level of digestible cell content (Van Soest, 1980; Hofmann, 1989; 2007; Jago, 1999). Wild ungulates that are characterized as intermediate feeders are red deer and European bison. The majority of the food of these species consists of grasses. During the winter they switch to twigs and bark of shrubs and trees (Van de Veen, 1979; Van Soest, 1982; Van de Veen and Van Wieren, 1980).

Horse and pig are not ruminants. They are hindgut fermenters. The fermentation of cellulose happens in the colon (Van Soest, 1982; Hofmann, 2007). Although the proportion of grass in the diet of the pig can be considerable, it is less capable to ferment cellulose than the horse. The grass has to be of good quality that is with a low content of cellulose, so growing green grass. In the autumn acorns from pedunculate and sessile oak (*Quercus robur* and *Q. petraea*), apples from crab apple (*Malus sylvestris*), pears from Wild pear (*Pyrus communis*) and fruits from Sorbus-species like Service tree (*Sorbus domestica*) are staple food for the pig in wood-pastures,

Figure 12.1

The aurochs (*Bos primigenius*), the wild ancestor of our domestic cattle



The aurochs became extinct in 1627 in Poland. Besides prehistoric cave paintings, this is the only one left. It is a lithograph from 1862 after a painting from the 16th century that got lost.

where they are herded. Acorns contain much starch. For making fat they need protein as a supplement on a diet of acorns. Without it they fell ill, because they start to mobilize protein form their muscle tissue in order to form fat (Hobe, 1805; Herrmann, 1915; Meyer, 1931; Hilf, 1938; Hesmer, 1958; Ten Cate, 1972; Mantel, 1990). Pigs get protein from animal food that is rich in protein and that they collect upon or by rooting in the soil, such as soil-dwelling insects and their larvae and slugs. Wild boars also eat grasses, acorns, and fruits from wild fruit trees as well as every animal's food they find, ranging from young mammals and birds and eggs in birds' nests to carrion (Groot-Bruinderink, 1994; Schley and Roper, 2003; Hofmann, 2007). Because the diet of pig and wild boar consists of both animal and vegetable food, they are not categorized as grazers, but as omnivorous (Hofmann, 2007).

To each category of feeding strategy that is discussed above applies that the bigger the species, the lower the quality of the food on which is can survive. This is the consequence of the relation between the content of the body of the animal that produces the body warmth by combustion and the surface of the body with which it loses its body warmth. The content of the body increases with the third power, while the surface of the skin rises with the second power. Therefore, large animals, loose less body warmth compared to smaller ones and need less quality food to keep their body on temperature (Van Soest, 1982). Therefore, as grazer, the small sheep is more selective on quality than the lager cattle; as browser, the small roe deer is more selective than the larger moose and as intermediate feeder, the smaller red deer is more selective for quality than the larger European bison. As hindgut fermenter is pig more selective than the larger horse (Hofmann, 1973; 1976; 1985; 2007; Van Soest, 1982; Van Wieren, 1996). Both feeding strategy and size make clear that neither of these animal species are interchangeable if it concerns their effect on the vegetation. They are complementary.

The effect of large ungulates on the vegetation in the wood-pasture

It is known from wood-pastures that grazing livestock has a great influence on its vegetation. (Watt, 1919; Hart, 1966; Flower, 1977; 1980; Rackham, 1980; Tubbs, 1988; Pott, 1992; Pot and Hüppe, 1991; Vera, 2000; 2013; Newton et al., 2013). The specialized grass-eaters, cattle and horse concentrate on the grass and herbs in open grassland. They facilitate there the establishment of light-demanding species such as spiny or thorny shrubs like blackthorn (*Prunus spinosa*), hawthorn (*Crataegus monogyna*) and poisonous herbaceous species that are defended by chemical substances, like great yellow gentian (*Gentaina luea*), Ragwort (*Jacobaea vulgaris*), Bracken (*Pteridium aquilinum*) and Heather (*Calluna vulgaris*) (Iason and Hester, 1993; Mountford and Peterken, 2003; Bakker et al., 2004; Smit et al., 2006; Smit and Ruifrok, 2011). These species are avoided by the large herbivores, and thereby can protect palatable seedlings and saplings of shrub and tree species against herbivores (Bakker et al., 2004; Bossuyt et al., 2005; Rousset and Lepart, 1999; Smit et al., 2006). This phenomenon is known as associational resistance (Callaway et al., 2000; Ollf et al., 1999; Milchunas and Noy-Meir, 2002; Smit et al., 2006). Seedlings of blackthorn and hawthorn however are palatable as long as they have not developed spines. Until then they need in grazed grassland the protection of so-called swards, where they establish. Swards are spots in the grasslands with tall herb species such as nettle (*Urtica dioica*) and tall grasses. They are the result of variability in the grazing intensity of the herbivores over years, for instance as the result of fluctuations in numbers from year to year, because - as mentioned above - of less availability of food or disease. The omnivorous pig and wild boar may also play an important role in the establishment of the nurse species by grubbing in the soil. In this way they create loose bare soil, which is a perfect establishment niche for sward species, as well as spiny nurse species blackthorn and hawthorn. Large-scale establishment of blackthorn and hawthorn in abandoned arable fields (Eglar, 1954; Klaudisová and Osbornová, 1990) is an indication of this. Carnivores such as foxes and badgers and birds seem the most important dispersers of the seed of blackthorn and hawthorn to swards in grazed grassland (Smit and Ruifrok, 2011). Swards in grazed grassland are less attractive to the large herbivores, and therefore offer the temporal protection to the spiny shrubs they need to develop as saplings with fully developed protective spines (Smit and Ruifrok, 2011). This takes at least two to three growing-seasons (Smit and Ruifrok, 2011). Once armed with spines blackthorn and hawthorn can offer protection against herbivores to palatable seedlings and saplings of shrub and tree species that germinate next or in the very close vicinity (Bakker et al., 2004; Bossuyt et al., 2005; Rousset and Lepart, 1999; Smit et al., 2006). However, those established spiny nurse species are not immune to herbivores for the rest of their lives. Their annual shoots lack spines. It takes at least one growing season to harden small branches as spines (Rackham, 1989). Therefore, during that period they are vulnerable to browsing by large herbivores (Bokdam, 1987; Buttenschøn and Buttenschøn, 1978; Bakker et al., 2004; Smit et al., 2010; Smit and Ruifrok, 2011). It takes up to three weeks for the spines to harden (Rackham, 1989). The browsing of unprotected twigs of blackthorn and hawthorn induces a divaricate branching, which in turn creates a thicket that is almost impenetrable for the snouts of the herbivores (Photograph 3). As a consequence, browsing large herbivores enhance the protection of the undefended palatable tree species within the thicket (Bakker et al., 2004).

Mature shrubs of blackthorn expand clonally into open grazed grassland by root-suckers at a rate of 0.3 or 0.5-1 $m.year^{-1}$ (Photograph 4). A blackthorn seedling can in this way expand into a hurst of 0.1-0.5 ha in 10 years. Tree seedlings establish in the fringes of the advancing blackthorn (Photograph 5). They settle only in the fringe,

Photograph 3: Hawthorn (*Crataegus monogyna*), browsed by free living cattle and horse in the nature reserve De Blauwe Kamer, The Netherlands. Up till the browsing height the thorny shrub reacted with a divaricate branching, forming impenetrable natural barbed wire (F. Vera).

Photograph 4: Blackthorn (*Prunus spinosa*) spreading clonally by rootsuckers in the grazed grassland. The Borkener Paradise, Germany (F. Vera).

Photograph 5: Seedling of oak in the fringe of the thorny scrub of blackthorn (*Prunus spinosa*). The Borkener Paradise, Germany (F. Vera).

Photograph 6: Blackthorn (*Prunus spinosa*), spreading into the grassland by rootsuckers, forming a scrub that acts as barbed wire for seedlings and saplings of palatable trees, which can grow up in that way within that scrub. The Borkener Paradise Germany (F. Vera).

Photograph 7: Trees, mainly pedunculate oak (*Quercus robur*) that emerged from the thorny scrub, forming a bundle of trees, named a grove. Their crowns grew together forming a closed canopy. The Borkener Paradise, Germany (F. Vera).

because within the thicket itself the level of daylight - less than 2 per cent - is too low for the seedlings, whether they are light demanding or shade tolerant (Dierschke, 1974; Tubbs, 1988; Vera, 2000). In this way, trees advance into the grassland with the speed of the spreading fringes of the thorny scrub (Pott and Hüppe, 1991; Watt, 1924) (Photograph 6). Because blackthorn expands in every direction, forming scrub which is characteristic convex shaped group of trees, called a grove (Bakker et al., 2004; Vera, 2000; Vera et al., 2006) (Photograph 7). In this way, a grove of 0.1 up to 0,5 ha can develop in the grassland during 10 years (Hard, 1975; 1976; Wolf, 1984; Wilmanns, 1989; Schreiber, 1993). Eventually a grove can have a surface varying from some tenth up to many hundreds of hectares (Vera, 2000). Combined cattle and rabbit grazing can importantly suppress the expansion of blackthorn; rabbit more than cattle (Bakker et al., 2004; Smit et al., 2010).

Trees growing up in thickets forming a grove compete for daylight. This results in trees with long branchless trunks small narrow crowns with branches growing on the trunk at an angle of about forty-five degrees, as known from forest grown trees (Photograph 8). Contrary to blackthorn, hawthorn does not spread, because it lacks

Photograph 8: The trees that emerged from the thorny scrub, forming a grove have small, narrow crowns, with upwards directed branches, because they competed for light. The shape of their crowns is like those in forest grown trees in forestry. The Borkener Paradise, Germany (F. Vera).

Photograph 10: Under the closed canopy of the trees forming a grove, the light demanding thorny scrubs of blackthorn (*Prunus spinosa*) disappear. It survives only in front of the grove under full daylight. It is typical for a wood-pasture that in the grove a shrub layer is lacking or almost lacking. The Borkener Paradise, Germany (F. Vera).

Photograph 9: Trees that grew up in openness, protected (nursed) by a single or a few thorny shrubs that do not spread vegetatively such as hawthorn (*Crataegus monogyna*) develop to open grown trees with a large crown that starts low at the trunk. The light demanding nurse shrubs disappear, because of the shade that casts the wide canopy of the tree that grew above it. In this way a savannah-like landscape develops. The Borkener Paradise, Germany (F. Vera).

Photograph 11: Large herbivores like cattle and horses enter the grove on places where there is a hole in the scrub surrounding the grove. Inside they prevent the regeneration of trees. In this way they prevent shade tolerant tree species to grow up under the canopy of oaks and outcompete them, which they do in former wood-pastures in the absence of these large herbivores. They also prevent the regeneration of trees in gaps in the canopy. The New Forest, England (F. Vera).

rootsuckers. Therefore, they mostly nurse a single tree or a few ones. In open grassland this results in open grown trees. These trees are characterised by a huge crown that starts very low at the trunk with very thick branches, growing on the stem at an angle of almost ninety degrees. This results with a savannah-like landscape (Photograph 9). In reality and dependent of the soil combinations of both types of landscapes will develop with as main character grasslands from different sizes, groves with different sizes and trees with different postures (Vera, 2013).

So, in time trees that are protected by associational resistance will grow above the thorny nurse species. The shade of the closed canopy of the grove and the large crown of open grown trees eventually kill the light-demanding nurse shrubs under the crowns, because they are light demanding and do not tolerate the shade of the canopy above them (Puster, 1924; Watt, 1924; 1934; Ekstam and Sjörgen, 1973; Ellenberg, 1986; Tubbs, 1988; Coops, 1988) (Photograph 10). In the case of hawthorn the large crown of the open-grown tree will kill the shrub. Clonally expanding blackthorn can stay ahead of the shade casting canopy of the grove with again and again, seedlings settling in the advancing edge of the thicket. Within the grove the regeneration of trees initially is prevented by the shade of the canopy, but moreover by the trampling and browsing by the large herbivores (Bakker et al., 2004; Mountford et al., 1999; Mountford and Peterken, 2003) (Photograph 11). They enter the grove through small gaps in the spiny mantle vegetation that surrounds the grove as the mantle and fringe vegetation. They do so to look for shade and to escape from biting flies. Densities of ungulates of 110-130 $kg.ha^{-1}$ (Flower, 1980;

Photograph 12: Because the large herbivores prevent the regeneration of trees by trampling and eating the seedlings and because they transport seeds of grasses and herbs with their dung, they create in gaps in the canopy grazed grassland which grow as more and more trees die by aging, fungi and or drought. The New Forest, England (F. Vera).

Photograph 13: The jay (*Garrulus glandarius*) collects and hoards acorns. The bird takes up to six acorns at a time, the largest or longest in its beak. It transports acorns up to several kilometers from the oak where they collect them (J. Korenromp).

Putman, 1986; Vera, 2000) up to 187 kg (Rackham, 1980) that were present in wood-pastures, and did facilitate the regeneration of trees in the grazed grassland, prevent at the same time the regeneration of trees in forests, also after a gap is formed in the canopy (Gill, 2006). As a result in due time the canopy of the grove opens up; a process that is facilitated by fungi and drought that kill more and more of the senile trees (Dobson and Crawley, 1994; Green, 1992). Grass seeds are brought in by the large ungulates in their dung and fur and as the grove becomes more open as more trees die, a grazed lawn develops (Bokdam, 2003; Mountford and Peterken, 2003). This process is well known as retrogressive succession of high forest towards open grassland or heath, and is considered in vegetation science and forest ecology as a degradation of high forest by retrogressive succession (Tansley, 1953; Ellenberg, 1988) (Photograph 12). In this way, groves change from the centre with the oldest trees onwards gradually into grassland again (Goriup et al., 1991; Mountford et al., 1999; Mountford and Peterken, 2003; Peterken, 1996). When the grassland has reached a certain surface, swards will locally develop because of variability in grazing intensity of the herbivores. Spiny and thorny nurse species will establish there again and in their wake palatable shrub and tree species, especially the light demanding ones. While the grove expands in the grassland, the centre of the groves disintegrates. Both processes are driven by large herbivores, resulting in a non-linear succession (Vera, 2000).

The dominance of oak and hazel in wood-pastures

A remarkable phenomenon in the wood-pasture in the lowlands of Europe is that compared to other tree species both oak species (*Quercus robur* and *Q. petraea*) regenerate very well (Buttenschøn and Buttenschøn, 1985; Smith, 1980; Tansley, 1922; 1953). They are very common in wood-pastures (Pott and Hüppe, 1991; Rackham, 1980; 2003; Watt, 1919). This phenomenon is caused by the activity of the jay (*Garrulus glandarius*) and the wood mouse (*Apodemus sylvaticus*). Both species hoard acorns in the ground, seed by seed, at different places (Bossema, 1979; Den Ouden et al., 2005). They are true scatter-hoarders, although wood mice will sometimes hoard several acorns in one catch (Den Ouden et al., 2005; Smit and Vermijmeren, 2011). The jay collects acorns in the oak and hoards them at a distance from the oak, from a few meters up to several kilometres, with a preference for open areas, such as large open spaces in forests, and open grasslands and fields (Bossema, 1979; Chettleburgh, 1952; Kollmann and Schill, 1996; Schuster, 1950) (Photograph 13). There they prefer a transitional area of short to long grass or brushwood, the outer edge of hedges and the fringes of thorny scrub that form mantle and fringe vegetation of the groves in wood-pastures (Bossema, 1979; Chettleburgh, 1952; Rousset and Lepard, 1999; Vullmer and Hanstein, 1995). Chettleburgh (1952) observed a jay flying down into a hawthorn bush and burying an acorn at the foot of the bush. This observation explains the phenomenon of oaks, which seem to grow entwined with hawthorn in wood-pasture (Photograph 14). In addition, jays like to bury acorns in places where the soil is loose and they can easily push the acorns into the ground (Bossema, 1979). This may be an indication of the facilitating role of pig and wild boar in wood-pastures. The distance between

Photograph 14: A jay can fly down into a hawthorn bush burying an acorn at the foot of the bush. This results in an oak which seem to grow entwined with hawthorn like on this photograph. The Borkener Paradise, Germany (F. Vera).

two hoarded acorns varies from 0.2-15 m, but is generally between 0.5 and 1 m (Bossema, 1979). Jays easily find the acorns they buried. The vertical structures for which jays appear to have a clear preference when they bury the acorns seem to serve as a beacon (Bossema, 1979). They dig up and eat the acorns they hide throughout the year, but do so far less in the period from April to August (Bossema, 1979). It is during this period that the seedlings appear. In June, together with their young, the jays start to look for seedlings that have grown from the acorns they buried the autumn before. When a parent bird finds a seedling, it takes hold of the stem with its beak and lifts the plant. This raises the acorn above the ground, or the soil that is brought up, and shows where it is hidden under the ground. The jay will then dig the acorn up. The jay removes the acorn from the seedling, peels it and feeds it to its young (Bossema, 1968; 1979). The development of the seedlings is not hampered in their growth by the removal of the cotyledons (Bossema, 1979), because the seedlings grow in full daylight, which is what seedlings of both oak species need to grow up (Krahl-Urban, 1959; Anderson and Frost, 1996; Sonessen, 1994). The chance that the young oak will be uprooted is small because in the full daylight immediately after germination they formed an extremely extensive root system with a long tap-root (Jarvis, 1964; Jones, 1959; Ziegenhagen and Kausch, 1995). This root system ensures that the seedling is securely anchored and not easily uprooted during the inspection of a jay. So, the disadvantage of the inspection is offset by the advantage of growing in extremely good light conditions. Only very young seedlings that have grown late in the season are occasionally totally pulled out of the ground with their roots by a jay. Wood mice transport acorns from the mother tree over a distance up to 50 m (Den Ouden et al., 2005). Like the jay, they predate on the acorns they hoarded.

Woodmice disperse acorns towards shrubs (Smit and Verwijmeren, 2011). At first sight, it looks like the wood mouse therefore contributes the most to the successful regeneration of oak in the spiny shrubs of wood-pastures. However, they hoard most acorns in the centre of the scrub where the chances of successful establishment of the light demanding oak species are less because of the very low level of daylight (Den Ouden et al., 2005; Vera, 2000). To a lesser extent they hoard acorns at the outer edge of the shrubs, where oak has the best opportunity to grow successfully in wood-pastures (Pott and Hüppe, 1991; Rackham, 1980; 2003; Tansley, 1922; 1953; Watt, 1919). This is where the jay prefers to hoard acorns (Bossema, 1979). This may mean that overall the jay contributes more to the successful regeneration of oak in wood pastures than wood mice (Den Ouden et al., 2005). Woodmice also hoard the seeds of beech (*Fagus sylvatica*) as does the nuthatch (*Sitta europaea*). However, nuthatch store mostly in bark crevices of trunks and thick branches and make few caches below ground (Källander, 1993; Moreno et al., 1981; Perea et al., 2011). This and the low density of avian seed removers in beech forests (Perea et al., 2011) may explain the observed infrequent appearance of beech seedlings and the frequent appearance of oak seedlings in the grassland and thorny scrub, even adjacent to beech woods (Tansley, 1922; Watt, 1925). Besides beechnuts, the nuthatch also hoards seeds of small-leaved and broad-leaved lime (*Tilia cordata* and *T. platyphyllos*), sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*) and hornbeam (*Carpinus betulus*). Like beechnuts, these are usually hidden in bark furrows, and in the cracks of trunks and branches of trees; places that are not regeneration niches for these species (Källander, 1993; Löhrl, 1967; Matthyssen, 1998). Therefore, they are dependent on the wind in order to disperse them to nurse species sites, and this happens by accident. Besides beech, lime, sycamore, ash and hornbeam, also silver fir (*Abies alba*), Norway spruce and elm species (*Ulmus glabra* and *U. leavis*) regenerate successfully in wood-pastures in spiny shrubs and thickets by associational resistance (Rackham, 1980 and 2003; Smit et al., 2006; Tansley, 1953). However, they also lack vectors like the jay and the wood mouse for the distribution of their seeds, vectors that give both oak species in a natural way a huge advantage in wood-pastures above other tree species (Den Ouden et al., 2005; Smit and Verwijmeren, 2011; Vera, 2000). This explains the dominance of oaks in wood-pastures in the natural distribution area of oak and the subordinate appearance in wood-pastures of the other tree species. Beech, silver fir, Norway spruce, sycamore, lime, hornbeam and elm species dominate only wood-pastures at heights where oak cannot grow, like in the more mountainous parts of the natural distribution area of both oak species, that is above 600 meters (Vera, 2000; Smit et al., 2006; 2007; 2008).

Besides the palatable tree species, palatable light demanding shrub species such as hazel (*Coryllus avellana*), guelder rose (*Viburnum opulus*), bird cherry (*Prunus padus*), spindle tree (*Euonymus europeus*), elder (*Sambucus nigra*) and privet (*Ligustrum vulgare*) grow successfully by means of associational resistance. The nuthatch collects hazelnuts (Hagerup, 1942; Källander, 1993; Löhrl, 1967; Matthyssen, 1998). A pair of territorial nuthatches can deprive hazel shrubs totally from their nuts in a few days (Löhrl, 1967). Although studies show that nuthatch hides few seeds in the ground, some data suggest that from all the seeds they collect, those of hazel are the most frequently stored in the ground, 60-73% compared to 16-20% of beechnuts (Källander, 1993; Matthyssen, 1998). It hides the hazelnut close to hazel shrubs by pushing and hammering it into the ground and covering the spot, as jays do for acorns (F. Vera, pers. obs.). That they store seeds close to the food source (up to 40 m away) (Matthyssen, 1998) and seedlings of hazel are found in open grassland and in the fringes of spiny scrub (Sanderson, 1958), makes it very plausible that the nuthatch acts as a vector for hazel, as the jay does for oak. The shrub itself can cope with heavy grazing outside the spiny scrub by forming new shoots from the roots (Bär, 1914; Jahn, 1991; Sanderson, 1958). It also spreads by underground runners (Sanderson, 1958). The other mentioned shrub species have fleshy seeds that are eaten by bird species, especially singing birds (Passeriformes) that defecate the seeds in the thorny shrubs, where they roost (Namvar and Spethmann, 1985; Snow and Snow, 1988). This can explain how these light-demanding shrub species are part of mantle and fringe vegetation (Ellenberg, 1988; Hondong et al., 1993; Pietzarka and Roloff, 1993; Smith, 1980; Vera, 2000).

Within the groves the large herbivores prevent the regeneration of trees, especially the livestock that are there in high densities. This is essential for the persistence of oak trees in the grove. It is well-known from former wood-pastures, such as forest reserves and national parks where livestock was removed and wild ungulates were absent or culled to such low densities that they did not prevent the regeneration of trees in forest that shade-tolerant tree species regenerate under the canopy of oaks. If they overgrow the oaks they kill them (Vera, 2000). The crown of oaks permits sufficient daylight to penetrate through the canopy for shade tolerant species like beech, broad-leaved and small-leaved lime and hornbeam to grow up. This is known from the practice in forestry for the production of wood for veneer. Beech and lime are planted under oaks in order to prevent with their shade that the oaks develop dormant buds on their trunks. They also ensure that the trunk grows as straight as possible. These branchless straight trunks provide the valuable wood for veneer (Mantyk, 1957; Hesmer and Günther, 1966; Rühl, 1968; Fricke, 1982; Koss, 1982; Jahn, 1987). Unless beech and lime are regularly cut back, they will overgrow the oaks and kill them (Schwappach, 1916; Wiedeman, 1931; Bonneman, 1956a; 1956b; Vera, 2000; Erteld, 1963; Hesmer, 1966; Hesmer and Günther, 1966; Böckmann, 1990). The process of displacement of light demanding oak species by shade tolerant tree species in forests is a well-known phenomenon and good documented issue in forest ecology and forestry (Schwappach, 1916; Wiedeman, 1931; Bonneman, 1956a,b; Krahl-Urban, 1959; Erteld, 1963; Hesmer, 1958; 1966; Hesmer and Günther, 1966; Bezanski, 1971; Fricke et al., 1980; Böckman, 1990; Dengler, 1990; 1992; Pigott, 1991). This happens in former wood-pastures where livestock has been removed and wild ungulates reduced by culling to densities they do not prevent the regeneration of trees in the forest (Morosow, 1927; Malmer et al., 1978; Fritzbørger and Emborg, 1996; Emborg et al., 1996; Emborg et al., 2000; Vera, 2000; Wijdeveen, 2004; Wolf, 2005; 2011; Rapp and Schmidt, 2006; Bobiec, 2012). Besides pedunculate and sessile oak also other light demanding tree species disappear, such as wild apple (*Malus sylvestris*), wild pear (*Pyrus pyraster*) and wild cherry (*Prunus avium*), as do light demanding shrubs species, such as hazel, blackthorn and Guelder rose (Malmer et al., 1978). According to historic data these species were all very common in wood-pastures (Brincken, 1826; Bühler, 1922; Hart, 1966; Rackham, 1980; Vera, 2000). They are not only outcompeted by beech and broad-leaved and small-leaved lime, but also by elm (*Ulmus* spp.), (*Tilia playphyllos* and *T. cordata*) hornbeam (*Carpinus betulus*), ash (*Fraxinus excelsior*), Field maple (*Acer campestre*) and sycamore (*A. pseudoplatanus*) (Malmer et al., 1978; Fritzbørger and Emborg, 1996; Emborg et al,, 1996; Emborg et al., 2000; Vera, 2000; Wijdeveen, 2004; Wolf, 2005; 2011; Rapp and Schmidt, 2006; Bobiec, 2012).

The cause of the displacement is the change of the wood-pastures into closed canopy forests. Both oak species as well as the other light demanding species cannot regenerate successfully in forests in the presence of the shade tolerant tree species, neither in gaps in the canopy, nor in large wind-blown areas (Dengler, 1990; Vera, 2000). In forestry oak is only successfully regenerated in the presence of shade tolerant tree species with a lot of human assistance. This assistance consists of working the soil by for instance ploughing, and further destroying tall grasses and herbs, and shrubs and trees that will kill the seedlings of oak by their shade. Confusingly, this way of human assisted regeneration in forests is called in forestry "natural regeneration". It suggests that it is a process which takes place under natural conditions in untouched nature. However, it is not. Since the beginning of the 20th century, "natural" regeneration is defined as: regeneration with seedlings which grow from seed dispersed by the trees forming the canopy (Bühler, 1922; Dengler, 1990). Whether the origin of the trees is by planting or not, does not matter (Cotta, 1865). The practice of forestry is that without this human assistance, "natural regeneration" of oak is impossible in forests (Bühler, 1922; Krahl-Urban, 1959; Tendron, 1983; Dengler, 1990; 1992; Vera, 2000).

The wood-pasture; a dynamic system

The wood-pasture is a dynamic system. There is grazed grassland first. Then thorny or spiny scrub or other unattractive (that is inedible) species of plants establish, either forming a clonally spreading scrub like blackthorn or remaining solitary like hawthorn. Then seedlings of palatable trees and shrubs establish successfully if they are protected by these inedible nurse species. Trees grow up solitary or forming groves (forests), depending on whether the nurse species' ability to spread clonally or not. Aged trees die in the groves and the groves change into grazed grassland again because large herbivores prevent the regeneration of trees within the groves (forests). Solitary trees die and give also space for grassland again. Then, in the grassland as a result of variability in the grazing intensity of the herbivores in temporarily not grazed parts swards develop, where spiny or thorny nurse species become established. Sward development can be facilitated by the rooting of pig or wild boar. Next, spiny, thorny or otherwise unpalatable plant species act as safe sites for seedlings and saplings of edible shrub and tree species, which grow up. Either open grown, solitary trees or clumps of trees, groves are formed. The solitary trees and trees in the groves eventually die of age. The single tree disappears and the grove disintegrates to grassland again. The process of the dying of the trees can be facilitated by drought and fungi. Then again in the grassland swards develop and in them thorny and spiny shrubs establish and finally single trees or clumps of trees, groves, develop. The cycle is then closed. In this way a nonlinear cyclical succession develops consisting of grassland → shrub and or scrub → single trees or grove (forest) → grassland again (Vera, 2000). The whole cycle is driven by large herbivores (Vera, 2000).

This system is based on chronosequences (space-to-time substitution) (Picket, 1987) in accordance with the autecology of the plant and animal species that inhabit the wood-pasture (Vera, 2013), which is a prerequisite for using chronosequences (Johnson and Miyanishi, 2008; Walker et al., 2010). Contrary to a closed canopy forest, the wood-pasture system enables light-demanding tree species to survive in the presence of shade-tolerant tree species (Vera, 2000; Vera et al., 2006). Hereafter I will show that especially light demanding plant species in the wood-pasture such as oak, hazel, wild fruit and grasses and herbs met the daily needs of the households of the commoners.

The wood-pasture as pasture

The wood-pasture provided food for livestock. We know this from written sources that date back to the 6th and 7th century. These regulations concern the use for grazing of pigs and other livestock, cutting foliage, collecting honey and protecting trees, including those which produced food (mast) for pigs, such as oak, wild apple, wild pear and wild cherry (Bühler, 1922; Meyer, 1931; Kaspers, 1957; Trier, 1963; Ten Cate, 1972; Mantel, 1990). The food for the livestock were not just grasses and herbs which are today in western and central Europe associated with food and with pasture for livestock. It consisted also of the twigs with leaves and the fruits of trees (Trier, 1963; Rackham, 1980; Mantel, 1980; Pott, 1983; Tack et al., 1993; Vera, 2000). According to texts dating from the Middle Ages and later, the wood-pasture indicated as "forestis", "Forst", "fôret", "Forest", "wald", "wold", "weld" or "weald", was the place with food for livestock, birds and bees (Vera, 2000). In the Frankish language, the place where animals found food or where food was collected was described as a "weide" (pasture) (De Vries, 1970; Van Veen and van der Sijs 1990 and 1991). Animals which were looking for food were engaged in "weiden" (pasturing). Cattle grazing grasses and herbs were engaging "weiden" (were pasturing) in the wood-pasture as did the pigs who ate the fruits fallen off the trees, the acorn, apples, pears and cherries, known as "waid" for pigs (Habets, 1891; Weimann, 1911; Kaspers, 1957; Ten Cate, 1972; Mantel, 1980). The bees that collected their nectar from flowering trees like the wild fruit trees as well as from broad-leaved and small-leaved lime trees were known as "Bienenweide" (bee-pasture). Bees also collected their nectar from flowering shrubs like Blackthorn, Hawthorn and from heath (*Calluna vulgaris*), and flowering herbs in the grasslands. References to this were mentioned the pasture of bees (seu apium pascuis) (Remling, 1852; Hesmer, 1958). Flowering trees like wild fruit and lime were important for bees. Bees were kept and honey was collected in wood-pastures (Krause, 1892; Hilf, 1938; Mantel, 1990; Vera, 2000).

Confusing for historical research is that in the modern meaning of "weiden" (pasturing or pasture), trees are not included, while in these historical texts they are. In texts dating from the Middle Ages, and for several centuries subsequently, words such as "forest", "Forst", "fôret" and "Wald", which nowadays according to modern dictionaries are translated as closed canopy forest, included pasture, that is the food ("weide") and the place (also "weide") where it was collected (Vera, 2000). Therefore these words include grassland. With research on historical texts for the meaning of the words "forest" and "wald" one will therefore look in vain for evidence of pasture in the modern meaning of grassland opposite or separate to grove or forest. The reason is that such a classification for the people at that time was meaningless, for grassland was the same as trees, namely providers of food for animals, therefore pasture ("weide"). So in contrast to our modern view, grasses, grasslands, trees and groves were all pastures. The people at that time looked from a utilitarian point of view to the landscape and not on the basis of vegetation science and forestry, as we do nowadays.

Regulations on grazing livestock were not concerned with the regeneration of trees at all (Bühler, 1922; Hesmer and Schroeder, 1963; Streitz, 1967; Mantel, 1968; Rackham, 1980; Buis, 1985; 1993). The absence of regulations about the regeneration of trees is because the regeneration took place without any action on the part of the users. After all, what happened spontaneously did not require regulations, and anything which did not require regulations was not laid down in practical rules (Bühler, 1922; Vanselow, 1926; Streitz, 1967; Rackham, 1980; Stamper, 1988; Mantel, 1990).

This is not surprising, knowing how the regeneration of trees in wood pastures is mediated by grazing and unpalatable plant species such as spiny shrubs. What was regulated was the use of grasslands, shrubs and trees that were there without human intervention. Therefore it was not necessary to create grasslands in the wilderness by felling trees in a so-called closed canopy forest. Felling was regulated, but for getting firewood and timber or to create a field for growing crops (Vera, 2000).

Trees; the pasture for livestock

As we saw above, light demanding tree species such as pedunculate and sessile oak and wild fruit species such as wild pear, wild apple and wild cherry are very common in wood-pastures. These fruits were important for the pannage that is to fatten the pigs on those fruits in autumn. Those fruits were known as the mast. The most important mast consisted of acorns (Endres, 1888; Hilf, 1938; Nietsch, 1939; Hesmer en Schroeder, 1963; Schubart, 1966; Ten Cate, 1972; Duby, 1968; Slicher van Bath, 1987; Mantel, 1990; Tack et al., 1993). These were also collected to feed the pigs when they were kept indoors (Hesmer, 1958; Tendron, 1983; Buis, 1985). The Anglo-Saxon word for acorn is "aecer" (Rackham, 1993). In Dutch the pannage of pigs was known as "aecker", "eycker, "eckel", "akeren"; in German, "Acker", "Ecker(ich)", "Geäcker", "Äkeret", "Acherum") (Habets, 1891; Hilf, 1938; Buis, 1985; Elerie, 1993; Tack et al., 1993). In French it was "le panage" from which the English word "pannage" is derived (Rackham, 1980; Tendron, 1983). The mast, or collection of acorns, was in Germanic languages known as "acker" (Hilf, 1938; Ten Cate, 1972). The "acker" was also the "acker", that is the place where the food, the acorns, the "acker", in Germanic languages the "weide" (the pasture), the mast was. They were brought to the place where they could find the acorns by a herdsmen (you cannot drive pigs), that is the "acker". Therefore, in medieval texts, the "acker" was a place where the oak trees and wild fruit trees were, and where the pigs were taken to be fattened (Hilf, 1938; Schubart, 1966; Ten Cate, 1972; Buis, 1985). So, the "acker" was situated in the uncultivated wilderness, the "forestis" or "Wald". In the Middle-Ages, pork, and particularly bacon, was an essential source of energy for the winter, and therefore an important part of the daily winter diet (Reed, 1954; Bogucki and Grygiel, 1983; Jahn, 1991; Tack et al., 1993).

The pigs were from a few weeks to about four months outside in the uncultivated in order to fatten on acorns and the fruit of wild pear, wild apple and wild cherry, berries of the whitebeam, sloe berries, rosehips and hazelnuts. These trees were described as "fruitful trees" or "fruit trees" ("arbores fructiferae" or "silva fructicans") or bearing trees ("tragenden", "tragbaren", "beerenden" or bärenden Bäumen") (Bühler, 1922; Vera, 2000). Although every commoner had a right to as much wood for building as he needed (Endres, 1888; Hesmer and Schroeder, 1963; Buis, 1985), it was prohibited to fell or to damage these trees in any other way (for instance by illegally peeling the bark from the oak for tanning leather) without express permission (Endres, 1888; Bühler, 1922; Meyer, 1931; 1941; Hilf, 1938; Nietsch, 1939; Kaspers, 1957; Hesmer and Schroeder, 1963; Trier, 1963; Hart, 1966; Schubart, 1966; Streitz, 1967; Ten Cate, 1972; Dengler, 1990; Mantel, 1990). A commoner did have to show that he really needed the timber (Endres, 1888; Reed, 1954). When this proof had been presented to and permission granted to fell a tree (almost always an oak) by an official who was in charge to apply the regulations, a "holtrichter" (wood assessor) or "forestarius", he was shown the tree by such an official who marked the tree with a special axe (Endres, 1888; Vanselow, 1926; Hesmer and Schroeder, 1963; Mantel, 1990; Buis, 1993).

The oldest regulations about the protection of fruit bearing trees refer specifically to oak, beech, wild apple, wild pear, wild cherry and service trees. Later, protected trees also included whitebeam, chestnut (*Castanea* spp.), walnut (*Juglans* spp.), hazelnut (*Corylus avellana*), and alder buckthorn (*Rhamnus frangula*). In all these regulations, the oak has a central place because of the importance of the acorns for pannage. There were barbaric punishments for infringements of these regulations (Kasper, 1957; Ten Cate, 1972; Mantel, 1990). The importance of pannage is also shown by the fact that in the medieval documents from the Netherlands, England and Germany, the size of an area was expressed in terms of the number of pigs that could be kept there (Herrmann, 1915; Ten Cate, 1972; Rackham, 1980; Buis, 1993; Stamper, 1988).

In German-speaking parts of Europe the fruit bearing trees were known as "Herrenholz" or "hovetbome" [trees of the court, the "curtis", that is the property of the lord] (Sloet, 1913; Hilf, 1938; Musall, 1969; Rackham, 1980; Hausrath, 1982). In England, the trees were named "highwood". They belonged to the lord and could be felled only with his express permission (Hart, 1966; Flower, 1977; Tubbs, 1988). In the 16th century, the term "highwood" was completely replaced by the term "timber" (Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; 1993). The protection of the "Herrenholz" in German-speaking parts of Europe was in contrast to so-called "herrenlose" wood (the wood – that is the material – that did not belong to the lord), also known as bad wood ("malae"), infertile wood ("unfruchtbarn holtz"), unreal wood ("unecholt"; "Unholtz"), useless wood ("unnützes"; unnützliches" holz) and dead, dry or harmless wood ("douffholtz" or "duisholt"). These names also referred to the shrubs (named: "fürholz", "vorholt" and "vorholtz", "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss"). These names mean what one sees if one stands in a wood-pasture in front of a grove. The spiny mantle and fringe vegetation that encloses the grove like a belt in a wood-pasture lies in front of the trees that are behind it and is down the trees. The firewood cutting was aiming for the wood that is the material in the belt, that was in front of and down the trees. The material is named in old Germanic languages "holt, or "holtz". "In front of" is in old Germanic languages: "voor", "vor" or "für". "Down" is in Germanic languages "under", "Unter", "onder". So the wood in the spiny belt that surrounded the grove as named as": "underwood" "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss", "brushwood" (Vera, 2000). In England "highwood" and "timber" was differentiated from "underwood" (Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; 1993). Another clear indication that these terms refered to the spiny mantle and fringe vegetation in wood-pastures is that regulations demanded that with the firewood cutting seedlings and young trees had to be spared. As shown before, the regeneration of trees in the wood-pasture takes place in the thorny and spiny shrubs. There are data to show that not all young trees called "heesters" had to be retained (Wartena, 1968; Buis, 1985). Besides the spiny shrubs trees which did not bear fruit and dead trees that could be used by the commoners freely to meet their own needs for firewood (Endres, 1888; Sloet, 1913; Kasper, 1957; Schubart, 1966; Mantel, 1990).

Leaf-fodder cutting from trees as food for livestock was also done in wood-pastures. References to cutting leaf-fodder for livestock are very old. They can be found in written sources as early as those dating from Roman times. The elm (*Ulmus*) was considered the best fodder, followed by rowan (*Sorbus aucuparia*), and ash (*Fraxinus excelsior*). In addition to these species, hazel, hawthorn and even conifers, such as juniper (*Juniperus communis*), and Scots pine (*Pinus sylvestris*), were cut as fodder throughout Central and Western Europe (Trier, 1952; Hart, 1966; Flower, 1977; Rackham, 1980; Pott, 1983; Meiggs, 1982; 1989; Austad, 1990; Andersen, 1990; Mantel, 1990; Tack et al., 1993). All the deciduous trees and shrubs that were used for cutting foliage for fodder have an enormous potential for regeneration (Trier, 1952; Bühler, 1922; Rackham, 1980; Koop, 1987; Mantel, 1990; Mayer, 1992). In the sense of evolution, this may have been an adaptation to browsing by animals. Fodder was collected by cutting branches or twigs with foliage from the crown of the tree or shrub. Depending on the shape acquired by the tree by cutting the foliage, this was known as coppicing, pollarding or shredding the tree. Apart from cutting the foliage from trees, it was also possible to cut or strip the shoots sprouting from a tree stump or shrub (Rackham, 1980; Pott, 1983; Tack et al., 1993). In the course of the Middle Ages, cutting or breaking the foliage was increasingly restricted and eventually even entirely prohibited because of the damage which was caused, particularly to the flowering and thereby the production of fruits by the trees which were the mast for the pigs (Endres, 1888; Mantel, 1980; Pott, 1983).

There are also reports and regulations about a certain thinning of young oak trees in the spiny scrub to prevent there being too many. The extra light the young oaks received ceases them to form a larger crown and therefore blossom more profusely (Woolsey and Greeley, 1920; Bühler, 1922; Meyer, 1931; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Rackham, 1980). As a result, the oaks produced more acorns and therefore more mast for the pigs (Woolsey and Greeley, 1920; Bühler, 1922; Meyer, 1931; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Rackham, 1980; Muller and Renkema, 1995). Such young oaks and young single oaks were also coppiced at a height of a few metres. These oak trees then formed low down on the trunk an open grown broad crown, and produced a relatively large number of acorns at a young age (Flörcke, 1967; Pott, 1983; Pott and Hüppe, 1991). The low crown made it possible for a herdsman to knock acorns from the tree with a stick, and provide the pigs that accompanied him with acorns. All the inhabitants in a settlement kept pigs to meet their meat requirements, especially bacon; not only those who cultivated the fields, but also craftsmen, like the smith, and all the people who lived in towns (Endres, 1888, Meyer, 1931; Hesmer, 1958; Schubart, 1966; Ten Cate, 1972; Weimann, 1911, quoted by Hesmer, 1958).

Cutting firewood in the wood pasture

The earliest regulations on cutting firewood in commons refer mostly to thorn bushes, hazel and holly (Hausrath, 1898; Meyer, 1941; Tubbs, 1964; 1988; Hart, 1966; Schubart, 1966; Streitz, 1967; Flower, 1977). Thorny bushes such as blackthorn and hawthorn were particularly popular for firewood (Rackham, 1980; Tack et al., 1993). These regulations refer clearly to the mantle and fringe vegetation in the wood-pasture that formed a belt around the groves (Vera, 2000). The regulation speak of cutting fire wood in "underwood", "brushwood", "fürholz", "vorholt" and "vorholtz", "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss". In the Middle Ages, these terms were used to refer respectively to shrubs, shrubbery, groups of shrubs, the sprouting stumps of shrubs, coppices and trees where wood was taken for firewood and timber (Hausrath, 1928; Trier, 1952; Hart, 1966; Rackham, 1975; 1980; Flower, 1977; Buis, 1985; Mantel, 1980; 1990; Dengler, 1990; Elerie, 1993; Best, 1998).

As mentioned above, there was thinning to provide light for young oaks. Another reason that is mentioned in documents is that when too many trees grew in the scrub, the shrubs may disappear and with this the scrub as potential firewood (Hart, 1966; Rackham, 1980; Simpson, 1998). As we have seen in the wood-pasture, the thorny scrub from which the trees emerge disappears when the crowns of the trees form a closed canopy as the result of the shade, casted by the canopy. According to Rackham (1980), the competition for light between timber (used for building) and underwood for firewood was generally recognized in England (Rackham, 1980). The commoners who had the right to cut underwood in the Forest of Dean tried to prevent the growth of "timber", because this was at the expense of underwood (Hart, 1966). Reports from German-speaking countries also indicate that the number of standing trees was limited in favor of the underwood (Hausrath, 1982; Mantel, 1980). Therefore, the strictly protected "fruitful wood", such as oak trees, which produced the mast for pigs, were also described as "harmful wood" ("schedlich Holz"), while the underwood was considered harmless ("unschedlich") (Endres, 1888; Gradmann, 1901; Hilf, 1938). Experience has shown that the canopy of the standing trees could not account for more than approximately 25%, as the "underwood" would otherwise be damaged too much by the shade of the trees (Cotta, 1865; Warren and Thomas, 1992). The stools of the thorny shrubs sprouted again, forming new firewood that could be cut again after some years. This regularly cutting is known as coppice (Vera, 2000).

It is clear that the spared seedlings became deprived from their protecting thorny and spiny nurse shrubs when these were cut as firewood. The primary was to protect them, but also the vegetative regeneration, the young shoots or spring from the stump of the spiny shrubs against livestock and wildlife, because new sprouts lack their protective spines in the first growing season. From the 13th century, there were regulated coppices, in the sense that the stools were cut down on plots according to an established rotation of the felling cycle (Schubart, 1966). The earliest references to this date from the 12th century (Rubner, 1960; Buis, 1985). It was the wish or the need to protect the shoots from the stools of trees and shrubs from being eaten by livestock, as well as increasing the production of wood, which was the most important reason for concentrating stools in plots (Bühler, 1922; Vanselow, 1926; Hart, 1966; Hesmer and Schroeder, 1963; Mantel, 1990). It was the cutting of firewood that regulations for grazing livestock in relation to the regeneration of trees were issued in the oaks of Western and Central Europe (Vera, 2000). So, one was obliged to protect seedlings, saplings as well as the sprouting stools. Protecting measurements were temporary fencing off the newly cut shrubs. Such measurements were digging ditches around them and creating earthen walls planted with dead or living shrubs, such as hawthorn and blackthorn (Grossmann, 1927; Meyer, 1941; Hesmer and Schroeder, 1963; Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; Buis, 1985; Tack et al., 1993; Best, 1998; Jones, 1998). Hardly any additional or supplementary measures were taken (Buis, 1985; Vera, 2000). The trees which were spared grew up above the scrub, which was used for coppicing. This is how the coppices with standards developed. The shrubs remained known as "underholt", "unterholz" or "underwood", while the trees were referred to as the "grote holt", "Oberholz", or high wood (Vera, 2000). Trees in the groves may have been thinned by felling, giving way to the scrub under an opened canopy. In this way the scrub may have reconquered space under the thinned canopy. As mentioned above, a canopy of standing trees that accounts for less than approximately 25% will make the growth of "underwood" possible. With a denser the canopies of the standing trees cast too much shade (Cotta, 1865; Warren and Thomas, 1992). This would mean a maximum cover of approximately 50 trees of 120-150 years old, per hectare (Cotta, 1865). In this way coppice with standards developed from the scrub with seedlings and saplings that formed the mantle and fringe vegetation around the grove (Vera, 2000).

There were at first no real regulations about the number of seedlings and saplings that had to be spared in the spiny scrub that was cut as firewood. They were each individually marked when the shrubs were to be cut down (Kaspers, 1967; Hart, 1966; Wartena, 1968; Buis, 1985). Because not all young trees were spared, young trees were also cut down with the shrubs. As mentioned above virtually all the species of shrubs and deciduous trees found in the lowlands of Western and Central Europe have been cut a great capacity for resprouting from the stool (Bühler, 1922; Rackham, 1980; Koop, 1987; Mayer, 1992). Initially the felling cycles of the coppices were short, that is 3 to 9 years (Tubbs, 1964; Rackham, 1980; Buis, 1985; Mantel, 1990; Best, 1998; Gulliver, 1998). With this rotation all the species of deciduous trees and shrubs, retained the capacity for forming sprouts from the stool, including beech, who has the least capacity to sprout from its stool. With cycles over 40 years long, beech does little or not at all (Cotta, 1865; Landolt, 1866; Hausrath, 1982; Ellenberg, 1988; Mantel, 1990; Pott, 1992). With the exception of yew, conifers do not have this sprouting property. The stools of the seedlings and saplings that have not been spared produced shoots, and the next time, these were coppiced, together with the other shoots. In this way, all the species of trees which regenerate in spiny shrubs and scrub such as oak, beech, birch, ash, and lime, as well as hazel that was part of the mantle and fringe vegetation eventually also became part of the coppice (Cotta, 1865; Trier, 1952; Schubart, 1966; Evans, 1992; Mantel, 1990; Watkins, 1990). With the short rotations they could be cut down regularly without much danger of the stools dying. Moreover, a tree species can reach a significantly higher age as a stool than as a tree (Rackham, 1980), and therefore produce wood without the necessity of generative reproduction by vulnerable seedlings and saplings. For example, an ash dies after 180-200 years if it is a tree, but as a stool, it can reach an age of about 300 years, and even ages of 500 to 1,000 years are possible (Rackham, 1980). If they are not regularly cut down, hazel trees reach an age of 70-80 years (Savill, 1991). However, as coppiced stools, they easily grow to an age of 300 years (Rackham, 1980). When a large small-leaved lime, 200 to 300 years old, is cut down, new shoots still sprout from the stool (Rackham, 1980: Pigott, 1991). There was no need to give any thought to the regeneration after each harvest of wood; it was merely a matter of preventing the livestock for a few years from eating the young shoots on the stools. This explains why in the regulations hardly any additional or supplementary measures are mentioned (Buis, 1985; Vera, 2000). Those that are mentioned are the replacement of stools which have died. The dead stumps were replaced by planting young trees. There are reports of this practice in Flanders and England, dating from the 17th century (Flower, 1977; 1980; Tack et al., 1993). As all species of trees regenerated from the stools, later on the regeneration of the standing trees could take place not only by sparing seedlings and saplings in the scrub, but also by leaving one shoot on the stool of an oak or other species (Hausrath, 1982). This shoot was known in Dutch as a "spaartelg", in German as a "Labreiser", and in English as a "staddle" (Bühler, 1922; Rubner, 1960;

Tubbs, 1964; Flower, 1977; Rackham, 1980; Haustrath, 1982; Buis, 1985; Mantel, 1990). In this way during centuries in at least parts of the wood-pastures the mantle and fringe vegetation of the groves and probably the groves themselves changed into coppices with standing trees that is coppice with standards. With the development of coppice with standards characterized by vegetative regeneration, people became less dependent of the generative regeneration of shrubs and trees. The fact that coppices with standards could provide the mast for pigs, as well as producing timber in different ages (Rackham, 1980) and firewood, it may have contributed to the fact that this form of exploitation increased significantly in the course of the 15th, 16th and 17th centuries and reached a peak in the 18th century (Bühler, 1922; Vanselow, 1926; Rubner, 1960; Mantel, 1990; Vera, 2000).

In addition to coppicing, regulations were issued from the 13th century about planting young trees, usually oaks in wood pastures. Commoners were often obliged to plant a single oak or a few oaks when they were allocated an oak to fell (Bühler, 1922; Grossmann, 1927; Meyer, 1941; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Mantel, 1990). The young trees which were planted had to be protected from the livestock by planting them in thorny scrub, placing them in the same planting hole with thorny shrubs, or surrounding them with thorn bushes (Puster, 1924; Grossmann, 1927; Rodenwaldt, 1951; Hesmer and Schroeder, 1963; Flower, 1977; 1980; Koop, 1981). In fact, this imitated the process of regeneration in thorny scrub. These measures were adopted until the 18th century (Grossmann, 1927; Meyer, 1941; Rodenwaldt, 1951; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Flörcke, 1967; Streitz, 1967; Koop, 1981; Buis, 1985).

If the coppice concerns only the spiny scrub, the sprouts emerge from the stools of the spiny shrubs are armed again with spines after one growing season. So after they have been deprived from livestock for at least three seasons as in the case of the shortest rotation, the sprouts form a spiny thicket that protects the seedlings and saplings again against livestock. Even the sprouts of the palatable shrubs like hazel and trees like oak needed times that fall within the rotation times mentioned in the regulations to grow to a thickness they could withstand livestock (Mayer, 1992; Vera, 2000). Therefore, these regulations did not apply to seedlings and saplings in groves or forests. People knew about the difference in growth of sprouts on a stool in a coppice and the growth of a seedlings is witnessed for instance by an English manual about cultivating oaks, dating from 1609. It says that coppices of oak needed to be fenced off for only seven to nine years, while a plot of land sown with acorns should be closed to grazing livestock for at least twenty years so that the seedlings could grow without any risk from the livestock (Flower, 1977). As mentioned above, shoots on stools grow faster, much taller and thicker for the first few years than a shoot from seed (Mayer, 1992), which explains that for regeneration from seed in the forest the traditional rule that shoots had to grow tall enough to be out of reach of the livestock was no longer appropriate (Cotta, 1865). Therefore, the difference in growth from sprouts from vegetative regeneration from stools in coppices and generative regeneration from seed explains why coppices needed only to be closed to livestock for such a relative short period of only three to five years under this traditional rule (Streitz, 1967; Mantel, 1980; Hausrath, 1982; Buis, 1985; 1993). Therefore the damage to seedlings by grazing livestock only really applied in Central and Western Europe after the tree forest had developed from coppices as a way of producing wood. According to written sources, the damage to seedlings by livestock in a regenerating tree forest only became a problem in the lowlands in the 18th century for the generative regeneration of the forest after this method of production had been generally introduced. Virtually all the preceding regulations about grazing livestock in relation to the regeneration of the forest relate only to vegetative regeneration in coppices.

The regulations on cutting firewood are believed to have been a result of the increasing demand for firewood for households because of the increasing population and population density and a growing demand for charcoal and firewood for industrial purposes that are the glass and metal furnaces (Bühler, 1922; Vanselow, 1926; Endres, 1929; Streitz, 1967; Schubart, 1966; Mantel, 1990; Perlin, 1991; Buis, 1993). Another indication of the increasing demand or even the scarcity of firewood as a result of the increasing population is that from the 14th to the 16th century, wood which was not "fruitful", the "non-fructiferae" or "malae" were banned from being cut freely. This included birch, aspen, alder, ash, sycamore, field maple, hornbeam, holly, thorns and juniper. They also became subject to regulated cutting (Rubner, 1960; Hesmer and Schroeder, 1963; Mantel, 1990).

It should be emphasized that none of the regulations on grazing livestock which were issued in the lowlands of Western and Central Europe from the 13th to the 18th century were aimed at regulating the grazing of livestock in general. They even clearly state that the coppicing should be organized in such a way that it obstructed the rights to graze livestock as little as possible (Endres, 1888; Hausrath, 1898; Bühler, 1922; Vanselow, 1926; Rodenwaldt, 1951; Hesmer and Schroeder, 1963; Hart, 1966; Flower, 1977; Mantel, 1980). In order to prevent damage to coppices by grazing livestock, it became eventually also compulsory for the livestock to be herded (Endres, 1888; Grossmann, 1927; Sloet, 1911, Reed, 1954; Hesmer, 1958; Mantel, 1990). The plots where the livestock were herded were indicated with signs (Grossmann, 1927; Mantel, 1990). In the 15th and 16th centuries, also regulations were issued for the protection of nurseries of young trees, which were established from that time (Hesmer, 1958; Hesmer and Schroeder, 1963; Buis, 1985; 1993; Mantel, 1990). In the 18th century, hawthorn and blackthorn were cultivated in "nurseries" so that they could be used to protect young trees planted in wood-pastures (Schubart, 1966; Pott and Hüppe, 1991). Characterizing for the view of the role of the spiny species for the regeneration of trees in wood-pastures was for instance an old saying in the New Forest: "The thorn is mother to the oak" (Penistan, 1974). Therefore in England, these thorny shrubs were sometimes described as the "nursery crop" for trees (Addison, 1981). Thorns and holly were actually considered so important for the regeneration of trees that a statute dating from 1768 laid down a punishment of 3 months of forced labor for damaging thorns and holly in the New Forest, starting every month with a number of lashes of the whip (Rackham, 1980). In a number of areas in Germany, the young oak trees were planted at relatively large intervals so that they would grow into good mast oaks that are oaks with large crowns, which therefore produced many acorns (Hesmer, 1958; Pott, 1983; Rapp, 2002). In this way "ackers" were created. Because of the modern meaning of the word "acker" in Germanic languages being an open field for growing crops, this has been misunderstood as felling trees for creating such open fields (Vera, 2000). The greatest pitfall in research of history based on written sources is language, because words remain the same, while their meaning may change over centuries (Vera, 2000; 2010).

There is one animal species that virtually subject to regulations or even total grazing prohibitions over the years throughout Western and Central Europe in order to protect the coppice. This was the goat. The reason was that goats browsed particularly on buds, leaves and young shoots in the coppice (Endres, 1888; Vanselow, 1926; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Reed, 1954; Hesmer, 1958; Hesmer and Schroeder, 1963; Hart, 1966; Streitz, 1967; Addison, 1981; Mantel, 1990). After the goat, most restrictions were imposed on sheep (Endres, 1888; Mantel, 1980; Buis, 1985). In many cases, sheep were treated in the same way as goats (Mantel, 1990). The reason for this is that they destroyed the grass because they cropped it very short (Grossmann, 1927). In many cases, the number of sheep that could be kept was determined in the regulations (Mantel, 1990). As a result of the emergence of a trading economy and the flourishing cloth industry in the 16th century, there was a great demand for sheep's wool, so that there was a great increase in the number of sheep despite the restrictions, and consequently in their effect on the vegetation (Mantel, 1990; Bieleman, 1992). Grazing livestock was completely prohibited only in odd cases, as, for example, in the coppiced woodlands of the Swiss city of Zurich, which were completely closed to grazing in 1376 and 1477 (Grossmann, 1927; Meyer, 1931). In the Netherlands, grazing livestock, as well as felling trees and taking humus, were prohibited for 40 and 60 years respectively in the Rheder Forest and the Worthreder Forest. This indicates that there cannot have been much of the coppice left (Buis, 1993). Therefore it was almost certainly a last attempt to allow the coppice, which had been destroyed by over exploitation, to recover.

In modern forestry literature the measures taken from the 13th century onwards to regulate the grazing of livestock are interpreted on the basis of the prevailing theory in the 20th century that Europe originally covered with a closed canopy forest in which trees regenerated naturally in the forest in gaps in the canopy or in large windblown areas (Watt, 1947; Leibundgut, 1959; 1978; Vera, 2000). This theory is based on the spontaneous development of the vegetation on abandoned agricultural land in the absence of indigenous large herbivores (Vera, 2000; 2009; 2013; Vera et al., 2006). For this reason they submit that all the measures taken from the 13th century onwards to regulate the grazing of livestock are in line with those issued in the 19th century to protect seedlings in a tree forest (Bühler, 1922; Vanselow, 1926; 1949; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Streitz, 1967; Mantel, 1980; Buis, 1985). They extrapolate the generative regeneration of closed forests by seedlings, back to the Middle Ages and earlier. For instance Bühler (1922) stated: "*The destruction of the forests was prohibited in many places in the Middle Ages. As livestock grazing destroyed the forest, grazing in forests was regulated*". This is not correct, as we established in this chapter. The provisions dating from before 18th century all relate to protecting recently coppiced areas, as well as the protection of nurseries for young trees in the so-called "kampen". It is only the provisions on the grazing of livestock dating from after the 18th century can relate to the regeneration of trees by means of seedlings in a forest in modern forestry by producing wood in high forests (Cotta, 1865; Vera, 2000).

The demise of the wood pasture

Many reports from the Netherlands, Germany and Switzerland show that, despite all the regulations, trees and shrubs were illegally cut down and felled in large numbers, and there was widespread illegal grazing, so that the trees and shrubs eventually disappeared. Illegal cutting of firewood resulted in the greatest devastation of both wood-pastures and coppices (Bühler, 1922; Vanselow, 1926; Meyer, 1931; Hesmeren Schroeder, 1963; Hart, 1966; Streitz, 1967; Buis, 1985; 1993; Mantel, 1990; Vera 2000). The fact that decrees against the devastation of "Holz" (wood as material) were issued on average every ten years in the 17th and 18th centuries, it shows the extent to which these decrees were not obeyed. Reports from the lowlands of Central and Western Europe on damage by livestock are virtually always related to the biting off of the shoots sprouting from the stools in coppices. However the historical sources from these regions rarely mention the destruction of seedlings by livestock as such (Cotta, 1865; Landolt, 1866; Gayer, 1886; Vanselow, 1926; Grossmann, 1927; Hesmer and Schroeder, 1963). Unlike the general statement that cattle prevented the regeneration of trees in the forest and that therefore the regulations mentioned were issued to prevent that (Buhler, 1922), there is no proof from historical data that livestock prevented in general the regeneration of trees. In wood-pastures, they did so inside the groves, but at the same time facilitated it in grazed grassland. The problem is in the classic forestry literature that wood-pastures are considered as degraded closed canopy forests (Tansley, 1953; Ellenberg, 1988), instead of well-functioning ecosystem driven by large ungulates. If there are problems with the regeneration of trees, it is in the first place of human actions that cause the problems and only in second instance the animals. In addition to the ignoring of the rules for protecting the coppice against livestock, an indirect form of damage for which the animals were blamed was caused by cowherds who started fires and ringed trees to increase the area of grassland for the grazing livestock (Hesmer and Schroeder, 1963; Mantel, 1980; 1990; Buis, 1993; Tack et al., 1993).

The increase in the population and an increase in the demand for firewood and pasture resulted in an enormous pressure on coppices and wood pasture. It caused a shift in the attitude towards thorny and spiny scrub. Gorse, juniper and thorny scrub became together with brushwood, heath and shifting sands considered as having replaced the original forests throughout the lowlands of Western and Central Europe (Hobe, 1805; Landolt, 1886; Gayer, 1886; Bühler, 1922; Vanselow, 1926; Grossmann, 1927; Hausrath, 1982; Rodenwaldt, 1951; Reed, 1954; Hesmer, 1958; Hesmer and Schroeder, 1963; Streitz, 1967; Holmes, 1975; Tendron, 1983; Buis, 1985; Van der Woud, 1987; Mantel, 1990). Thorny shrubs and juniper spread in grazed grassland, but unlike being consideerd as nurse species in the 18th century thorns are seen as irritating weeds which have to be destroyed. In many parts of Europe, blackthorn and juniper are still considered to be weeds (Grossmann, 1927; Ellenberg, 1986). They were removed because they impeded grazing and also took the place of more valuable sorts of wood, was the opinion then (Hobe, 1805; Landolt, 1886; Gradmann, 1901; Bernìtsky, 1905; Sloet, 1913; Vanselow, 1926; Grossmann 1927; Meyer, 1931; 1941; Nietsch, 1939; Hausrath, 1928; Hilf, 1938; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Musall, 1969).

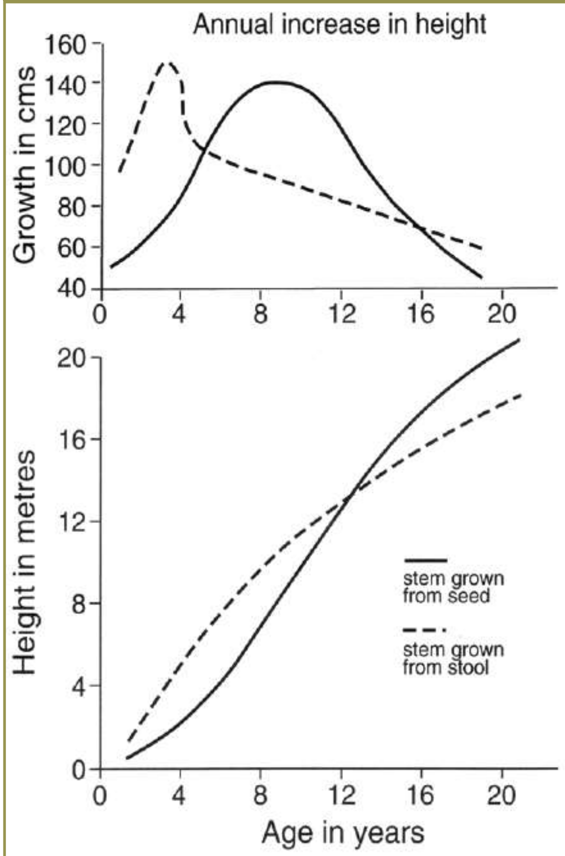
That grazing livestock was blamed is not surprising when one examines the density of livestock and the biomass recorded in the literature. For example, in 1784 in Prussia, there were 19 horses, 53 head of cattle and 215 sheep on 100 hectares of forest (319 kg per hectare) (The numbers of animals are converted into kilograms of biomass/hectare on the basis of the following weights: 1 sheep 40 kg; 1 cow 350 kg; 1 horse 250 kg; 1 pig 70 kg , verbal communication, S.E. van Wieren, 1997). The pigs have been left out of consideration in the comparison, as they were put out to pannage in the woods for only a few weeks to 4 months. Initially the other livestock grazed there throughout the year (Mantel, 1990). In addition, the commoners also had the right to collect acorns, beech nuts and other fruits, and to take litter. When these rights came to an end for instance the Bramwald in Germany, in 1870, there were 1,700 head of cattle, 3,880 pigs and 17,500 sheep on an area of 1,800 hectares (719 kg per hectare) (Krahl-Urban, 1959). In one particular part of Hessen in Germany, with an area of 2,409 hectares, there were 15,100 sheep in the 19th century (250 kg per hectare) (Gothe, 1949), while in one area in the west of Switzerland, 135 cows and 155 horses grazed on 250 hectares (344 kg per hectare) (Meyer, 1941). Moreover, grazing occurred even when there was no right to graze. Therefore there was illegal grazing, which means that the actual densities were higher than those suggested by the official figures (Hesmer, 1958; Peters, 1992). Therefore almost all the records about the damage of grazing for the regeneration of trees always date from the 18th century and later (Cotta, 1865; Landolt, 1866; Gayer, 1886; Vanselow, 1926; Grossmann, 1927; Hesmer and Schroeder, 1963). However, the real and final blow for the wood-pasture system was the invention of modern forestry in the 19th and 20th century with techniques such as shelterwood cutting, the selection system and group selection system. All these techniques aimed to regenerate the trees within the forest without the protection of thorny and spiny shrub species (Cotta, 1865; Landolt 1866; Vera, 2000).

At the beginning of the 18th century, there was a change in the demand of household and metal furnaces for firewood in the German states. The demand increased and people no longer wished to have the wood delivered in bundles of twigs or sticks, but in blocks (Vera, 2000). To obtain the necessary thickness, the usual coppice cycle was doubled, or even tripled, to 30 to 50 years and later extended even further to 60 to 80 years (Vanselow, 1926; Schubart, 1966; Mantel, 1990). As a result the coppices changed from a shrub layer under the standing trees, in a so-called pole-forest, known in German as "Stangenholz" or "Heisterwald" (Vanselow, 1926; Schubart 1966; Mantel, 1990). These forests of deciduous trees first appeared between 1700 and 1730 in Hessen in Germany (Hausrath, 1982, Mantel, 1990). The longer coppice cycle caused problems for the regeneration of beech, as the stool of this species sprouts little or not at all, with cycles over 40 years long (Cotta, 1865; Landolt, 1866; Hausrath, 1982; Ellenberg, 1986; Mantel, 1990; Pott, 1992). Therefore new young beech trees had to be planted after every felling. For this purpose, increasing numbers of beech were grown from seed in nurseries (in Germanic: "kampen" or "Kämpe") in the 18th century for planting (Hesmer and Schroeder, 1963). When the coppice cycle was increased to 60 or 80 years, there was some spontaneous growth from seed on the forest floor (Hobe, 1805). Shoots of beech coppices actually develop flowers and seed after 20 to 30 years (Ellenberg, 1986). This resulted in a pole-forest with beech seedlings (Vanselow, 1926; Hesmer and Schroeder, 1963). Beech seedlings can survive for years under a virtually closed canopy in certain soils (Kraft, 1894; Bühler, 1918; Vanselow, 1949; Dengler, 1990; Korpel, 1995). Both recently germinated and dormant seedlings will grow without any problem when they receive more light when old beech trees above them are removed (Bühler, 1918; Woolsey and Greeley, 1920; Vanselow, 1949; Mayer, 1992). This happened when trunks were removed from the pole-forest in about 1740, as it was systematically introduced in Hessen in Germany (Bühler, 1922; Schubart, 1966; Mantel, 1990). The canopy was thinned out by felling part of the poles in the wood in a regular pattern, so that the beech seedlings had an opportunity to grow. As the young beech trees continued to grow, more and more old beech trees were successively felled until all the poles were finally cleared and the whole area was covered by a new generation of beech (Vanselow, 1926; Mantel, 1990). This resulted in a forest now known as a productive standing forest, in which the regeneration of the trees took place in the forest, instead of in spiny scrub as is the case in a wood-pasture.

According to the regulations at that time livestock were still grazed in the pole-forest in accordance with the traditional rule which applied to coppices that a regenerated plot had to be opened up to grazing when the "growth" (that is in this case from seed) had grown up above the reach of the animals. However then it was ordered that when the regeneration from seed was the main aim, no livestock could graze in the forest at all. This was a break with the past, as well with the order in the second half of the 18th century that the cycle of the forest should be extended from 80 to 140 years (Schubart, 1966; Vera, 2000). The reason was that when the regeneration of trees is from seed within the forest the traditional livestock grazing according to regulations became a severe problem for the regeneration. The traditional rule of thumb that a regenerating plot could be opened to grazing when the shoots had grown above the reach of the livestock, that is after closing times of 3 up to 6 years, was not adequate anymore. Shoots growing from seed are not safe, even when they are higher up than where the livestock can reach them. They are still so thin that the animals can easily knock them over to get to the tips of the shoots and bite them off. A shoot on a stool grows to a much greater height and thickness in the first years of growth than the stem of a seedling. Seedlings of pedunculate and sessile oak reach a height in the first year of respectively 20 cm and 16 cm, while a shoot on the stool of an oak grows at least two meters that is ten times more. It reaches after one year a thickness of 2.5 cm, which makes it after more than 3 to 6 years impossible for livestock to knock it down. The height a sprout of a coppice reaches in one year is reached by the sprout of a seedling only after six or seven years (Turbang, 1954; Trier, 1963; Watkins, 1990; Rackham, 1993) (Figure 12.2). So, it takes much longer for seedlings to grow tall enough to be out of reach of the livestock and thick enough not to bowed by the animals and eaten. Empirically it was known that in high woods of beech, silver fir, hornbeam and oak, in areas where trees have been seeded they should not be opened to livestock in less than an average of 20 years. In woods of elm, ash and sycamore this should not happen in less than 15 years (Cotta, 1865; Hart, 1966; Darby, 1970; Flower, 1977; Rackham, 1980; Tubbs, 1988; Perlin, 1991). The strong rejection by foresters of allowing livestock to graze in the forest can be explained by this difference in growth of the stems of seedlings compared with the shoots on a stool of a particular tree species (Cotta, 1865; Mayer, 1992). It was this change in the regeneration of trees that grazing livestock as well

Figure 12.2

Growth curves of Grey alder (*Alnus glutinosa*)



It makes clear that the spring from a stool (coppice), i.e. vegetative regeneration grows much more rapidly in the first few years than growth form seeds, i.e. generative regeneration. This makes clear that stools in coppice are better able to withstand browsing animals which will try to bow down the spring (from Vera, 2000, redrawn from Mayer, 1992, p. 198).

as wild ungulates became entitled as the greatest enemy of forests (Landolt, 1866). Thus from the middle of the 19th century, there was an increasing insistence in forestry circles that grazing livestock in forests made regeneration impossible and should therefore be stopped altogether (Landolt, 1866; Gayer, 1886; Bühler, 1922; Vanselow, 1926; Grossmann, 1927; Meyer, 1941; Schubart, 1966; Mantel, 1990).

In the 19th century, cutting of poles in long rotation times giving way to seedlings of beech to grow was developed as a regular wood harvest and forest regeneration technique. It is known as the shelterwood system. This technique meant that increasingly large gaps were made in the (grove) forest canopy by means of thinning out trees at intervals from several years to a decade. As the canopy become thinner, the seedlings of the standing trees grow taller. The term "shelterwood" system is based on the fact that after every felling, the remaining trees are so spread out their crown and form a screen that shelters the young trees against dryness and frost. Finally, after the last felling or clearing, there is only an open area left with a new generation of growing trees. Fort beech this last felling was after 40 years (Vera, 2000). This technique was eminently suitable for the regeneration of beech in a beech forest, because of the shade tolerance of beech. However, it was not successful for regenerating the light demanding oak in a forest. The reason that "natural" regeneration of the oak using the technique of the shelterwood system initially failed, is the greater amount of light required by the oak, compared, for example, with beech (Vanselow, 1926; Krahl-Urban, 1959). Only after the modification that the canopy of the oak forest was thinned out much more and faster than was usual for the regeneration of beech, and the last trees of the shelter removed within 10 years, that oak was also successfully regenerated with this technique (Bühler, 1922; Vanselow, 1926; Hausrath, 1982; Krahl-Urban, 1959; Vera, 2000). Even then oak requires a great deal of human intervention, such as removing other sorts of trees, such as lime, hornbeam, elm and beech, which would outcompete oak (Cotta, 1865; Landolt, 1866; Gayer, 1866; Bühler, 1922; Vanselow, 1949; Dengler, 1990). Confusingly, this technique is described in forestry literature as "natural" regeneration, although unnatural measures such as working the soil or destroying unwanted plants, shrubs and trees are part of this "natural" regeneration. The development of "natural" regeneration showed that the oak needs a great deal of human intervention to be able to regenerate in forests. Without this help, it is impossible for oak to regenerate "naturally".

The abolishment of livestock grazing because of the destruction of the forest

On the basis of the prevailing theory that the original vegetation in the lowlands of Europe was a closed canopy forest, 20th century authors believe that the original vegetation of the lowlands of Central and Western Europe was a closed forest (Vera, 2000). For this reason they submit that all the measures taken from the 13th century onwards to regulate the grazing of livestock are in line with those issued in the 19th century to protect seedlings in a tree forest. They were all aimed at protecting seedlings in the forest (Bühler, 1922; Vanselow, 1926; 1949; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Hesmer, 1958; Streitz, 1967; Hesmer and Schroeder, 1963; Mantel, 1980; Buis, 1985). They extrapolated the generative regeneration of closed forests by seedlings, back to the Middle Ages. This also applies to the tree forest itself, with the conclusion that the remaining virgin forests of Europe, which were proclaimed as "forestes", and where regulations on the grazing of livestock were passed over the years, were originally closed forests. For example, Bühler (1922) stated: "The destruction of the forests was prohibited in many places in the Middle Ages. As livestock grazing destroyed the forest, grazing in forests was regulated" (Bühler, 1922). An additional argument which supports this hypothesis is the measures taken for the protection of fruitful trees, which go back to the early Middle Ages. They are interpreted as a measure for regeneration in the form of the shelterwood system. According to this view, the measures relating to the grazing of livestock were additional measures, and served to protect seedlings in the closed forest (Bühler, 1922; Vanselow, 1926; Meyer, 1931; Hess, 1937; Hausrath, 1982; Hesmer, 1958; Rubner, 1960; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Dengler, 1990). They do not refer in any way to firewood cutting.

According to written sources, the damage to seedlings by livestock in a regenerating tree forest became a problem in the lowlands in the 18th century for the regeneration of trees after this method of wood production had been generally introduced. Foresters insisted on the end of the eternal grazing rights of commoners and a division between pasture and the cultivation of wood (Landolt, 1866; Grossmann, 1927; Vanselow, 1926; Meyer, 1941; Hesmer, 1958; Schubart, 1966; Buis, 1985; Mantel, 1990). For the realization of this division the abolition of the commons was necessary and after that the distribution of the common land. With the exception of a few places this took place in Western and Central Europe during the course of the 18th and 19th centuries (Hobe, 1805; Grossmann, 1927; Buis, 1985; Mantel, 1990). This division between pasture and the cultivation of wood still applies today. In this way, the landscape changed from a combination of fields with crops, coppices and wood-pastures into one of fields and open grasslands as pasture ("weide") on the one hand, and closed forests for wood production on the other hand. The words "forest", "forêt", "Forst", "Wald" or "woud" still applied on the uncultivated, but became synonymous with the uncultivated only intended for wood production, the high forest (Vera, 2000). The consequence of this division is that when it comes to trees, it seems that people and scientists can only see them in the context of the forest, and not as individual species with different requirements in relation to daylight (Vera, 2013).

The division between pasture and wood production meant also a division between forest and ungulates. From now on ungulates were only seen and characterised in terms of damage to the forest (Vera, 2000; 2013). As a consequence of the theory that the original natural vegetation was a high forest, as mentioned above, the wood-pasture as a whole was considered to be a degraded high forest (Ellenberg, 1988; Tansley, 1953). The grazing of livestock in wood-pastures was considered as unnatural because livestock were considered to be exotic species, introduced by man (Forbes, 1902; Moss, 1913; Tansley, 1911). Grasslands and heaths in wood-pastures were therefore characterized as 'stolen' from the forest (Warming, 1909). The evidence for the theft that when grazing ends, trees 'spring up' and the forest returns, as well as tree return in pieces of pasture that are fenced off from the grazing animals (Forbes, 1902; Krause, 1892; Tansley, 1911). Grazing livestock was seen as the greatest enemy of forests, which made any improvement of forestry impossible (Landolt, 1866; Vera, 2000). This separation between ungulates and forests caused eventually a great loss of biodiversity.

The wood-pasture and biodiversity

Unlike to the closed-canopy, high-forest, the wood-pasture system enables light-demanding and shade tolerant tree species to survive in the context of one system. As mentioned above these are sessile and pedunculate oak and wild fruit species such as wild apple, wild pear and wild cherry and European sorbus species such as whitebeam (*S. aria*), service tree (*S. domestica*), the chequers tree (*S. torminalis*) also includes all indigenous shrub species (Vera, 2000). On a European scale, some of these are threatened species (Kätzel et al., 2011). The wood-pasture is also a very diverse landscape, varying from savannah-like to park-like (see Photograph 1, 6 and 9). This results in a high diversity of tree shape, namely grove-grown and open-grown trees. The grove-grown trees are in shape like the closed-canopy grown trees, while the open-grown trees have short trunks and low at the trunk are massive spreading branches forming a majestic huge broad crown. They are very impressive and often recognisable individually by the shape of their crown. These open grown trees themselves are important for many plant and animals species, in combination with the open surroundings (Antonsson and Jansson, 2001; Butler et al., 2001; Green 2009; Manning et al., 2006). This applies especially to both oak species to which more species are connected that any other indigenous European tree (Morris, 1974; Schuffenhauer, 2011; Ek and Johanesson, 2005; Vodka et al., 2009). Many species, like for instance the rare hermit beetle (*Osmoderma eremita*), need trees of a very old age, called the veteran tree stage. In a closed-canopy high forest, oak will never reach this stage because of the low stature that is its characteristic. This low stature is caused by the downward growth of oak starting at the age of around 300 years. The upper canopy dies off while new branches and canopy forms lower down the trunk (Green, 2009) (Photograph 15). This results ultimately in the characteristic short conic formed oak of an age of about a thousand years. Such oaks can be seen in Windsor Great Park in England and other wood-pasture systems (Pater, 2010). An oak cannot develop such a shape because it will be killed before that by the shade of the trees that regenerate in the gap in the canopy that is formed by the downwards growth of the oak, or it will be killed by higher neighbouring trees (Alexander et al., 2011; Vera, 2000). The killing of veteran oaks is known from all former wood-pastures (Pater, 2010; Rapp and Schmidt, 2006; Sperber and Thierfelder, 2008). Both individual genetic characteristics as well as the genetic characteristics of the individual species of trees are revealed by the wood-pasture-system.

The epiphytic demanding lichen flora in the New Forest in England forms one example of the floristic richness of a wood-pasture. The large majority of lichens requires light, and is found mainly on the fringes of groves (Rose, 1974; 1992). With 278 species is this flora the richest of the lowlands of Western Europe (Rose, 1974; 1992; Tubbs, 1988). The groves richest in this flora contain 130 to 178 species per km^2. By way of comparison, there is no forest area known in the lowlands of the continental part of Western Europe which contains more than 150 species (Rose and James, 1974, cited by Tubbs, 1988). The blackthorn scrub also contains flora of characteristic beard moss (*Usnea* sp.). The two species of oak are particularly rich in epiphytes, and up to 150 species of epiphytes can be found on them (Rose, 1974). Because this flora contain species which do no spread easily, and which are found, in so far as it is possible to check this, only in places where there has been a continuous cover of trees, Rose and James (1974) believe that their presence goes back to the Atlantic primeval forest (Rose and James, 1974, cited by Tubbs, 1988). However, in view of the importance of the two species of oak for this flora, and the fact that these epiphytes are mainly found on the periphery of forests, it could also be maintained that this character indicates the historical continuity of a park-like landscape, and the factors responsible for this, such as the large herbivores (Rose, 1974).

Photograph 15: A conic formed oak. This shape develops after the crown dies back and new branches are formed low at the trunk forming a second crown. The trunk grows then thicker, which eventually result in this typical conic shape. Such trees harbor a typical beetle assemblage with nowadays rare species. Because of it characteristic low stature it cannot survive in a closed canopy forest, because it would be killed by adjacent higher trees. Calk Abbey Park, England (F. Vera).

The mosaic of grasslands, shrubs, thickets, trees and groves – the last of these surrounded by mantle and fringe vegetation – vary in relation to each other in surface. The grasslands in the wood-pasture also contain a lot of grass and herb species. The grasslands of the wood-pastures are very rich in species (Salisbury (1918; Adamson, 1921; 1932; Tansley, 1953; Müller, 1962; Tüxen, 1952; Sjörgen, 1988; Dierschke, 1974; Rosén, 1988; Tubbs, 1988; Pott and Hüppe, 1991; Rodwell, 1991; Kollman, 1992;

Photograph 16: A dead oak (*Quercus* spp.) in a former wood-pasture, killed by shade tolerant tree species like beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) that came up after grazing by livestock ceased. The thick branches low at the trunk of the dead tree shows that it grew up in open landscape. It is nowadays presented as a new primeval forest. Sababurg, Germany (F. Vera).

Hondong et al., 1993; Pietzarka and Roloff, 1993; Bossuyt et al., 2005). It can be stated that it can contain all the species of grasses and plants which are now found only in various types of agricultural grasslands (Hillegers, 1986; Wolkinger and Plank, 1981; Ellenberg, 1988).

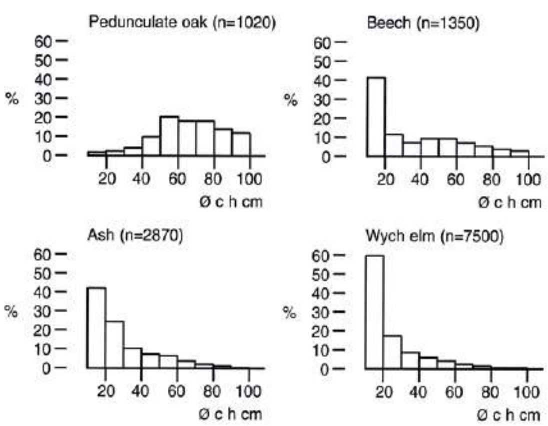
The variability in vegetation types, vegetation structures and combinations of these makes a high diversity of animal species possible. This is because of the high diversity (Alexander, 2011; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Schuffenhauer, 2011; Schulze-Hagen, 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009). Wood-pastures are characterised by a large diversity of species of invertebrates, including insects (Darlington, 1974; Morris, 1974; Tubbs, 1988; Hondong et al., 1993; Alexander, 1998, 2001; 2005; Alexander et al., 2006; Appelqvist et al., 2001; Ranius et al., 2005; 2008; Vodka et al., 2009; Schuffenhauer, 2011). More than 50% of all the species of insects found in the whole of Great Britain live in the New Forest alone (20.000 hectares) (Tubbs, 1988). The New Forest and Windsor Forest are the richest areas in England. The cause of this is the presence of the very old trees in particular (Alexander, 1998). Of all the European species of butterflies, 80% live in a habitat combining grasslands, scrub and groves with mantle vegetation (Bink, 1992). The oak has a special place as a host for insects. There is no other species of tree in Europe associated with so many species of insects (Darlington 1974; Morris, 1974; Vodka et al., 2009; Schuffenhauer, 2011). As we read above, the oak plays a prominent role in wood-pasture. Furthermore, there is an enormous variety of species of birds in grazed, park-like landscapes (Smith, 1980; Tubbs, 1988; Hondong et al., 1993; Schepers, 1993; Cramp and Simmons, 1980; 1988; 1992). These include the nightingale (*Luscinia megarhynchos*), whitethroat (*Sylvia communis*), lesser whitethroat (*Sylvia cuorruca*), garden warbler (*Sylvia borin*), red-backed shrike (*Lanius collurio*), song thrush (*Turdus philomelos*), all the species of woodpeckers, and many birds of prey, including the common buzzard (*Buteo buteo*), goshawk (*Accipiter gentilis*), hobby (*Falco subbuteo*) and Imperial eagle (*Aquila heliaca*). Many species of birds, particularly songbirds, are dependent on the combination of grassland, scrub and groves. Grazed, park-like landscapes are even the last places in Europe where the imperial eagle breeds (Cramp and Simmons, 1980; Voous, 1986). In their turn, the birds contribute to the diversity in grazed landscapes, as noted above. Apart from the jay, whose role in the establishment of oak was discussed earlier in detail, songbirds are particularly important for the establishment of species of plants with fleshy fruits, such as wild fruit trees, hawthorn and blackthorn.

The wood pasture as the closest modern analogue of the natural vegetation

The wood-pasture system driven by indigenous large herbivores enables light-demanding tree species to survive in the presence of the shade-tolerant in the context of one system. Besides all light-demanding tree species mentioned before, it provides habitat to various shrub species such as hazel, common spindle (*Euonymus europeus*), Guelder rose (*Viburnum opulus*) common

Figure 12.3

The percentage diameter distribution of four species of trees in diameter categories in the National Park Dalby Söderskog in South Sweden



Only trees with a trunk diameter of >10cm at chest height are included. Pedunculate oak (*Quercus robur*) is a light demanding tree species with a bell-shaped distribution, which means that it is a population that is dying out. Beech (*Fagus sylvativca*), Ash (*Fraxinus excelsior*) en Wych elm (*Ulmus glabra*) are shade tolerant tree species. Their population shows an inverse J-curve, which means they have healthy population (from Vera, 2000, redrawn from Malmer et al., 1978, p.20).

privet (*Ligustrum vulgare*), blackthorn, hawthorn, common dogwood (*Cornus sanguinea*), elder (*Sambucus nigra*), common gorse (*Ulex europaeus*), broom (*Cysticus scoparius*), barberry (*Berberis vulgaris*), red currant (*Ribes silvestre*) and black current (*R. nigrum*). As far as it concerns wind pollinated species this is proven by pollen diagrams from the primeval vegetation. This is contrary to the closed-canopy, high-forest system where all light demanding tree and shrub species become extinct as proven in former wood-pastures that changed into closed canopy forests after large ungulates were removed or made functionally non-existent by culling (Malmer et al., 1978; Vera, 2000; 2009; 2013) (Photograph 16 and Figure 12.3). The wood-pasture system therefore can be regarded as the closest modern analogy of the natural vegetation (Smit and Putman, 2011; Vera, 2000; 2009; 2013). As mentioned above, the wood-pasture system is a very diverse landscape varying from savannah-like to park-like. This mosaic is shaped by a reciprocal interaction between plant and animal species. Beside a high diversity of shrub and tree species, the system is also characterized by a high diversity of animal species. This is because of the high diversity in vegetation types, vegetation structures and combinations of these (Alexander, 1998, 2001; 2005; Alexander et al., 2006; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Ranius et al., 2005; 2008; Schuffenhauer, 2011; Schulze-Hagen., 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009).

References

Adamson, R.S., 1921. The woodlands of Ditcham Park, Hampshire. *Journal of Ecology*, 9: 114-219.

Adamson, R.S., 1932. Notes on the natural regeneration of woodland in Essex. *Journal of Ecology*, 20: 152-156.

Addison, W., 1981. *Portrait of Epping Forest*. Robert Hale, London.

Alexander, K.N.A., 1998. *The Links between Forest History and Biodiversity: the Invertebrate Fauna of Ancient Pasture-Woodlands in Britain and its Conservation*. In: Kirby, K.J. and Watkins, C. (Eds.) The Ecological History of European Forests. CAB International, Wallingford, United Kingdom, 73-80.

Alexander, K., 2001. *What are veteran trees? Where are they found? Why are they important?* In: Read, H., Forfang, A.S., Marciau, R., Paltto, H., Andersson, L. and Tardy, B. (Eds.), Tools for preserving woodland biodiversity, Textbook 2. Nanonex, programme September 2001, Leonardo da Vinci, Sweden, 28-31.

Alexander, K., 2005. Wood decay, insects, palaeoecology, and woodland conservation policy and practice – breaking the halter. *Antenna*, 29: 171-178

Alexander, K., Butler, J. and Green, T., 2006. The value of different tree and shrub species to wildlife. *British Wildlife*, October 2006, 18-28.

Alexander, K., Sticker, D. and Green, T., 2011. Rescuing veteran trees from canopy competition. *Conservation Land Management*, Spring 2011, 12-16.

Andersen, S. Th., 1990. *Changes in Agricultural Practices in the Holocene Indicated in a Pollen Diagram from a Small hollow in Denmark*. In: Birks, H.H. Birks, H.J.B. Kaland P.E. and Moe, D. (Eds.), The Cultural Landscape. Past, Present and Future. Cambridge University Press, Cambridge, 395-407.

Andersson, C. and Frost, I., 1996. Growth of *Quercus robur* seedlings after experimental grazing and cotyledon removal. *Acta Botanica Neerlandica*, 45: 85-94.

Antonsson, K. and Jansson, N., 2001. *Ancient trees and their fauna and flora in the agricultural landscape in the County of Östergötland*. In: Andersson, L., Marciau, R. and Paltto, H. (Eds.), Tools for preserving woodland biodiversity, Textbook 2. Nanonex, programme September 2001, Leonardo da Vinci, Sweden:, 37-41.

Appelqvist, T., Gimdal, R. and Bengston, O., 2001. *Insect and mosaic landscapes*. In: Andersson, L., Marciau, R. and Paltto, H. (Eds), Tools for preserving biodiversity in nemoral and boreonemoral biomes of Europe. Textbook 1. Nanonex, Leonardo da Vinci, nature and culture, 14-24.

Austad, I., 1990. *Tree Pollarding in Western Norway*. In: Birks, H.H. Birks, H.J.B. Kaland, P.E. and Moe, D. (Eds.), The Cultural Landscape, Past, Present and Future. Cambridge University Press, Cambridge, 11-29.

Bakker, E.S., Olff, H., Vendenberghe, C., De Maeyer, K., Smit, R., Gleichman, J.M. and Vera, F.W.M., 2004. Ecological anachronisms in the recruitment of temperate light-demanding tree species in wooded pastures. *Journal of Applied Ecology*, 4: 571-582.

Bär, J., 1914. Die Flora des Val Onsernone. *Mitteilungen aus dem botanischen Museum der Universität Zürich*, 59: 223-563.

Bernátsky, J., 1905. Anordnung der Formationen nach ihrer Beeinflussung seitens der menschlichen Kultur und der Weidetiere. *Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie*, 34: 1-8, Leipzig.

Best, J.A., 1998. *Persistent Outcomes of Coppice Grazing in Rockingham Forest, Northamptonshire, UK.* In: Kirby, K.J. and Watkins, C. (Eds.), The Ecological History of European Forests. CAB International, Wallingford, United Kingdom, 63-72.

Bezacinský, H., 1971. Das Hainbuchenproblem in der Slowakei. *Acta Facultatis Forestalis*, 8: 7-36.

Bieleman, J., 1992. *Geschiedenis van de landbouw in Nederland 1500-1950. Verandering en verscheidenheid*. Boom, Meppel/ Amsterdam.

Bink, F.A., 1992. *Ecologische Atlas van de Dagvlinders van Noordwest-Europa*. Instituut voor Bos- en Natuuronderzoek en Unie van Provinciale Landschappen, Schuyt & Co, Haarlem.

Bobiec, A., 2012. Białowieża Primeval Forest as a remnant of culturally modified ancient forest. *European Journal for Forest Research*, 131: 1269-1285.

Böckmann, T., 1990. Wachstum und Ertrag der Winterlinde (*Tilia cordata* Mill.) in Niedersachsen und Nordhessen. Dissertation Universität Göttingen, Göttingen.

Bogucki, P., 1988. *Forest Farmers and Stockholders. Early Agriculture and its Consequences in North-Central Europe*. Cambridge University Press, Cambridge.

Bogucki, P. and Grygiel, R., 1983. Early Farmers of the North European Plain. *Scientific American*, 48: 104-112.

Bokdam, J., 1987. *Foerageergedrag van jongvee in het Junner Koeland in relatie tot het voedselaanbod.* In: De Bie, S., Joenje, W., and Van Wieren, S.E. (Eds.), Begrazing in de natuur Pudoc, Wageningen, 165-186.

Bokdam, J., 2003. Nature Conservation and Grazing Management. Free-Ranging Cattle as Driving Force for Cyclic Vegetation Succession. PhD. thesis, Wageningen University, Wageningen.

Bonnemann, A., 1956a. Eichen-Buchen Mischbestände. *Allgemeine Forst- und Jagdzeitung*, 127: 33-42.

Bonnemann, A., 1956b. Eichen-Buchen Mischbestände. *Allgemeine Forst- und Jagdzeitung*, 127: 118-126.

Bossema, J., 1968. Recovery of acorns in the European jay (*Garrulus* G. *glandarius* L.). *Proceedings Koninklijke Nedederlandse Akademie van Wetenschappen Serie C, Biological and Medical Sciences*, 71: 10-14.

Bossema, J., 1979. Jays and Oaks: An Eco-Ethological Study of a Symbiosis. PhD. Thesis Rijksuniversiteit Groningen, Groningen (Also published in *Behaviour*, 70: 1-117.).

Bossuyt, B., De Fré, B. and Hoffmann, M., 2005. Abundance and flowering success patterns in a short-term grazed grassland: early evidence of facilitation. *Journal of Ecology*, 93: 1104-1114.

Brincken, J., 1826. *Mémoire Descriptive sur La Forêt Impériale de Białowieża en Lithuanie*. Annoté et commenté par Piotr Daszkiewicz, Bogumila Jędrzejewska and Tomasz Samojlik. Epigraf (2004), Paris.

Bühler, A., 1918. *Der Waldbau nach wissenschaftlicher Forschung und praktischer Erfahrung*. I Band. Eugen Ulmer, Stuttgart.

Bühler, A., 1922. *Der Waldbau nach wissenschaftlicher Forschung und praktischer Erfahrung*. II Band. Eugen Ulmer, Stuttgart.

Buis, J., 1985. *Historia Forestis: Nederlandse bosgeschiedenis*. Deel 1 en 2. H & S Uitgevers, Utrecht.

Buis, J., 1993. *Holland Houtland. Een geschiedenis van het Nederlandse bos*. Prometheus, Amsterdam.

Butler, J. E., Rose, F. and Green, T.E., 2001. *Ancient trees, icons of our most important wooded landscapes in Europe*. In: Read, H., Forfang, A.S., Marciau, R., Paltto, H., Andersson, L. and Tardy, B. (Eds.), Tools for preserving woodland biodiversity, Textbook 2. Nanonex, programme September 2001, Leonardo da Vinci, Sweden, 28-31.

Buttenschøn, J. and Buttenschøn, R.M., 1978. The effect of browsing by cattle and sheep on trees and bushes. *Natura Jutlandica*, 20: 79-94.

Buttenschøn, J. and Buttenschøn, R.M., 1985. Grazing Experiments with Cattle and Sheep on Nutrient Poor, Acidic Grassland and Heath. IV.: Establishment of Woody Species. *Natura Jutlandica*, 21: 47-140.

Callaway, R. M., Kikvidze, Z. and Kikodze, D., 2000). Facilitation by unpalatable weeds may conserve plant diversity in overgrazed meadows in the Caucasus Mountains. *Oikos*, 89: 275–82.

Chettleburgh, M.R., 1952. Observations on the collection and burial of acorns by jays in Hinault Forest. *British Birds*, 45: 359-64. Also further note (1955), 48: 183-4.

Clutton-Brock, J., 1989. *A Natural History of Domesticated Mammals*. Cambridge University Press, British Museum (Natural History), London.

Coops, H., 1988. Occurence of blackthorn (*Prunus spinosa* L.) in the area of Mols Bjerge and the effect of cattle- and sheep-grazing on its growth. *Natura Jutlandica*, 9: 169-176.

Cotta, H., 1865. *Anweisung zum Waldbau*. (Neunte, neubearbeitete Auflage) Arnoldische Buchhandlung, Leipzig.

Cramp, S. (Ed.), 1980. *Handbook of the Birds of Europe, the Middle East, and North Africa. The Birds of the Western Palearctic. Vol II. Hawks to Bustards.* Oxford University Press, Oxford.

Cramp, S. (Ed.), 1988. *Handbook of the Birds of Europe, the Middle East, and North Africa. The Birds of the Western Palearctic. Vol V, Tyrant Flycatchers to Thrushes*. Oxford University Press, Oxford.

Cramp, S. (Ed.), 1992. *Handbook of the Birds of Europe, the Middle East, and North Africa. The Birds of the Western Palearctic. Vol VI, Warblers.* Oxford University Press, Oxford.

Darby, H.C., 1970. *The Clearing of the Woodland in Europe.* In: Thoman, Jr.W.L. (Ed.), Man's Rôle in Changing the Face of the Earth. The University of Chicago Press, Chicago, London, 183-216.

Darlington, A., 1974. *The galls on oak*. In: Morris, M.G. and Perring, F.H. (Eds.), The British oak. Its History and Natural History. The Botanical Society of the British Isles, E.W. Classey, Berkshire, 298-311.

De Vries, J., 1970. *Etymologisch woordenboek. Waar komen onze woorden vandaan?* Het Spectrum, Utrecht/Antwerpen.

Den Ouden, J., Jansen, P.A., and Smit, R., 2005. *Jays, Mice and Oaks: Predation and Dispersal of Quercus robur and Q. petraea in North-western Europe*. In: Forget, P.-M., Lambert, J.E., Hulme, P.E. and Vander Wall, S.B. (Eds.), Seed Fate: Predation, Dispersal and Seedling Establishment, CAB International, Wallingford, Chapter 13, 223-239.

Dengler, A., 1990. *Waldbau auf ökologischer Grundlage, Zweiter band. Baumartenwahl, Bestandesbegründung und Bestandespflege*. 6th. edn. by Röhrig, E. and Gussone, H.A. Verlag Paul Parey, Hamburg and Berlin.

Dengler, A., 1992. *Waldbau auf ökologischer Grundlage, Erster Band. Der Wald als Vegetationsform und seine Bedeutung für den Menschen*. 6th. edn. by Röhrig, E. and Gussone, H.A. Verlag Paul Parey, Hamburg and Berlin.

Dierschke, H., 1974. *Saumgesellschaften im Vegetations- und Standortsgefälle an Waldrändern.* Scripta Geobotanica, Göttingen, 6, 3-246.

Dobson, A. and Crawley, M., 1994. Pathogens and the structure of plant communities. *Trends in Ecology and Evolution*, 9, 393–398.

Duby, G., 1968. *Rural Economy and Country Life in the Medieval West*. Edward Arnold Publishers. Translated from the French.

Eglar, F.E., 1954. Vegetation science concepts. I. Initial floristic composition, a factor in old-field vegetation development. *Vegetatio*, 4, 412-417.

Ek, van T. and Johannesson, J. (eds.), 2005. *Multi-purpose management of oak habitats. Examples of best practice from the county of Östergötland, Sweden*. County administration of Östergötland, Report 2005, 16 p.

Ekstam, U. and Sjörgen, E., 1973. Studies on Past and Present Changes in Deciduous Forest Vegetation on Öland. Zoon, Uppsala, Suppl. 1: 123-135.

Elerie, J.N.H., 1993. *Cultuurhistorie en de ecologie van een veldcomplex op de Hondsrug*. In: Elerie, J.N.H. (Ed.), Landschapsgeschiedenis van de Strubben/Kniphorstbos. Archeologische en historisch-ecologische studies van een natuurgebied op de Hondsrug. Van Dijk en Foorthuis REGIO-PRoject, Groningen, III: 79-165.

Ellenberg, H., 1986. *Vegetation Mitteleuropas mit den Alpen in ökologischer Sicht*. Vierte, verbesserte Auflage. Verlag Eugen Ulmer, Stuttgart.

Ellenberg, H., 1988. *Vegetation Ecology of Central Europe*. 4th edn. Cambridge University Press, Cambridge.

Emborg, J., Christensen, M. and Heilmann-Clausen, J., 1996. The structure of Suserup skov. A near-natural temperate deciduous forest in Denmark. *Forest and Landscape Research*, 1: 311–333.

Emborg, J., Christensen, J. and Heilman-Clausen, J., 2000. The structural dynamics of Suserup Skov, a near-natural temperate deciduous forest in Denmark. *Forest Ecology and Management*, 126: 173-189.

Endres, G., 1929. Die Eichen des Spessarts. *Forstwissenschaftliches Centralblatt,* Märzheft, 149-228.

Endres, M., 1888. *Die Waldbenutzung von 13. bis Ende des 18. Jahrhunderts. Ein Beitrag zur Geschichte der Forstpolitik.* Verlag der H. Laupp'schen Buchhandlund, Tübingen.

Erteld, W., 1963. Über die Wachstumsentwichlung der Linde. *Archiv für Forstwesen*, 12: 1152-1158.

Evans, J., 1992. *Coppice forestry; an overview*. In: Buckley, G.P. (Ed.) Ecology and Management of Coppice Woodland. Chapman & Hall, London, pp. 18-27.

Felius, M., Beerling, M-L., Buchanan, D.S., Theunissen, B., Koolmees, P.A. and Lenstra, J.A., 2014. On the History of Cattle Genetic Resources. *Diversity*, 6: 705-750.

Flörcke, E., 1967. *Vegetation und Wild bei Sababurg im Reinhardswald in Vergangenheit und Gegenwart*. Geobotanische Mitteilungen, 48. R. Knapp, Giessen.

Flower, N., 1977. *An Historical and Ecological Study of Inclosed and Uninclosed Woods in the New Forest*. Hampshire. MSc thesis, King's College, University of London.

Flower, N., 1980. The management history and structure of unenclosed woods in the New Forest, Hampshire. *Journal of Biogeography*, 7: 311-328.

Forbes, A.C., 1902. On the regeneration and formation of woods from seed naturally of artificially sown. *Transactions of the English Arboricultural Society*, 5: 239-270.

Fricke, O., 1982. Die Entwicklung von Eichen-Jüngwüchsen und -Jüngbeständen mit gleichalten Mischbaumarten. Thesis Univesrity of Göttingen, Göttingen.

Fricke, O. Kürschner, K. and Röhrig, E., 1980. Unterbau in einem Stieleichenbestand. *Forstarchiv*, 51: 228-232.

Fritzbørger, B. and Emborg, J., 1996. Landscape History of the Deciduous Forest Suserup Skov, Denmark, Before 1925. *Forest and Landscape Research*, 1: 291-309.

Gayer, K., 1886. *Der gemischte Wald, seine Begründung und Pflege, insbesondere durch Horst- und Gruppenwirtschaft*. Paul Parey, Berlin.

Gill, R., 2006. *The influence of large herbivores on tree recruitment and forest dynamics*. In: Danell, K., Duncan, P., Bergström, R., & Pastor, J. (eds.) Large Herbivore Ecology, Ecosystem Dynamics and Conservation, Cambridge University Press, Cambridge, 170-202.

Goriup, P.D., Batten, L.A. and Norton, J.A. (eds.), 1991. *The conservation of lowland dry grassland birds in Europe*. Proceedings of an international seminar held at the University of Reading, 20-22 March 1991. Joint Nature Committee, Peterborough.

Gothe, H., 1949. Forstmeister Friedrich Jäger und sein Wirken im Forstamt Schlitz. *Forstwissenschaftliches Centralblatt*, December, 761-769.

Gradmann, R., 1901. Das mitteleuropäische Landschaftsbild nach seiner geschichtlichen Entwicklung. *Geographische Zeitschrift*, 7: 361-447.

Green, T., 2009. *Ancient trees growing downwards*. [http://www.treeworks.co.uk/downloads/Veteran_Environmental_Papers/Growing_Downwards_ancient_trees_Jan_05.pdf.]

Green, T., 1992. The forgotten army. *British Wildlife*, 4: 85–6.

Groot Bruinderink, G.W.T.A. Hazebroek, E. and Voet, H. van der, 1994. Diet and condition of wild boar, *Sus scrofa scrofa*, without suplementary feeding. *Journal of Zoology*, 233: 631-648.

Grossmann, H., 1927. Die Waldweide in der Schweiz. Promotionsarbeit, Zürich.

Guliver, R., 1998. *What were Woods Like in the Seventeenth Century? Examples from the Helmsley Estate, Northeast Yorkshire, UK*. In: Kirby, K.J. and Watkins, C. (Eds.), The Ecological History of European Forests. CAB International. Wallingford. United Kingdom, 135-153.

Habets, J., 1891. *Limburgse wijsdommen. Dorpscostumen en gewoonten, bevattende voornamelijk Bank- Laat- en Boschrechten*. Oude Vaderlandsche Rechtsbronnen. Martinus Nijhoff, 's-Gravenhage.

Hagerup, O., 1942. The Morphology and Biology of the Corylus-fruit. Biologiske Meddelelser, *Kongolige Danske Videnskabernes Selskab*, 17(6): 1-42.

Hard, G., 1975. Vegetationsdynamik und Verwaldungsprozesse auf den Brachflächen Mitteleuropas. *Erde*, 106: 243-276.

Hard, G., 1976. *Vegetationsentwicklung auf Brachflächen*. In: Bierhals, E. von Gehle, L. Hard, G. and Nohl, W. (Eds.), Brachflächen in der Landschaft KTBL-Schriften-Vertrieb im Landwirtschaftsverlag, Münster-Hiltrup, KTBL-Schrift, 195, 243-276.

Harding, P.T. and Rose, F., 1986. *Pasture-woodlands in Lowland Britain. A review of their importance for wildlife conservation*. Natural Environment Research Council. Institute of Terrestrial Ecology, Huntingdon.

Hart, G.E., 1966. *Royal Forest. A History of Dean's Woods as Producers of Timber*. Clarendon Press, Oxford.

Hausrath, H., 1898. *Forstgeschichte der rechtsrheinischen Theile des ehemaligen Bisthums Speyer*. Julius Springer, Berlin.

Hausrath, H., 1928. Beiträge zur Geschichte des Nieder- und Mittelwaldes in Deutschland. *Allgemeine Forst- und Jagdzeitung*, 104: 345-348.

Hausrath, H., 1982. *Geschichte des deutschen Waldbaus. Von seinen Anfängen bis 1850*. Hochschulverlag Freiburg (Breisgau).

Herrmann, H., 1915. Die Eichelmastnutzung einst und jetzt. *Forstwissenschaftliches Centralblatt*, 37: 51-60.

Hesmer, H., 1958. *Wald- und Forstwirtschaft in Nordrhein-Westfalen*, Hannover.

Hesmer, H., 1966. *Ökologisches und waldbauliches Verhalten der Winterlinde*. Landwirtschaft- Angewandte Wissenschaft, 123: 17-19.

Hesmer, H. and Schroeder, F-G., 1963. *Waldzusammensetzung und Waldbehandlung im Niedersächsischen Tiefland westlich der Weser und in der Münsterschen Bucht bis zum Ende des 18 Jahrhunderts. Forstgeschichtlicher Beitrag zur Klärung der natürlichen Holzartenzusammensetzung und ihrer künstlichen Veränderungen bis in die frühe Waldbauzeit*. Decheniana, Beiheft, 11: 1-304.

Hesmer, H. and Günther, K-H., 1966. Kulturversuche und Aufforstungserfahrungen auf Pseudogleyböden des Kottenforstes. *Forstarchiv*, 37: 1-26.

Hess, E., 1937. Die Bewirtschaftung der Eichenwälder von Blois in Frankreich. *Schweizerische Zeitschrift für Forstwesen*, 88: 91-100.

Hilf, R.B., 1938. *Wald und Weidwerk in Geschichte und Gegenwart*. Erster Teil. Der Wald. Akademische Verlaggesellschaft Athenaieon, Potsdam.

Hillegers, H.P.M., 1986. Klagraslanden. *Natuur en Techniek*, 54(4): 262-275.

Hobe, J.H. von, 1805. *Freymüthige Gedanken über verschiedene Fehler bey dem Forsthaushalt, insbesondere über die Viehude in den Holzungen, deren Abstellung und Einschränkung*. Thal-Ehrenbreitstein, in der Gehraschen Hofbuchhandlund.

Hofmann, R.R., 1973. *The Ruminant Stomach: Stomach Structure and Feeding Habits of East African Game Ruminants*. East African Literature Bureau, Nairobi, Kenya.

Hofmann, R.R., 1976. Zur adaptiven Differenzierung der Wiederkäuer: Untersuchungsergebnisse auf der Basis der vergleichenden funktionellen Anatomie des Verdauungstrakts. *Praktische Tierärtzt*, 57: 351-358.

Hofmann, R.R., 1985. Digestive Physiology of the Deer. Their Morphophysiological Specialisation and Adaptation. *The Royal Society of New Zealand Bulletin*, 22: 393-407.

Hofmann, R.R., 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*, 78: 443-457.

Hofmann, R. R., 2007. *Wildtiere in Bildern zur vergleichenden Anatomie*. M.& H. Schaper, Hannover.

Holmes, G.D., 1975. History of forestry and forest management. *Philosophical Transactions of the Royal Society of London Series B*. 271: 69-80.

Hondong, H., Langner, S. and Coch, T., 1993. *Untersuchungen zum Naturschutz an Waldrändern*. Bristol-Schriftenreihe, Band 2, Bristol-Stiftung, Ruth und Herbert UHL - Forschungsstelle für Natur- und Umweltschutz.

Hongo, H., Pearson, J., Öksüz, B. and Ilgezdi, G., 2009. The Process of Ungulate Domestication at Çayönü, Southeastern Turkey. A Multidisciplinary Approach focussing on *Bos* sp. and *Cervus elaphus*. *Anthropozoologica*, 44(1): 63-78.

Huygelen, C., 1997. The Immunization of Cattle against Rinderpest in Eighteenth-Century Europe. *Medical History*, 41: 182-196.

Iason, G. R. and Hester, A.J., 1993. The response of heather (*Calluna vulgaris*) to shade and nutrients – predictions of the carbon-nutrient balance hypothesis. *Journal of Ecology*, 81: 75–80.

Jago, B., 1999. *Feral Goat (Capra hircus) in Queensland. Pest Status Review – Land Protection*. Queensland Government Natural Resources and Mines. Department of Natural Resources and Mines, Queensland.

Jahn, G., 1987. Zur Frage der Eichenmischwaldgesellschaften in nordwestdeutschen Flachland. *Forstarchiv,* 58: 154-163 and: 194-200.

Jahn, G., 1991. *Temperate deciduous forests of Europe*. In: Röhrig, R. and Ulrich, B. (Eds.), Temperate Deciduous Forests. Ecosystems of the World, 7. Elsevier, Amsterdam: 377-503.

Jarvis, P.G., 1964. The adaptability to light intensity of seedlings of Quercus petraea (Matt.) Liebl. *Journal of Ecology*, 52: 545-571.

Johnson, E.A. and Miyanishi, K., 2008. Testing the assumptions of chronosequences in succession. *Ecology Letters,* 11: 419-431.

Jones, E.W., 1959. Biological Flora of the British Isles, *Quercus* L. *Journal of Ecology*, 47: 169-222.

Jones, M., 1998. *The rise, decline and extinction of spring wood management in south-west Yorkshire.* In: Watkins, C. (ed.), European Woods and Forests. Studies in Cultural History. CAB International. Wallingford. United Kingdom, 55-71.

Källander, H., 1993. Food caching in the European Nuthatch *Sitta europaea*. *Ornis Svecica*, 3: 49-58.

Kaspers, H., 1957. *Comitatus nemoris. Die Waldgrafschaft zwischen Maas und Rhein*. Beiträge zur Geschichte des Dürener Landes, Band 7, Düren und Aachen.

Kätzel, R., Schulze, T., Becker, F., Schröder, J., Riederer, J., Kamp, T., Wurm, A. and Huber, G., 2011. *Seltene Baumarten in Deutschland – Erfassung und Erhaltung*, AFZ-DerWald, 19, 39-41.

Klaudisová, A. and Osbornová, J., 1990. *Abandoned fields in the region*. In: Osbornová, J., Kovářová, M., Lepš, J. and Prach, K. (Eds), Succession in Abandoned Fields. Studies in Central Bohemia, Czechoslovakia. Geobotany 15. Kluwer Academic Publishers, Dordrecht: 3-21.

Kollmann, J., 1992. Gebüschenwicklung in Halbtrockenrasen des Kaiserstuhls. *Natur und Landschaft*, 67: 20-26.

Kollmann, J. and Schill, H.-P., 1996. Spatial patterns of dispersal, seed predation and germination during colonization of abandoned grassland by *Quercus petraea* and *Corylus avellana*. *Vegetatio*, 125: 193-205.

Koop, H., 1981. *Vegetatiestructuur en dynamiek van twee natuurlijke bossen: het Neuenburger en Hasbrucher Urwald*. Pudoc Centrum voor Landbouwpublicaties en Landbouwdocumentatie, Wageningen.

Koop, H., 1987. Vegetative reproduction of trees of some European natural forests. *Vegetatio*, 72: 103-110.

Korpel, S., 1995. *Die Urwälder der Westkarpaten*. Gustav Fischer Verlag, Stuttgart.

Koss, H., 1982. Verbreitung, ökologishe Ansprüche und waldbauliche Verwendung der Winterlinde (*Tilia cordata* Mill.). *Forst- und Holzwirtschaft*, 37: 381-385.

Kraft, G., 1894. Zur Erziehung der Eiche, mit besonderer Rücksicht auf den Spessart. *Zeitschrift für Forst- und Jagdwesen,* 26: 389-405.

Krahl-Urban, J., 1959. *Die Eichen. Forstliche Monographie der Traubeneiche und der Stieleiche*. Paul Parey, Berlin.

Krasińska, M. and Krasiński, Z.A., 2007. *European Bison*. The Nature Monograph. Mammal Research Institutre Polish Academy of Sciences Białowieża, Białowieża.

Krause, E.H.L., 1892. Die Heide. Beitrag zur Geschichte des Pflanzenwuchses in Nordwesteuropa. *Engleis Botanisches Jahrbuch*, 14: 517-539.

Landolt, E., 1866. *Der Wald, seine Verjüngung, Pflege und Benutzung*. Schweizerischer Forstverein, Zürich.

Larson, G., Dobney, K., Albarella, U., Fang, M., Matisso-Smith, E., Robins, J., Lowden, S., Finlayson, H., Brand, T., Willerslev, E., Rowley-Conwy, P., Andersson, L. and Cooper, A., 2005. Worldwide Phylenography of Wils Boar Reveals Multiple Centers of Pig Domestication. *Science*, 11 March, 307: 1618-1621.

Leibundgut, H., 1959. Über Zweck und Methodik der Struktur und Zuwachsanalyse von Urwäldern. *Schweizerische Zeitschrift für Forstwesen*, 110: 111-124.

Leibundgut, H., 1978. Über die Dynamik europäischer Urwälder. *Allgemeine Forstzeitschrift*, 33: 686-690.

Löhrl, H. 1967. *Die Kleiber Europas*. Die Neue Brehm-Bücherei, Ziemsen Verlag, Wittenberg Lutherstadt.

Ludwig, A., Pruvost, M., Reissmann, M., Benecke, N., Brockman, G.A., Castanos, P., Cieslak, M., Lippold, S., Llorente, L., Malaspinas, A.S. Slatkin, M. and Hofreiter, M., 2009. *Coat color variation at the beginning of horse domestication*. Science 24 April, 384; 485 plus supplement.

Malmer, N. Lindgren, K. and Persson, S., 1978. Vegetational succession in a south-swedish deciduous wood. *Vegetatio*, 36: 17-29.

Manning, A.D., Fischer, J. and Lindenmayer, D.B., 2006. Scattered trees are keystone structures – Implications for conservation. *Biological Conservation*, 132 (3): 311–321.

Mantel, K., 1968. Die Anfänge der Waldpflege und Forstkultur im Mittelalter unter der Einwirkung der lokalen Waldordnung in Deutschland. *Forstwissenschaftliches Centralblatt*, 67: 75-100.

Mantel, K., 1980. *Forstgeschichte des 16. Jahrhunderts unter dem Einfluß der Forstordnungen und Noe Meurers*. Paul Parey, Hamburg und Berlin.

Mantel, K., 1990. *Wald und Forst in der Geschichte*. M. und H. Schaper, Alfeld-Hannover.

Mantyk, A., 1957. Mehr Beachtung unseren Linden! *Forst- und Jagdzeitung*, 7: 84-86.

Matthyssen, E., 1998. *The Nuthatches*, T & A D Poyser, London.

Mayer, H., 1992. *Waldbau auf soziologisch-ökologischer Grundlage*. 4. Teilweise neu bearbeitete Auflage, Gustav Fischer, Stuttgart.

Meiggs, R., 1982. *Trees and timber in the ancient Mediterranean world*. Clarendon Press, Oxford.

Meiggs, R., 1989. *Farm forestry in the ancient Mediterranean.* Social Forestry Network. Network Paper 8b Odi. Agricultural Administration Unit. Regent's College, London.

Meyer, K.A., 1931. Geschichtliches von den Eichen in der Schweiz. *Mitteilungen der Schweizerischen Centralanstalt für das forstlichen Versuchswesen*, 16: 231-452.

Meyer, K.A., 1941. Holzartenwechsel und frühere Verbreitung der Eiche in der Westschweiz; Kanton Waadt: Vom Jura zum Jorat. *Mitteilungen der Schweizerischen Centralanstalt für das forstlichen Versuchswesen*, 22: 63-141.

Milchunas, D. G. and Noy-Meir, I., 2002. Grazing refuges, external avoidance of herbivory and plant diversity. *Oikos*, 99: 113–30.

Moreno, J., Lundberg, A. and Carlson, A., 1981. Hoarding of individual nuthatches *Sitta europaea* and marsh tits *Parus palustris*. *Ecography*, 4: 263–269.

Morosow, G., 1928. *Die Lehre vom Walde* (Translatian in German). Neumann, Neudamm.

Morris, M.G., 1974. *Oak as a habitat for insect life*. In: Morris, M.G. and Perring, F.H. (Eds.), The British Oak, Its History and Natural History. The Botanical Society of the British Isles, E.W. Classey, Berkshire, 274-297.

Moss, C.E., 1913. *Vegetation of the Peak District*. The University Press, Cambridge.

Mountford, E.P., Peterken, G.F., Edwards, P.J. and Manners, J.G., 1999. Long-term change in growth, mortality and regeneration of trees in Denny Wood, an old-growth wood-pasture in the New Forest (UK). *Perspectives in Plant Ecology, Evolution and Systematics*, 2: 223-72.

Mountford, E.P. and Peterken, G., 2003. Long-term change and implications for the management of wood-pastures: experience over 40 years from Denny Wood, New Forest. *Forestry*, 76: 19-43.

Muller, F. and Renkema, E.H., 1995. *Beknopt Latijns-Nederlands Woordenboek*. 12th. edn. Wolters-Noordhoff, Groningen.

Müller, T., 1962. *Die Saumgesellschaften der Klasse Trifolio-Geranietea sanguinei*. Mitteilungen. Floristisch-Soziologische Arbeitsgemeinschaft N.F., 9, 94-140.

Musall, H., 1969. *Die Entwicklung der Kulturlandschaft der Rheinniederung zwischen Karlsruhe und Speyer vom Ende des 16. bis zum Ende des 19. Jahrhunderts*. Heidelberger Geografische Arbeiten, 22.

Namvar, K. and Spethmann, W., 1985. Die Baumarten der Gattung Sorbus: Vogelbeere, Mehlbeere, Elsbeere und Speierling. *Allgemeine Forstzeitschrift*, 40: 937-943.

Newton, A.C., Cantarello, E., Lovegrove, A., Appiah, D. and Perella, L., 2013. *The influence of grazing animals on tree regeneration and woodland dynamics in the New Forest, England*. In: Rotherham, I. (Ed.), Trees, Forested Landscapes and Grazing Treescapes. Routledge, London: 163-179.

Nietsch, H., 1939. *Wald und Siedlung im vorgeschichtlichen Mitteleuropa*. Mannus-Bücherei 64, Rabitzsch Verlag, Leipzig.

Ollf, H. Vera, F.W.M. Bokdam, J. Bakker, E.S. Gleichman, J.M. Maeyer, K. de and Smit, R., 1999. Shifting mosaics in grazed woodlands driven by the alternation of plant facilitation and competition. *Plant Biology*, 1: 127-137.

Ottoni, G., Flink, L.G., Evin, A., Geörg, C., De Cupere, B., van Neer, W., Bartosiewicz, L., Linderholm, A., Barnett, R., Peters, J., Decorte, R., Waelkens, M., Vanderheyden, N., Ricaut, F-X., Çakirlar, C., Çevik, Ö., Rus Hoelzel, A., Mashkour, M., Karimlu, A.F.M., Seno, S.S., Danjat, J., Brock, F., Pinhasi, R., Hongo, H., Perzez-Enciso, M., Rasmussen, M., Frantz, L., Megens, H-J., Crooijmans, R., Groenen, M., Arbuckle, B., Benecke, N., Vidarsdottir, U.S., Burger, J., Cuchi, T., Dobney, K. and Larson, G., 2013. Pig Domestication and Human-Mediated Dispersal in Western Eurasia Revealed through Ancient DNA and Geometric Morphometrics. *Molecular Biology and Evolution*, 30(4): 824-830.

Outram, A.K., Stear, N.A., Bendrey, R., Olson, S., Kasparov, A., Zaibert, V., Thorpe, N. and Evershed, R.P., 2009. The earliest horse harnassing and milking. *Science*, March 6, 323(1519): 1332-1335.

Pater, J., 2010. *Europas alte Bäume. Ihre Geschichten, ihre Geheimnisse*. Kosmos, Stuttgart.

Penistan, M.J., 1974. *Growing oak*. In: Morris, M.G. and Perring, F.H. (Eds.), The British Oak, Its History and Natural History. The Botanical Society of the British Isles, E.W. Classey Ltd., Berkshire, 98-112.

Perea, R., San Miguel, A. and Gil, L., 2011. Flying vs. climbing: Factors controlling arboreal seed removal in oak-beech forests. *Forest Ecology and Management*, 262: 1251-1257.

Perlin, J., 1991. *A Forest Journey: The Role of Wood in the Development of Civilization*. Harvard University Press, Cambridge.

Peterken, G.F., 1996. *Natural Woodland. Ecology and Conservation in Northern Temperate Regions*. Cambridge University Press, Cambridge.

Peters, K., 1992. *Begrazing door runderen gedurende de laatste eeuwen in het woud van Białowieża (N.O. Polen/ W. Wit-Rusland)*. Landbouwuniversiteit Wageningen, Vakgroep Natuurbeheer, verslag no. 3022, Wageningen.

Picket, S.T.A., 1987. *Space - for - Time Substitution as an Alternative to Long-Term Studies*. In: Likens, G.E. (Ed.), Long-Term Studies in Ecology. Approaches and Alternatives. Springer Verlag, New York, 110-135.

Pietzarka, U. and Roloff, A., 1993. Dynamische Waldrandgestaltung. Ein Modell zur Strukturverbesserung von Wald aussenrändern. *Natur und Landschaft*, 68: 555-560.

Pigott, C.D. 1991. Biological flora of the British Isles. *Tilia cordata* Miller. *Journal of Ecology*, 79: 1147-1207.

Pott, R., 1983. *Geschichte der Hude-und Schneitelwirtschaft in Nordwestdeutschlands und ihre Auswirkung auf die Vegetation*. Oldenburger Jahrbuch, Bd. 83, 357-384.

Pott, R., 1992. Entwicklung der Kulturlandschaft Nordwestdeutschlands unter dem Einfluss des Menschen. *Zeitschrift der Universität Hannover*, Hochschulgem, 19: 3-48.

Pott, R. and Hüppe, J., 1991. *Die Hudenlandschaften Nordwestdeutschlands*. Westfälisches Museum für Naturkunde, Landschafsverband Westfalen-Lippe. Veröffentlichung der Arbeitsgemeinschaft für Biol.-ökol. Landesforschung, ABÖL, nr. 89, Münster.

Prins, H.H.T. and Jeugd, H.P. van der, 1993. Herbivore population crashes and woodland structure in East Africa. *Journal of Ecology*, 81: 305-314.

Pruski, W., 1963. Ein Regenerationsversuch des Tarpans in Polen. *Zeitschrift für Tierzüchtung und Züchtungsbiologie*, 79: 1-30.

Puster, D., 1924. Auenwirtschaft. *Forstwissenschaftliches Centralblatt*, 68: 448-460.

Putman, R.J., 1986. *Grazing in Temperate Ecosystems: Large Herbivores and the Ecology of the New Forest*. Croom Helm, Londen.

Rackham, O., 1975. *Hayley Wood. Its History and Ecology*. Cambridgeshire and Isle of Ely Naturalists' Trust. Cambridge.

Rackham, O., 1980. *Ancient Woodland. Its history, vegetation and uses in England*. Edward Arnold, London.

Rackham, O., 1989. *The Last Forest. The Story of Hatfield Forest*. Phoenix, London.

Rackham, O., 1993. *The History of the Countryside. The classic history of Britain's landscape, flora and fauna*. J.M. Dent, London.

Rackham, O., 2003. *Ancient Woodland. Its history, vegetation and uses in England*. New Edition. Castlepoint Press, Kirkcudbrightshire, Scotland.

Ranius, T., Aguado, L.O., Antonson, K., Audisio, P., Ballerio, A., Carpaneto, G.M., Chobot, K., Gjurašin, B., Hanssen, O., Huijbregts, H., Lakatos, F., Martin, O., Necualiseanu, Z., Nikitsky, N.B., Paill, W., Pirnat, A., Rizun, V., Tamutis, V., Telnov, D., Tsinkevich, V., Versteirt, V. Vignon, V., Vögeli, M. and Zach, P., 2005. *Osmoderma eremite* (Coleoptera, Scarabaeidea, Cetoniitae) in Europe. *Animal Biodiversity and Conservation*, 28: 1-44.

Ranius, T., Eliasson, P. and Johansson, P., 2008. Large-scale occurrence patterns of red-listed lichens and fungi on old oaks are influenced both by current and historical habitat density. *Biodiversity Conservation*, 17: 2371-2381.

Rapp, H-J. and Schmidt, M. (Hsg.), 2006. *Baumriesen und Adlerfarn. Der "Urwald Sababurg" Im Reinhardswald*. Euregioverlag, Kassel.

Rapp, H-J., 2002. *Reinhardswald. Eine Kulturgeschichte*. Euregio Verlag.Kassel

Reed, J.L., 1954. *The forests of France*. Faber & Faber, London.

Remling, F.X., 1852. *Urkundenbuch zur Geschichte der Bischöfe zu Speijer*. Band I. Ältere Urkunden. Neudruck der Ausgabe Mainz, 1852. Scientia Verlag, Aalen, 1970.

Rodenwaldt, U., 1951. Reviergeschichte als eine Grundlage der Waldbauplanung. Die Entwicklung der gräfl. Erbach-Arbachsen Waldungen in Odenwald. *Forstwissenschaftliches Centralblatt*, 70: 469-514.

Rodwell, J.S. (Ed.), 1991. *British Plant Communities. Volume I. Woodlands and Scrub*. Cambridge University Press, Cambridge.

Rose, F. 1974. *The epiphytes of Oak*. In: Morris, M.G. and Perring, F.H. (Eds.), The British Oak. Its History and Natural History. The Botanical Society of the British Isles. E.W. Classey, Berkshire, pp. 250-273.

Rose F., 1992. *Temperate forest management: its effects on bryophyte and lichen floras and habitats*. In: Bates, J.W. and Farmar, A.M. (Eds.), Bryophytes and Lichens in a Changing Environment. Clarendon Press, Oxford, pp. 211-233.

Rose, F. and James, P.W., 1974. Regional Studies on the British Lichen Flora. I. The corticolous and lignicolous species of the New Forest, Hampshire. *Lichenologist*, 6: 1-72.

Rosén, E., 1988. Shrub expansion in alvar grassland on Öland. In: Sjögren, E. (ed.) Plant cover on the limestone Alvar of Öland. Ecology, Sociology and Taxonomy. *Acta Phytogeographica Suecica*, 76: 76-100.

Rousset, O. and Lepart, J., 1999. Shrub facilitation of Quercus humilis regeneration in succession on calcareoud grasslands. *Journal of Vegetation Science*, 10: 493-502.

Rubner, H., 1960. *Die Hainbuche in Mittel- und Westeuropa. Untersuchungen über ihre ursprünglichen Standorte und ihre Förderung durch die Mittelwaldwirtschaft*. Forschungen zur Deutschen Landes- und Volkskunde 121.

Rühl, A., 1968. Lindenmischwälder im südlichen Nordwestdeutschland. *Allgemeine Forst- und Jagdzeitung*, 139: 118-130.

Salisbury, E.J., 1918. The ecology of scrub in Hertfordshire. A study in colonization. *Transactions of the Hertfordshire National History Society and Field Club*, 17: 53-64.

Sanderson, J.L., 1958. The autecology of *Corylus avellana* (L.). in the neighbourhood of Sheffield with special reference to its regeneration. PhD. Thesis, The University of Sheffield, Sheffield.

Savill, P.S., 1991. *The Silviculture of Trees Used in British Forestry.* C.A.B. International, Wallingford.

Schepers, F., 1993. De broedvogels van Koningsteen in 1991 en 1992. *Natuurhistorisch Maandblad*, 82: 245-251. (With Englisch Summary).

Schley, L. and Roper, T.J., 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. *Mammal Review*, 33(1): 43-5

Schreiber, K-F., 1993. Standordsabhängige Entwicklung von Sträuchern und Bäumen im Sukzessionsverlauf von Brachgefallenem Grünland in Südwestdeutschland. *Phytocoenologia*, 23: 539-560.

Schubart, W., 1966. *Die Entwicklung des Laubwaldes als Wirtschaftswald zwischen Elbe, Saale und Weser.* Aus dem Walde. Mitteilungen aus der Niedersächsischen Landesforstverwaltung 14.

Schuffenhauer, F., 2011. Einheimische Eichenwälder als Orte der Biodiversität im Wald. *AFZ-DerWald*, 19: 32-35.

Schulze-Hagen, K., 2004. Allmenden und ihr Vogelreichtum – Wandel von Landschaft, Landwirtschaft und Avifauna in den letzten 250 Jahren. *Charadrius*, 40: 97-12.

Schuster, L., 1950. Über den Sammeltrieb des Eichelhähers (*Garrulus glandarius). Vogelwelt*, 71: 9-17.

Schwappach, A., 1916. Zur Entwicklung der Mischbestände von Eiche und Buche. *Forst- und Jagdwesen,* 38: 615-623.

Simpson, G., 1998. *English cathedrals as sources of forest and woodland history*. In: Watkins, C. (Ed.), European Woods and Forests: Studies in Cultural History. CAB, 39-53.

Sinclair, A.R.E., 1979. *The Eruption of the Ruminants*. In: Sinclair, A.R.E. and Norton-Griffiths, M. (Eds.), Serengeti. Dynamics of an Ecosystem. The University of Chicago Press. Chicago and London, pp. 82-103.

Sjögren, E., 1988. Studies of vegetation on Öland; changes and development during a century. In: Sjögren, E. (Ed.), Plant cover on the limestone Alvar of Öland. Ecology, Sociology and Taxonomy. *Acta Phytogeographica Suecica*, 76: 5-8.

Slicher van Bath, B., 1987. *De agrarische geschiedenis van Europa 500-1850.* 6th edn. Aula, Spectrum, Utrecht.

Sloet, J.J.S. Baron, 1911. *Gelderse markerechten. Oud-vaderlandse rechtsbronnen*. Werken der Vereeniging tot Uitgaaf der Bronnen van het Oud-Vaderlands Recht, Utrecht. Tweede reeks no. 12, Martinus Nijhoff, 's-Gravenhage.

Sloet, J.J.S. Baron, 1913. *Gelderse markerechten. Oud-vaderlandse rechtsbronnen*. Werken der Vereeniging tot Uitgaaf der Bronnen van het Oud-Vaderlands Recht, Utrecht. Tweede reeks no. 15, Martinus Nijhoff, 's-Gravenhage.

Smit, C., Den Ouden, J. and Müller-Schärer, H., 2006. Unpalatable plants facilitate tree saplings survival in wooded pastures. *Journal of Applied Ecology*, 43: 305-312.

Smit, G., Vandenberghe, Ch., Den Ouden, J. and Müller-Schärer, H., 2007. Nurse plants, tree seedlings and grazing pressure: changes in facilitation along a biotic environmental gradient. *Oecologia*, 152(2): 265-273.

Smit, C., Den Ouden, J. and Díaz, M., 2008. Facilitation of *Quercus ilex* recruitment by shrubs in Mediterranean open woodlands. *Journal of Vegetation Science*, 19: 193-200.

Smit, C., Bakker, E.S., Emile F. Apol, M. and Olff, H., 2010. Effects of cattle and rabbit grazing on clonal expansion of spiny shrubs in wood-pastures. *Basic and Applied Ecology*, 11: 685-692.

Smit, C. and Putman, R., 2011. *Large herbivores as "environmental engineers"*. In: Putman, R., Appolonia, M. and Andersen, R. (Eds,), Ungulate Management in Europe. Cambridge University Press, Cambridge, pp. 260-283.

Smit, C. and Ruifrok, J.L., 2011. From protégé to nurse plant: establishment of thorny shrubs in grazed temperate woodlands. *Journal of Vegetation Science*, 22: 377-386.

Smit, C. and Vermijmeren, M., 2011. Tree-shrub associations in grazed woodlands: first rodents, then cattle. *Plant Ecology*, 212: 483-493.

Smith, C.J., 1980. *Ecology of the English Chalk*. Academic Press, London.

Snow, B. and Snow, D., 1988. *Birds and Berries. A studie of an ecological interaction*. T. and A.D. Poyser, Calton.

Sonnesson, L.K., 1994. Growth and survival after cotyledon removal in *Quercus robur* seedlings, grown in different natural soil types. *Oikos*, 69: 65-70.

Sperber, G. and Thierfelder, S., 2008. *Urwälder Deutschlands. Nationalparks, Naturwaldreservate und andere Schutzgebiete*. BLV Buchverlag, München.

Stamper, P., 1988. *Woods and Park*s. In: Astill, G. and Grant, A. (Eds.), The Countryside of Medieval England. Blackwell Scientific Publications, Oxford, pp. 128-148.

Sternbach, G., 2003. The History of Antrax. *The Journal of Emergency Medicine*, 24(4): 463-467.

Streitz, H., 1967. Bestockungswandel in Laubwaldgesellschaften des Rhein-Main-Tieflandes und der Hessischen Rheinebene. Dissertation Forstlichen Fakultät der Georg-August-Universität zu Göttingen in Hannover, Münden.

Szafer, W., 1968. The Ure-ox, Extinct in Europe Since the Seventeenth Century: an Early Attempt at Conservation that Failed. *Biological Conservation*, 1: 45-47.

Tack, G. Bremt,, P. van den and Hermy, M., 1993. *Bossen van Vlaanderen: een historische ecologie*. Davidsfonds, Leuven.

Tansley, A.G. (ed.), 1911. *Types of British Vegetation*. Cambridge University Press, Cambridge.

Tansley, A.G., 1922. Studies on the vegetation of the English Chalk II. Early stages of redevelopment of woody vegetation on chalk grassland. *Journal of Ecology*, 10: 168-177.

Tansley, A.G., 1953. *The Britisch Islands and their Vegetation*. Vol. 1 and 2. 3th edn. Cambridge University Press, Cambridge.

Ten Cate, C.L., 1972. *"Wan god mast gift....". Bilder aus der Geschichte der Schweinezucht im Walde*. Pudoc, Wageningen.

Tendron, G., 1983. *La fôret de Fontainebleau. De l'ecology à la sylviculture*. Office National des Fôrets, Fontainebleau.

Trier, J., 1952. *Holz. Etymologien aus dem Niederwald*. Münstersche Forschungen 6, Böhlau Verlag, Münster/Köln.

Trier, J., 1963. *Venus: Etymologien um das Futterlaub*. Münstersche Forschungen 15, Böhlau Verlag, Münster/Köln.

Tubbs, C.R., 1964. Early Encoppicements in the New Forest. *Forestry*, 37: 95-105.

Tubbs, C.R., 1988. *The New Forest. A natural history*. The New Naturalist. Collins, London.

Turbang, J., 1954. Contribution à l'étude de la régéneration naturelle du Chêne en Lorraine Belge. *Bulletin Institut Agronomique et Stations de Recherches de Gembloux* (Belgium), 22: 90-133.

Tüxen, R. von, 1952. Hecken und Gebüsche. *Mitteilungen Geographische Gesellschaft in Hamburg*, 50: 85-117.

Van der Woud, A., 1987. *Het Lege Land. De ruimtetelijke orde van Nederland 1798-1848*. Meulenhoff Informatief, Amsterdam.

Van de Veen, H.E., 1979. Food selections and habitat use of the red deer (*Cervus elaphus*). PhD. thesis, Rijksuniversiteit Groningen, Groningen.

Van de Veen, H.E. and van Wieren, S.E., 1980. *Van grote grazers, kieskeurige fijnproevers en opportunistische gelegenheidsvreters; over het gebruik van grote herbivoren bij de ontwikkeling en duurzame instandhouding van natuurwaarden*. Rapport 80/11, Instituut voor Milieuvraagstukken, Amsterdam.

Van de Veen, P.A.F. and van der Sijs, N., 1990 and 1991. *Etymologisch woordenboek. De herkomst van onze woorden*. Van Dale Lexicografie, Utrecht/Antwerpen.

Van Soest, P.J., 1982. *Nutritional Ecology of the Ruminant. Ruminant metabolism, nutritional strategies, the cellulolytic fermentation and the chemistry of forages and plant fibers*. O and B. Books, Corvallis.

Van Wieren, S.E., 1996. Browsers and grazers: foraging strategies in ruminants. Chapter 9. PhD. Thesis. Agricultural University Wageningen, Wageningen.

Vanselow, K., 1926. *Die Waldbautechniek im Spessart. Eine historisch-kritische Untersuchung ihrer Epochen*. Verlag von Julius Springer, Berlin.

Vanselow, K., 1949. *Theorie und Praxis der natürlichen Verjüngung im Wirtschaftswald*. Neumann Verlag, Berlin.

Vera, F.W.M., 2000. *Grazing Ecology and Forest History*. CABI Publishers, Wallingford.

Vera, F., 2007. *Wilderness in Europe. What really goes on between the trees and the beasts*. Tirion Natuur, Baarn and Staatsbosbeheer, Utrecht.

Vera, F.W.M., 2009. Large-scale nature development – the Oostvaardersplassen. *British Wildlife*, 20 (special supplement): 28-36.

Vera, F.W.M., 2010. *Großherbivoren und die Naturlandschaft.* In: Baier, H. und Wölfel, L. (Eds.), Biodiversität und Landschaft. Schriftenreihe des Landesamtfür Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern, Heft 2, pp. 79-109.

Vera, F., 2013. *Can't see the trees for the forest*. In: Rotherham, I. (Ed.), Trees, Forested Landscapes and Grazing Treescapes. Routledge, London, pp. 99-126.

Vera, F.W.M, Bakker, E. and Olff, H., 2006. *The influence of large herbivores on tree recruitment and forest dynamics*. In: Danell, K., Duncan, P., Bergström, R. and Pastor, J. (Eds.), Large Herbivore Ecology, Ecosystem Dynamics and Conservation. Cambridge University Press, Cambridge, pp. 203-231.

Vodka, S., Konvika, M. and Cizek, L., 2009. Habitat preferences of oak-feeding xylophagous beetles in a temperate woodland: implications for forest history and management. *Journal of Insect Conservation*, 13: 553-562.

Voous, K.H., 1986. *Roofvogels en Uilen van Europa*. Nederlandse Vereniging tot Bescherming van Vogels; Wereld Natuur Fonds. E.J. Brill/W. Backhuis, Leiden.

Vullmer, H. and Hanstein, U., 1995. Der Beitrag des Eichelhähers zur Eichenverjüngung in einem naturnah bewirtschafteten Wald in der Lünerburger Heide. *Forst und Holz*, 50: 643-646.

Walker, R.L., Wardle, D.A., Bardgett, R.D. and Clarkson, B.D., 2010. The use of chronosequenties in studies of ecological succession and soil development. *Journal of Ecology*, 98: 725-736.

Warming, E. assisted by Vahl, M., 1909. *Ecology of Plants: an introduction to the study of plant communities*. Oxford, Clarendon Press.

Warren, M.S. and Thoman, J.A., 1992. *Butterfly responses to coppicing*. In: Buckley, G.P. (Ed.), Ecology and Management of Coppice Woodland. Chapman & Hall, London, 249-270.

Wartena, R., 1968. Vier eeuwen bosbeheer in Gelderland 1400-1800. *Tijdschrift Koninklijke Nederlandse Heidemij*, 79: 33-40; 94-100; 182-191.

Watkins, C., 1990. *Britain's Ancient Woodland. Woodland Management and Conservation*. Davis and Chasler, London.

Watt, A.S., 1919. On the causes of failure of natural regeneration in Britisch oakwoods. *Journal of Ecology*, 7: 173-203.

Watt, A.S., 1924. On the ecology of British beech woods with special reference to their regeneration. Part II. The Development and Structure of Beech Communities on the Sussex Downs. *Journal of Ecology*, 12: 145-204.

Watt, A.S., 1925. On the ecology of British beech woods with special reference to their regeneration. Part II, sections II and III. The Development and Structure of Beech Communities. *Journal of Ecology*, 13: 27-73.

Watt, A.S., 1934. The vegetation of the Chiltern Hills with special reference to the beechwoods and their seral relationship. Part II. *Journal of Ecology*, 22: 445-507.

Watt, A.S., 1947. Pattern and process in the plant community. *Journal of Ecology*, 35: 1-22.

Weimann, K., 1911. *Die Mark- und Walderbengenossenschaften des Niederrheins*. Untersuchungen zur Deutschen Staats- und Rechtsgeschichte 106 Heft. M & H, Marcus, Breslau.

Wiedemann, E., 1931. Eichen-Buchen-Mischbestände. *Zeitschrift für Forst- und Jagdwesen*, 63: 614-638.

Wijdeveen, S.M.J., 2004. *Stand dynamics in Fontainebleau.*

Dynamics in beech forest structure and composition over 17 years in La Tillaie forest reserve, Fontainebleau, France. Alterra-rapport 1124, Alterra, Wageningen.

Wilmanns, O., 1989. Zur Entwicklung von Trespenrasen im letzten halben Jahrhundert: Einblick-Ausblick-Rückblick, das Beispiel des Kaiserstuhls. *Düsseldorfer Geobotanischen Kolloq*., 6: 3-17.

Wolf, A., 2005 Fifty year record of change in tree spatial patterns within a mixed deciduous forest. *Forest Ecology and Management*, 215: 212-223.

Wolf, A., 2011. Determining the rate of change in a mixed deciduous forest monitored for 50 years. *Annals of Forest Science*, 68: 485-495.

Wolf, R., 1984. *Heiden im Kreis Ludwigsburg.* Beiträge Veröff. Naturschutz und Landschaftspfl. Bad.-Württ., Karlssruhe, 35: 1-76.

Wolkinger, F. and Plank, S., 1981. *Dry grasslands of Europe*. European Committeee for the Conservation of Nature and Natural Resources, Council of Europe. Nature and Environment Series no. 21. Strasbourg.

Woolsey Jr., T.S. and Greeley, W.B., 1920. *Studies in French Forestry.* John & Wiley and Sons, New York.

Wrześniowski, A., 1878. Studien zur Geschichte des polnischen Tur (Ur, Urus) Bos primigenius Bojanus. *Zeitschrift für wissenschaftliche Zoologie*, 30, Supplement 45: 493-555.

Ziegenhagen, B. and Kausch, W., 1995. Productivity of young shaded oaks (*Quercus robur* L.) as corresponding to shoot morphology and leaf anatomy. *Forest Ecology and Management*, 72: 97-108.

Chapter 13
The ancient woodland concept as a practical conservation tool: the Turkish experience

Simay Kırca, Alper H. Çolak, Ian D. Rotherham

Abstract

Why ancient woodlands and wood species restoration and rehabilitation is necessary? In Turkey there are over 500 taxa of trees and shrubs, however only a few of them play a vital role both naturally and culturally. The technical term here is 'intergenerational equity', or in plainer language, not messing things up for our children and grandchildren. In ancient woodland restoration and rehabilitation approach in Turkey, there is no lack of knowledge to implement suitable strategies, however what is more often lacking is an understanding of the overall landscape and the factors that determine whether different land-uses are mutually reinforcing or in conflict. These applications need to accommodate new perspectives and ideas to put ancient woods back into the natural and cultural landscapes. The experience gained indicates that such implementations require supportive local and national policy frameworks and a strong constituency of local-level support. As a country with already significant areas of a highly degraded nature, but also containing diverse natural and cultural landscapes, Turkey should apply suitable techniques to bring these ancient woods back into their original landscapes in order to sustain its cultural and natural heritage. Ascertaining, and then maintaining, the condition of ancient woodland in Turkey like in UK will be a major challenge for the future.

Turkey contains ancient cultural landscapes with distinctive ancient wood and ancient woodlands. They are strongly influenced by human activity reaching back far into history. This is very obvious in Anatolia, a region where eastern and western civilizations meet. The region has also been recognized by eastern and western civilizations nearly as a 'tree paradise' with its diverse tree species adapted to different climatic and geomorphological conditions. In this context, it has been aimed to; (1) emphasize the interaction between cultural features and diverse forest landscapes with ancient woodlands, (2) introduce the understanding of ancient woodland concept in Turkey, (3) determine the typical prominent ancient woodland taxa, (4) represent some techniques in order to restore degraded ancient woodland ecosystems in Turkey and (5) seek opportunities for the planning of undisturbed ancient landscapes as a cultural heritage.

Additionally, the importance of developing strategies in order to prevent the loss of ancient woodlands was tried to be illustrated by two case studies on Common yew (*Taxus baccata* L.) and Common boxwood (*Buxus sempervirens* L.), which have been continuosly present in Anatolia since thousands of years, became an important component of cultural landscapes, however strongly influenced by human activity resulting with the degardation and loss of their habitats.

Landscape alteration in Anatolia and its reflections on ancient woodlands through history

Anatolia is a region where eastern and western civilizations meet and one of the oldest continually inhabited regions in the world. It has been repeatedly a battleground for foreign powers, being noted as a melting pot of cultures. From the first known urban city (Çatalhöyük c. 7500 BC) to the historically famous Troy, and from the Ionians to the great empires of the world (e.g. Roman, Byzantine, and Ottoman) many cultures (e.g. Sumers, Cimmerians, Cilicans, Phoenicians, Lydians, Carians, Persians, Hellenes, etc.) were established in this geography. Even the earliest major empire of the region (the Hittite Empire) derived its name from the dominant prehistoric culture of Anatolia (Hatti, Khetas or Hetas) (Çolak and Rotherham, 2006).

In accordance with its rich historic background, Turkey contains ancient cultural landscapes with distinctive ancient woods and woodlands. People have used these woodlands and to some extent have been shaped by woodland environments for thousands of years. However, these areas have also been strongly influenced by human activity reaching back far into history. Over the last 2000 years, anthropogenic impacts have significantly reduced forest area containing distinctive ancient wood, most markedly in the last five centuries. All these civilizations and especially their cities required wood, timber, agricultural land and grazing land, while their armies played a particular role in the depletion of forests. Woodlands were the sources of wood for their fleets, weaponry and war machines, while they also provided cover for the armies. For example, the ancient Assyrians, like many more recent armies, deliberately burned the woodlands of their enemies (McNeill, 2004). Indeed the Roman poet and philosopher of the first century BC, Titus Lucretius Carus, listed armies and agricultural use among the four reasons behind the alteration and total destruction of woodlands because of forest fires (lightning and hunting parties were the others) (Carus, 1916):

'Now for the rest: copper and gold and iron
Discovered were, and with them silver's weight
And power of lead, when with prodigious heat
The conflagrations burned the forest trees
Among the mighty mountains, by a bolt
Of lightning from the sky, or else because
Men, warring in the woodlands, on their foes
Had hurled fire to frighten and dismay,
Or yet because, by goodness of the soil
Invited, men desired to clear rich fields
And turn the countryside to pasture-lands,
Or slay the wild and thrive upon the spoils.
(For hunting by pit-fall and by fire arose
Before the art of hedging the covert round
With net or stirring it with dogs of chase.)'

Major trends in the use wood and their effects on the ancient woodlands can be traced back to Neolithic Ages in Anatolia. Palynological and dendrochronological studies as well as pollen analyses demonstrate valuable information on the landscape alteration and dominant ancient wood or ancient tree species through history. For example, a sediment core from a volcanic lake near Acigöl, in Central Anatolia indicates a steady advance of oak woodland from 10000-8000 BC onwards and a maximum expansion between 8000 and 4000 BC, followed by its dramatic and almost complete, man-induced destruction (Woldring and Cappers, 2001). Additionally, the study of archeological wood-charcoal macro-remains has been viewed mainly as a tool for reconstructing past vegetation and climate patterns, as well as gaining some insights into the local strategies for woodland exploitation (Willcox, 1992, 1995; Vernet, 1997; Figueiral and Mosbrugger, 2000; Asouti and Austin, 2005; Dufraisse, 2006). The studies held in the Neolithic city of Çatalhöyük in Central Anaolia also indicated the expansion of oak woodlands followed by the use of oak wood particularly for fuel wood and construction purposes (Mellaart, 1967; Asouti, 2005). The surrounding landscape of the city

Photograph 1: Oak (*Quercus* sp.) (A. Ince; Archive of General Directorate of Forestry-Turkey).

was composed of three vegetation types as; (1) riparian and marsh vegetation, (2) woodland steppe and treeless steppe and (3) oak-park woodland (Asouti, 2005), while this landscape pattern has been transformed mostly into the Central Anatolia A*rtemisia fragrans* steppe and partly to salt steppe and *Quercus pubescens* (*Quercus pubescens* subsp. *anatolica*) forest steppe today (Noirfalise, 1987) as a result of felling and overgrazing, and only in some mountainous areas can ancient oak woodlands be found (Woldring and Cappers, 2001) (Photograph 1).

On the way to the east Strabo (1856) describes Mazaca (province in ancient Cappadocia) as entirely barren and uncultivated like almost all other provinces in Cappadocia with the exception of the woodlands surrounding Argaeus (Mount Erciyes). Ancient oak woodlands have also been started to decline moderately by the same period in Lake Van, in south-eastern Anatolia, with the effect of increasing human activity and summer drought and reached its highest point after the clearing about 600 years ago (Wick et al., 2003). Deforestation in the highlands of eastern Turkey during the Late Bronze Age is also apparent through increased sedimentation along the Euphrates River Valley, because of slope erosion due to human practises like land clearing, grazing and agriculture as well as precipitation depletion and irregularity

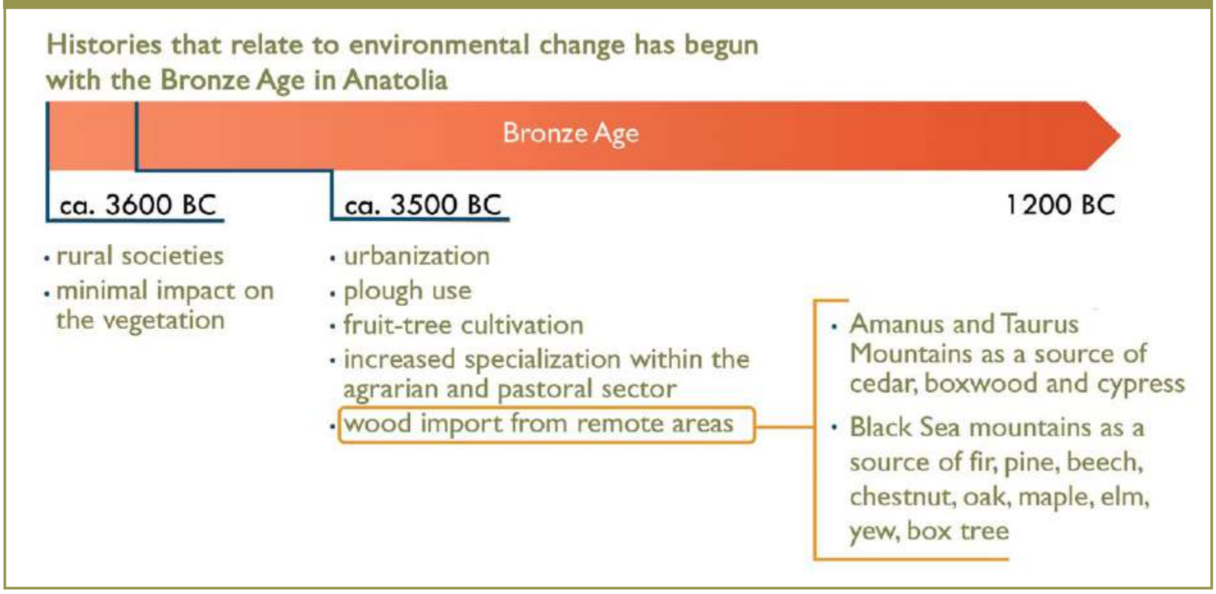
Photograph 2: Ancient Black pine (*Pinus nigra* subsp. *pallasiana* stands in Kartal Gölü Nature Protection Area (Beyagaç/Denizli) (R. Çetiner).

(Kuzucuoğlu, 2003; Longford et al., 2009). These findings have also been supported by pollen diagrams on the ancient woodland vegetation of Çatalhöyük (7500 BC to 5700 BC) in Central Anatolia, which indicate the presence of formerly extensive Xero-Euxinian open oak ancient woodlands (*Quercus macrolepis* Kotschy, *Q. trojana* Webb, *Quercus* sp.) with *Juniperus excelsa* M.Bieb., *J. oxycedrus* L. and *Pinus nigra* Arnold stands (Asouti and Hather, 2001) (Photograph 2). Furthermore, there should have been well-stocked forests within easy reach of Phyrigian capital-city of Gordium (southwest of Ankara) considering the unrestricted use of wood in the city (Young, 1974; Aytuğ, 1988). In 1402 Timburlaine was also able to conceal his herd of elephants in a wood outside the city of Ankara (Meiggs, 1982). Unfortunately this mosaic has left its place mostly to the present-day steppic elements formed as a result of high timber demand for firewood, fuel, building construction (esp. ancient woods like oak, black pine, cedar), forest fires as well as agriculture and over-grazing.

Further studies revealed that by the beginning of the Bronze Age societies were quite rural, probably impacting the vegetation only minimally in Anatolia, but shortly after (ca. mid-3rd millennium BC) became urbanized. It is also the period when plough use and fruit-tree cultivation became increasingly applied, and increased specialization within the agrarian and pastoral sector occurred (Figure 13.1). It is also of interest that one of the Middle Bronze Age rulers claimed to have intensively cut cedars and pines from the mountains, hence imported wood from remote areas (Deckers and Pessin, 2010), while Assyrian merchants imported wood from Anatolia between 1700-2100 BC (Dölarslan and Ok, 2006). Histories that relate to environmental change begin with Bronze Age (3500-1200 BC) cuneiform records, including mention of the Amanus Mountains as a source of cedar (*Cedrus libani*

Landscape alteration in the Bronze Age in Anatolia and some reflections on ancient woodlands (Kırca et al., 2015)

Figure 13.1



A.Rich), boxwood (*Buxus sempervirens* L.), and cypress (*Cupressus sempervirens* L.) (Rowton, 1967). Early timber was likely floated down rivers on the east side of the Amanus to the Aksu and the Euphrates. Some timber was also floated down western Amanus rivers and into the Mediterranean (Beach and Beach, 2008). Sumerians also associated some mountains with their dominant tree species by using tree-toponyms; i.e. allānu "oak", burāšu "a juniper tree", erēnu "cedar", meḫru and supālu (pine trees) and taskarinnu "boxwood". For example, they named the Eastern Taurus after "ḫašurru" or "šurmēnu", the earlier term used for *Cupressus sempervirens* L. var. *horizontalis* (Mill.) Cord., which no longer exists there today. Probably this species grew in sheltered parts of the Eastern Taurus, where there was sufficient precipitation and at lower attitudes where the winter was mild. However the exceptional fragrance of its wood should have made it used as timber for the construction of temples and palaces, and exploited in large quantities, while it was also confined to lower altitudes and therefore easily accessible (Rowton, 1967).

Mediterranean climate zone was also dominated by deciduous-oak forest up until 3000 BC, while the destruction of the primary forest (ancient woodland) subsequently initiated the spread of maquis vegetation (Woldring and Cappers, 2001). Here Taurus range and Amanus Mountains have suffered much more serious damage than other parts of this zone, since ancient woods (especially cedar and black pine) were exported to the great Mediterranean and near-east civilizations in order to provide timber for building and ship construction (Diodorus, 1946; Senitza, 1989). There was also great abundance of *Cupressus sempervirens* L. in Lycia (c. 1250-546 BC- western Mediterranean Region) (Theophrastus, 1999b), while this ancient tree shows relative rare distribution mostly forming mixed stands with *Pinus brutia* Tenore and *Quercus coccifera* L. (Mayer and Aksoy, 1998). However Kotschy (1858) reports about forests still well-stocked with oak, and pine on the lower slopes continuing with cedar, fir, pine and juniper towards the eastern end of Taurus in the middle of the 18th century, which severely declined particularly with the effect of increasing conversion of forest to agriculture and grazing. These forests were also called upon to meet the large demands of Egypt, especially when the Suez Canal was being built (Meiggs, 1982). It is also known that, there were still good reserves of cedar, juniper, pine and some amount of cypress in western Mediterranean Region by the beginning of 20th century (Philippson, 1910).

There is a striking contrast between the forests of northern Anatolia (i.e. southern parts of Sea of Marmara and Black Sea coast) and other parts of Asia Minor. These forests had a high reputation in ancient Greece and Rome, as well as Byzantium and Ottoman Empire and they have always had a rich range of trees including fir, pine, beech, chestnut, oak and maple (Meiggs, 1982) (Photograph 3). Towards the end of the 19th century Cuinet (2001) was also impressed by the dense forests present on east of

Photograph 3: Oriental beech (*Fagus orientalis*) (Kamilet Valley-Borçka-Artvin) (A. Ince; Archive of General Directorate of Forestry-Turkey).

Trabzon and the size of timbers being cut and exported from Sinop, Zonguldak and Izmit, which Xenophon so much admired and named as "sea of trees" (from which most of them classified as ancient tree species like oak, elm, beech, fir, yew, box tree, pine). According to Rowton (1967), this region represented the main source of timber for the whole Roman Empire, to the point that "timber to the Pontus" had much the same connotation as "coals to Newcastle" in the 19th century England. In spite of the historical evidence showing the great amount of wood these forests provided for building, fuel and ship construction (Theophrastus, 1999c; Meiggs, 1982; Olson, 1991; McNeill, 2004; Ágoston, 2005), there are still substantial forest reserves containing considerable amount of unfragmented ancient woodlands in this region. However this cannot be told for the remaining forest landscapes on the southern part of North Anatolian Mountains. The woodlands still dominated by *Pinus sylvestris* L. and oak species in Erzurum in the 4th century BC (Xenophon, 1976; Longford et al., 2009) were mainly transformed to 'naked landscapes' by the beginning of 17th century (Tournefort, 1636). Accordingly in the 17th century the forests from which the Ottoman Empire drew its naval timber stood as much as 50 kilometers inland, behind the coasts of the Black Sea, Sea of Marmara, and the northeastern Aegean (McNeill, 2004). As a result, the cumulative effects of timber use by a large number of civilations caused the total destruction, alteration of species composition or reduction of ancient woodlands.

Photograph 4: *Quercus hartwissiana* (K. Cengiz; Archive of Zonguldak Forest Enterprise)

An overview of the interaction between people and ancient wood in Anatolia

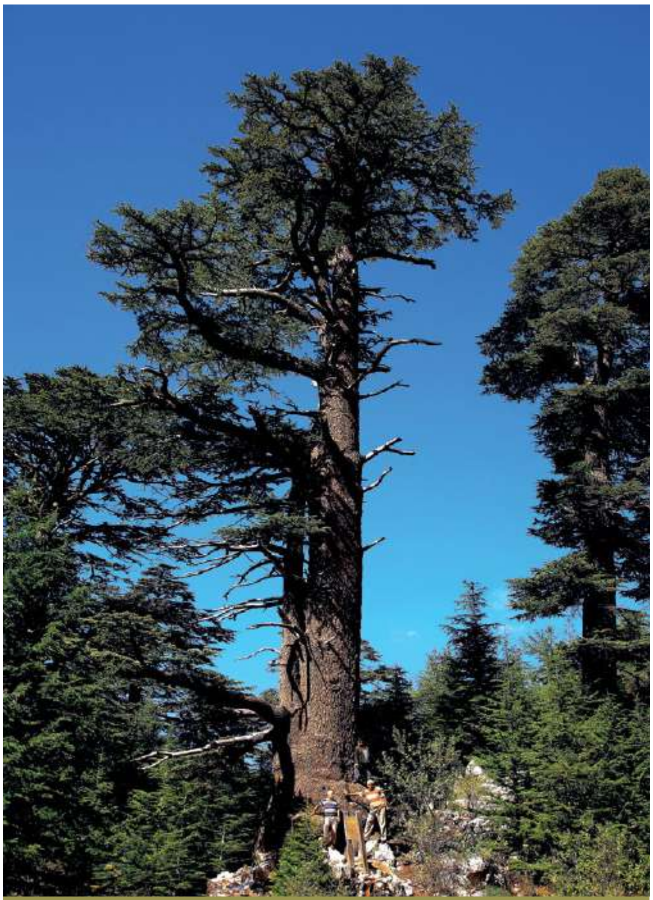
Fuel for heating and cooking was one of the most basic, irreducible needs of settled human existence in Anatolia, while every civilization had to develop its own fuel exploitation strategy which may differ mainly according to local wood resources. People relied on firewood and charcoal to satisfy their energy requirements for centuries, while in main urban centres this must have been a major (and potentially quite profitable) industry. According to Asouti (2005) people relied on dung fuel as well as firewood gathered mainly from the surrounding riverine vegetation in the early stages of the iconic Neolithic site of Çatalhoyuk, when the consumption of wood was relatively low. However firewood exploitation increased after 7000 BC and this was characterized by the predominance of oak, greater diversity of the riverine taxa, and the higher frequency of juniper, wild plum and wormwoods in the samples of wood macro-remains and charcoal. Asouti and Fairbairn (2002) also refers to the different types of fuel valued for different purposes in Çatalhoyuk (e.g. the slow burning and long-lasting dung fuel for cooking and firewood for heating, smoking and/or lighting), while oak became one of the dominant wood preferred as fuel material in this Neolithic settlement of Central Anatolia (Photograph 4). Use of oak as fuel was also common in the ancient Mediterranean civilizations. Even a simple peasant in the countryside could gather virtually all his fuel in the form of cuttings and prunings from his own land or nearby forests, as the ancient Greek dramatist Menander (ca. 341/42-ca. 290 BC) remarks: 'Everall after an oak falls, every man gets wood for himself' (Olson, 1991).

Theophrastus (c. 371-c. 287 BC) (1999c) indicated the necessity of fuelwood for different purposes in the Ancient Mediterranean World: 'Individual households needed heat and a way to cook their food; businesses such as bakeries and bathhouses required supplies of wood and charcoal on a daily basis; industries like metalworking and refining and pottery making were absolutely dependent on a steady supply of fuel to heat forges and fire kilns and often needed specialized types of charcoal made from particular woods. He also specified the varying uses of charcoal made of different woods. For example, people used charcoal made of *Quercus* sp., *Quercus ilex* L. and *Arbutus* sp. in silver mines for the first smelting of the ore, since these are the most solid woods and they last longest and strongest. However men required softer wood (*Castanea sativa* Mill.) for the charcoal used in iron mines, when the iron has been already smelted and they used charcoal of pine-wood in silver mines, while these kinds were also used by the crafts. Smiths of the Mediterranean required charcoal of fir rather than oak, although it is not so strong, but it blows up better into a flame and it's less apt to smoulder and its flames are fiercer. Theophrastus (1999c) also mentions the suitability of olive for kindling because of its close and oily texture, while he favoured *Rhamnus* sp., *Quercus coccifera* L. and *Tilia* sp. for firesticks. Homer (1990) also describes the traditional function of oak, 'the strongest burner among woods', in the Mediterranean culture which was collected from Mount Ida (Kaz Dağı) after a challenging journey for the cremation of Patroclus.

Wood was also the main material for building construction and furniture, while cedar, fir, oak species, cypress and juniper were the most preferred tree species because of their different features like resistance to climatic conditions and insects, aromatic scent, easiness to work and polish as well as aesthetic beauty. For example the royal tomb in the capital city of ancient Phrygia, in Gordium, is one of the great monumental examples for the use of ancient wood in construction, while *Cedrus libani* A.Rich, *Pinus sylvestris* L., *Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe, *Juniperus excelsa* M.Bieb., *Buxus sempervirens* L. were the main tree species used (Meiggs, 1982). The most striking issue is the variety in the age of trees that were felled for the tomb, which were between 200 and 800 years old (Kuniholm, 1977). Similarly King Solomon is reputed to have sent 30.000 workers to the Taurus Mountains of southern Turkey in order to cut trees of about 30 m in height for the construction of his temple in Jerusalem and Hall of Judgement (Senitza, 1989), 'covering the interior from floor to rafters with wood…All was cedar, no stone was left visible' (Meiggs, 1982). Pliny the Elder (1855) also reports about the durability of cedar used by the roof-beams of temple of Artemis in Ephesus considering their good condition after 400 years of its construction. According to Meiggs (1982), the kings of Mesopotamia and Egypt chose cedar before fir for several reasons. As a tree it was a patrician, the fir plebeian. The wood of the cedar, unlike the fir, resisted rot and insects and was very durable. It also had an attractive aromatic scent, took a good polish, and was appreciated by carpenters and cabinet-makers because it had a close, straight grain and was easy to work (Photograph 5). The wood of cypress and juniper had very similar qualities. Like cedars their wood was of a reddish brown colour; they too had an aromatic scent, and the juniper was stronger than the cedar (Photograph 6). But both cypress and juniper were less handsome and neither could compare with the cedar in height.

Analyses on marine pile examples from the ancient Byzantine port of Eleutherius/Theodosius in Istanbul (4th century BC) indicate the use of *Cupressus sempervirens* L., *Castanea sativa* Mill., *Quercus ithaburensis* Decne., *Q. pontica* C.Koch., *Quercus* sp. and *Fagus* sp. (Doğu et al., 2011), from which oak was also favoured by Theophrastus (1999c) for its usefulness in building and particularly in underwater work. *Buxus sempervirens* L. was another important ancient wood mostly used for furniture and musical instruments in the ancient Mediterranean world (for which the sources are far more eloquent than anywhere else in the world at that time) and the most famous boxwood was obtained from Amanus Mountains and Cytorus (Central Blacksea coast) (Theophrastus, 1999a).

In ancient world naval power was mainly based on the presence of high quality wood, which was mainly provided from ancient woodlands. Theophrastus (1999a) describes the use of tree species for different purposes. For example Triremes and other warships were made of mountain fir because it is lightweight, allowing ships to be fast and maneuverable. Merchantmen were made of pine, which was more durable, while on the Syrian and Lebanon coast, shipwrights used cedar because it was abundant. Keels required sturdy oak, because they had to withstand hauling over beaches or rocks. He also gives a list of areas that could supply good timber-ship for the ancient Mediterranean civilizations: in Europe Macedon, parts of Thrace and south Italy; in Asia the territories of Sinop and Amasya (Black Sea coast of northern Anatolia), Mt. Olympus (Uludağ in southern Marmara Sea) and Mt. Ida (Kaz Dağı in Biga Peninsula on the shore of Aegean Sea). Taurus and Amanus Mountains were also important sources for ship timber, while Antony gave Cleopatra –the queen of Egypt- a well forested area in Cilicia to provide timber for an Egyptian fleet (Meiggs, 1982). In Ottoman Empire wood continued to dominate as the main ship construction material until the second half of the 19th century, while oak (esp. *Quercus ilex* L.), pine, elm, fir, larch, chestnut, hornbeam, ash tree and lime tree were the most preferred tree species (Zorlu, 2008). However armies consumed more timber than fleets either by burning as the ancient Assyrians, like many more recent armies, who deliberately burned the woodlands of their enemies (McNeill, 2004), or by cutting to cook, provide warmth, open their way, deny cover to an enemy, construct bridges or roads and produce weapons (clubs, spears, slings, bows, and arrows) (Meiggs, 1982). In Anatolia production of gunpowder for the army also played an important role by the depletion of forest resources. The manufacture of gunpowder from saltpeter, for example, required fuelwood, about fifteen to twenty tons of wood for each ton of saltpeter. In the Ottoman Empire, annual saltpeter production in the mid-17th century used as much fuel as a city of 100.000 to 200.000 people (Ágoston, 2005).



Photograph 5: Lebanon cedar (*Cedrus libani*) /Çıglıkara-Elmalı-Antalya) (A. Ince; Archive of General Directorate of Forestry-Turkey).

Photograph 6: Juniper (*Juniperus* sp.) (R. Çetiner).

Mayer and Aksoy (1986), referring to Evliya Çelebi (a famous 17th century traveller and writer), note that thousands of timber (e.g. cedar, black pine, oak) producers lived in northwest Anatolia in 1648 AD. Thus, whilst the civilizations in Anatolia were destroying forests on the one hand, on the other they used the ancient wood for a variety of purposes.

Figure 13.2

Definition of the term "ancient woodland" in Turkey and UK
(Kırca et al., 2015; prepared after Peterken, 1983; Goldberg et al., 2007; Kırca et al., 2012)

The term '*ancient woodland*' in UK:
An area that appears to have been wooded continuously since at least 1600 (1750 in Scotland). This includes all primary woodland, the lineal descendants of UK's primeval woodland, whose wildlife communities, soils and sometimes structure have been least modified by human activities.

The term '*ancient woodland*' in Turkey:
A primary or natural / near natural forest area containing tree species, whose existence can be traced back from hundreds of years to neolithical ages. These are appreciated as icons of most important wooded landscapes in Turkey, as well as history of different civilizations in Anatolia.

What is meant by the term 'ancient woodland' in Turkey?

The concept of ancient woodland can be traced back to at least the 19th century (Watkins, 1988), but was actively promulgated in this form about 40 years ago by Peterken (1977) and Rackham (1976). Ancient woods were perceived to be particularly important for nature conservation, and were also under threat from agricultural clearance, development and modern forestry methods. Rackham (1976) pessimistically believed that there would be almost no ancient woodland left by the turn of the century (i.e. 2000) except in nature reserves (Goldberg et al., 2007). In United Kindom (UK), ancient woodland is widely understood to be an area that appears to have been wooded continuously since at least 1600 (1750 in Scotland). These areas have all been managed in some way, which sometimes involved temporary clearance of trees by felling. 'Ancient woodland' includes all primary woodland, the lineal descendants of UK's primeval woodland, whose wildlife communities, soils and sometimes structure have been least modified by human activities (Peterken, 1983; Goldberg et al., 2007). In Turkey, ancient woodland is defined as a primary or natural/near natural forest area containing tree species, whose existence can be traced back from hundreds of years to neolithical ages. These are appreciated as icons of most important wooded landscapes in Turkey, as well as history of different civilizations in Anatolia. This indicates an obvious difference in description of terms between UK and Turkey, as a result of geomorphological, climatic, ecological and historical backgrounds (Figure 13.2).

Photograph 7: Plane trees (*Platanus* sp.) scattered in individual groups. Sütçüler-Isparta (A. Ince; Archive of General Directorate of Forestry-Turkey).

Photograph 8: Old-growth black pine protection forest (R. Çetiner).

How small can an ancient woodland be?

The answer to the question 'how small can an ancient woodland be?' also differs between Europe and Turkey. According to many research Goldberg et al. (2007) notes the primeval wooded landscapes greater than 2 ha as ancient woodland. However in Turkey it wouldn't be suitable to define a minimum areal limit, since degraded ancient woodlands may cover hundreds of hectares as a whole, scattered in fragmented individual groups (Photograph 7 and 8).

By the determination of ancient woodlands and wood species origin plays an important role in order to qualify a

Figure 13.3

The minimum size of ancient woodlands and determination of ancient woodlands and wood species (prepared after Goldberg et al., 2007; Kırca et al., 2012)

How small can an ancient woodland be?

In Europe	In Turkey
According to many research the primeval wooded landscapes greater than 2 ha are noted as ancient woodland.	It wouldn't be suitable to define a minimum areal limit, since degraded ancient woodlands may cover hundreds of hectares as a whole or scattered in fragmented individual groups.

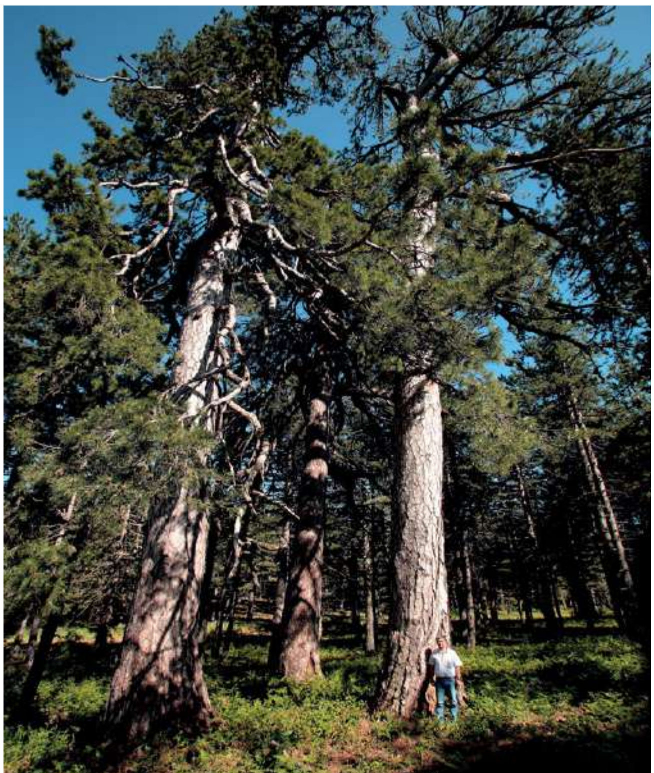
By the determination of ancient woodlands and wood species, origin plays an important role in order to qualify a wood to be ancinet in Turkey as well as in other countries.

- comparison of wood and polen records of particular species
- understanding the degree of continuity between ancient woods and the wildwood

wood to be ancient in Turkey as well as in other countries. Therefore comparison of wood and polen records of particular species is widely used as a technique in order to understand the degree of continuitıy between ancient woods and the wildwood (eg. Rackham, 2003). In Turkey the identification of woods that might be primary (land that has never been completely cleared of trees), or at least had probably arisen by natural regeneration in a relatively unimproved landscape plays a vital role by the inventory of ancient woodlands. However a generic system for the classification of different patches (plantations with non-native tree species, monocultures, degraded areas, etc.) is still lacking. For example in UK, the areas of ancient woodland with non-native trees planted on them, termed Plantations on Ancient Woodland Sites (PAWS), and those areas of ancient semi-natural woodland (ASNW) (Goldberg et al., 2007), (Figure 13.3).

Prominent ancient tree species of Turkey

Turkey, consists of European Turkey and Anatolia, is the meeting place of three phytogeographical regions: 'Euro-Siberian, Mediterranean and Irano-Turanian'. The vascular flora of Turkey contains over 9000 taxa and is the richest of the Near East and Middle East regions (Çolak, 2001). Its richness is of interest for both the total number of species and especially the number of endemics, of which there are c. 3000 (Ekim, 1995; Ekim et al., 2000). As a result of a variety of phyto-geographical regions Turkish landscape is divided into distinctive forest communities, which consist of more than 500 native species of trees and shrubs. Despite centuries of human activity, much of the forest in Anatolia is still relatively natural. There are still some residual virgin forest areas, but much has been degraded from near natural to semi-natural and altered (Çolak et al., 2010) (Photograph 9). The main forest regions found in these phyto-geographical regions partly contain same tree species, while they mainly differ from each other resulting with the rich diversity of species (Photograph 10, 11 and 12). However some species come into prominence with their typical characteristics and classified as ancient wood in Anatolia. In Figure 13.4 the distribution of main tree species to forest regions in Anatolia is summarized with the ancient wood distinction criteria.

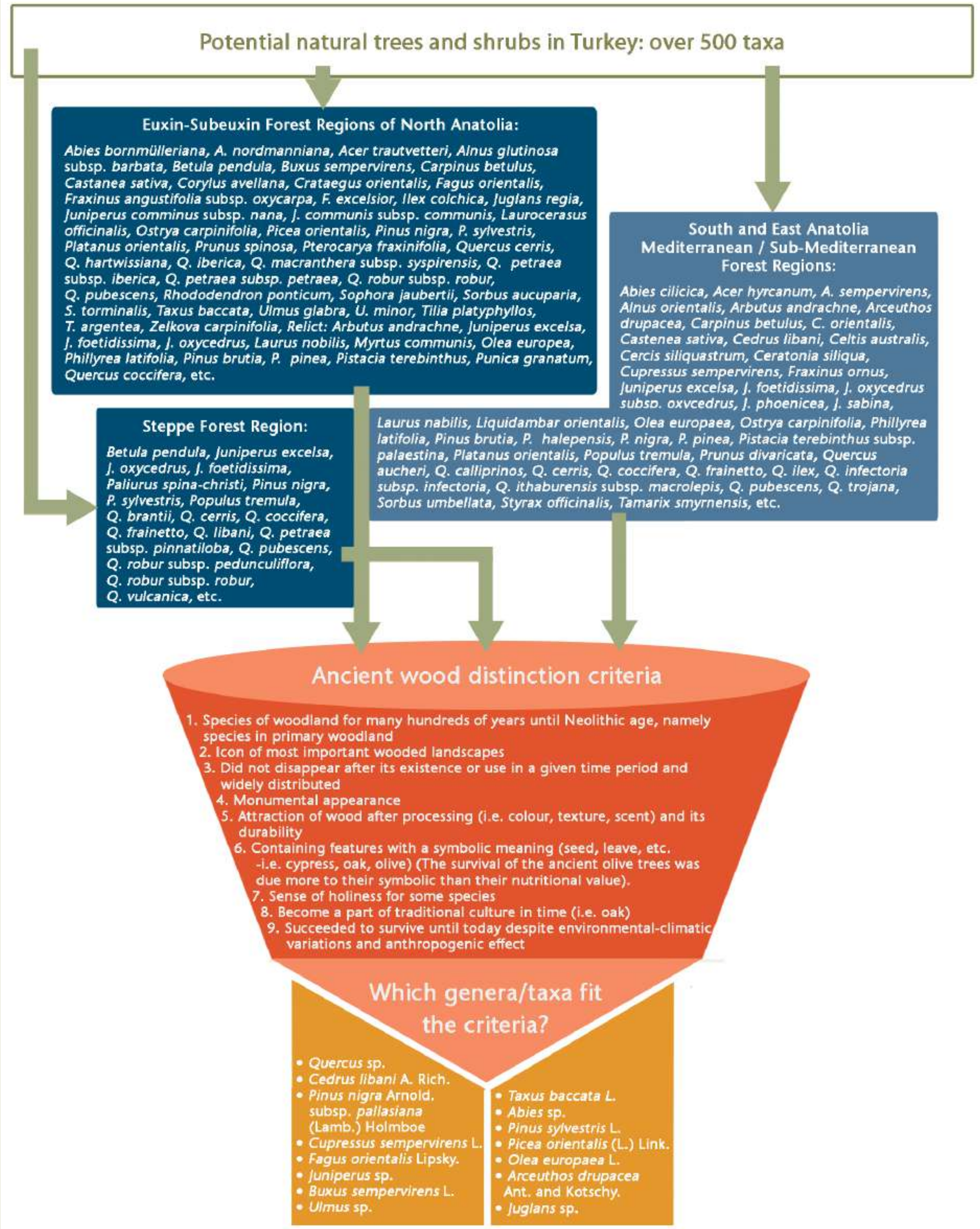


Photograph 9: Black pine (*Pinus nigra.* subsp. *pallasiana*) trees in a degraded forest (Dursunbey-Balıkesir) (A. Ince; Archive of General Directorate of Forestry-Turkey).

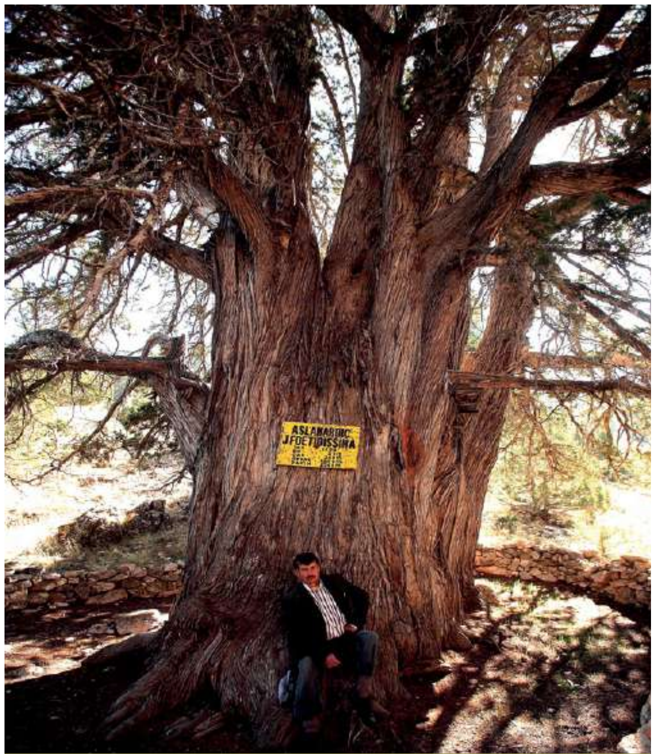
These criteria were generated due to the natural and cultural features of Turkish forest landscapes. For example, according to the results of pollen analyses made at lakes Abant and Yeniçağa (western Black Sea Region) (Bottema and Van Zeist, 1989), there have been no significant changes in vegetation (mainly in tree species) during the last 1000 years. The vegetation around Ilgarini cave (Kastamonu) in 1000 BC was composed of high mountain forests, containing mainly broad-leaved forest trees such as *Fagus orientalis* Lipsky., *Corylus colurna* L., *Carpinus betulus* L., *Carpinus orientalis* Miller, *Ostrya carpinifolia* Scop., *Castanea sativa* Miller, *Quercus* sp. and *Abies bornmülleriana* Mattf. (Akkemik et al., 2004). Such evidence is commonly used as a practical tool in

Figure 13.4

Prominent ancient tree species of Turkey and ancient wood distinction criteria
(Kırca et al., 2012)



Photograph 10: Kasnak Oak (*Quercus vulcanica*) typically found in Steppe forest region (Yukarıgökdere Village-Egirdir-Isparta) (A. Ince; Archive of General Directorate of Forestry-Turkey).



Photograph 12: Stinking juniper (*Juniperus foetidissima*) typically found in South and East Anatolia Mediterranean/Sub-Mediterranean forest region (Çıglıkara-Elmalı-Antalya) (A. Ince; Archive of General Directorate of Forestry-Turkey).

Photograph 11: Nordmann fir (*Abies nordmanniana*) typically found in Euxin-Subeuxin forest region of North Anatolia (Karaköy-Savsat-Artvin (A. Ince; Archive of General Directorate of Forestry-Turkey).

order to compare species composition of present forest cover with a specific time period. However it can't be the only criteria for the determination of ancient wood species as emphasized in Figure 13.4, since its intrinsic values (holiness, monumental appearance, etc.) as well as functional uses over time (characteristics of wood, purpose of use, etc.) play an important role. Pliny the Elder (1855) also indicates the intersection between spiritual meanings of ancient trees/woodlands and daily life in ancient world: '*Trees were once the temples of divine powers and, following traditional ritual, simple country people dedicate a tree that is particularly grand to a god. Nor do we honour with our worship wooden images gleaming with gold and ivory more than sacred groves and their silence*'. Ecological analyses and cultural survey show that oak species, Lebanon cedar, black pine, Mediterranean cypress, oriental beech, juniper species, as well as some other taxa given in Figure 13.4, come into prominence as ancient wood in Anatolia.

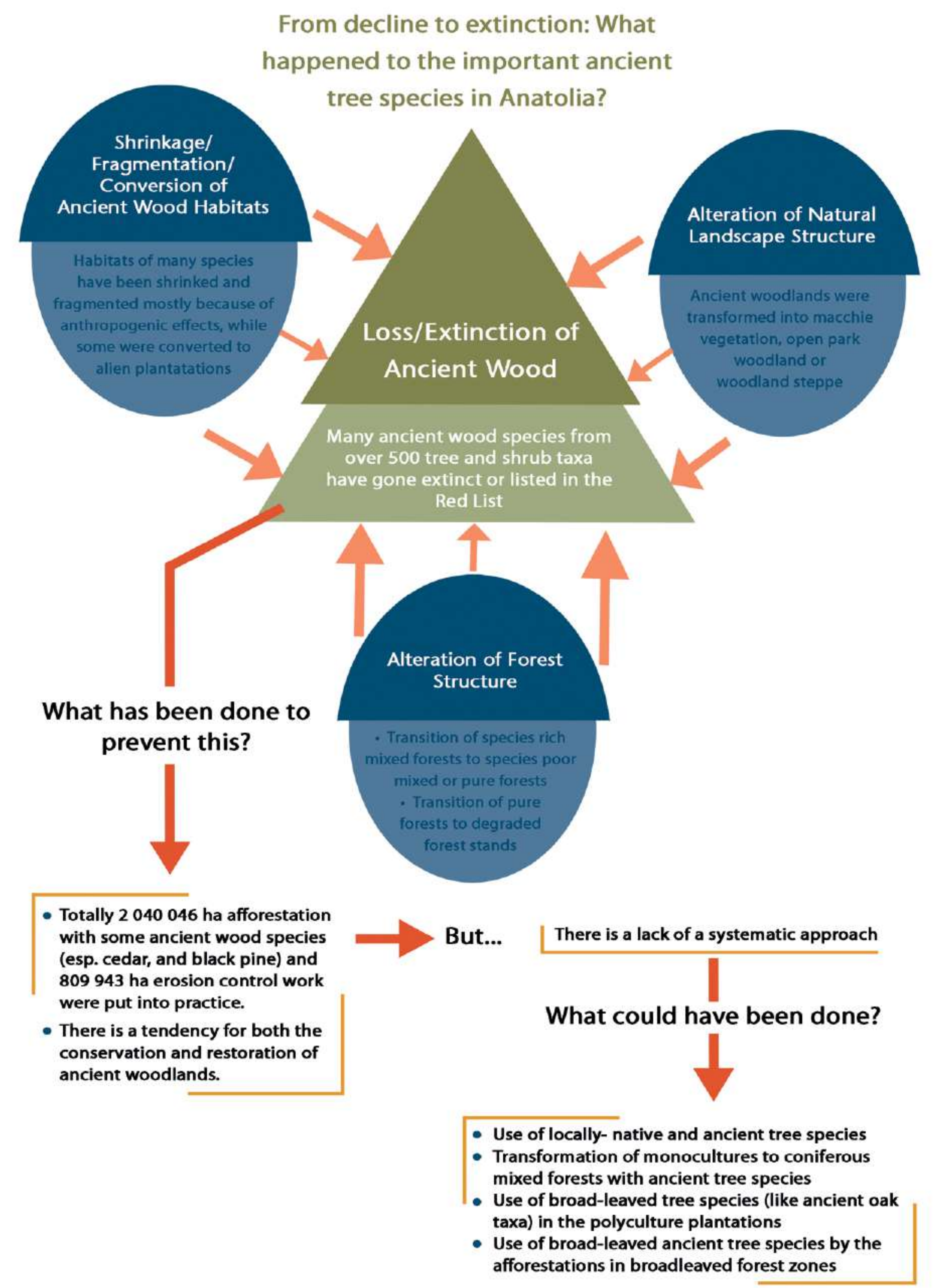
Restoring degraded ancient woodland landscapes to bring back ancient tree species into their native habitats

Historical records and contemporary research suggest Anatolia had 60-70% forest cover and 10-15% steppe around 2000 BC (Walter, 1956). The forest area has declined to 26% as a result of over-grazing, over-cutting, fires, spread of agricultural lands, wars etc., and steppe has increased to 24% in the intervening 4000 years (Louis, 1939; Walter, 1956). As mentioned before people played a particular role in this process resulting with the shrinkage/fragmentation and sometimes the conversion of ancient wood habitats. On the other hand natural landscape structure has been altered as in the case of Central Anatolia, which contained distinctive ancient woodlands but represented mainly with steppe vegetation today. Forestry implementations also played a particular role, while some species rich ancient forests were transformed into species poor mixed stands or pure forests, or severely degraded (Çolak et al., 2010). This resulted with the loss or extinction of many ancient tree species, from which some of them have been listed in Red List of Threatened Species (Figure 13.5). These phenomena indicate the urgent need for the restoration of ancient woodlands in Turkey.

As the periods before the establishment of Turkish Republic are examined, not many implementations come

Figure 13.5

What happened to the important ancient tree species and what could have been done? (Kırca et al., 2016; transformed after Kırca et al., 2012).

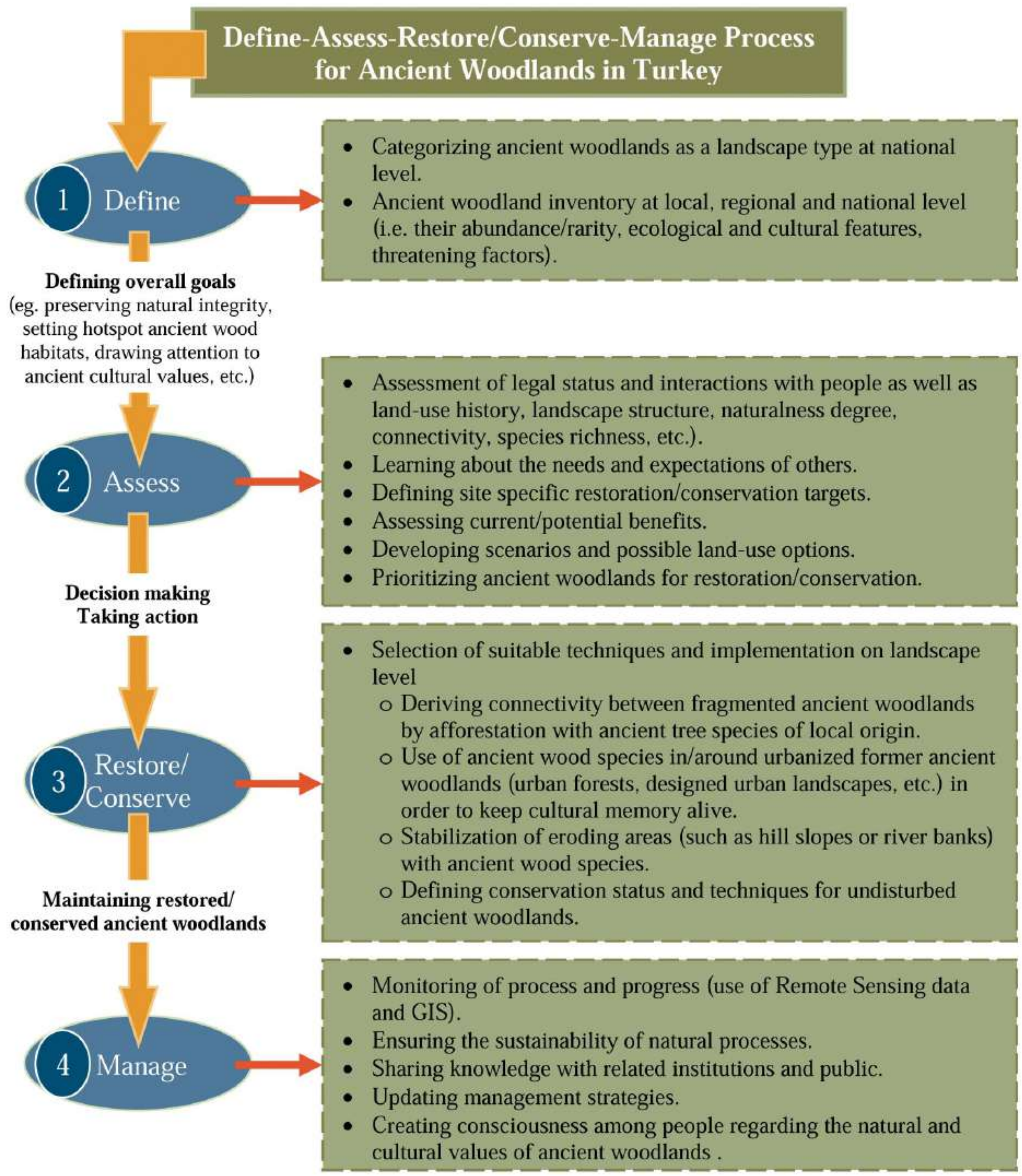


across on ancient woodland restoration issue. Therefore the afforestation work (including with some ancient tree species) done before the Republic Period should be accepted as discrete practices, while regular applications could only start after the period of World War II (Ürgenç, 1998). As a matter of fact, 'totally 2.040.046 ha afforestation with some ancient wood species (esp. cedar, and black pine) and 809.943 ha erosion control work' were put into practice (Çolak et al., 2010). However, it is considered that 10.2 million ha of forest (from which ancient woodlands constitute an important part of it) is still 'degraded' or 'highly degraded'. Therefore, a forest restoration concept considering ancient tree species/ woodlands and potential ancient woodlands play an important role in Turkey.

In Turkey the enthusiasm for prompt afforestation of the degraded areas led to some afforestation with monoculture coniferous and exotic tree species. However, in more recent works locally- native and ancient tree species have been used. Later on, monocultures were organized as coniferous mixed forests with ancient tree species, while broad-leaved tree species (like ancient

Figure 13.6

Actions to be taken for the restoration/conservation of ancient woodlands in Turkey: Define-Assess-Restore/Conserve-Manage Process (Kırca et al., 2012)



oak taxa) have begun to be included in the polyculture plantations afterwards. Today, in broadleaved forest zones afforestation work is implemented with broad-leaved ancient tree species. Such implementations indicate the tendency for both the conservation and restoration of ancient woodlands, but on the other hand a systematic approach is still lacking. The general framework for the conservation and restoration of ancient woodlands in Turkey has been summarized as 'Define-Assess-Restore/Conserve-Manage Process' in Figure 13.6.

In this framework the assessment of landscape structure, naturalness degree and species richness plays a particular role for decision making and further steps. Rose (1999) emphasizes the use of vascular plants as an indicator for nature protection in ancient woodlands considering the general rule 'the older the habitat, the more species it will support'. Peterken (1983) also noted that the wildlife communities are generally (but not invariably) richer than those of more recent woods. They contain a very high proportion of the rare and vulnerable wildlife species. Many of these species require the stability afforded by the continuity of suitable woodland. Where large, old trees have been present for several centuries they provide refuges for characteristic inhabitants of primeval woodland such as lichens. They are reservoirs from which the wildlife of the countryside has been maintained (and could be restored). Ancient woodland often contains other natural features which rarely survive in an agricultural setting such as streams in their natural watercourses and microtopographical conditions formed under periglacial conditions (Goldberg et al., 2007). For instance oaks (also an important ancient wood in Turkey) are renowned for the diversity of species associated with them. There is no other species in Europe with so many species of insect associated with the foliage (Darlington, 1974). Oaks have 350 species of lichens associated with them and as they age they are host to a range of very rare and endangered species especially saproxylic and mycorrhizal and epiphytic ones. Many other trees too as they age become host to assemblages of species which are extremely rare in Europe (Butler et al., 2001).

Thus, such an approach summarized in Figure 13.6 would provide multiple benefits both for countless species and human beings considering enrichment of habitat quality as well as maintaining/building habitat connectivity, which would improve people's life quality in urban and rural landscapes. This issue is exemplified with the following case studies on two ancient woodland species as *Taxus baccata* L. and *Buxus sempervirens* L.

Case study 1

Wise residents of ancient woodlands: *Taxus baccata* L. in Anatolian forests (from Kırca et al., 2015)*

The companionship between trees and human beings can be traced back to the first existence of man on earth, but undoubtedly, yew has played a particular role in this long journey. In addition to being used because of its valuable wood for turnery, marquetry and wood carving, as well as for manufacturing weapons (i.e. bows, spears and knives) (Forestry Compendium, 2005), yew had various symbolic meanings in the spiritual world of people in many different cultures (DeLong and Prange, 2006; Hageneder, 2013). For example yew was held sacred by the early Indo-European people, while believed to be immortal and considered as a symbol of everlasting life probably because of remaining resolutely green like 'an island of life and colour' all through the year, having the ability to live for thousands of years and hosting numerous living organisms (Parker and Levington, 1999). Although it became known as the 'tree of death' in the 17th and 18th centuries in Europe, because of its toxicity and it was frequently seen in the graveyards and associated with the mass slaughters of the Middle Ages, this tree was well favoured by many artists and scientists like Charles Darwin, Felix Medelssohn-Bartholdy, T.S. Eliot, William Shakespeare, William Wordsworth, etc. (Hageneder, 2013). Yew has also been widely used in landscaping as an ornamental plant and in windbreaks, and considered as one of the most suitable plants for topiary with *Buxus* sp. (Hobhouse, 2002), while it is associated with sacred sites mostly in western countries (Forestry Compendium, 2005). Although yew has an ancient reputation as a toxic and magical plant (Itokawa, 2003), it has been traditionally used in the cure of various diseases such as headache, diarrhoea, cardiac problems, etc. (Forestry Compendium, 2005). Today, taxol found in *Taxus* species is used to treat cancer (Itokawa, 2003; DeLong and Prange, 2006).

Unlike some countries (i.e. Ireland, UK, Spain, U.S.A. and Canada) yew is not widespread in Turkey, while only *Taxus baccata* L. natively grows mainly in the broadleaf forests of northern Anatolia as a relict species. However Parker and Levington (1999) emphasized that some fine stands of monumental *T. baccata* growing in broadleaf forests still exist in north-eastern Turkey outside Europe (Photograph 13). Actually the presence of *T. baccata* in different parts of Anatolia can be traced back far into history. Theophrastus (1999a) gave detailed information about the yew trees on Mount Ida (western Anatolia), where *T. baccata* was also quite rare as today: '*The yew has also but one kind, is straight-growing, grows readily, and is like the silver-fir, except that it is not so tall and is more branched. Its leaf is also like that of the silver-fir, but glossier and less stiff. As to the wood, in the Arcadian yew it is black or red, in that of Ida bright yellow and like prickly cedar; wherefore they say that dealers practise deceit, selling it for that wood: for that it is all heart,*

Photograph 13: Common yew (*Taxus baccata*) stand in Gümeli Nature Monument (Alaplı/Zonguldak) (K. Cengiz; Archive of Zonguldak Forest Enterprise-2016).

Photograph 14: Common yew (*Taxus baccata*) stand in Gümeli Nature Monument (Alaplı/Zonguldak) found as groups of trees in a mixed stand (N. Aksoy).

when the bark is stripped off; its bark also resembles that of prickly cedar in roughness and colour, its roots are few slender and shallow. The tree is rare about Ida, but common in Macedonia and Arcadia; it bears a round fruit a little larger than a bean, which is red in colour and soft; and they say that, if beasts of burden eat of the leaves they die, while ruminants take no hurt. Even men sometimes eat the fruit, which is sweet and harmless'. Ancient yew symbols on the finds from Troy and some evidence related to Hittite culture also indicate that *T. baccata* was present in that region in ancient times, while it was embraced as the ultimate symbol of life and renewal (Hageneder, 2013). Ancient documents do also reveal that Amanus Mountains (south eastern Anatolia) were not only a source of cedar, boxwood, and cypress (Rowton, 1967) but also of yew, while yew was well favoured by Egyptian palace-furniture makers (Meiggs, 1982). Furthermore, one of the finest heads that have survived from Ancient Egypt, of Queen Tiu, wife of Amenhophet III, and some coffin boards are made of yew, which was probably exported from Amanus Mountains (Meiggs, 1982). Surprisingly, some structures made of yew were found in Central Anatolia, in Gordium, the capital city of ancient Phrygia, whose neighbourhood is almost treeless today. Juniper and yew logs were used for the construction of the outer wall of a royal tomb (Meiggs, 1982), while there was a stool whose front and back faces made of boxwood were elaborately inlaid with yew (Young, 1974; Simpson, 2012).

Although yew still retains its traditional and trade value in Turkey as well as many European countries, they have been strongly depleted mainly because of the direct and indirect actions of mankind (i.e. deforestation, selective felling, grazing or inaccurate planning and management) and partly of their weak competitive ability (Iszkulo et al., 2012). So today, they occur either as individual trees or group of trees in a mixed forest stand, or small patches of yew forests (Mayer and Aksoy, 1986; Svenning and Magård, 1999; Thomas and Polwart, 2003; Piovesan et al., 2009) (Photograph 14), while they represent one of the most endangered priority habitats in a great part of their distribution in Europe (Farris et al., 2012) and *Taxus* have received priority habitat status under Annex I of the EU Habitats Directive in seven different habitat types (European Comission, 2007). Thus, there is an urgent need to define remaining *T. baccata* habitats and apply effective conservation and restoration techniques in Turkey before these wise residents of ancient woodlands become history.

Considering the intensive use of yew through time in Turkey, ancient woodlands with yew have been highly degraded, while remaining ancient stands still continue to be threatened by many natural and social factors. This requires the urgent need for integrative techniques for the conservation and restoration of woodlands containing yew trees.

Can we classify common yew as an ancient wood?

In Turkey, yew is defined as a species whose existence can be traced back from hundreds of years to neolithical ages in primary or natural/near natural woodlands. These are not only appreciated as icons of most important wooded landscapes, but also as unique components of cultural heritage. In this context the main reasons of the classification of yew as an ancient wood is summarized in Figure 13.4 and explained in detail below:

- Yew has been continually used by many civilizations not since hundreds, but thousands of years. This indicates its ability to survive as a woodland species for such a long time, while on the other hand shows its resistance to climatic variability and over-exploitation.
- The wood of ancient yew is of high quality and in high demand, while old individuals of age as 500 can be found in their natural habitats. Yew is a slow-growing species.
- Yew has potentially wide distribution area in Turkey, considering its native stands in northern, western and southern Turkey.
- Yew is easily pruned and shaped and has been a common component in parks, gardens, palaces, cemeteries and churches for centuries and is widely used as a hedging plant in all amenity situations.
- Yew has been an important element of tree symbolism for thousands of years in many different cultures.

Where to find *Taxus baccata* in Turkey?

Taxus baccata L. has a distribution area concentrated mainly in the Euxine broadleaf mixed forest zone in northern Turkey. Other main distributions are on Kaz Mountains (western Anatolia) and Amanus Mountains (eastern Taurus range in southern Turkey (Figure 13.7). Mayer and Aksoy (1986) reported some other locations of *T. baccata* between the altitudinal zones 500 to 1400 m a.s.l., while Davis (1965) remarked some further locations as Çilingoz (Istanbul), Yedigöller National Park (1000 m a.s.l.), Küre to Inebolu (Kastamonu-1000 m a.s.l.), Çoruh (1400 m a.s.l.), Bozdağ (Denizli-1800 m a.s.l.), Gülek Boğazı (İçel) and Amanus (Hatay-1800/1900 m a.s.l.).

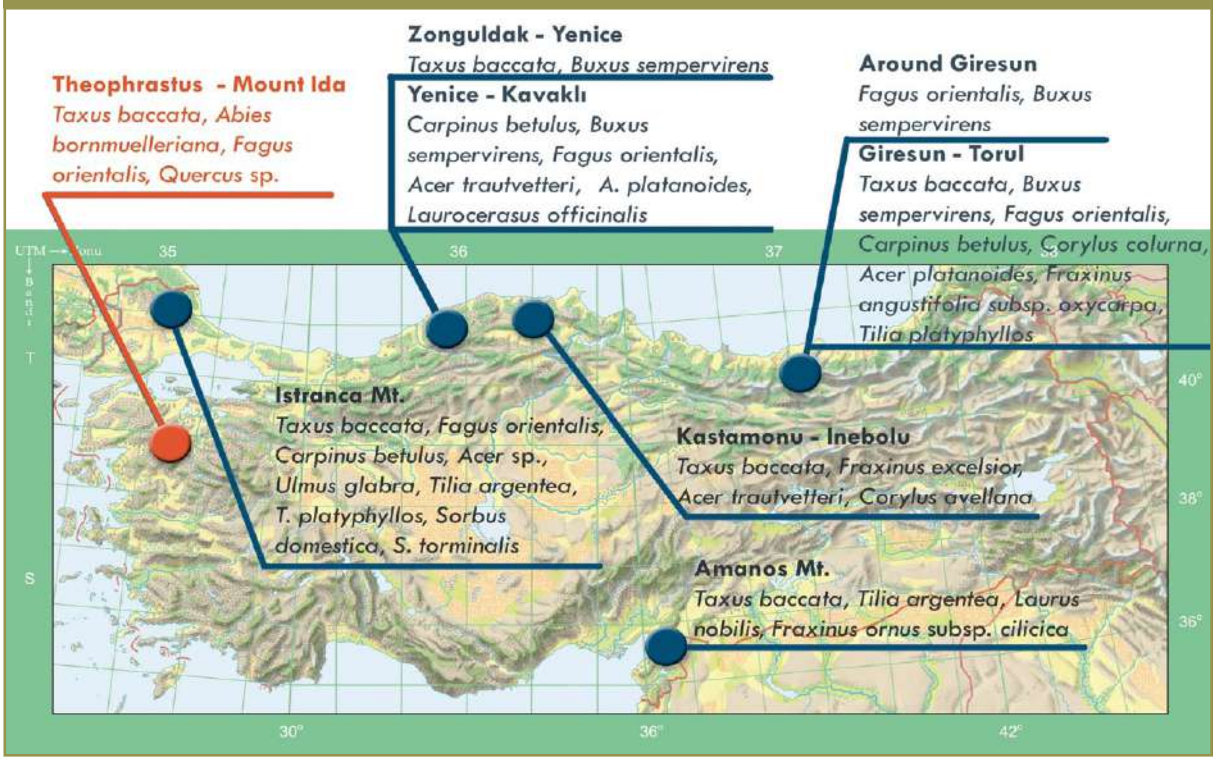
Conservation and restoration of common yew stands in Turkey

In Turkey, populations of yew have been destroyed and others are under threat in many parts of its native range, as it is not able to regenerate or broaden its population (so is the situation with boxwood too). Basically human induced effects (i.e. careless treatment, over-exploitation, unsuitable forestry practises) caused the clear reduction of its distribution area to its present state. Actually, the story of dramatic decline of yew populations in Turkey corresponds well with the story of many other ancient tree species (Figure 13.5). Therefore, today, yew is in the 'Red List of Endangered Species' in Turkey. However a designation for its conservation is still lacking, as well as its restoration in degraded forest landscapes containing ancient yew. It is thought to be very important to research native areas where yew is under threat and to conserve/restore these sites (Çolak et al., 2012) (Photograph 15).

There are some simple, but very important steps to be taken for conserving as well as providing the sustainability of the remaining ancient yew in Turkey based on fundamental principles of nature protection. For example when we consider that *Taxus baccata* L. is distributed in different parts of Turkey and mostly found either as individual or group of old trees scattered

Figure 13.7

Main distributions of *Taxus baccata* and accompanying tree species
(according to Mayer and Aksoy (1986) from Kırca et al., (2016)

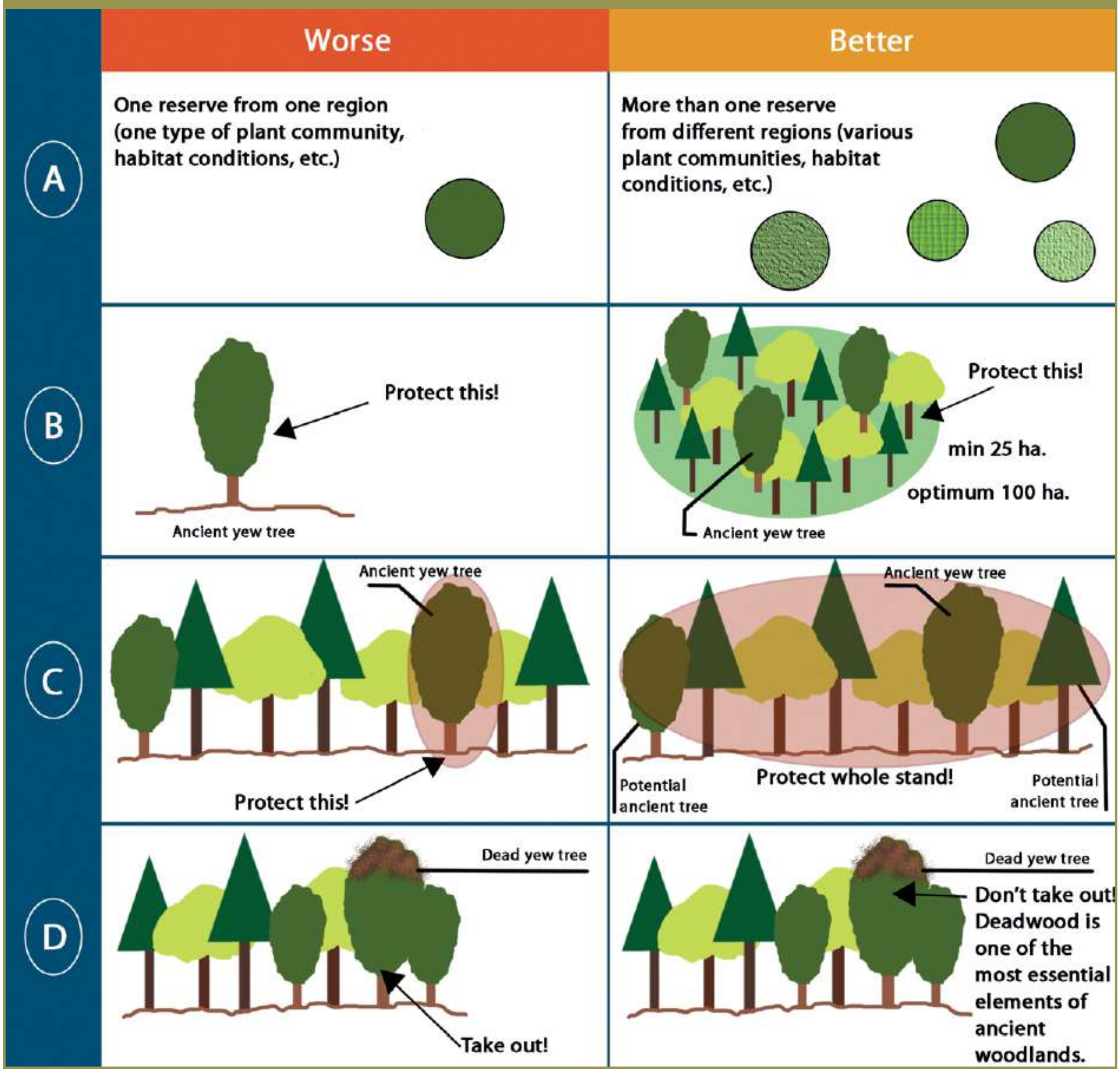


Photograph 15: Common yew (*Taxus baccata*) stand in Gümeli Nature Monument (Alaplı/Zonguldak) (F. Hageneder).

in a forest stand, first of all there is an urgent need to understand that one reserve from one region is not enough. Such an approach would lead to conserve one type of plant community, habitat conditions, etc. that yew has grown into, but overlook other remaining habitats. So, selecting more than one reserve from different regions would provide protecting various plant communities and habitat conditions of ancient yew stands (Figure 13.8a). On the other hand, a landscape approach should be adopted rather than protecting one single ancient yew tree considering that generally minimum of 25 ha reserve area is recommended for providing the sustainability of a tree population (Figure 13.8b). However protecting only the ancient yew trees in a forest stand also wouldn't be enough, while other trees of different species should be considered as potential ancient trees as well (Figure 13.8c). Eventually special attention should be given to dead yew trees, since deadwood of yew as well as of other species is one of the most essential elements of

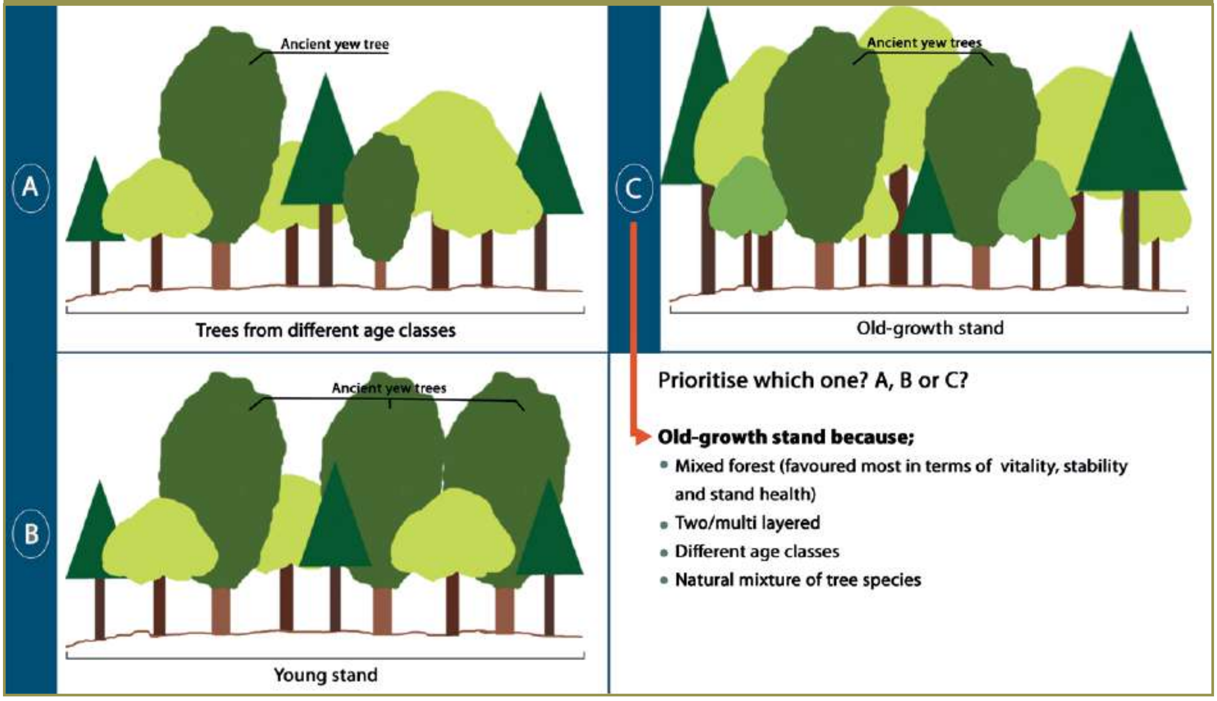
Figure 13.8

Some simple but important issues providing the sustainability of the remaining ancient yew in Turkey (Kırca et al., 2016)



Prioritising stands in reserve selection by the conservation of ancient yew (Kırca et al., 2016)

Figure 13.9



ancient woodlands (Figure 13.8d).

Yew is generally found in broadleaf mixed forests that represent different characteristics in Turkey, while there must be some further criteria by selecting reserves in order to determine which one(s) need to be protected/restored first. Thus understanding the stand structure plays a vital role for prioritising yew landscapes, which are mainly stands containing trees from different age classes (Figure 13.9a), young stands (Figure 13.9b) or old-growth stands (Figure 13.9c). In this situation old-growth stands should be prioritised firstly because of their stand structure as being composed of mixture of natural deciduous and broadleaf trees and having a two/multi layered stand structure of different age classes (Photograph 16). Such an old-growth stand structure was described by Peterken (1983) and Goldberg et al. (2007) as habitats containing a very high proportion of rare and vulnerable plant and wildlife species as well as providing refuges for characteristic inhabitants of primeval woodlands such as lichens.

A very good example to why prioritising old-growth stands may be given from northern Turkey, Kavaklı (Yenice) located on the slopes facing Black Sea (Figure 13.10). This stand does not only contain yews with a diameter over 110 cm reaching ca 2 m, but these trees are also accompanied by *Carpinus betulus, Fagus orientalis* and *Acer platanoides* who are quite old as well. Furthermore *Buxus sempervirens*, a very rare ancient tree species is also found under *Taxus baccata* as seen in stand profile (Aksoy, 1982) (Figure 13.10). Such a stand would represent an ideal example by the reserve selection in order to understand what to protect first.

The conservation and restoration of ancient common yew in Turkey requires a systematic approach in the landscape level. After defining some basic principles as explained above, there is a need to take some main steps in order to respond to the questions 'What' and 'How' to conserve/restore?. There are also some other important issues to be considered by the implementation of conservation and restoration actions, which are summarised below (after Çolak et al. 2012; Kırca et al., 2016):

Photograph 16: Multi-layered common yew (*Taxus baccata*) stand in a mixed forest (Gümeli Nature Monument - Alaplı/ Zonguldak) (N. Aksoy).

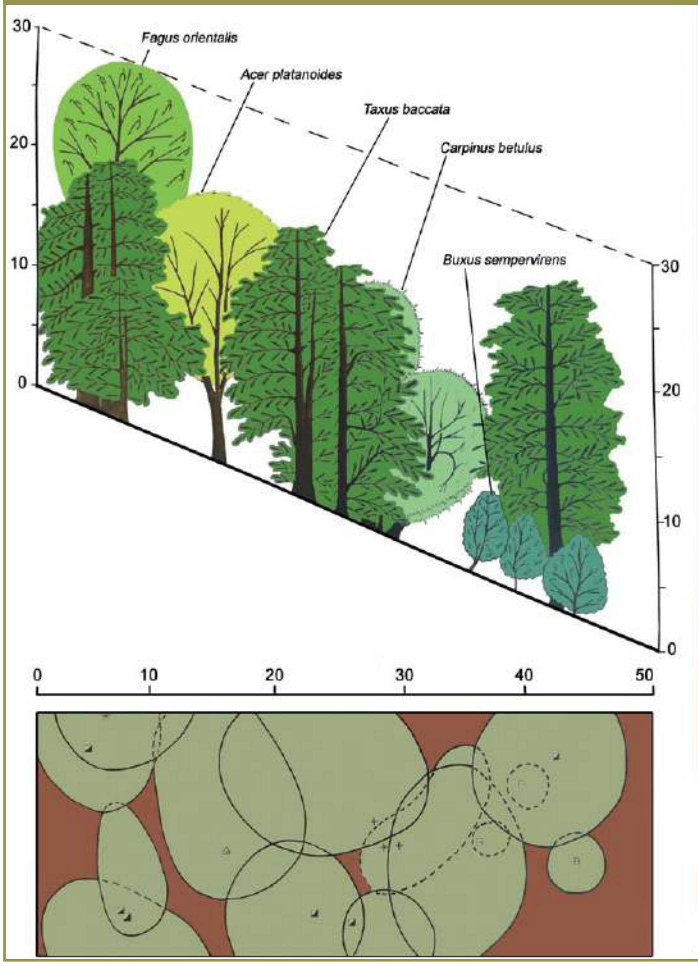
- In natural stands, yew does not easily re-invade areas where it was once present, endangering its existence in managed areas with careless treatment and over-exploitation. It is necessary to keep and preserve yew as groups or strips under tree stands with a dense understorey. It grows very slowly with a very low annual increment, therefore it is important that old individuals should be preserved in terms of nature conservation (Photograph 17).

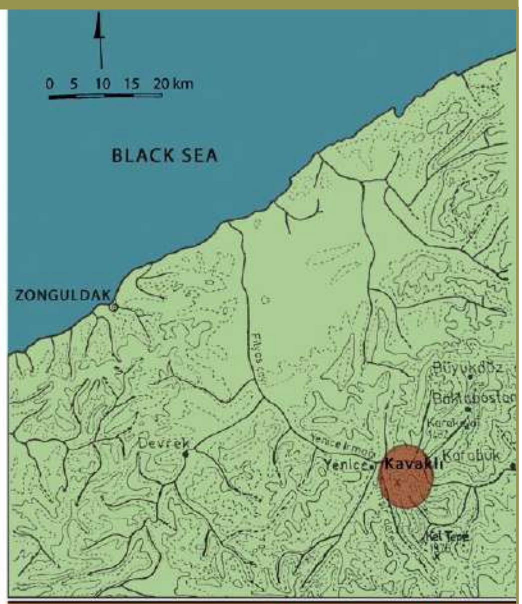
- It grows naturally from low altitude to high mountains. Therefore adaptation of basic principles of mountain forestry plays an important role by the restoration and conservation of ancient yew forests.
- Yew is shade-tolerant understorey species in pure forests (i.e. beech) and mixed broadleaved forests (Vegetation types: deciduous forests; mixed forests; mountain forests; coniferous forests; riparian forests). In Turkey, it is found in very different forest communities (Mayer and Aksoy, 1986) such as *Carpinus orientalis-Pinus sylvestris forest with Arbutus andrachne, Juniperus oxycedrus, Ulmus minor, Carpinus orientalis, Pinus sylvestris, Quercus macranthera* ssp. *syspirensis* and *Pictacia terebinthus* in northern Turkey, and in *Fagus orientalis-Acer platonoides-Taxus baccata-Carpinus orientalis* forest in western Turkey. Therefore varying conservation/restoration and silvicultural strategies are required in habitats of different forest plant communities.

Photograph 17: An old common yew (*Taxus baccata*) found in a mixed stand with a dense understorey in Gümeli Nature Monument (Alaplı/Zonguldak) (N. Aksoy).

Figure 13.10

A stand profile from Kavaklı (Yenice) containing Taxus baccata and diameter and height values of tree species (transformed by Kırca et al., 2016; after Aksoy, 1982)





Tree species	Diameter (cm)	Height (m)
Taxus baccata	194 143 116	19 22 21
Carpinus betulus	111 75	19 14
Fagus orientalis	109	29
Acer platanoides	90	22

Case Study 2

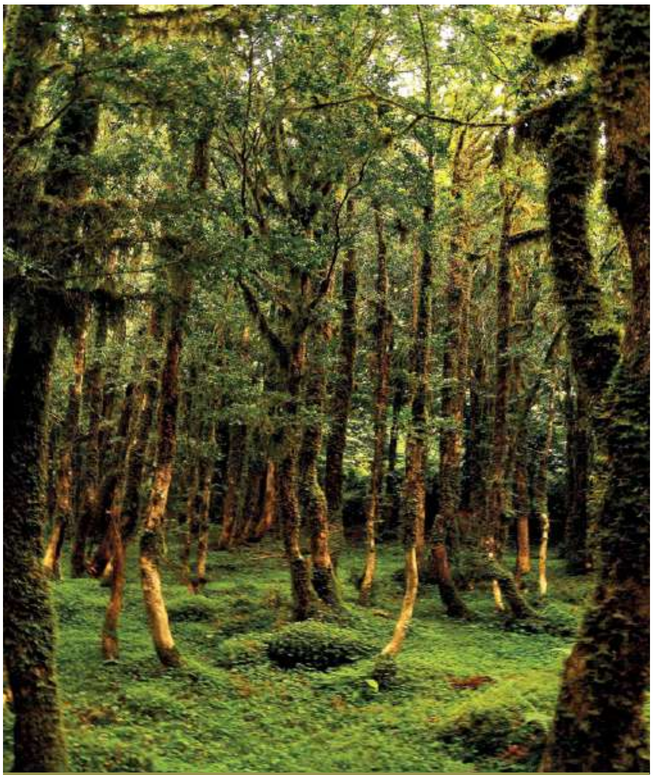
What happened to the ancient common boxwood (*Buxus sempervirens* L.)?: From boxwood forest to the red list of endangered species in Turkey (from Çolak et al., 2012)

The word *Buxus* comes from the Greek word 'pyxos, pykos' which means 'hard', and Aristotle and Theophrastus used this name for *B. sempervirens* (Hecker, 1995). In Latin, 'sempervirens' means 'evergreen' indicating its green in all seasons (Çolak, 2003b). Common boxwood had many functions throughout the history and was highly appreciated by cabinet-makers because it had a close, straight grain, was hard and strong but easily worked, and because it had an attractive pale colour with little difference between heart and sapwood. Common boxwood rarely grows to a great height and never produces a thick trunk (Photograph 18), but was a valuable wood for small objects or parts of objects which had to be strong and might need delicate workmanship. It was therefore particularly associated with combs and musical instruments, especially the flute and lyre. In furniture it could be used for beds, couches, chairs, and small tables, but it was more commonly used in inlays and veneers where its pale colour provided an attractive contrast with darker woods (Meiggs, 1982). The hard, highly polished wood of the boxwood was used in Solomon's temple in Jerusalem too (Isaiah, 60:13).

King Assurnaspial (881-859 BC) had shown the Assyrian appreciation of boxwood by including in his booty from a campaign in Syria, after he had crossed the Euphrates at Charchemish, 'beds of boxwood, chairs of boxwood, tables of boxwood inlaid with ivory' (Meiggs, 1982). On the other hand Phyrgians in Central Anatolia used to make their furniture from cedar, aromatic juniper, boxwood, pine wood and walnut. A Phrygian burial mound of the 8th century BC at Gordium (the capital city of ancient Phrygia) contained an ornate boxwood table with intricate geometric juniper inlays and a walnut top. Other furniture from the Gordium mounds shows that Phrygian craftsmen also used maple, oak, cedar, pine, and yew (Young, 1974). Thus boxwood has been widely used particularly for the production of furniture, stick, ashtray, spoon, fork, etc., which still continues today.

In the Roman period, the boxwood was so closely associated with certain objects that Latin poets used the word 'buxum' for comb, flute and top. Since that period it has been widely used for musical instruments. A Roman jury law specifies that the ballots shall be of boxwood, and it may be added that balls of boxwood are used in drawing lots for fixtures in the annual English football-cup competition. Boxwood was also used in Greece for writing exercises and in Rome for drawing exercises as it was in Italy during the Renaissance. In the Erechtheum accounts use of boxwood is found for the frames of ceiling coffers (Meiggs, 1982).

B. sempervirens wood has been used for centuries, and was traditionally used in England particularly to make looms (Hegi, 1957). It was also used for making printing blocks in China many centuries ago. The statue of Apollo in Olympos-Hellas was carved from *B. sempervirens* wood. It is also commonly used to make flutes and other wind instruments, is the best wood of all materials for wood-engraving and is highly prized by turners. Other major uses of *B. sempervirens* are for making chess figures, pipe heads, printing blocks, bowls, combs, jewellery boxes, walking sticks, tool handles, rulers and other such articles (Hausen, 1981; Brondegaard, 1992; Çolak, 2003a). Root wood is also specially prized by turners and cabinetmakers (Chiej, 1984).



Photograph 18: Common boxwood (*Buxus sempervirens*) stand in Kaçkar Mountains National Park (Çamlıhemsin/Rize) (O. Kurtoglu).

Anatolia played an important role, particularly for Mediterranean civilizations, in ancient wood (cedar, oak, pine, fir, etc.) supply, while common boxwood comes into prominence among over 500 shrub and tree taxa found in Turkey. After boxwood sources were severely depleted in Syria, it was no longer an important source of supply for Romans and Greeks. According to Theophrastus (1999a) the most famous box came from Mount Cytorus (Amasra) in Paphlagonia (Central Black Sea Region) and the neighbouring district, and the association of box with the mountain was so close that 'cytoreus' was even used as a synonym for 'buxeus' (Meiggs, 1982). Thus Strabo (1856) also reports that Cytorus was the marketplace and was a source for common boxwood.

In Turkey, the plant has different traditional uses in folkloric medicine too. For instance, the tea form of common boxwood, named as 'şimşir' in Turkish, is drunk a glass per day prior to meals for antihelminthic, diaphoretic, and cholagogue purposes in Anatolia (Baytop, 1999). Common boxwood owes its popularity not only to tradition, but also to its many landscape uses. Some of the ways the plant can be used are noted by Relf (2001) and Hobhouse (2002). These are (1) As plants alone or in combination with other plant material in structure plantings for homes and public buildings; (2) To separate, define, enclose, or screen areas; (3) To provide background for other plantings; (4) To provide the overall pattern or framework of a formal garden; (5) For framing vistas; to outline a terrace, parking area, flower border, or walk; (6) For planter boxes or large containers; and (7) As topiary pieces, in lieu of sculptures. After the 18th century, the plant was also introduced to the Ottoman gardens (e.g. palace gardens, home gardens through the Bosphorus, etc.) and was highly appreciated. It also featured in gardens of the Middle Ages (i.e. monastery and palace gardens) and baroque gardens in Europe (Çınar and Kırca, 2010). Therefore, the box tree could also be noted as one of the symbols of transition from a naturalistic to a formal garden style in Ottoman gardens.

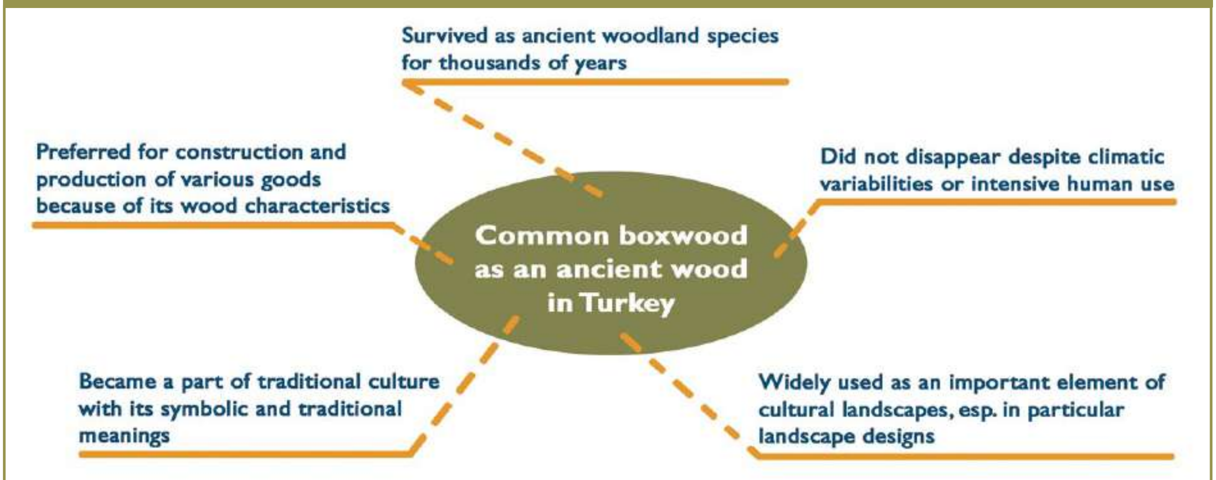
Why common boxwood is classified as ancient wood

The main reasons of the classification of common boxwood as an ancient wood is summarized in Figure 13.11 and explained in detail according to Çolak (2005) below:

- Common boxwood has been continually used by many civilizations not for hundreds but thousands of years. This indicates its ability to survive as a woodland species for such a long time, while on the other hand shows its resistance to climatic variability and over-exploitation.
- The wood of ancient common boxwood is of high quality and in high demand, while old individuals of age as 500 can be found in their natural habitats.
- Common boxwood is a slow-growing species. Seedlings grow very slowly between 1 and 7 years, typically being 15 cm tall after 4 years. Diameter increments are also very slow, with for example, trunks of only 5 cm diameter achieved after 100 years in France (Aichele and Schwegler, 1996), 6.5 cm and 12 cm diameter after 103 and 140 years respectively in Turkey (Çolak, 2003b), with tree trunks up to 50 cm diameter after 500 years according to Erlbeck et al. (1998). The slow growth of common boxwood leads to the formation of a very dense annual ring. The specific gravity of fresh cut wood is 1.2-1.26 g/cm^3, and 0.99-1.02 g/cm^3 when air-dry, and will sink in water (Çolak, 2003a). Large box tree to 8-12 m high and 60 cm in trunk diameter still exist in Rize (Northeast Anatolia) (Aksoy, 1998). The wood is very hard, heavy, compact and fine-grained. The heartwood is a pale yellow colour, takes a beautiful polish, is not liable to insect attack and it is twice as hard as oak species (Grieve, 1984). The diameter of wood used in turnery is generally about 10 cm and for that reason, large-sized common boxwood have been used for a long time and have mostly disappeared in natural areas such as those in Spain and Turkey from where large quantities of common boxwood have been exported.
- Common boxwood is easily pruned and shaped and is a common component of parks, gardens, palaces, cemeteries, churches and is widely used as a hedging plant in all amenity situations.
- Box tree has a potentially wide distribution area in Turkey, considering its native stands in northern and southern Turkey.
- Common boxwood has been an important element of tree symbolism for thousands of years in many different cultures. It is a revered plant in some Christian cultures, supposedly warding off evil spirits. The tree has numerous religious uses, notably in Europe, which Crosnier (1998) considers to be due to the persistent evergreen foliage of common boxwood symbolizing the continuity of life between this world and the next (holly, *Ilex aquifolium*, is often thought of in the same

Main reasons for the classification of common boxwood (*Buxus sempervirens* L.) as an ancient wood in Turkey (transformed after Çolak et al., 2012)

Figure 13.11



way). In France, branches are cut on Palm Sunday and put on graves, hung inside houses and stables, and even placed in cultivated fields, as protection against misfortune and illness. Sacred common boxwood is supposed to protect a household against anything that might upset the stability of life, including storms, fires and diseases; and for disposal it should be burnt, never thrown away (Crosnier, 1998). In other parts of Europe it is also hung in sanctified homes on Palm Sunday, protecting them from witches and diseases (Hegi, 1957), and in some cultures is symbolically used on woman's day, 15 August (Schmidt, 1990a). Leaves of the plant were also used as an ornament for brides in Thrace (north-west of Turkey) (Kültür, 2008).

From decline to extinction: what happened to the ancient common boxwood in Anatolia?

In Turkey, in many parts of its native range, populations of common boxwood have been destroyed and others are under threat, as it is not able to regenerate or broaden its population (Çolak, 2003c). Basically human induced effects (i.e. careless treatment, over-exploitation, unsuitable forestry practices) caused the clear reduction of its distribution area to its present state. For example, Hegi (1957) reports that 10.000 tonnes of large common boxwood timbers were brought to England from North Anatolia, Turkey in 1876, and clearly, the felling of such quantities of wood in a single year would rapidly deplete a native stand.

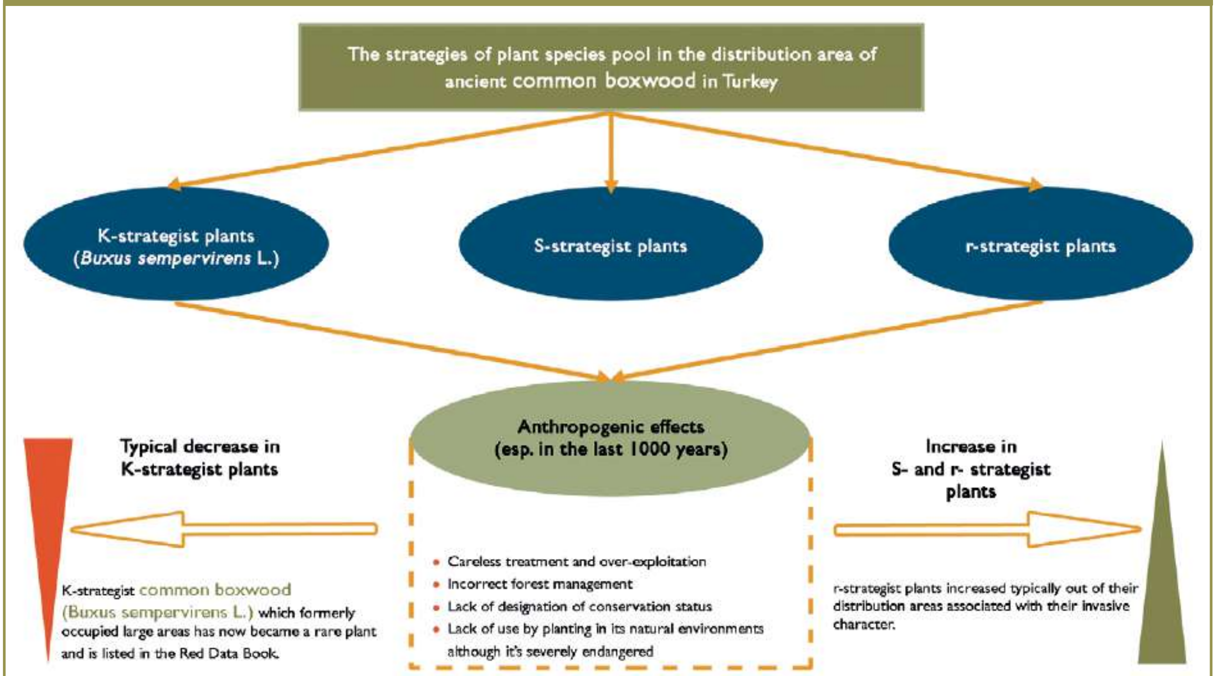
On the other hand, knowing the life strategy of the common boxwood is not only a starting point for nature conservation but will also be very useful in the practice of close-to-nature silviculture. Failure to take notice of the strategies will result in some species declining in abundance while others could invade the forests (Figure 13.12). Based on the research by Çolak (2003a,b,c) common boxwood is characterized as a K-strategist. Therefore, today, common boxwood is on the 'Red List of Endangered Species' in Turkey (Çolak, 2003b). However, a designation for its conservation is still lacking, as well as its restoration in degraded forest landscapes with ancient common boxwood. It is thought to be very important to research native areas where common boxwood is under threat and to conserve/restore these sites.

Restoring degraded forest landscapes to bring back ancient common boxwood into their native habitats

Common boxwood has been widely introduced outside its natural range over many centuries as an ornamental and hedge tree due to its evergreen foliage, but not as a plantation species for wood production (Çolak, 2005). Some typical examples are seen in central Europe where common boxwood has been a major ornamental plant in the palace gardens, baroque gardens, churchyards, villages and cemeteries (Çolak, 2003a). In the Middle Ages, it was planted in churchyards due to its pharmaceutical characteristics and for religious reasons; Great Karl, for example, encouraged the planting of common boxwood in churchyards (Schmidt, 1990b). The American Boxwood Society reports the first planting in the USA in 1653 at

Figure 13.12

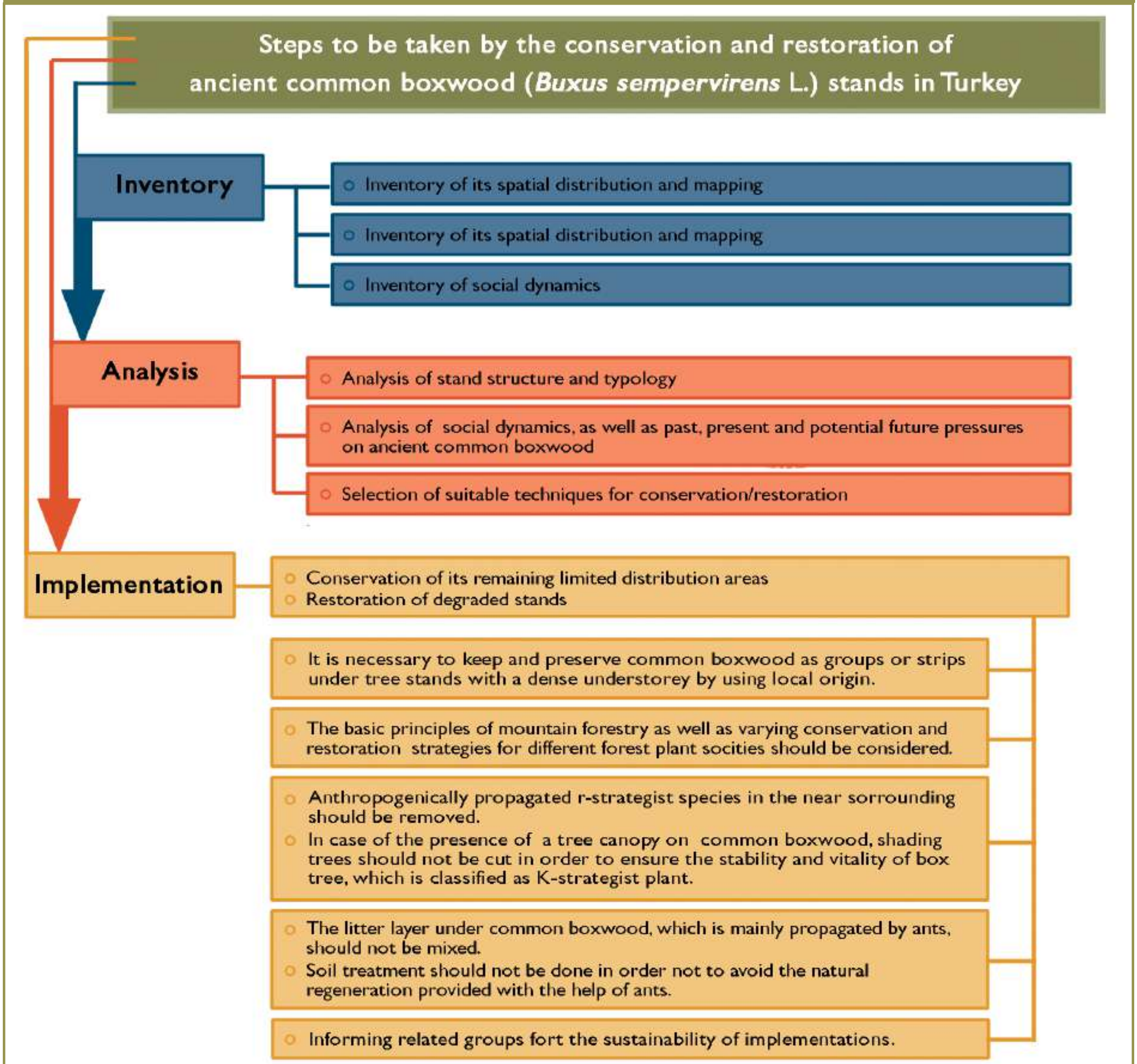
Extinction of common boxwood (*Buxus sempervirens* L.) as a prominent ancient woodland species (transformed after Çolak et al., 2012)



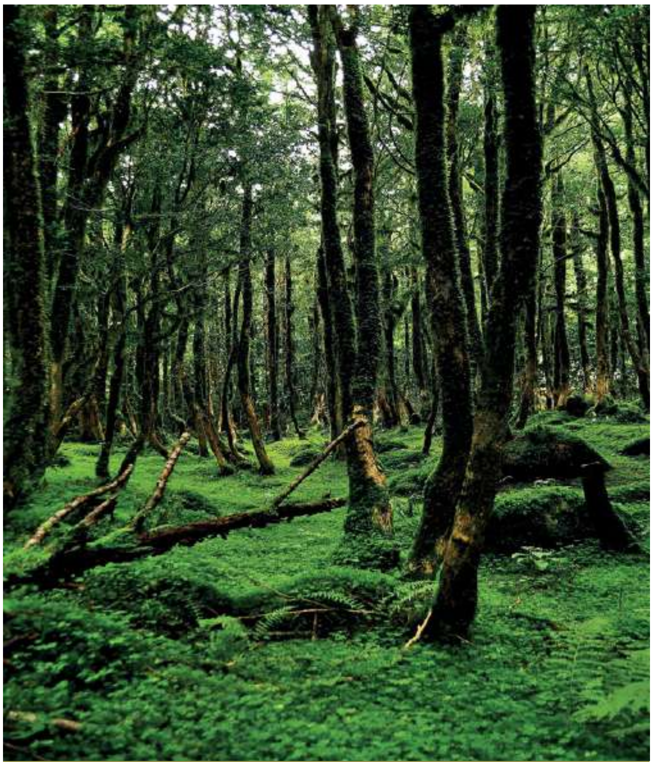
Sylvester Manor on Shelter Island, off Long Island in New York State. The seed came from Amsterdam and it can be seen growing in many public and private gardens in the USA, most frequently in the Mid-Atlantic area. It is probably far more widespread as an introduced species than is indicated in the distribution list. In other words common boxwood is raised today by many nurserymen, landscapers and homeowners for horticultural interests as it is a slow growing, evergreen and easily formed tree, tolerant of pruning, and commonly used in parks, gardens, borders, fountains, hedges, domestic gardens, large formal gardens and in many places individually, in groups and/or hedges. It can be trained to grow in various shapes such as prostrate, globe, half-erect, weeping, columnar, and pyramidal. There are also low or tall forms and fast- or slow-growing cultivars. It is specifically grown in containers, for topiary, and as a bonsai. In Europe, the species is also common in graveyards and churchyards (Çolak, 2005). Far from its use basically in landscape designs in Europe, boxwood has been particularly appreciated for its functional features in construction and art works in Anatolia over thousands of years. Therefore conservation of the last remains of its ancient habitats and restoration of degraded ancient common boxwood stands is not only an ecological need, but also a measure against the loss of 'cultural heritage'. The basic principles for the conservation and restoration of ancient common boxwood in Turkey is summarized in Figure 13.13, while it is represented in 3 main steps which are: (1) inventory of the spatial distribution of remaining ancient common boxwood stands with stand structure and topology (this step should also contain a social inventory in order to understand the social dynamics effecting species' distribution in a given area); (2) analysis of the obtained data and selection of suitable techniques for conservation/restoration and (3) implementation of

Figure 13.13

Basic steps for the conservation and restoration of ancient common boxwood (*Buxus sempervirens* L.) as a prominent ancient wood in Turkey
(transformed after Çolak et al., 2012)



Photograph 19: Common boxwood (*Buxus sempervirens*) grows very slowly with a very low annual increment (Kaçkar Mountains National Park, Çamlıhemsin/Rize) (O. Kurtoglu).



Photograph 20: It is necessary to keep and preserve Common boxwood (*Buxus sempervirens*) as groups or strips under tree stands with a dense understorey (Kaçkar Mountains National Park, Çamlıhemsin/Rize) (O. Kurtoglu).

conservation/restoration practises (Çolak et al., 2012).

In natural stands, common boxwood does not easily re-invade areas where it was once present, endangering its existence in managed areas with careless treatment and overexploitation. It is necessary to keep and preserve common boxwood as groups or strips under tree stands with a dense understorey. It grows very slowly with a very low annual increment, therefore it is important that old individuals should be preserved in terms of nature conservation (Çolak, 2003b) (Photograph 19 and 20). For the continued existence of common boxwood, it is recommended that different regional and altitudinal genetic reserve areas are established, as the species cannot easily regenerate and is classified as an endangered K-strategic species (Çolak, 2003c).

It grows naturally from low altitude to high mountains, rising to 800 m in the Jura, Switzerland, 1500 m in Anatolia, Turkey, 1600 m in the Pyrenees, France, 1900 m in Spain and 2000 m in the Olympics, Greece (Hegi, 1957; Erlbeck et al., 1998). Where introduced, it grows at even higher altitudes, such as in the Andes at 2830 m in Ecuador and 3600 m in Bolivia (Missouri Botanical Garden, 2003). Therefore adaptation of basic principles of mountain forestry plays an important role by the restoration and conservation of ancient box tree forests.

Common boxwood is shade-tolerant understorey species in pure forests (i.e. beech) and mixed broadleaved forests (Vegetation types: deciduous forests; mixed forests; mountain forests; coniferous forests; riparian forests) (Hegi, 1957; Çolak, 2003a). In Turkey, it is found in very different forest communities (Mayer and Aksoy, 1986; Çolak, 2003b) such as *Carpinus orientalis-Pinus sylvestris* forest with *Arbutus andrachne, Juniperus oxycedrus, Ulmus minor, Carpinus orientalis, Pinus sylvestris, Quercus macranthera* ssp. *syspirensis* and *Pictacia terebinthus* in northern Turkey, and in *Fagus orientalis-Acer platonoides-Taxus baccata-Carpinus orientalis* forest in western Turkey. Therefore varying conservation/restoration and silvicultural strategies are required in habitats of different forest plant communities.

Common boxwood has a low reproductive capacity because of the low levels of seed production (Çolak, 2003c). The seed dissemination capacity is also low, most seeds falling within 1-5 m of the source tree to a maximum distance of 20-25 m whereas the majority of the fallen seeds are transported by ants. Seedlings do not emerge on sites where there is no litter layer. Young seedlings are, however, very tolerant to shade, growing with 3.4-65% full sunlight, and demonstrate good growth in small gaps in forest stands. Thus while natural regeneration may be seen in sparsely populated stands, seedlings rarely grow in stratified closed stands with 2-3 strata and regeneration is not observed in open or exposed sites. In the first year, many seeds germinate but the number of seedlings decreases rapidly in following years. However, since there is re-sprouting from the stem and roots following damage to the tree, regeneration is common from such sprouts. Leaves and the bark are reported as lethally poisonous

(Çolak, 2003c). Planting common boxwood requires special attention. The wide planting hole should be deep enough to place the root-ball, and backfilled with porous topsoil which promotes rapid root growth. Balled plants should be planted no deeper than they were growing in the nursery as deep planting causes an early loss of plant vigour and eventual plant death. Periodic heavy watering is more beneficial than frequent light watering as water should reach the entire root-ball, necessary for the development of a healthy, well-branched root system, resistance to drought and nutritional stress (Relf, 2001). It should also be considered that fresh growth is very sensitive to late spring frosts.

Conclusion

The solitary wild fruit trees, which characterize much of the Anatolian landscape today, are considered by Zohary (1973) and Mayer and Aksoy (1986) to be remnants of the woodlands that occupied most of inner Anatolia before the interference of man. As also seen in both case studies population growth and the subsequent need for firewood and timber, as well as the increasing need for cultivated land, reduced the woodlands to their present state, leaving only isolated trees within the fields. These actions also led to the change of species compositions in many forest landscapes, as well as species loss. In this context palaeoecological studies have greatly increased our knowledge of Late Quaternary environmental changes in Turkey and the eastern Mediterranean arising from both climate change and human impact (e.g. Bottema et al., 1993a, 1993b; Eastwood et al., 1998, 1999). However, in Turkey many palynological studies are spatially very limited (e.g. Aytuğ, 1970; Aytuğ and Görcelioğlu, 1993, 1994; Bottema et al., 1993a, 1993b) and correlation of sediment profiles from different regions is often impossible, because of the very distinct local differences in deposition rates. Furthermore, there are chronological problems, particularly for the mid-Holocene onwards, in relation to vegetation development in different regions of the Near East (Çolak and Rotherham, 2006). Still scientific evidences indicate that many tree species (i.e. *Cedrus libani* A. Rich., *Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe, *Cupressus sempervirens* L., *Fagus orientalis* Lipsky., *Juniperus* sp., *Buxus sempervirens* L., *Ulmus* sp.) succeeded to survive in their original habitats from neolithical times until today. Therefore ancient wood in Anatolian is still more ‘original’ or ‘natural’ in its composition (see; Schwarz, 1936; Walter, 1968; Schmidt, 1969; Zohary, 1973). Furthermore, many of ancient wood of the vegetation types are felt to have a high ecological resistance and an ability to regenerate.

Considering the previous degradation and the advantages of natural diversity there’s an urgent need for integrative conservation and restoration approaches for ancient woodlands in landscape level in Turkey. In this context cultural richness may play a vital role as well as natural diversity. For example, according to Okan and Ok (2006), beliefs on ‘yatır’ or ‘türbe’ (graves of ancient holy persons) found on many places in Anatolia create an opportunity for nature protection by transferring tree cult of old shaman Turks. These places and vegetation surrounding them (i.e. oak, pine, beech) are mostly protected. When a single tree or small woodland different from the others is seen, probability of finding such a holy grave or a story about it is strongly high (Okan and Ok, 2006). Some of these trees or woodlands are even the last remnants of ancient vegetation characterizing the area, while some of them may be plantations.

Today the priorities for nature conservation have changed. Woodland conservation priorities are now much broader than preserving ancient fragments, while continuity and connectivity of these particular habitat patches in the landscape level are newly appreciated concepts (Taylor et al., 1993; Tischendorf and Fahrig, 2000; Kırca, 2009) in Turkey. For instance in UK the main threat to woodland is less often the catastrophic loss of whole woods, but the more insidious, creeping attrition, for example, from the prevention of tree regeneration by over-grazing, and the slow death of an aging population of trees in the uplands (Goldberg et al., 2007). Rackham (2003) comments as: ‘The ancient woods will remain on the map. A very few will be strenuously protected. More will escape through isolation or small size. The rest will have their guts eaten out of them by deer and sheep’. However in Turkey, the situation seems rather different, while the lack of recognition of importance and therefore gradual loss of ancient trees through clearance for firewood (particularly near rural settlements) or unsuitable forest management practises plays an important role in this process. On the other hand urbanization and industrialization, tourism, human induced forest fires (i.e. Mediterranean region), over-grazing, rural pressure and expansion of infrastructure are still effective as by the continuing isolation and fragmentation of ancient wood habitats.

Recently rediscovered ideas of close-to-nature silviculture are particualrly recommended to be implemented, so the great economic and ecological significance of many ancient woodland species can be recognized. Greater awareness should also be raised about woodland succession, not only in theory but also in practice. On the other hand, many studies showed that approval and active support of the society plays an important role for such projects to be implemented and result successfully (Pimbert and Pretty, 2000; Berkes, 2004; Miller, 2005; Naveh, 2005). If conservation/restoration and the satisfaction of community objectives in a given area could be simultaneously achieved, then the interests of both could be served. Many restoration and conservation practices in Turkey, have been controversial because community development objectives were not necessarily consistent with conservation/restoration objectives in many cases. The needs of different stakeholders were mostly ignored or not taken seriously into consideration by the professionals. Therefore, an integrated approach combining knowledge of ecology, silviculture, landscape planning and social sciences should be embraced in order to bring ancient woodland species back into their natural habitats in Turkey. Use of these species in specially designed landscapes (e.g. representing their native habitat in some parts of parks, giving information about their traditional use on specially designed signboards placed by the plants, etc.) in or near urban areas would also be helpful to stimulate and increase the knowledge among people for their conservation and restoration.

References

Ágoston, G., 2005. *Guns for the Sultan: Military Power and the Weapon Industry in the Ottoman Empire.* Cambridge University Press, Edinburgh, UK.

Aichele, D.R. and Schwegler, H.W.A., 1996. *Der Kosmos-Pflanzenführer: Blütenpflanze, Farne, Moose, Flechten, Pilze, Algen in 653 Farbbildern.* Franckh-Kosmos Verlag, Stuttgart, Germany.

Akkemik, U., Aytuğ, B. and Güzel, S., 2004. Archaeobotanical and Dendroarchaeological Studies in Ilgarini Cave (Pinarbasi, Kastamonu, Turkey). *Turkish Journal of Agriculture and Forestry* 28: 9-17.

Aksoy, H., 1982. *Eiben- und Eichen-Urwaldreste im Forstamt Yenice (Türkei).* In: Urwald-Symposium Wien, 149-163.

Aksoy, N., 1998. Expeditions to the Box (*Buxus sempervirens*) forest at Firtina Cachment area (Camlihemsin, Rize). *The Karaca Arboretum Magazine* 4(3): 98-108.

Asouti, E., 2005. *Woodland vegetation and the exploitation of fuel and timber at Neolithic Çatalhöyük: report on the wood charcoal macro-remains.* In: Hodder, I. (ed.). Inhabiting Çatalhöyük: Reports from the 1995-9 Seasons, McDonald Institute Monographs 38, McDonald Institute for Archaeological Research and British Institute at Ankara, Cambridge and London, 213-258.

Asouti, E. and Austin, P., 2005. Reconstructing woodland vegetation and its relation to human societies, based on the analysis and interpretation of archaeological wood charcoal macro-remains. *Environmental Archaeology* 10: 1-18.

Asouti, E. and Fairbairn, A.S., 2002. *Subsistence economy in Central Anatolia during the Neolithic: the archaeobotanical evidence.* In: Gerard, F. and Thissen, L. (ed.), The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia CAL BC, Istanbul: Ege Yayınları, 181-192.

Asouti, E. and Hather, J., 2001. Charcoal Analysis and the Reconstruction of ancient woodland vegetation in the Konya Basin, south-central Anatolia, Turkey: results from the Neolithic site of Catalhöyük East. *Vegetation History and Archeobotany* 10: 23-32.

Aytuğ, B., 1970. Arkeolojik araştırrmaların ışığında İç Anadolu stebi (La Steppe D'Anatolie Centrale a la Lumiere Des Recherches Archeologiques). *Journal of the Faculty of Forestry Istanbul University* Series A, 20(1): 127-143.

Aytuğ, B., 1988. *Le mobilier funéraire du roi Midas.* Wood and Archaeology, Acts of the European Symposium, Louvain-la-Neuve, Council of Europe, Strasbourg, PACT 22: 357-368.

Aytuğ, B. and Görcelioğlu, E., 1993. Anadolu bitki örtüsünün Geç Kuvaterner'deki değişimi. *Journal of the Faculty of Forestry Istanbul University*, Series B, 43(3-4): 27-46.

Aytuğ, B. and Görcelioğlu, E., 1994. *Archaebotany in Anatolia*. Archaeometry 94: The Proceedings of the 29th International Symposium on Archaeometry, Ankara, 393-400.

Baytop, T., 1999. *Therapy with Medicinal Plants in Turkey (past and present).* Istanbul University Publications, No: 3255, Nobel Press House, Istanbul.

Beach, T.P. and Beach, S.L., 2008. Geoarchaeology and aggradation around Kinet Höyük, an archaeological mound in the Eastern Mediterranean, Turkey. *Geomorphology* 101: 416-428.

Berkes, F., 2004. Rethinking Community-Based Conservation. *Conservation Biology* 18: 621-630.

Bottema, S. and Van Zeist, W., 1989. *Middle East vegetation in the Pleistocene and Holocene Examples*. Dr. Ludwig Reichert Verlag, Wiesbaden.

Bottema, S., Woldring, H. and Aytuğ, B., 1993a. Late Quaternary vegetation history and climate in northern Turkey. *Palaeohistoria* 35/36: 13-72.

Bottema, S., Woldring, H. and Aytuğ, B., 1993b. *Palynological investigations on the relation between prehistoric man and vegetation in Turkey*. Proceedings of the 5th Optima Congress, September 1986, Istanbul. 315-328.

Brondegaard, V.J., 1992. Der Buchsbaum. *Forst und Holz* 47(2): 39.

Butler, J.E., Rose, F. and Green, E.E. 2001. *Ancient trees, icons of our most important wooded landscapes in Europe.* In: Read, H., Forfang, A.S., Marciau, R., Paltto, H., Andersson, L., Tardy, B. (ed.), Tools for Preserving Woodland Biodiversity, EU: Naconex, 20-26.

Chiej, R., 1984. *The Macdonald encyclopedia of medicinal plants*. Macdonald, London.

Crosnier, C., 1998. *La cueillette des savoirs: Les usages du végétal, Morvan - Bourgogne.* Parc Naturel Régional du Morvan, Saint-Brisson, France.

Cuinet, V., 2001. *La Turquie d'Asie. géographie administrative, statistique.* Isis, Istanbul.

Çınar, S. and Kırca, S., 2010. Perception of Garden in Turkish Culture. *Journal of the Faculty of Forestry Istanbul University* 60(2): 59-68.

Çolak, A.H., 2001. *Nature Protection in Forest.* Milli Parklar ve Av-Yaban Hayatı Genel Müdürlüğü Yayını. Orman Bakanlığı, Ankara.

Çolak, A.H., 2003a. A General Evaluation of Box (*Buxus sempervirens* L.) under Threat. Deutsche Rhododendron-Gesellschaft, *Immergrüne Blätter* 42: 58-65.

Çolak, A.H., 2003b. Examination of box (*Buxus sempervirens* L.) in Northwest Anatolia, Turkey: a contribution for the preservation of biological diversity and nature conservation. *Swiss Forestry Journal* 154(3/4): 81-89.

Çolak, A.H., 2003c. Research and Observation on r-K-Strategy Plants in the Northwest Anatolian Mountains and Their Significance for Forest Management and Nature Conservation. Deutsche Rhododendron-Gesellschaft, *Rhododendron und immergrüne Laubgehölze Jahrbuch* 123-142.

Çolak, A.H., 2005. *Buxus sempervirens L*. In: Forestry compendium 2005, CABI, Oxford.

Çolak A.H. and Rotherham I.D., 2006. A review of the Forest Vegetation of Turkey: its status past and present and its future conservation. *Royal Irish Academy, Journal of Biology and the Environment* 106(3): 343-355.

Çolak, A.H., Kırca, S., Rotherham, I.D. and Ince, A., 2010. *Restoration and Rehabilitation of Deforested and Degraded Forest Landscapes in Turkey.* Ministry of Environment and Forestry, General Directorate of Afforestation and Erosion Control, Tor Ofset, Istanbul, 566 p.

Çolak, A.H., Kırca, S. and Rotherham, I.D., 2012. *What Happened to the Ancient Common Boxwood (Buxus sempervirens L.)?: From Boxwood Forest to the Red List of Endangered Species in Turkey.* In : Trees Beyond the Wood: An exploration of concepts of woods, forests and trees Conference, Wildtrack Publishing, Sheffield, UK, 105-118.

Darlington, A., 1974. *The galls on oak.* In: Morris, M.G., Perring, F.H. (ed.), The British Oak: Its History and Natural History, The

Botanical Society of the British Isles, E.W. Classey, Berkshire, 298-311.

Davis, P.H., 1965. *Flora of Turkey and the East Eagean Islands – Volume I*. Edinburgh University Press, UK, 567 p.

Deckers, K. and Pessin, H., 2010. Vegetation development in the Middle Euphrates and Upper Jazirah (Syria/Turkey) during the Bronze Age. *Quaternary Research* 74: 216-226.

DeLong, J.M. and Prange, R.K., 2003. *Taxus* spp.: Botany, Horticulture, and Source of Anti-Cancer Compounds. *Horticultural Reviews* 32: 299-327.

Diodorus, S., 1946. *Library of History.* Volume IV, Books 9-12, Loeb Classical Library No. 375, Harward University Press, UK.

Doğu, D., Köse, C., Kartal, S.N. and Erdin, N., 2011. Wood Identification of Wooden Marine Piles from the Ancient Byzantine Port of Eleutherius/Theodosius. *BioResources* 6(2): 987-1018.

Dölarslan, E.S. and Ok, K., 2006. *Conflicts between traditional knowledge and official applications on sustainable forest management: a case from Turkey*. In: Parrotta, J., Agnoletti, M., Johann, E., International Conference on Cultural Heritage and Sustainable Forest Management: the role of traditional knowledge, Florence, Italy, 122-130.

Dufraisse, A. (ed.), 2006. *Charcoal Analysis: New Analytical Tools and Methods for Archaeology*. British Archeological Reports, Book 1483, 111 p.

Eastwood, W.J., Roberts, N. and Lamb, H.F., 1998. Palaeoecological and archaeological evidence for human occupance in southwest Turkey: the Beysehir Occupation Phase. *Anatolian Studies* 48: 69-86.

Eastwood, W.J., Roberts, N., Lamb, H.F. and Tibby, J.C., 1999. Holocene environmental change in southwest Turkey: a palaeoecological record of lake and catchment-related changes. *Quaternary Science Reviews* 18: 671-96.

Ekim, T., 1995. *Türkiye Florası ve Endemikler.* Yeni Türkiye Yayınları, 1/5, Ankara.

Ekim, T., Koyuncu, M., Vural, M., Duman, H., Aytaç, Z. and Adıgüzel, N., 2000. *Red Data Book of Turkish Plants (Ptreidophyta and Spermatophyta).* Ankara. Barışcan Ofset.

Erlbeck, R., Haseder, I.E. and Stinglwagner, G.K.F., 1998. *Das Kosmos Wald- und Forstlexikon*. Kosmos Verlag, Stuttgart, Germany.

European Commission, 2007. *Interpretation Manual of European Union Habitats.* Eur 27. DG Environment, 142 p.

Farris, E., Fenu, G. and Bacchetta, G., 2012. Mediterranean *Taxus baccata* woodlands in Sardinia: a characterization of the EU priority habitat 9580. *Phytocoenologia* 41(4): 231-246.

Figueiral, I. and Mosbrugger, V., 2000. A review of charcoal analysis as a tool for assessing Quaternary and Tertiary environments: achievements and limits. *Palaeogeography, Palaeoecology, Palaeoclimatology* 164: 397-407.

Forestry Compendium, 2005. *Taxus baccata L*., Wallingford, UK: CAB International.

Goldberg, E., Kirby, K., Hall, J. and Latham, J., 2007. The ancient woodland concept as a practical conservation tool in Great Britain. *Journal for Nature Conservation* 15(2): 109-119.

Grieve, A., 1984. *A Modern Herbal.* Penguin Books, London, UK.

Hageneder, F., 2013. *Yew*. Reaktion Books, 224 p.

Hausen, B.M., 1981. *Wood injurious to human health*: *A manual*. Walter de Gruyter.

Hecker, U., 1995. *Bäume und Sträucher*. BLV Handbuch, München, 480 pp.

Hegi, G., 1957. *Illustrierte Flora von Mitteleuropa*. Vol. 3, Hansen, München.

Hobhouse, P., 2002. *The Story of Gardening*. Dorian Kindersly, UK, 468 p.

Homer, 1990. *Book 23: Funeral Games of Patroclus*. In: The Iliad. Penguin Books, USA, 559-587.

Iasiah, 60:13. *NIV Study Bible.* Cambridge University Press, 2008, UK.

Iszkuło, G., Didukh, Y., Giertych, M.J., Jasińska, A.K., Sobierajska, K. and Szmyt, J., 2012. Weak competitive ability may explain decline of *Taxus baccata*. *Annals of Forest Science* 69(6): 705-712.

Itokawa, H., 2003. *Taxus: the genus taxus*. Taylor and Francis, London, 453 pp.

Kırca, S., 2009. *Research on the Determination of Landscape Continuity Value Around Belgrade Forest (Istanbul)*. Master Thesis, Istanbul University Institute of Sciences.

Kırca, S., Çolak, A.H. and Rotherham, I.D., 2012. *A Review of the Important Ancient Woods and Ancient Woodland of Turkey: Its Status Past and Present and Its Future Conservation*. In: Trees Beyond the Wood: An exploration of concepts of woods, forests and trees Conference, Wildtrack Publishing, Sheffield, UK, 199-216.

Kırca, S. Çolak A.H., Özalp, G. and Rotherham, ID., 2015. *Wise residents of ancient woodlands: Taxus baccata L. in Anatolian forests*, In: Aksoy, N., Aslan, S. (eds.) Proceedings of the 1st International Yew Workshop 2015, Duzce University, 74-88.

Kotschy, T., 1858. *Reise in den cilicischen Taurus über Tarsus*. Gotha, Perthes.

Kuzucuoğlu, C., 2007. Climatic and Environmental Trends during the Third Millennium B.C. in Upper Mesopotamia. *Varia Anatolica* 19(1): 459-480.

Kültür, S., 2008. An ethnobotanical study of Kırklareli (Turkey). *Phytologia Balcanica* 14(2): 279-289.

Kuniholm, P.I., 1977. *Dendrochronology at Gordion and on the Anatolian Plateau.* Unpublished Ph.D. dissertation (University of Pensylvania).

Longford, C., Drinnan, A. and Sagona, A., 2009. *Archaeobotany of Sos Höyük, northeast Turkey.* In: Fairbairn, A. O'Connor, S. and Marwick, B. (ed.) New Directions in Archaeological Science (Terra Australis 28), Australian National University E Press, Canberra, 121-136.

Louis, H., 1939. *Das naturliche Pflanzenkleid Anatoliens.* Geographische Abhandlungen, 12, Stuttgart.

Carus, L.T., 1916. B*ook V-Beginnigs of Civilization*. In: De Rerum Natura (trans. by William Ellery Leonard). E. P. Dutton & Co. New York. l, 1241-1255.

Mayer, H. and Aksoy, H., 1986. *Wälder der Türkei*. Gustav Fischer Verlag, Stuttgart, 290 p.

McNeill, J.R., 2004. Woods and Warfare in World History. *Environmental History* 9(3): 388-410.

Meiggs, R., 1982. *Trees and Timber in the Ancient Mediterranean World.* Oxford Unniversity Press, New York, 598 p.

Mellaart, J., 1967. *Çatal Hüyük: A Neolithic Town in Anatolia*. New Aspects of Archeology, Mc Graw Hill, New York, 232 p.

Miiler, J.. 2005. Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution*, 20(8): 430-434.

Missouri Botanical Garden, 2003. *Vascular Tropicos database.* St. Louis, USA: Missouri Botanical Garden [http://mobot.mobot.org/W3T/Search/vast.html].

Naveh, Z., 2005. Epilogue: Toward a Transdisciplinary Science of Ecological and Cultural Landscape Restoration. *Restoration Ecology* 13: 228-234.

Noirfalise, A. (ed.), 1987. *Carte de la végétation naturelle des Etats membres des Communautéseuropéennes et du Conseil de l'Europe*. 1 : 3.000.000, deuxième édition. – Luxembourg (Office public. off. Comm. europ.), feuilles 1-4.

Okan, T. and Ok, K., 2006. *Opportunities in Turkish cultural heritage for conservation of natural values.* In: Parrotta, J., Agnoletti, M., Johann, E. (ed.), International Conference on Cultural Heritage and Sustainable Forest Management: the role of traditional knowledge, Florence, Italy, 428-435.

Olson, S.D., 1991. Firewood and Charcoal in Classical Athens. *The Journal of the American School of Classical Studies at Athens*

60(3): 411-420.

Parker, E. and Levington, A., 1999. *YEW- The guardian of time.* In: Ancient Trees - trees that live for 1000 years. Collins and Brown Ltd. Great Britain, 66-75.

Peterken, G.F., 1977. Habitat conservation priorities in British and European woodlands. *Biological Conservation* 11: 223-236.

Peterken, G.F., 1983. *Woodland conservation in Britain.* In: Warren, A. and Goldsmith, F.B. (ed.), Conservation in perspective, Chichester:Wiley, 83-100.

Philippson, A., 1910. *Reisen und Forschungen im westlichen Kleinasien-Heft 5. Karien südlich des Mäander und das westliche Lykien.* Perthes, Gotha.

Pimbert, M.P. and Pretty, J.N., 2000. *Parks, People and Professionals: Putting Participation into Protected Area Management.* In: Ghimire, K.B., Pimbert, M.P. (ed.), Social Change and Conservation, Earthscan Publications, UK, 297-330.

Piovesan, G., Presutti Saba, E., Biondi, F., Alessandrini, A., Di Filippo, A. and Schirone, B., 2009. Population ecology of yew (*Taxus baccata* L.) in the Central Apennines: spatial patterns and their relevance for conservation strategies. *Plant Ecology* 205(1): 23-46.

Pliny the Elder, 1855. *The Natural History of the Forest Trees*. In: Natural History of Pliny, Vol. 3, Bohn's Classical Library, London, 339-435.

Rackham, O., 1976. *Trees and woodland in the British landscape.* London, Dent, 204 p.

Rackham, O., 2003. *Ancient Woodland: its history, vegetation and uses in England* (2[nd] ed.), Castlepoint Press, 624 p.

Relf, D., 2001. *Boxwood in the Landscape*. Publ. No: 426-603, Virginia Tech. USA: Virginia Cooperative Extension.

Rose, F., 1999. Indicators of ancient woodland: The use of vascular plants in evaluating ancient woods for nature conservation. *British Wildlife* April, 241-251.

Rowton, M.B., 1967. The Woodlands of Ancient Western Asia. *Journal of Near Eastern Studies* 26: 261-277.

Schmidt, G., 1969. *Vegetationsgeographie auf ökologisch-soziologischer Grundlage*. Leipzig. G. Teubner Verlagsgesellschaft.

Schmidt, A., 1990a. *Der Buchsbaum (Buxus sempervirens* L.*).* In: Bayerischer Forstverein (Hg.), Sträucher im Wald und Flur. Ecomed, Landsberg, Germany, pp. 87-93.

Schmidt, O., 1990b. *Vögel und Sträucher*. In: Bayerischer Forstverein (Hg.), Sträucher im Wald und Flur, Ecomed Landsberg, Germany, pp. 499-509.

Schwarz, O., 1936. Die Vegetationsverhaltnisse West-anatoliens. *Botanisches Jahrbuch* 67: 297-436.

Senitza, E., 1989. *Waldbauliche Grundlagen der Libanonzeder (Cedrus libani A. Rich) im Westtaurus/Türkei.* Dissertation 34, Wien, Universität für Bodenkultur.

Simpson, E., 2012. *Royal Phrygian Furniture and Fine Wooden Artifacts from Gordion.* In: The Archaeology of Phrygian Gordion, Royal City of Midas: Gordion Special Studies 7. (C. B. Rose, Ed.), University of Pennsylvania Press, 149-164.

Strabo, 1856. *The Geography of Strabo*. Trans.: H.C. Hamilton, Esq., W. Falconer, M.A., Vol.2, John Childs and Son, London.

Svenning, J.-C. and Magård, E., 1999. Population ecology and conservation status of the last natural population of English yew *Taxus baccata* in Denmark. *Biological Conservation* 88(2): 173-182.

Taylor, P.D., Fahrig, L. Henein, K. and Merriam, G., 1993. Connectivity Is a Vital Element of Landscape Structure. *Oikos*, 68(3): 571-573.

Theophrastus, 1999a. *Book 3: Of Wild Trees.* In: Enquiry Into Plants, Harward University Press, Edinburgh, UK, 159-286.

Theophrastus, 1999b. *Book 4: Of The Trees and Plants Special to Particular Districts and Positions.* In: Enquiry Into Plants, Harward University Press, Edinburgh, UK, 287-416.

Theophrastus, 1999c. *Book 5: Of the Timber of Various Trees and Its Uses.* In: Enquiry Into Plants, Harward University Press, Edinburgh, UK, 417-475.

Thomas, P.A. and Polwart, A., 2003. *Taxus baccata* L. *Journal of Ecology* 91(3): 489-524.

Tischendorf, L. and Fahrig, L., 2000. On the usage and measurement of landscape connectivity. *Oikos* 90(1): 7-19.

Tournefort, J.P., 1636. *A Voyage into the Levant*. print. by I.L. for Andrew Crooke, 2. Ed.

Ürgenç, S., 1998. *Ağaçlandırma*. İ.Ü. Orman Fakültesi Yayını, Bahçeköy, İstanbul.

Vernet, J.-L., 1997. *L'homme et la forêt méditerranéenne de la préhistoire à nos jours*. Editions Errance, Paris, 241 p.

Walter, H., 1956. Das Problem der zentralanatolischen Steppe. *Naturwissenschaften* 43(5): 97-102.

Walter, H., 1968. *Die Vegetation der Erde* (Band 2). Jena, VEB. Gustav Fischer Verlag.

Watkins, C., 1988. *The Idea of Ancient Woodland in Britain from 1800.* In: Salbitano, F. (ed.) Human Influence on Forest Ecosystems Development in Europe, Pitagora Editrice, Bologna, 237-246.

Wick, L., Lemcke, G. and Sturm, M., 2003. Evidence of late glacial and Holocene climatic change and human impact in eastern Anatolia: High-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. *The Holocene* 13(5): 665-675.

Willcox, G., 1992. Bilan des données anthracologiques du Proche-Orient. *Bulletin de la Société Botanique de France* 139: 539-551.

Willcox, G., 2002. *Evidence for ancient forest cover and deforestation from charcoal analysis of ten archaeological sites on the Euphrates.* In: Thiébault S. (Ed.), Charcoal Analysis. Methodological Approaches, Palaeoecological Results and Wood Uses, BAR Int. Series, 1063: 141-145.

Woldring, H. and Cappers, R., 2001. The Origin of the "Wild Orchards" of Central Anatolia. *Turkish Journal of Botany* 25: 1-9.

Xenophon, 1976. *Anabasis - Book IV*. University of Oklahoma Press, USA.

Young, R.S., 1974. Phrygian Furniture from Gordion. *Expedition* 16(3): 2-13.

Zohary, M., 1973. *Geobotanical foundations of the Middle East*. 2 Vol., Gustav Fischer Verlag, Stuttgart.

Zorlu, T., 2008. *Innovation and Empire in Turkey: Sultan Selim III and the Modernisation of the Ottoman Navy*. Tauris Academic Studies, London.

Chapter 14
Using pollen data and models to asses landscape structure and the role of grazers in pre-agricultural Denmark

Anne Brigitte Nielsen

Abstract

Pollen records can provide information on past landscape structure, but the interpretation is not straightforward, as plants differ in their pollen production and -dispersal properties. Especially open areas are generally under-represented in pollen diagrams. However, in recent years new models have been developed, which take these factors into account and allow us to correct for them, for example by simulating pollen sedimentation in hypothetical landscapes.

In this study, simulated landscapes were created based on landscapes without and with different levels of grazing impact. Pollen deposition in these landscapes was simulated using a model of pollen representation, dispersal and deposition, and the resulting pollen spectra were statistically compared to existing pollen records from Denmark from the Atlantic period (ca. 6800-3900 BC).

The analysis showed that many of the pollen diagrams from eastern Denmark were most similar to the scenarios based on a rather closed forest landscape with some wetland areas, whereas for many diagrams in western Denmark, the pollen diagrams are compatible with a landscape which was more open. This openness was possibly due to a larger impact from grazing animals, which had a higher diversity in western than in eastern Denmark, but other factors, especially soil types and the frequency of fire disturbance, may also have played a role, as these also differ between eastern and western Denmark. Certain aspects of the pollen signal, for example the large proportion of Hazel, were not well explained by any scenarios, and require further study.

Introduction

Preserving or recreating natural habitats and landscape types can be considered among the most important goals of good nature management. Other such goals may include promoting the highest possible biodiversity or protecting specific organisms, such as rare or endangered species. These different goals may not always be compatible when it comes to management decisions.

But which landscapes and habitats are actually natural? There hardly exists an area in Europe today which can be considered completely free from human impact. Therefore, much of our knowledge about the present natural landscape is obtained from studies of relict areas with limited human impact. Such areas are often small, and this limits our interpretation possibilities of natural processes at a larger spatial scale. Another approach is to use palaeoecological data to reconstruct what the landscape looked like in the past, and which processes affected and shaped it.

Studies of pollen grains preserved in lake and bog sediments are an important source of data on the past landscape. Pollen records can provide information on past landscape structure and vegetation composition, which can potentially provide information of the role of grazing animals in different periods. However, the interpretation of the pollen data is complicated by differences in pollen production between plant species; by differences in pollen dispersal between plant species and between different types of pollen sites; and by mixing of local and regional scale pollen signals within the record.

Thus, pollen percentages cannot be regarded as a simple measure of vegetation composition. For example, landscape openness is often underestimated, because many tree species produce more pollen than most herb species (Broström et al., 2008) and their pollen is dispersed more effectively. However, in recent years, new models have been developed, which have improved our possibility to quantitatively interpret fossil pollen data. By using models of pollen dispersal and deposition (Prentice, 1985; Sugita, 1993, 1994) combined with estimates of the relative pollen productivity of different species (e.g. Broström et al., 2008) it is now possible to calculate the expected pollen spectra in different simulated landscapes using the programmes MOSAIC and HUMPOL (Bunting and Middleton, 2005). These models can be applied to interpret the composition of pollen spectra from different sites. One method is the so called Multiple Scenario Approach (Bunting and Middleton, 2009) where hypotheses about the structure and composition of past landscapes are transformed into a number of simulated landscapes. Using HUMPOL, pollen loading to different sites in these landscapes is calculated, and these simulated pollen spectra are then compared to observed fossil pollen spectra using analogue matching techniques.

This is the approach taken in the current study, which focuses on the Danish landscape during the Atlantic period, ca. 6800-3900 BC. This is the latest period of the Mesolithic i.e. before agriculture was introduced to Denmark.

Traditionally, the pre-agricultural Danish landscape has been interpreted as mainly closed deciduous forest with rather sparse herb vegetation, where the recruitment of trees occurs in small gaps created by old trees dying or by storm felled trees. This interpretation was described by among others Iversen (1973), and is based partly on pollen evidence, but without the application of pollen dispersal and representation models. It is also supported by the observation that most European landscapes today quickly become tree covered in the absence of human impact. The climax forest hypothesis has until recently been widely accepted by ecologists and nature managers. More recently however, this interpretation of the pre-agricultural landscape has been questioned by several researchers. Especially the book by Franz Vera (2000): ”Grazing ecology and forest history” has received a lot of attention. Here, large wild grazing animals, such as aurochs, wild horse and red deer, are considered to play a leading role in the natural dynamics of the landscape. According to this hypothesis, the natural landscapes of Northwest Europe were a mosaic of forest groves, open park like areas and dense shrubs. In the groves, practically no recruitment of young trees is expected, due to shade and grazing pressure. The grove persists until the trees age and gradually collapse, after which the area becomes open, with single old tress and grassland or heathland type vegetation, depending on soil types. The vegetation is kept open for a certain time by the grazing animals, but gradually shrubs of mainly thorny bushes becomes established. Inside these, young trees can grow up, sheltered from the animals, and when the tree are large enough to shade out the shrubs, a new grove is formed.

Finds of bones show that aurochs, red deer, moose and wild boar were present in Denmark at the beginning of the Atlantic period, but they do not show how abundant the animals were (Aaris-Sørensen, 1998). During the first half of the Atlantic, aurochs and moose became extinct on the eastern Danish island of Zealand, while they still remained in Jutland and on the island Funen. In the later part of the period, wild horse reappeared in these western parts of Denmark, after being extinct in the early Holocene (Aaris-Sørensen, 1998).

Material and methods

Pollen productivity estimates exist for most tree genera and the most important herb types from Southern Sweden (Sugita et al., 1999; Broström et al., 2004), which can be applied in the Danish landscape to simulate pollen loading to lakes and bogs from hypothetical landscapes. This approach has been validated for small lakes in Denmark (Nielsen, 2004).

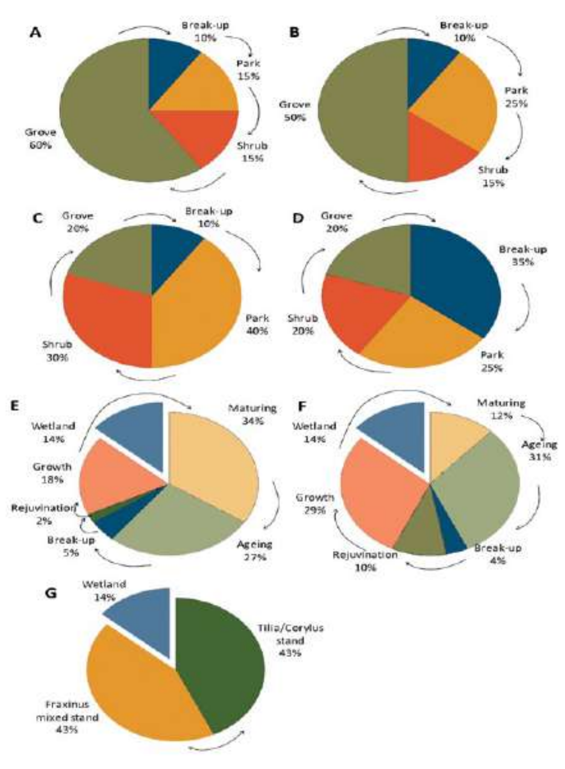
Existing pollen data from the Atlantic period (ca. 6800-3900 BC), the last period before the introduction of Agriculture in Denmark, were collected for comparison with the pollen simulations. Data from 17 sites, including large raised bogs, mediums sized lakes and small forest hollows were collected partly in the form of raw data from the pollen analysts, partly from publications (Nielsen, 2009).

Simulation set up

To investigate the potential role of large grazing animals, a series of simulated landscapes were created with different levels of grazing impact. The vegetation structure and compositions of these were based on the landscapes modeled by Kirby (2004), who presented a possible

Figure 14.1

Schematic illustration of the dynamic between different patch types assumed in each simulation, and the proportions of different patch types



The species composition of the patch sizes is described in Table 13.2.

quantitative interpretation of a landscape following the Vera (2000) hypothesis, based on the expected duration and spatial extent of the different elements of the landscape mosaic. Another set of simulated landscapes were based on present day vegetation structure in two natural forests in Denmark without grazing, i.e. Suserup forest in eastern Denmark (Christensen et al., 2007) and Draved forest in western Denmark (Andersen, 1970). The vegetation patch types and their proportions in the different landscapes are illustrated in Figure 14.1, and the basic simulation setup is described in Table 14.1.

Each of the simulated landscapes consisted of different vegetation patch types, and to each patch type a species composition was assigned. For the landscapes with grazing (landscapes A-D), the species composition was based on the descriptions of the landscape scenarios by Kirby (2004). For the closed forest scenarios (Landscapes E-G), the composition of the modern forests (Christensen et al., 2007; Andersen, 1970) had to be adjusted due to the fact that *Fagus*, which is a dominant species in the Danish forests today, had not yet immigrated in the Atlantic period. Thus the species composition was based on a combination of the modern forest data and the descriptions of the Atlantic forest by Iversen (1973). Several different species compositions were tested (Nielsen, 2009) (Table 14.2), but the one presented here resulted in the best resemblance between modeled and observed pollen assemblages. It follows Iversen (1973) in assuming that *Quercus* occurred on the wetter soils, but did not play an important role in the upland forest.

Pollen deposition at randomly placed sampling sites in these virtual landscapes was simulated using HUMPOL, based on the Prentice (1985) model of pollen dispersal and deposition and on pollen productivity estimates from

Table 14.1

Simulation setup (Nielsen, 2009)

Landscape	Landscape structure	Landscape size	No. of landscapes	No. of sampling points
A: Low grazing pressure	Kirby 2004 scenario 3b	50 x 50 km	2	2 x 9 = 18
B: Medium grazing pressure	Kirby 2004 scenario 1	50 x 50 km	2	2 x 9 = 18
C: High grazing pressure	Kirby 2004 scenario 3a	50 x 50 km	2	2 x 9 = 18
D: "Savannah like"	Kirby 2004 scenario 5	50 x 50 km	2	2 x 9 = 18
E: No grazing 1	Suserup forest 1992	5 x 5 km	5	5 x 4 = 20
F: No grazing 2	Suserup forest 2002 (after storm)	5 x 5 km	5	5 x 4 = 20
G: Wetland forest	Simplified Draved forest	50 x 50 km	2	2 x 9 = 18

Table 14.2

Patch types and species composition used in the simulated landscapes (Nielsen, 2009)

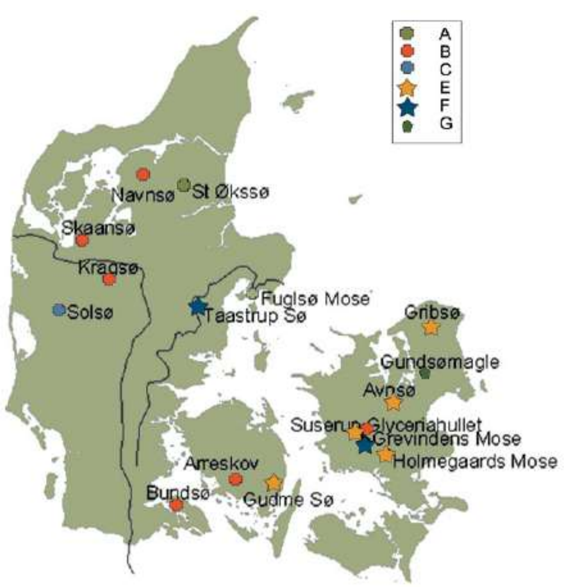
Patch type	Fraxinus	Quercus	Tilia	Ulmus	Alnus	Betula	Corylus	Poaceae	Cyperaceae	Salix	Calluna
Landscapes A-D											
Shrub	4	4	4	4	2	8	70	10	6	13	3
Grove	20	10	20	20	10	6	20	3	2	2.5	2
Break-up	5	13	10	10	2	20	0	15	5	0	5
Park	0	3	2	0	0	4	4	50	20	1	10
Landscapes E-F											
Maturing	15	0	40	35	0	0	10	0	0	0	0
Ageing	10	0	45	40	0	0	5	0	0	0	0
Break-up	15	0	30	25	0	5	10	10	5	0	0
Rejuvination	41	0	11	11	0	10	10	10	5	0	2
Growth	35	0	30	25	0	0	10	0	0	0	0
Wetland	26	12	0	7	35	6	6	10	10	10	2
Landscape G											
Tilia/Corylus stand	0	12.04	22.06	5.79	10.83	7.18	40	10	10	0	1
Fraxinus mixed stand	14.45	15.65	6.79	4.86	11.12	13.79	0	15	15	0	1
Wetland	26	12	0	7	35	6	6	10	10	10	2

south Sweden (Sugita et al., 1999; Broström et al., 2004) and the resulting pollen spectra were compared using Squared Chord Distance (SQD) to the actual collected fossil pollen records.

Results

The analysis showed that many of the pollen diagrams from eastern Denmark were most similar to the scenarios based on closed forest landscape with some wetland areas (scenarios E and F) (see Figure 14.2). This indicates that the pollen assemblages from these sites are most compatible with those expected, according to the pollen dispersal model, in closed forest landscapes with small gaps. A restricted occurrence of more light demanding plants (Poaceae, Cyperaceae and *Calluna* in the analysis) to the gaps and to wetland areas seems to be enough to explain the proportions of these pollen types observed in the eastern pollen diagrams. Also the occurrence of *Quercus* can be explained by occurrence on wetter ground, and does not in itself require larger open areas. Most eastern sites have the majority of the closest analogues in landscape structure E, corresponding to Suserup forest before the big storm in 1999 (Christensen et al., 2007), while Taastrup Sø and Grevindens Mose have most analogues in landscape F, corresponding to the structure after the storm, with higher proportions of rejuvenation and growth (see Figure 14.1), and thus somewhat more Poaceae and Betula in the simulated vegetation. However, the analysis indicated that the difference in the expected pollen assemblages in these two landscapes was rather small.

Map of Denmark showing the results of the analysis — **Figure 14.2**



The symbols indicate which simulated landscape group the majority of the 5 closest analogues for each site belong to. None of the closest analogues were found in landscape D.

Although the best analogues for these eastern sites were to be found in the landscapes based on Suserup forest, there were some differences between the simulated and observed pollen assemblages, resulting in relatively high SQD values. Especially the observed proportions of *Corylus* pollen was higher than could be explained by the simulated landscape composition.

For many diagrams in western Denmark, the analysis indicates that landscape was more similar to landscapes A-D (see Figure 14.2). The landscape here appears to have been more open, as the proportions of Poaceae, Cyperaceae and Calluna pollen are higher than would be expected from a landscape like those at Suserup and Draved forests, and correspond more to those expected from the grazing scenarios. For the sites in Jutland, the SQD values a generally lower than for the sites on the Danish islands, indicating a better fit between modelled and observed pollen proportions, but even here observed *Corylus* pollen proportions are higher than the simulated values, despite the fact that *Corylus* makes up a large proportion of the vegetation in the shrub phase in the grazing scenarios. For Bundsø on the small island Als, and Arreskov Sø on Funen, the SQD values are somewhat higher.

Only for one site, Gundsømagle Sø (Rasmussen et al., 1998), did the pollen assemblages most resemble those from scenario G, based on Draved forest, although some good analogues were also found among the Kirby scenarios. Gundsømagle Sø is surrounded by high proportions of wetland, which may explain the resemblance to Draved forest, which is also characterized by a high groundwater table (Møller and Bradshaw, 2001).

The three small forest hollows among the pollen sites analyzed, Grevindens Mose and Glyceria hollow (Andersen, 1985) and Suserup hollow (Hannon et al., 2000) are located within a few kilometers from each other on central Zealand. Pollen from such sites represents the local vegetation vegetation with ca. 20-50 m around the site. Interestingly, their pollen assemblages are very different, and their closest analogues among the simulated landscapes fall in different landscape groups, landscapes E, F and C respectively. This indicates a large heterogeneity in the landscape at a small spatial scale during the Atlantic period, larger than that captured by the patchiness of each of the single simulation scenarios.

Discussion

At first glance, the results of the simulation and analogue matching study lends some support to the Vera hypothesis, that grazing animals were important in determining the vegetation structure before the introduction of agriculture. Applying the models of pollen dispersal and deposition generally reveals that the landscape was not as densely tree covered as may be assumed from the uncorrected tree pollen percentages. At most of the sites in western Denmark, the pollen assemblages fit better with the

Kirby scenarios, while those in eastern Denmark indicate a more closed forest with smaller gaps. We know that the diversity of grazers in the Atlantic period was higher in western Denmark, while aurochs, wild horse and Moose went extinct on Zealand (Aaris-Sørensen, 1998). Therefore, a more closed vegetation structure here could be expected.

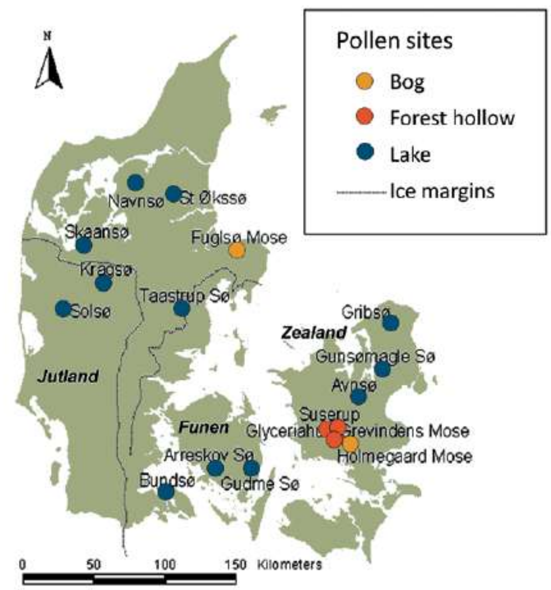
However, while the pollen composition and the degree of openness which is indicated by the pollen data from western Denmark could fit with grazed landscapes as those suggested by Kirby (2004), this analysis does not exclude that other factors, especially soil type, wind and fire, may have been the determining factors for landscape openness. Soil types differ between eastern and western Denmark. The southwestern part of Jutland was not glaciated during the Weichelian at all, and much of eastern Jutland was deglaciated rather early, while the young Baltic ice sheet only reached a short distance west of the present eastern coast of Jutland (Lagerlund and Houmark-Nielsen, 1993) (see Figure 14.3). For this reason, soils in the west are sandier and more nutrient poor than those in the east, which are richer in clay and more calcareous.

The sandy soils in the west may have in themselves have led to a naturally more open landscape structure (Odgaard, 1994), as secondary succession after a disturbance will be slower when the plants have fewer nutrients available (Kalis et al., 2003). Sandy soils are also more well drained, providing drier conditions at the soil surface during the summer, despite the fact that precipitation is somewhat higher in western than in eastern Denmark, and these drier conditions have probably resulted in more frequent natural fires. This is supported by records of relatively high amounts of subfossil charcoal from western Jutland throughout the Holocene, and the occurrence of fires may have been a very important factor in maintaining a more open landscape with higher proportions of light demanding plant species, including dwarf shrubs (especially Calluna) and grasses (Odgaard, 1994). Thus, the differences in soil conditions may be able to explain the east-west gradient in the pollen modeling results, without including the difference in the occurrence of large grazing animal species as a determining factor.

That soil type may be the more important cause for determining landscape openness is supported by the fact that Taastrup Sø, east of the east Jutland ice margin, has a similar pollen spectrum as the sites on Zealand, although the same animal species would have occurred here as in other parts of Jutland, and that the most open landscape is found around Solsø in the far west. However, there are also sites east of this line which have their closest analogues among the grazing type simulations, i.e. Fuglsø Mose and Bundsø (Aaby, 1986), Arreskov Sø (Nielsen, unpublished) and Glyceriahullet (Andersen, 1985).

Large amounts of wetland areas can also contribute to landscape openness. The 14% wetland used in the forest scenarios is based on the situation in Denmark around AD 1800, i.e. before modern drainage of the agricultural

Figure 14.3 Map of Denmark showing the pollen sites included in the comparison, indicating site type



The maximum ice extent of the Late Weichselian and of the young Baltic east Jutland stage is also shown.

land and forests, but it is possible that the proportion was even higher in the Atlantic period. This might explain the larger openness than expected from the forest scenarios, but does not account for the difference between east and west.

The occurrence pollen types from plant species which are more often associated with grazed than ungrazed landscapes today (Nielsen, 2009) indicate that grazing animals probably did influence the vegetation in some places, at least at a local scale. This may also explain the large heterogeneity between the small eastern Danish forest hollows. But the extent of their impact at a landscape scale cannot be determined based on these finds of indicator species, which only occur in quite low numbers. In order to disentangle the effect of grazers and soil on landscape openness and plant species composition it would be useful to include pollen data from neighboring countries, to study variations in the two factors independently.

However, to determine the causality behind the composition and structure of the landscape, it will be necessary to combine pollen studies with other palaeoecological proxies. Plant macrofossils can often be identified to species, and can therefore provide more information on the occurrence of indicator species than pollen. Remains of beetles can also be identified, and as many species are specific to either open of closed forest conditions, and certain species are tied to animal dung, they are important indicators for the role of grazing (Whitehouse and Smith, 2010). Other insects and mollusks can also be indicators of landscape openness. Of course, a better knowledge of the occurrence and abundance of grazing animal from bone finds would be very valuable, but such studies are restricted to sites where bone can be preserved.

Certain aspects of the pollen signal, especially the large proportion of *Corylus* (Hazel) pollen, were not well explained by any of the scenarios. The abundance of *Corylus* is one of the arguments used in favour of the Vera hypothesis, as this species does not regenerate well in closed canopy conditions (Vera, 2000). However, even in the grazing based scenarios, the expected pollen proportions of *Corylus* are lower than those observed. This shows that we probably do not yet understand the ecology, and possibly the pollen productivity of *Corylus* in the Atlantic landscape very well. On the other hand, the observed occurrence of *Quercus* pollen in the Danish pollen diagrams, another of the key species for the Vera (2000) hypothesis, can be explained by relatively low numbers of *Quercus* trees growing on wetter soils, where there would have been better light conditions even without grazing animals, as the shade trees, particularly *Tilia* do not thrive there (Iversen, 1973).

Conclusions

Comparing the Atlantic pollen assemblages from Danish sites with simulated pollen signals from model landscapes with and without grazing shows that the pollen finds in most of western Denmark is compatible with the grazing landscapes, while those in the east indicate more closed forest. However, the analysis does reveal the cause of the difference in landscape openness, which could be assigned to differences in soil types, related variations in fire frequency, or to differences in the occurrence of large grazers.

While models of pollen dispersal and deposition are a powerful tool to study past landscape composition and openness in quantitative terms, and thus improve the interpretation possibilities of pollen data, it may be necessary to also include other proxies than pollen, such as plant macrofossils and insect remains, as well as more studies on the occurrence of large mammals, to shed more light on the question of the role of grazing animals in the natural landscape.

References

Aaby, B., 1986. *Trees as anthropogenic indicators in regional pollen diagrams from eastern Denmark.* In K. E. Behre (Ed) Anthropogenic Indicators in Pollen Diagrams. A.A.Balkema, Rotterdam.

Aaris-Sørensen, K., 1998. *Danmarks Forhistoriske Dyreverden*. Gyldendal, København.

Andersen, S.T., 1970. *The Relative Pollen Productivity and Pollen Representation of North European Trees, and Correction Factors for Tree Pollen Spectra.* Danmarks Geologiske Undersøgelser, Copenhagen.

Andersen, S.T., 1985. Natur- og kulturlandskaber i Næsbyholm Storskov siden istiden. Fortidsminder. *Antikvariske Studier*, 7: 85-107.

Broström, A., Sugita, S. and Gaillard, M.-J., 2004. Pollen productivity estimates for the reconstruction of past vegetation cover in the cultural landscape of southern Sweden. *Holocene*, 14: 368-381.

Broström, A., Nielsen, A.B., Gaillard, M-J., Hjelle, K., Mazier, F., Binney, H., Bunting, J., Fyfe, R., Meltsov, V., Poska, A., Räsänen, S., Soepboer, W., Stedingk, H. von, Suutari, H. and Sugita, S., 2008. Pollen productivity estimates of key European plant taxa for quantitative reconstruction of past vegetation: a review. *Vegetation History and Archaeobotany*, 17: 416-478.

Bunting, M.J. and Middleton, R., 2005. Modelling pollen dispersal and deposition using HUMPOL software, including simulating windroses and irregular lakes. *Review of Palaeobotany and Palynology*, 134: 185-196.

Bunting, M.J. and Middleton, R., 2009. Equifinality and uncertainty in the interpretation of pollen data: the Multiple Scenario Approach to reconstruction of past vegetation mosaics. *The Holocene*, 19: 799-803.

Christensen, M., Emborg, J. and Nielsen, A.B., 2007. The forest cycle of Suserup Skov – revisited and revised. *Ecological Bulletins*, 52: 33-42.

Hannon, G. E., Bradshaw, R. and Emborg, J., 2000. 6000 years of forest dynamics in Suserup Skov, a seminatural Danish woodland. *Global Ecology and Biogeography*, 9: 101-114.

Iversen, J., 1973. The development of Denmark's nature since the last glacial. Danmarks. *Geologiske Undersøgelse V.række,* 7(C): 1-126.

Kalis, A.J., Merkt, J. and Wunderlich, J., 2003. Environmental changes during the Holocene climatic optimum in central Europe - human impact and natural causes. *Quaternary Science Reviews,* 22: 33-79.

Kirby, K.J., 2004. A model of a natural wooded landscape in Britain as influenced by large herbivore activity. *Forestry*, 77: 405-420.

Lagerlund, E. and Houmark-Nielsen, M., 1993. Timing and pattern of the last deglaciation in the Kattegat region, southwest Scandinavia. *Boreas*, 22: 337-347.

Møller, P.F. and Bradshaw, R.H.W., 2001. Draved skov – et dansk forskningsprojekt gennem mere end 50 år. *Geologi- Nyt fra GEUS*, 4: 1-16.

Nielsen, A.B., 2004. Modelling pollen sedimentation in Danish lakes around AD 1800 - an attempt to validate the POLLSCAPE model. *Journal of Biogeography*, 31: 1693-1709.

Nielsen, A.B., 2009. *Urskovsklandskabets åbenhed og sammensætning og græsningens betydning i Atlantisk tid belyst ved palæobotaniske metoder.* GEUS report 2009/23, Geological survey of Denmark and Greenland, Copenhagen.

Odgaard, B.V., 1994. *The Holocene vegetation history of northern West Jutland, Denmark*. Opera Botanica, 123.

Prentice, I.C., 1985. Pollen Representation, Source Area, and Basin Size: Toward a Unified Theory of Pollen Analysis. *Quaternary Research*, 23: 76-86.

Rasmussen, P., Hansen, H.J. and Nielsen, L.B., 1998.

Kulturlandskabet i et langtidsperspektiv. To sjællandske områder gennem de sidste 6000 år. *Nationalmuseets Arbejdsmark,* 1998: 101-113.

Sugita, S., 1993. A Model of Pollen Source Area for an Entire Lake Surface. *Quaternary Research,* 3(2): 239-244.

Sugita, S., 1994. Pollen representation of vegetation in Quaternary sediments: Theory and method in patchy vegetation. *Journal of Ecology,* 82: 881-897.

Sugita, S., Gaillard, M.-J. and Broström, A., 1999. Landscape openness and pollen records: A simulation approach. *The Holocene,* 9(4): 409-421.

Vera, F.W.M., 2000. *Grazing Ecology and Forest History*. CABI Publishing, Wallingford.

Whitehouse, N.J. and Smith, D., 2010. How fragmented was the British Holocene wildwood? Perspectives on the “Vera” grazing debate from the fossil beetle record. *Quaternary Science Reviews,* 29: 539-553.

Chapter 15
Tanneries and Treescapes: the Influence of the Tanning Industry on Woodland Management

Christine Handley, Ian D. Rotherham

Abstract

The relationship between supply and demand for wood, timber and bark in different markets, geographical areas, and times is complex, but there are common themes. These relationships have influenced the form, structure and management of woodlands; and their legacies can be seen today. Using examples from the UK and the USA, these common themes are considered and some complexities arising from responses to local economic conditions highlighted. Bark is sometimes described as a waste by-product of other wood and timber industries. However, it is clear that with the high economic value of the tanning industry as a whole, and the central role of leather goods in society for centuries, the impact on woodlands to ensure a ready supply of tree-bark for tanning varied but could be immense.

Introduction

From an early twenty-first century, Western perspective, it is difficult to appreciate the central role that leather and woodland products once had. Furthermore, even the memories of past, traditional uses have often been lost (see for example, Rotherham, 2007; Rotherham et al., 2008)). They were fundamental to everyday lives and their economic influence shaped the way societies developed. Problems of supply of tree-bark, rich in tannins, to meet the demand for leather were eventually solved by finding alternative reliable sources of tanning agents. However, this did not start to have a significant impact until later in the nineteenth century; until then the woodland resource had to be used. Varying around the world, but in Britain by the late 1800s and early 1900s, concerns were being expressed about the collapse and loss of traditional rural industries and crafts. FitzRandolph & Hay (1926) and Jones (1927) for example, provide detailed accounts of the rural industries including 'Oak-Bark Tanneries' in England, and 'Tannery and its subsidiary industries' in Wales. These accounts provide in-depth insights into the processes, the products, the craftsmen, and the markets. We consider these in detail in a later paper. Interestingly however, some writers do not seem to recognise tanning as a rural craft (e.g. Green, undated, late 1800s).

Earlier writers have not considered how bark was exploited in different circumstances, and the way this has affected the present woodland resource. However, we begin to address these issues in outline below.

Leather Goods

Before the widespread use of rubber and plastics, leather supplied the material for making a vast range of goods. These ranged from the everyday water buckets, boots and shoes, belts and harnesses, saddles, aprons, gauntlets, gloves and bellows to military and ceremonial costumes, luxury items and belts for driving industrial machinery. Many of the products needed different types of leather. These were produced using different animal hides and tanning techniques. The variation in the technique s included using different tanning agents in different concentrations for variable amounts of time. In England, this eventually led to the development of tanning industries in different parts of the country specialising in making specific types of leather. For example, glove making was important in Wiltshire, boot and shoe making in Northamptonshire, and 'heavy' harnesses and saddles in Walsall in the West Midlands. The Sheffield area was also noted for producing "... the best sort of thick or Bend Leather" (Farey, 1817) which was used for the soles of boots and shoes. Farey (1817) goes on to say that the bark was not crushed or ground but chopped "in pieces about an inch square, the slow spending of which among the Hides was supposed to convey to this Bend Leather, much of its valuable properties ..."

During the Ottoman Empire, a specialised leather industry grew up producing fine highly decorated leathers known as 'Moroccan leather', which was exported across

Europe. This led to the growth of a large tanning industry in Istanbul building on the older industries in Anatolia. A range of plant-based tanning agents were used which included oak (acorns and oak galls) but also included alder, maple, chestnut leaf and pomegranate husks. These gave the leather distinctive colours in contrast to the darker colours, which resulted from oak-bark tanning.

As well as specialist producers and regions, there were still domestic-scale tanners and fellmongers who would cater for local markets. They would exist in most large villages and towns in the UK and elsewhere, converting hides from locally slaughtered horses, cattle, sheep, goats etc. into leather, working alongside the butchers and tallow manufacturers. The tanners would need a convenient source of tanbark. The fellmongers produced 'light leathers' which had not been through the heavy tanning process but used agents such as a mixture of alum, sodium chloride and egg yolks to preserve the hides. These light leathers were similar to the 'Moroccan leather' already mentioned.

The Tanning Industry

The tanning industry, the process of preserving animal hides and skins by turning them into leather, is an ancient one. Originally starting with small-scale production as a way of preserving hides from animals slaughtered domestically, the industry grew eventually into small, medium and large-scale commercial businesses. The methods used follow a similar pattern as in earlier times, although the ingredients in the preparation and preservation of the hides and skins may differ across countries and have changed over the centuries. The hides and skins first have to be cleaned and prepared before they can be turned into leather. Then they are dried and finished before being turned into leather goods. The stages in the tanning process are illustrated in the photographs taken at Claytons of Chesterfield, one of the few remaining large tanneries in England (Photograph 1). Although tree-bark tannins to turn the hides into leather are no longer used at the Chesterfield site, the series of tanpits has been reused. The hides are passed through the sequence of tanpits, which have increasing concentrations of tannins in them until the hides are fully cured. A process that used to take up to two years using bark now takes around six months.

The chemical used as the preservative can come from mineral or plant sources. Until the late nineteenth century, most of the industry used tannins from plants. Tannin occurs in high concentrations especially in the bark of some tree species, for example, oak, mimosa, tanoak and hemlock. This gave rise to the widespread practice of harvesting and processing tree bark for use in the tanning industry. Whilst mineral sources have been derived from chromium and alum salts for thousands of years, it is only in the last 150 years, as the technology changed, that these have become the most commonly used agents.

Tanneries also make use of wood and timber in a variety of other ways. For example, the tanpits are lined

Photograph 1: The Tanning Process at Claytons of Chesterfield in 2006. (a) Liming pit, (b) The hide preparation frame, (c) Tanning pit, (d) Drying room (Collection of C. Handley / I.D. Rotherham).

with wooden planks, the hides are suspended from wooden poles into the pits, and the drying rooms and frames are constructed from wood. This is evidenced by early records as for example, Mead (1989) noted, in 1881 a local tanner bought 100 tan-poles for 6d from the Ashburnham estate in Sussex. Where bark was crushed in a mill before being mixed with water to make the tanning liquid, the cogged grinding wheels were also made of wood. Whilst not needing the equivalent quantity of wood and timber as bark, these uses illustrate the additional need for woodland products in tanning activities.

The processes involved in tanning and the length of time that it took to turn hides into leather meant that capital costs were high for tanners and tanyards could be extensive. Tanners were sometimes wealthy businessmen with interests in livestock farming and also owning woodlands. For example, the Birks family from the Sheffield area who owned the main tannery in the Woodhouse district during the nineteenth century were also livestock farmers. They had farmed in Woodhouse since the early seventeenth century and had rights to pasture their cattle on Woodhouse Common. They were allocated land under the parish Enclosure Act in 1805; some was wood pasture and other fields are shown as woodland plantations in a land survey of the mid-nineteenth century. The Birks' connection with the tannery industry in other parts of Sheffield and Rotherham stretches back to the seventeenth century and included intermarriage with one of the other major tannery families in the Sheffield area, the Rawsons (Frost, 1995). The village of Woodhouse was a local centre for the tannery industry from at least the seventeenth century to the mid-nineteenth century with three separate tanneries at the edge of the village. Records from bark sales in nearby 'Oaken Cliff Wood', in 1710, show that Lyonel Keyworth, a tanner in Woodhouse paid 10 guineas for 62 qts of bark, which had been peeled and dried in the wood (Jones, 2009). The main market for the leather in Woodhouse at this time appears to be for boot and shoe manufacture; there were 10 shoemakers in the village out

Photograph 2: Workers at P.P. Birks Tannery, Woodhouse (Sheffield, UK) with the bark-stack in the background (1905) (Collection of C. Handley / I.D. Rotherham).

of a total population of around 200 at the 1841 census. By the late nineteenth century, the Birks' tannery was the only one remaining but the business was still expanding (Photograph 2). Woodhouse was also growing rapidly because of the coalmining industry and the tannery, which had once been on the edge of the village, was now in the commercial centre. A consequence of the changed context was that it could not expand further and develop in response to new markets. The result was that the Birks' tannery closed in 1906; one of the reasons being that the pollution from the tannery processes regularly overloaded the new parish sewage system. This caused huge problems for the village and surrounding area and the cost of remediating this fell to the tannery. This example of a small to medium size business appears to be typical of the tanneries that were common across England up to the late nineteenth century. For example, the Batners Tannery in Lingfield, Surrey, owned by the Kelsey family in the nineteenth century (Bateson, 2006) followed a similar pattern. In the 1841 census, the owner was described as a 'farmer and tanner' and employed four tanners; and there were sixteen shoemakers and two saddlers and harness makers in the parish. By 1881, the number of tanners had risen to seventeen but by 1891, the number had fallen to nine. According to Bateson, it continued to supply boot-makers, shoemakers and saddlers until it closed in 1897.

Larger tanneries such as the Ormerod business in Shropshire had to source their bark supplies from a wide area. In the mid to late nineteenth century, they were buying 250 to 300 tons of bark annually and sourcing it over a twenty-mile radius. This would traditionally be Oak (Quercus robur and Q. petraea) in the UK but by the nineteenth and early twentieth centuries other trees such as Sweet Chestnut (Castanea sativa) were sometimes used as tanneries began to experiment with other sources of tannin. Ormerod's continued to use bark until the first world war when the increased demand for leather meant that they needed to find a quicker method of production. Using oak bark took between 15-18 months but this could be cut to 6-12 months using other non-vegetable tanning agents.

Economics

The overlying trends in the rise and fall of bark prices in the UK from the late seventeenth to the early nineteenth centuries has been well documented and discussed by Clarkson (1965; 1966) and Rackham (2006) amongst others. They also discuss the difficulty in arriving at an average price because of the multitude of ways that the bark was harvested and sold in different areas of the UK. Prices for bark fluctuated annually, sometimes influenced by speculative harvesting and stockpiling versus a stable supply and steady income. Prices were also influenced by whether the bark was seen as a by-product of harvesting wood and timber for other purposes e.g. charcoal production for metalworking or house and shipbuilding or as the prime commodity. In some woods, most of the income for the owners came from charcoal production, others the balance between income from wood and bark was more even. In some cases, bark production was the prime focus. The balance between incomes from different woodland products also changes over time as shown by Tittensor and others in their work on the economic value of Scottish coppice woods. Around Loch Lomond and Knapdale, industrial coppice woodlands first developed in response to Lancashire iron-founders moving into the area in the seventeenth century to exploit the woods for charcoal as supply in Lancashire could not keep pace with the demand for iron. A further market developed in the later eighteenth century for the coppice woods supplying tanbark to large tanneries in the Glasgow area. Charcoal production decreased as the techniques in smelting iron changed but the need for coppice wood continued with increased demand from the tanneries. It was only when other tanning agents became common in the later nineteenth century when demand for the oak coppice wood dwindled and coppice management was abandoned.

Tanners needed a ready supply of hides, water, lime and bark. This would preferably be a guaranteed supply chain or at least one, which they had some control over. They may enter into long-term contracts, have favoured suppliers or keep stocks in reserve. From the perspective of the tanners, there were four main scenarios for the procurement of tanbark, all of which would influence the price paid. Firstly, tanners purchased the peeled bark from the woodland owners or their agents who let the process of peeling on an annual basis or at each fall to groups of 'peelers'. The bark could be 'rough' i.e. unprocessed, part-processed or fully processed (cleaned, dried and chopped in pieces and put into sacks). Secondly, tanners negotiated contracts with the woodland owners or their agents and were themselves responsible for getting the bark peeled, dried and taken away. Thirdly, woodland owners organised or let the areas of woodland separately to peelers/ barkers and timber merchants who then sold the product to tanners. Lastly, the timber and wood merchants had the contracts with woodland owners and they organised all work in the woodland to harvest the range of products and sell the bark to tanners.

The Woodlands

In the UK the best source of plant-based tannin, was from the bark of the oak tree. Indeed, in medieval England oak was the only legal source of bark for tanning (Muir, 2005) and in 1603 an Act of Parliament set out detailed regulations for cutting, peeling and selling bark (Rotherham, 2013). This was in response to local entrepreneurs stockpiling quantities of bark creating artificial shortages leading to higher prices. The Act was not repealed until 1808 by which time market conditions had already changed considerably and bark was being imported and exported abroad as well as across regions.

Peeling the bark is a destructive process for the tree so it commonly took place when the tree was being harvested for its wood or timber. This was not always the case and in some parts of the UK, trees were peeled and then left standing to be harvested later. This seemed to be the common practice in parts of Derbyshire and the West Riding of Yorkshire where a shortage of labour was given as the reason. However, it also occurred in Sussex where timber merchants left peeled trees standing in the belief that it speeded up the 'seasoning' process so that "allowing it to stand in that state three years, to season before felling it, has the same effect ... as allowing the tree to stand with the bark on it for 25 years longer.." (Young, 1813). The concentration of tannin in the bark also varies with the age of the tree and the timing of peeling. It was found that bark from trees that were between 18 and 32 years old gave the best yield, the exact age varied because of the growth conditions of the tree. Therefore, in the west of Scotland the optimum age for the tree was older than in southern England.

The rise of the 'oak coppice with standards' woodland in the medieval period where multi-stemmed oak trees were cut on a cyclical basis and standard timber trees harvested on a longer cycle also served the needs of the tanning industry. If the tanners had access to bark harvested at the right age, (when the coppice was cut), they were able to extract the maximum amount of tannin from the minimum amount of harvested bark. 'Coppice-with-standards' became the preferred model for industrial woodland production until the end of the nineteenth century in many parts of the UK; it served the need for wood, charcoal and timber as well as bark (Photograph 3). In these woodlands oak was favoured above other species such as Birch, Aspen, Hazel, Alder and Willow. In Scotland, these were known as 'barren timber' and were selectively removed to be replaced by planted oaks imported from England (Tittensor, 1974). This practice also occurred in other areas where oak was the most economically valuable tree for the woodland owner. In some of the arable areas of the UK different tree species were used as standards and coppice stools, for example oak or beech as standards and hazel as coppice, in the local woodlands. These species also reflected the uses made of them in support of agriculture or local industries. As Farey says in the survey of Agriculture in Derbyshire (1817), hazel was removed from local

Photograph 3: Outgrown Oak Coppice Woodland in South Yorkshire (Collection of C. Handley / I.D. Rotherham).

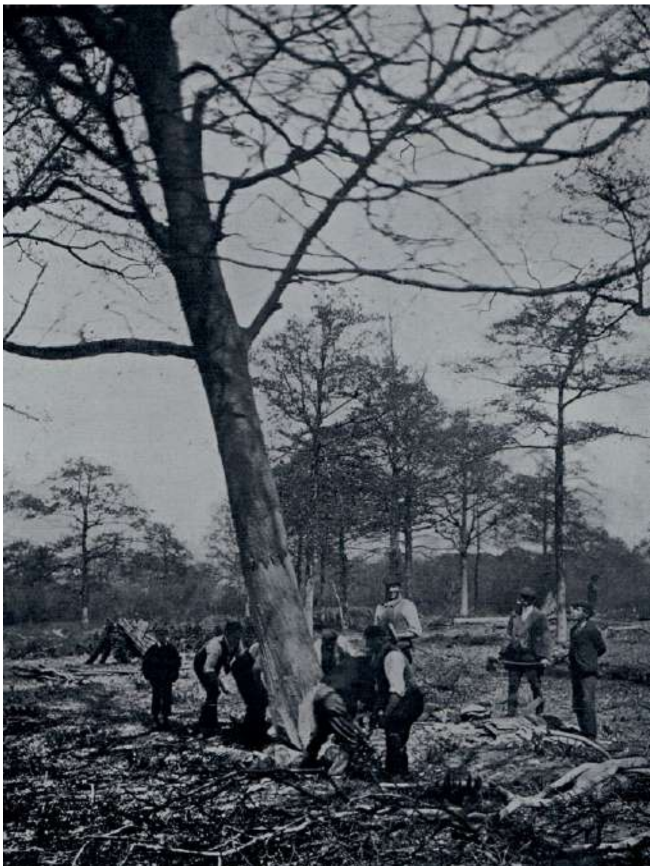
woodlands although it occurred in hedgerows because "... [it was] an unprofitable Underwood ... owing to it having no particular Application or Use in this County, as it has to the crates of the potter and glass-maker in Staffordshire, to the coal corves in Durham ... to small Cask Hoops, wattled Hurdles, &c. in other places." He also comments that woodland owners in Derbyshire were not following the general trend of removing coppice woodland from areas with good soils and converting the land to agriculture something of which he approved. And goes on to say, "... that the want of value in the Roots and Fire-wood, and the high price of labour, would occasion an expense of 20l . to 25l. per acre to clear the Wood lands fit for cultivation ..." The owners felt this was not worthwhile when they still had a good market for their coppice products.

In some areas such as the southern West Riding of Yorkshire, the Sussex and Kent Weald, the West Midlands, Wyre Forest and the Forest of Dean in the Wye valley, these industries developed side-by-side both needing woodland products and an abundant supply of water. Their underlying geology provided ironstone and the soil conditions, which favoured the growth of oak. The agricultural system was more pastoral than arable and there was a local industrial economy based on dual occupations. This was geared towards a system of small entrepreneurs, manufacturers and labourers who were also farmers and had other seasonal occupations.

In areas such as the Vale of York, with a different geology from the Sheffield study area, and where in medieval times, many of the coppice woodlands were owned by the Church, it was firewood for York, not charcoal, that was the main commodity. There were occasional sales of bark and underwood recorded in the accounts but this was a small proportion of the whole. The area, originally fenland, became good agricultural land after it was drained, and there was increasing pressure on the woodlands themselves as the population grew and York expanded. After the mid-sixteenth century with the religious upheaval and appropriation of Church lands, pressure on the woodlands increased (Kaner, 1997). The market was principally still for underwood and timber to supply faggots for fires and building projects to keep pace with the growth of York and the area around it. As Kaner (1997) points out this was not always sustainable and furthermore the woods' survival depended on whether the income generated from exploiting the woodland outweighed the income that could be generated from converting to other uses. She points out that unlike other areas in North Yorkshire there was no local metalworking industry, which needed constant supplies of charcoal and the proportion of woodland declined drastically. In common with most other large towns there was a tanning industry in York but it does not appear to have been sufficiently large enough to exert an obvious influence on local woodland management.

Larger coppice woods were sub-divided into compartments so that they could be managed on rotation to provide a steady supply of woodland products and regular income for the owner. This was a long-term commitment as the interval between coppice harvesting could be at least 15 years and often more, and for timber trees, may be anything from 40- 50 years. The woodland would need to be managed and protected at least in the first years after the coppice was cut to make sure the new shoots were growing well. When the trees were ready for harvesting, the woodland owner could have several different avenues open to him to ensure that he got the maximum return on his investment. For example, he may use his own estate workers to harvest the trees and sell the constituent parts to charcoal makers, tanners, millwrights, carpenters etc. Alternatively, more usually, his agent would negotiate with the peelers/barkers, timber merchants, charcoal makers and woodland craftsmen etc. to allow them to harvest and use the relevant parts of the trees for their trades.

If bark was part of the harvest, the peelers and barkers would be the first people in the wood starting work in the spring as this was the season when the sap was rising, the bark was easiest to peel and had the highest concentration of tannin. Whole coppice stools and standard trees (which were to be felled in that cycle) would first have a section of bark removed to allow the coppice poles and trees to be cut down without damaging the bark (Photograph 4). Once cut down, the remaining bark would be removed from the coppice poles, tree trunks and branches straightaway before it dried out and became difficult to peel (Photograph 5). Smaller branches and twigs were also peeled so that nothing was wasted. Women and children often undertook this latter work, whilst men carried out peeling of the larger branches and trunks. Once peeled the bark then needed to be picked clean of moss and lichens and set out to dry on frames. When it was sufficiently dry it would be gathered into large piles which would be covered with rushes or straw (thatch) and stored until transported to the tanneries. In the English Lake District, the bark was stored in stone built barns (Photograph 6).



Photograph 4: Felling the Tree to Peel the Bark, North Kent (UK) in the 1930s (Collection of C. Handley / I.D. Rotherham).

Photograph 5: Peeling the Bark, North Kent (UK) in the 1930s (Collection of C. Handley / I.D. Rotherham).

Harvesting the bark was seasonal work and in some parts of England would be carried out by families working in groups who would travel from woodland to woodland harvesting the bark. In Sussex and the Weald, these were known as 'flawing gangs' who worked on circuits travelling north as the bark harvest progressed (Mead, 1989). The timing of the bark-peeling harvest was critical if it was to be done at the easiest time for peeling and if they were to get the highest yield of tannin. The season varied across the UK, starting earlier in the

Photograph 6: Bark Barn in Roudsea Wood, Cumbria, UK (Collection of C. Handley / I.D. Rotherham).

south of England (early April) and later in the west of Scotland (May) but usually lasted about 8 weeks and was dependent on the start of the sap rising through the tree. Albert Link, a bark-peeler from the Wyre Forest, described how he would cut a slit in the bark on the east side of the tree to see if the sap had started to rise. According to Albert, the east side of the tree was usually the one, which gets the most sunshine and where the sap would start to rise first. If the bark came away easily, it was time to start harvesting the bark.

In other areas of the UK, such as the southern West Riding of Yorkshire and North Derbyshire, which also had 'coppice-with-standards' oak woodland, the coppice stools and timber trees were peeled at the same time but the timber trees were left standing to be felled later. This may have been driven by the demand for tanbark, the lack of demand for timber, the lack of labour to fell and process the timber or the understanding that the timber would not become unusable if left standing for a few months. 'Coppice-with-standards' woodlands developed in England as multi-purpose economic units which could cater flexibly for different demands, changing as markets developed. They were a response to pressures on land use where food production was of primary importance and there was still a huge need to provide domestic sources for wood and timber.

Moving away from the traditional 'coppice-with-standards' woodlands style of management, the harvesting of bark can be seen as a more straightforward economic process. Lindsay, Tittensor and others have described how the 'coppice with standards' system was imported from England to western Scotland to cater for the increased demand for charcoal and bark. Some of these woodlands were already being harvested for bark, wood and timber but not in a controlled economically sustainable way. It was only when the increased investment needed to set up and manage 'coppice-with-standards' woodlands became worthwhile with expanding markets, long-term planning, and significant economic returns, that this system developed in Scotland from the late seventeenth century. By the middle of the nineteenth century, it was already in decline because of changing economic conditions. During the two hundred years or so that the woodlands were managed using the coppice system the species composition also changed with oak planted in preference to other species. As the demand for oak coppice decreased new local industries, such as pyroligneous chemical manufacture were developed and species such as Birch and Alder were favoured again. Some coppice woodland was converted into high forest for timber production, whilst other areas were allowed to revert to pasture woodland. This was either deliberately, as owners focussed on sheep, or through neglect as the coppice compartment boundaries were not maintained. The result was that the type of woodland common and thought typical in Scotland was more extensive and varied than the heavily managed coppice woods of southern England. Many of the English woods were also converted to high forest later in the nineteenth century and into the twentieth century as markets for the coppice produce changed and declined. However this was not uniform and even into the late twentieth century some woods were managed using a coppice system where there was still a market for products such as 'pit props' for coal mines and fence posts. In a few of these woods, for example the Wyre Forest in the West Midlands there was also still a market for bark supplying the few small tanneries which continued to use oak bark in the tanning process. However, by the middle of the twentieth century almost all of the remaining tanneries in the UK used other tanning agents, which were easier to handle, and tanned the hides more quickly. The Downton tannery in Wiltshire closed in 1998 by which time it was using extracts of mimosa imported from South Africa as its source of tannin.

The changes and impact on woodland is particularly evident in the development of the tanning industry across the USA. In the Northeast and Mid-west, the tree with the highest tannin content in its bark is Western Hemlock (Tsuga heterophylla) rather than oak. It gave a rich reddish-brown colour to the leather in contrast to leather from the Southern USA, which was tanned using oak, and had a lighter yellowish colour (Canham, 2011). Further west, in California the Tanoak (Lithocarpus densiflorus), an evergreen hardwood, was harvested. The tannins from the bark of this tree also contain acetic and gallic acid which is particularly suitable for producing heavy leather such as saddles and harnesses (Tappeiner, McDonald and Roy, 1990). Both species of tree can form pure stands on mountainsides in humid situations but also grow mixed with pines and other species. The old-growth forest and woodland was exploited across the country to support the tanning industry with large areas of trees harvested solely for their bark and timber often left to rot in situ.

In the 1880s, in the Rib Lake area of Wisconsin, the peeled hemlock trees were left standing but by the 1890s the timber was being used to make cheap coffins which could be covered in cloth (Rusch, 1981). The quantity of Hemlock available coupled with the rapid growth of the tanning industry which was linked to the rise in cattle ranching did not lend itself to the establishment of a coppice system modelled on that of countries such as England. Instead, bark was harvested intensively on an industrial scale until the supply was exhausted in a local area and then the workers and industry moved to a new area. Until the expansion of the railway network in the late nineteenth century, which improved transport, links it was better financially in the Eastern states to site the tanneries nearer to the source of the bark because of the difficulties of moving the large quantities of bark needed by road. In the early twentieth century, the tannery industry in the San Francisco area of California received their bark supplies by ship. The bark was brought from the peeling camps initially by pack mule to collection points and then transferred to ports at the coast. Most of the supplies were shipped as pieces of bark but there was also a processing plant at Greenwood where the tannin was extracted from the bark in heated vats and the tanning liquid shipped in containers to the tanneries in San Francisco (Moungovan, 1906).

Canham (2011) describes how the tanning industry first moved into the foothills of the Catskills where hemlock was abundant. Whole towns developed around the tanneries, some such as Tannersville and Prattsville survive today. At Prattsville, the tannery operated for just twenty years (1825-1845) but in that time it used "100,000 cords of hemlock bark from an estimated 400,000 trees". When the supply of bark was exhausted from the local area the tanneries closed and moved further inland (and into the mountains) to new areas where hemlock was abundant and new tanneries were opened. These tanneries operated at a large industrial scale employing hundreds of people directly and indirectly. The pollution from the tanneries and the waste from leaving the timber to rot exacerbated the problems for the regeneration of the hemlock forests.

The Rib Lake, Wisconsin tanneries did not open until the 1890s as European immigrants and farming moved west. These tanneries were one of the main centres, which again developed close to hemlock forests. Rusch (1981) says that in the early 1900s there was so much hemlock bark being harvested that "a steam hauler was used to bring the bark from outlying lumber camps". As well as the commercial companies harvesting bark, local farmers were also involved. Around 1900, farmers were paid about 6US$ per cord delivered to the tannery. As Rusch remarks, "by the economic barometer of the time, [this] was good money and farmers could peel many cords in a season". The farmers used horse-drawn sleds at the beginning of winter to transport the bulky dried bark, as this was the easiest form of transport.

The same tools and terms were used which would have been familiar to the barkers and peelers and 'flawing' gangs in the English countryside. This is not surprising as the workforce was drawn from European immigrant labour nevertheless the accounts of the work give interesting insights into how the work was organised. Moungovan (1906) writing about the work of the lumberjacks in Mendocino County, California also describes the work of the barkers and peelers. Although he says that the tanbark camps and logging camps were separate operations, he describes how, "when the logs were cut into saw logs, the barkers started to peel the logs, one barker or peeler to a log." He also describes the implement that was used to peel the bark, "the peeler bar was a steel bar from four to five feet in length ...with a wide bit of the finest tool steel which was welded onto the bar..." Rusch (1981) describes a similar implement in use in Wisconsin and calls it a 'spud'(Photograph 7), a term for the implement as well as the implement itself, which would also be familiar to the English peelers.

Photograph 7: A barking iron or 'spud' from South Yorkshire, England used to peel bark from trees. Courtesy of Joan Jones, 2012 (Collection of C. Handley / I.D. Rotherham).

Photograph 8: Old Tanning Vat, Santa Cruz, California (Collection of C. Handley / I.D. Rotherham).

Warren Ormsby, who worked in the bark peeling camps in the coastal forests of California at the beginning of the twentieth century, gives a similar picture to Moungovan but says that two men worked as a team peeling the bark and "two men who could peel four cords a day were considered to be good woodsmen". Their day was from six in the morning to six at night, with half an hour for lunch. Mendocino County where Warren worked was the centre of the tanoak bark industry. Here the peelers felled trees, which were between 18inches and 3 feet in diameter, opening up areas so that the lumberjacks could move in and fell the Redwoods and Douglas Firs that remained. He also goes on to describe that over the years that he worked in the industry the camps had to move into more remote areas and the job became more difficult as the stands of tanoak were depleted.

Tanning also took place on a domestic scale on individual ranches and in small settlements across the USA as elsewhere. The illustration in Photograph 8 shows a tanning 'vat' in California carved from the trunk of a single tree which was probably used in domestic small-scale production. It gives a further example of the uses of wood and timber in the tanning industry over and above the harvesting of bark.

The Legacy in Today's Woodlands

Rackham (2006) makes the point about the importance of the tanning industry at the peak of production in shaping today's woodland legacy in parts of England, "There were thousands of acres of oak coppice in which timber production was deliberately sacrificed for an increased yield of bark; their remains are still one of the most widespread British woodland types." Timber production could be sacrificed because there were alternative sources of timber trees from abroad, unless supply lines were disrupted because of conflicts. Much of the coppice also fuelled the metalworking trades as well as the tanning industry and for woodland owners represented a quicker and more repeatable return on their investments than timber production. These relict oak coppice woodlands with their carpets of spring woodland ground flora are quintessentially seen as 'typical' Ancient Woodland with all the values that the name imparts. These Ancient Woodlands in Britain are now afforded some protection for nature conservation reasons. Examples of these woods and the relicts of the industrial past can be found in woodlands across South Yorkshire, the Sussex and Kent Weald, the Wyre Forest, the Wye valley and the Southern Lake District to name just a few areas.

In parts of England like Bishopwood (the largest in medieval wood in the Vale of York), where bark and charcoal were not the main commodities, the type of woodland evident today "is now a complete patchwork ... of deciduous wood, oak and ash with an understorey of hazel and ancient woodland indicators mixed with patches of conifers." (Kaner, 1997). She goes on to say that in other parts of the Vale, for example at the Forest of Galtres around Easingwold, the main woodland resource by the early seventeenth century was pollarded oaks and heathy areas with poor soil. These woodlands, where they still exist, may be less obvious than the typical Ancient Woodland but may be able to demonstrate just as long a continuity as woodland.

The woodlands in the western highlands of Scotland had an industrial coppice tradition, which started later and was short-lived in comparison to England. The legacy and impact of this tradition is less obvious today. As demand for coppice products declined, landowners turned to alternative sources of income, largely either grazing or forestry (timber production), and the coppice woods were allowed to deteriorate. Extensive unregulated grazing and lack of protection of the coppice stools is shown today in the upland 'shadow woods' (Photograph 9) and wood-pasture type of landscape. The growth of commercial forestry, which obscured and changed some of the coppice woods, also occurred elsewhere in the UK. These woods and forestry plantations, which may retain some of the ancient woodland ground flora, have been identified under Planted Ancient Woodland Sites (PAWS) as areas, which could be restored to mixed broad-leaf woodland after felling operations.

Photograph 9: A shadow wood in upland England (Collection of C. Handley / I.D. Rotherham).

In the USA, Canham (2011) states how "early writers saw denuded hillsides with rotting hemlock trees stripped of their bark and bitterly lamented the destruction of majestic hemlock forests which had stood for hundreds of years." and that at the beginning of the twentieth century the popular view was that these forests were gone forever. Observation showed that the clear-felled hemlock forests did not easily regenerate compounded by problems of silted streams and eroded soils and in some cases "piles of hemlock bark left rotting in the woods." However, by the beginning of the twenty-first century some of the hemlock forests have recovered and stands form part of the mix in the hardwood forests of New England, New York state and Pennsylvania. The timber is now harvested for wood pulp. There is a similar picture in California where there are sufficient quantities of tanoak that it is a designated commercial species also used for wood pulp and here, for fuel.

These different examples show the effects of the tannery industry on woodlands varied depending on the longevity and intensity of the industry at particular points in time. They also show that the legacy of the industry has helped to shape today's woodlands, their species composition and their impact on the landscape. The relationships of this industry and craft to its communities, its landscapes and to other activities are complex and clearly merit further work. FitzRandolph & Hay (1926) and Jones (1927) document the disappearance of small, rural tanneries and bark merchants across England and Wales. They also attribute this in part to changing demand in various markets. So the reduction of reliance on horsepower in the early twentieth century and hence a decline in the market for small-scale tanneries and saddlers, with moves for both towards large, more industrial-scale providers. These are interesting interactions related to wider issues of woodland management and local economic history, and will repay further studies in more detail.

References

Bateson, J.H., 2006. *Tanning and Tanners*. RH7 History Group Factsheet. [www.rh7.org/factsheets/tannery.html]

Canham, H.O., 2011. *Hemlock and Hide: The Tanbark Industry in Old New York, Northern Woodlands*. Summer 2011.

Clarkson, L.A., 1965. *The English Bark Trade, 1660–1830.* Agricultural History Review, 13.

Clarkson, L.A., 1966. *The Leather Crafts in Tudor and Stuart England*. Agricultural History Review, 14.

Cripps, A. 1974. *The Countryman Rescuing the Past*. Readers Union Group of Book Clubs, Newton Abbot. pp 106-115.

Dick, M., 2003. *Woodland Industries in the Wyre Forest*. Bewdley Museum. [http://www.search.revolutionaryplayers.org.uk/engine/resource/exhibition/standard/default.asp?resource=749]

Elliott, B., 1987. Lime, Liquor and Leathermen. *Hallamshire Historian*, 2(1), Winter 87/88.

Farey, J., 1817. *General View of the Agriculture and Minerals of the County of Derbyshire*. Volume 2, Board of Agriculture, HMSO London.

FitzRandolph, H.E. and Hay, M.D., 1926. *The Rural Industries of England & Wales.* A survey made on behalf of The Agricultural Economics Research Institute Oxford. Volume I, Clarendon Press, Oxford.

Frost, J., 1995. *The Birks Family of Woodhouse. unpublished family history.* Rotherham Local Studies Library-Frank Coupe Collection.

Green, J.L. (undated, late 1800s). *The Rural Industries of England*. Marlborough & Co., London.

Handley, C., Rotherham, I.D. and Coupe, K.F., 2009. *A South Yorkshire Case Study: the Tanning Industry in Woodhouse, Sheffield.* Presented at British Association of Local Historians Autumn Conference, Hull. On-line at www.ukeconet.co.uk

Jones, A.M., 1927. *The Rural Industries of England & Wales.* A survey made on behalf of The Agricultural Economics Research Institute Oxford, Volume IV, Clarendon Press, Oxford.

Jones, M., 2009. *Sheffield's Woodland Heritage*. 4th Edition, Wildtrack Publishing, Sheffield.

Jones, M., 2012. *Trees and Woodland in the South Yorkshire Landscape: A Natural, Economic and Social History.* Wharncliffe Books, Barnsley.

Kaner, J., 1997. *Historic Woodland in the Vale of York in Atherden.* M.A. and Butlin, R.A. (eds) Woodland in the Landscape: Past and Future Perspectives, Leeds University Press, Leeds.

Le Tall, B., 1897. *Le Tall's Woodhouse.* 1984 Fascimile Edition, Holly Press, Sheffield.

Lindsay, J.M., 1975. The History of Oak Coppice in Scotland. *Journal of Scottish Forestry*, 29, 87-93.

Marren, P., 1990. *Britain's Ancient Woodland: Woodland Heritage*. David & Charles, London.

Mead, G., 1989. The Sussex Leather Industry in the Nineteenth Century. *Journal of the Sussex Industrial Archaeological Society*, 19.

Moungovan, T.O., 1906. *Logging with Ox Teams – an Epoch in Ingenuity.* Mendocino County Historical Society, California, USA.

Muir, R., 2005. *Ancient Trees Living Landscapes*. Tempus Publishing Ltd., Stroud.

Ormsby, W., 1971. *Peeling the Tanoak*. Reprint by Mendocino County Historical Society, California, USA. [http://www.mendorailhistory.org/1_redwoods/tanbark.htm]

Rackham, O., 2003. A*ncient Woodland: its history, vegetation and uses in England*. New Edition. Castlepoint Press, Dalbeattie.

Rotherham, I.D., 2007. The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: a UK case-study. *Forest Ecology and Management*, 249, 100-115.

Rotherham, I.D., 2013. *Ancient Woodland History, Industry and Crafts*. Shire Publications, Oxford.

Rotherham, I.D., Jones, M., Smith, L. and Handley, C. (eds), 2008. *The Woodland Heritage Manual: A Guide to Investigating Wooded Landscapes*. Wildtrack Publishing, Sheffield.

Rusch, R. (ed.), 1981. *A Pictorial History of the Rib Lake Area: The 'Tan Bark' Peelers*. McMillan Memorial Library, Wisconsin, USA.

Rymer, L., 1977. The Exploitation of Woodlands in the Parish of North Knapdale, Argyllshire. *Journal of Scottish Forestry*, 31(4): 244-250.

Shepherd, J.B., 1990. *Woodhouse in the mid 19th Century*. unpublished undergraduate dissertation, University of Sheffield.

Tappeiner II, J.C., McDonald, P.M. and Roy, D.S., 1990. *Tanoak in Burns*. R.M. and Honkala, B.H., Silvics of North America: Volume 2 Hardwoods, USDA Forest Service.

Tittensor, R., 1970. History of the Loch Lomond Oakwoods: Part1 The Ecological History. *Journal of Scottish Forestry*, 24: 100-110.

Tittensor, R., 1970. History of the Loch Lomond Oakwoods: Part 2, Period of Intensive Management: 1790-1920. *Journal of Scottish Forestry*, 24: 110-118.

Turkish Leather Council, 2012. *Leather in Turkish History*. [http://www.turkishleather.com/dtgeng/StaticPages/showpage.aspx?fname=altsektorler0.htm]

Young, A., 1813. *General View of the Agriculture of Sussex*. Board of Agriculture, HMSO London.

Chapter 16
A hidden treasure in Turkey - old oaks with unique values

Nicklas Jansson, Ogün Ç. Türkay, Mustafa Avcı

Diversity of oaks and its role for species richness

The oaks (*Quercus* spp.) in Turkey have the widest distribution area among all deciduous trees and cover 6 million hectares of the land area or 23% of the forests (Çolak and Rotherham, 2006). Different oak species are distributed all over the country, with the highest diversity in Marmara region (Uslu et al., 2011).

Globally, oaks include a wide range of about 500 species of trees and shrubs in the northern hemisphere, exclusive of the Arctic and about half of these are in the New World. Oak is an interesting genus for phytogeographers, foresters and ecologists, but is also one of the most problematical groups in the Turkish flora since widespread hybridization and introgression have much obscured specific limits (Hedge and Yaltırık, 1982). Depending on what taxonomic concept used, there are about 26 species of oak known from all the countries north of the Mediterranean, 18 of these are known from Turkey, plus nine additional subspecies (Hedge and Yaltırık, 1982; Greuter et al., 1986). This makes Turkey the richest country in the western Palearctic in terms of oak biodiversity (Uğurlu et al., 2012). Various species of oak can tolerate a very wide range of climatic- and soil conditions, including hot or cold temperatures, highly saline or alkaline soils (Özcan and Baycu, 2005; Uğurlu and Oldeland, 2012). Some of the Turkish species have a very restricted distribution in the world and some are endemic to the country e.g. *Quercus aucheri* and *Q. vulcanica* (Photograph 1) (Uslu et al., 2011).

Oaks can become very large and old. There are examples of oaks nearly 1000 years old and with a circumference of 14 meter in breast height. Some of the older oaks we have seen in Turkey are for sure more than 500 years old. With dendrology analysis, the age can be calculated, but as the trees often are hollow and the central part of the trunk are missing (Photograph 2) the age must be an estimation.

Photograph 1: The leaves from the two rare and endemic oak species a) *Quercus vulcanica* and b) *Q. aucheri* (N. Jansson).

Photograph 2: Old hollow oaks from Gölhisar region of Turkey (N. Jansson).

Traditional use of Oak

Large parts of Turkey are intensively grazed since many centuries and old trees are very rare. As in most countries in Europe (Emanuelsson, 2009) the trees in Turkey have been very important for humans through history. Not only as producers of timber, but also for extracting leaf fodder for the animals and firewood for heating and cooking. This is the reason why most of the old oaks in Turkey have been regularly pollarded (Photograph 3).

Photograph 3: Thousands of pollarded oaks near Gülnar in Mersin region of Turkey (N. Jansson).

Photograph 4: Acorns from two of the Oak species, (a) *Quercus brantii* and (b) *Q. infectoria* ssp. *boisseri* in Turkey used as food for people in Turkey (N. Jansson).

Photograph 5: Plantations of (a) Lebanon cedar (*Cedrus libani*) and (b) Turkish pine (*Pinus brutia*) in Turkey (N. Jansson).

Acorns as fodder for animals are known from many countries, but use as food for humans is almost unknown. The practice have been around for thousands of years and can be found virtually everywhere oaks are found (Bainbridge, 1986; Lieutaghi, 1998). It occurs in the early town settlements in the Zagros Mountains in Iran and at Çatalhöyük in Turkey (6000 BC) and were a staple food for many people until after 1900 AD (Bainbridge, 1986). In Turkey two species has been commonly used for this purpose: *Quercus brantii* and *Q. infectoria* ssp. *boisseri* (Photograph 4) (Mason and Nesbitt, 2009) .

The Turkish forest authorities have quite recently started to reforest the landscape. In this process, many of the last sites with old oaks are transformed to Turkish pine (*Pinus brutia*) or Lebanon cedar (*Cedrus libani*) plantations (Photograph 5).

The oak habitats in the Mediterranean region, including Turkey, is currently only a fragment of its original extent. Many remnants of forests that remained are now grazed, but differ in size as well as in structure and shape, depending on the current land-use management (Grove and Rackham, 2003; Westphal et al., 2009). In Turkey the old oaks are cut mainly when transforming the oak habitats into plantations of mainly Turkish pine (*Pinus brutia*), but at higher altitudes also black pine (*Pinus nigra*) and Lebanon cedar (*Cedrus libani*) for timber production.

Old Oaks with high species richness

Old oaks are exceptionally species-rich in Europe, but in most countries the habitat has declined substantially. Saproxylic insects associated with old trees and dead wood is one of the most endangered invertebrate groups in Europe, as their habitat has severely decreased (McLean and Speight, 1993). These insects are living in fungal fruit bodies, dead wood outside the tree (in branches, twigs or parts of the trunk) or inside the tree in hollows (Palm, 1959; Speight, 1989; Dajoz, 2000). Many species dependent on large, old and hollow trees have survived in small remnant woodlands of ancient trees, often in the agricultural landscape (Speight 1989; Warren and Key, 1989). A large proportion of them are rare and red-listed saproxylic insect species (Jonsell et al., 1998; Gärdenfors, 2010; Ranius and Jansson, 2000). In general the knowledge of the Turkish beetle fauna is poor in comparison to other European countries. In comparison to others there are some beetle families i.e. longhorn beetles and jewel beetles (Cerambycidae and Buprestidae) (Photograph 6), with large amount of saproxylic species, with relatively good knowledge of what species existing in Turkey.

When oaks age, hollows in the trunks fills with wood mould, i.e. wood soften by decomposing fungi, often with remains from animal nests and insect fragments and droppings from insect larvae. Trunk hollows with wood mould harbor a specialized fauna, mainly consisting of beetles and flies (Dajoz, 1980). The beetle fauna in tree hollows has intrigued entomologists for a long time, but only recently quantitative methods have been used in the studies (Ranius and Jansson, 2000; Brustel, 2004; Jonsell, 2004; Buse et al., 2008).

In northern Europe the pedunculate oak (*Quercus robur*) is known to harbor the richest wood living beetle fauna compared to other tree species. In Sweden 540 species are known to use oak wood for their larval development (Palm, 1959). Saproxylic insects associated with old trees are one of the most endangered invertebrate groups in Europe, as their habitat has severely decreased (McLean and Speight, 1993) and a large proportion are rare and red-listed (Jonsell et al., 1998; Ranius and Jansson, 2000).

The largest beetle in Europe is the stag beetle (*Lucanus cervus*). The stag beetles in southeastern Turkey are larger than their European conspecifics, and the males can be up to 12 cm, including their mandibles (Photograph 7a). The larvae of this beetle are living in the ground eating dead roots of oaks. The development takes 3-5 years and

Photograph 6: Examples of Turkish species of flower chafers and longhorn beetles (Cetonidae and Cerambycidae) living on oaks: (a) *Protaetia aeariginosa,* (b) *Ergates gaillardoti* (Chevrolat) and (c) *Prinobius myardi* (N. Jansson).

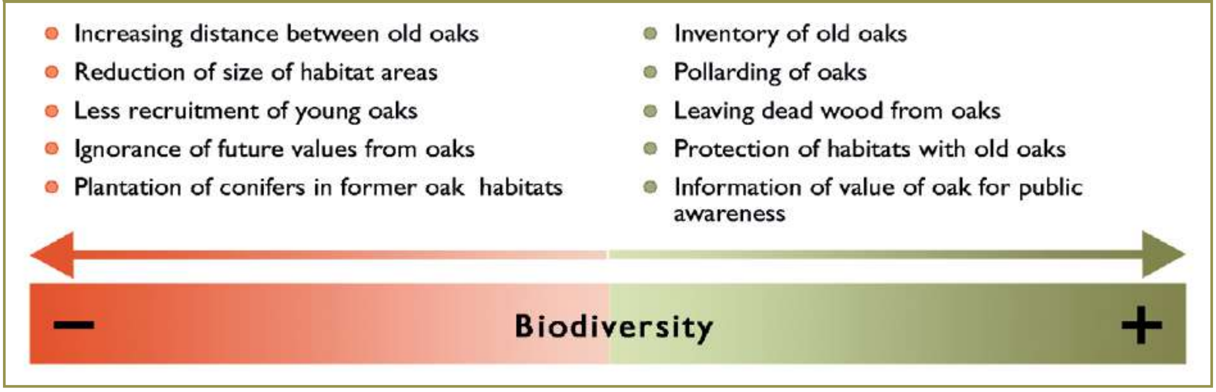
the adults can be seen in May-July. Another large and interesting species living on oaks in Turkey is the large scarab beetle *Propomacrus bimaculatus*. The forelegs of the males are extended and bended creating an extreme shape (Photograph 7b). The species is dependent upon old trees as the larvae develops in the cavities eating the rotten wood produced by fungal activities.

Most of the beetles are small and have a cryptical life, most hidden for us. However, some are as imago, in sunny days, visiting flowers, feeding on nectar and pollen. Some of these are from the scarab family called chafers. The largest (20 mm) and most beautiful among those in Turkey are the multi-colored *Protaetia aeriginosa* (Photograph 6a). The species needs old hollow trees for its larval development. The beetle fauna associated with old oaks in Turkey is virtually unknown, but very threatened. A project started in Turkey in 2005, aiming to describe the diversity of beetles on old oaks in Turkey have found a fantastic diversity and many interesting species. Until now, 28 species new to science have been described (Schillhammer et al., 2007; Novak et al., 2011, 2013, 2014; Platia et al. 2011, 2014; Sama et al., 2011; Mazur et al., 2013; Schulke et al., 2013) (Photograph 8). One could guess that these are very small species hard to recognize, but many belong to famous well-known families like the click beetles (Elateridae). The largest

Photograph 7: (a) Two males of the Turkish stag beetle (*Lucanus cervus* ssp. *judaicus*) and (b) a male of the scarab beetle *Propomacrus bimaculatus* (N. Jansson and O.Ç. Türkay).

Photograph 8: Some of the species found new to science: (a) *Elathous adiyamani* (Family-Elateridae), (b) *Hesperus gozukarai* (Family-Staphylinidae), (c) *Allecula turcica* (Family-Alleculidae), (d) *Hister arboricavus* (Family-Histeridae) (G. Platia, H. Schillhammer, O.Ç. Türkay and S. Mazur).

How different activities affect the saproxylic beetle fauna and other biodiversity on oaks in Turkey — **Figure 16.1**



species, given the name *Elater turcicus* is from this family and is 18 mm long. Probably the larvae, as most larger click beetles, is a predator living in the soft rotten wood inside hollow trunk of oaks.

High values are threatened

It has been suggested that beetles living in hollow trees have low dispersal capacity (McLean and Speight, 1993; Nilsson and Baranowski, 1997; Ranius and Hedin, 2001) and are sensitive to reductions of the number of suitable trees in the landscape. As the competition for land by agriculture, forest industry and urban development has intensified in Turkey, it is important to identify the remaining oak patches and estimate their conservation value to be able to make cost-efficient use of the limited resources allocated to conservation. To protect the unique endemic beetle fauna living on old trees, it would be of great value if the most important areas with old oaks could be identified and protected in Turkey. Patches with old oaks in the landscape are probably also positive for the surrounding productive forests. The predators in the oak forests such as woodpeckers, parasitic wasps and beetles like *Calosoma sycophanta* (Weber, 1881) can help in regulating the pest species in plantations of pine and cedar, for instance (Kanat and Özbolat, 2006) (Figure 16.1). But further studies in this field are needed.

Many birds need cavities for their nesting. Old trees can serve birds from small-sized ones like tits and nuthatch to large ones like owls. Recent studies of birds in oak forests in Turkey showed a higher number of secondary cavity nesters in older forest stands in comparison with young (Bergner et al., 2015) and woodpeckers prefer foraging and nesting in larger oaks with deeper bark furrows and a higher amount of dead wood (Bergner et al., 2016). Some of the insect species in the cavities also gain from the bird activities like different materials left by the birds. Old oaks are also important as foraging habitats for some of the birds as the insect density often are high and species like woodpeckers (Photograph 9) find food in the rotten wood and under dead bark etc.

Photograph 9: Middle spotted woodpecker (*Dendrocopus medius*) from Isparta region, Turkey (O.Ç. Türkay).

Although the Mediterranean region is considered to be a biodiversity hotspot (Medail and Quezel, 1999; Myers et al., 2000), only a few systematic studies report on the biodiversity of beetles in Mediterranean tree habitats (e.g. Brin and Brustel, 2006; Buse et al., 2008; Jansson and Coskun, 2008; Mico et al., 2013).

Many of the beetle species found (i.e. 12) are very rare and are listed in the European red-list (Nieto and Alexander, 2010). One good example of this from the Turkish material was the violet rose chafer (*Protaetia mirifica* Mulsant) which is a very rare species and only known from less than 15 sites in the entire Mediterranean region. Other examples of interesting beetles found were the click beetles *Limoniscus violaceus* (Müller), *Reitterelater dubius* (Platia and Cate) and *Ischnodes sanguinicollis* (Panzer) (Photograph 10). They are very rare beetles all over their European range and are considered to be so-called Urwald relict species with high conservation values (Whitehead, 2003; Müller et al., 2005). The violet click beetle (*Limoniscus violaceus*) is also listed in Annex II of the EC Habitats Directive. An important message to spread from the project is that all the beetles mentioned in this article are living on old or

Photograph 10: Some of the species on the European redlist: (a) *Protaetia mirifica,* (b) *Limoniscus violaceus* (c) *Ischnodes sanguinicollis* (N. Jansson).

dying trees and never attack younger trees. Actually this is true for all wood living beetles on oaks, except a very small number.

Conclusions

The results from the on going studies, first confirm the status of Turkey as being a major biodiversity hot spot, but also one of the less explored areas, in the western Palearctic. The findings of many species rare in Europe make the oak habitat in Turkey of high value for future scientific research. Thus, it is vital that some of the last areas are protected to prevent many of the unique and often endemic species from going extinct. The risk is high due to the small area left and the high speed of transformation from old oak habitats to other forest types or land uses.

References

Bainbridge, D.A., 1986. *Use of Acorns for Food in California: Past, Present, Future*. Presented at the Symposium on Multiple-use Management of California's Hardwoods, November 12-14.

Bergner, A., Avcı,M., Eryiğit, H., Jansson, N., Niklasson, M., Westerberg, L. and Milberg, P. 2015. Influences of forest type and habitat structure on bird assemblages of oak (*Quercus* spp.) and pine (*Pinus* spp.) stands in southwestern Turkey. *Forest Ecology and Management* 336: 137-147.

Bergner, A., Sunnergren, A., Yeşilbudak, B., Erdem, C. and Jansson, N. 2016. A*ttributes of trees used by nesting and foraging woodpeckers (Aves: Picidae) in an area with old pollarded Oaks (Quercus spp.) in the Taurus Mountains, Turkey*. Zoology in the Middle East. ISSN: 0939-7140. [http://dx.doi.org/10.1080/09397140.2016.1226242]

Brin, A. and Brustel, H., 2006. Saproxylic beetles response to cork-oak forests heterogeneity in the Massif des Maures (France). *Revue d'Ecologie-La Terre Et La Vie* 61(4): 327-342.

Brustel, H., 2004. *Biological value of French forests assessed with saproxylic beetles: a way to conserve this natural heritage.* Proceedings of the 3rd European Symposium and Workshop on the Conservation of Saproxylic Beetles. Riga, Latvia, July 7th-11th 2004.

Buse, J., Ranius, T. and Assmann, T., 2008. An endangered longhorn beetle associated with old oaks and its possible role as an ecosystem engineer. *Conservation Biology* 22: 329-337.

Çolak A.H. and Rotherham I.D., 2006. A review of the Forest Vegetation of Turkey: its status past and present and its future conservation. *Royal Irish Academy, Journal of Biology and the Environment* 106(3): 343-355. Çolak, A.H., 2001. *Nature Protection in Forest.* Milli Parklar ve Av-Yaban Hayatı Genel Müdürlüğü Yayını. Orman Bakanlığı, Ankara.

Çolak, A.H., Kırca, S., Rotherham, I.D. and Ince, A., 2010. *Restoration and Rehabilitation of Deforested and Degraded Forest Landscapes in Turkey.* Ministry of Environment and Forestry, General Directorate of Afforestation and Erosion Control, Tor Ofset, Istanbul, 566 p.

Cypert, E. and S.W. Burton., 1948. Yield and use by wildlife of acorns of water and willow oaks. *Journal of Wildlife Management* 12(3): 227-231.

Dajoz, R., 1980. *Écologie des insectes forestiers*. Gauthiers-Villars, Bordas.

Davis, P.H., 1965. *Introduction*. In: Davis, P.H. (ed.) Flora of Turkey and the East Aegean Islands Vol. 1. pp. 1-26. Edinburgh University Pres, Edinburgh, UK.

Davis, P.H., 1971. *Distribution Patterns in Anatolia with Particular Reference to Endemism, Plant Life of South-West Asia*. The Botanical Society of Edinburgh.

Ekim, T., Koyuncu, M., Vural, M., Duman, H., Aytaç, Z. and Adıgüzel, N., 2000. *Red Data Book of Turkish Plants (Pteridophyta and Spermatophyta)*. Ankara, Barışcan Ofset.

Emanuelsson, U., 2009. *The rural landscapes of Europe: How the man landscaped European nature*. Swedish Research Council Formas, 383 p.

Greuter, W., Burdet, H.M. and Long, G. (eds.), 1986. *Med-checklist.* 3. Conservatoire et Jardin botaniques, Genève, CH.

Grove, A.T. and Rackham, O., 2003. *The Nature of Mediterranean Europe: An Ecological History*. Second printing with corrections ed., New Haven and London: Yale University Press.

Hedge, I.C. and Yaltırık, F., 1982. *Quercus* L. In: Flora of Turkey and The East Aegean Islands, (Ed.): P.H. Davis. Vol. 7: University Press, Edinburgh, 659-683.

Jansson, N. and Coşkun, M., 2008. How similar is the saproxylic beetle fauna on old oaks (*Quercus* spp.) in Turkey and Sweden? *Revue d'Ecologie-La Terre Et La Vie Suppl.* 10: 91-99.

Jonsell, M., 2004. Old park trees: a highly desirable resource for both history and beetle diversity. *Journal of Arboriculture* 30: 238-243.

Jonsell, M., Weslien, J. and Ehnström, B., 1998. Substrate requirements of red-listed saproxylic invertebrates in Sweden. *Biodiversity and Conservation* 7: 749-764.

Kanat, M., and Özbolat, M., 2006. Mass Production and Release of *Calosoma sycophanta* L. (Coleoptera: Carabidae) Used Against the Pine Processionary Moth, *Thaumetopoea pityocampa* (Schiff.) (Lepidoptera: Thaumetopoeidae), in Biological Control. *Turkish Journal of Zoology* 30: 181-185.

Ketenoğlu, O., Tug, G.N., Bingöl, U., Geven, F., Kurt, L. and Güney, K., 2010. Synopsis of taxonomy of Turkish forests. *Journal of Environmental Biology* 31:71-80.

Lieutaghi, P., 1998. *La plante compagne*. 37, Actes Sud.

Mason, S. and Nesbitt, M., 2009. *Acorn as food in southeast Turkey: Implications for prehistoric subsistence in Southwest Asia.* In: Fairbairn, A.S. and Weiss, E. (eds.), 2009. From Foragers to Farmers. Oxbow books. Oxford and Oakville.

Mazur, S., Öncül, T., Varli, S., Mokrzycki, T. and Jansson, N. 2013. *Hister arboricavus* sp. n., a new Dendrophilous species from Turkey (Coleoptera: Histeridae). *Baltic Journal of Coleopterology* 13(1): 51-56.

McLean, I.F.G. and Speight, M.C.D., 1993. *Saproxylic invertebrates - The European context*. In: K.J.D., Drake, C. M. (eds). Dead wood matters: the ecology and conservation of caproxylic invertebrates in Britain. English Nature, 21-32.

Médail F. and Quézel P., 1999. Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. *Conservation Biology* 13: 1510-1513.

Micó, E., García-López, A., Brustel, H., Padilla, A.,E. and Galante, E., 2013. Explaining the saproxylic beetle diversity of a protected Mediterranean area. *Biodiversity and Conservation* 22(4): 889-904.

Müller, J., Bußler, H., Bense, U., Brustel, H., Flechtner, G., Fowles, A., Kahlen, M., Möller, G., Mühle, H., Schmidl, J. and Zabransky, P., 2005. Urwald relict species-Saproxylic beetles indicating structural qualities and habitat tradition. *Waldökologie Online* 2: 106-113.

Myers, N., Mittermeier, R., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.

Nieto, A. and Alexander, K.N.A., 2010. *European Red List of Saproxylic Beetles.* Luxembourg: Publications Office of the European Union.

Nilsson, S.G. and Baranowski, R., 1994. Indikatorer på jätteträdskontinuitet - svenska förekomster av knäppare som är beroende av grova, levande träd. *Entomologisk Tidskrift* 115: 81-97.

Novak, V., Jansson, N., Avcı, M., Sarıkaya, O., Coşkun,, M., Atay, E. and Gürkan, T., 2011. New Allecula species (Coleoptera: Tenebrionidae: Alleculinae) from Turkey studies and reports. *Taxonomical Series* 7: 335-346.

Novak, V., Avcı, M., Jansson, N., Sarıkaya, O., Atay, E., Kayış, T., Coşkun, M. and Aytar, F. 2013. A new Mycetochara species (Coleoptera: Tenebrionidae: Alleculinae) from Turkey. *Journal of the Entomological Research Society* 15(2): 51-58.

Novak, V., Öncül Abacıgil, T., Varlı, S.V. and Jansson, N. 2014. *Mycetochara kazdagiica* sp. Nov. from Turkey (Cleoptera: Tenebrionidae: Alleculinae: Mycetocharini. *Folia Heyrovskyana* Series A, 22(2-4): 134-141.

Özcan, T. and Baycu, G., 2005. Some elemental concentrations in the acorns of Turkish *Quercus* L. (Fagacae) taxa. *Pakistan Journal of Botany* 37(2): 361-371.

Palm, T., 1959. *Die Holz- und Rinden-Käfer der Sud- und Mittelschwedishen Laubbäume.* Meddelanden Fran Statens Skogsforskningsinstitut, Band 40, Nr 2, 242 p.

Platia, G., Jansson, N., Avcı, M., Sarıkaya, O., Coskun, M. and Kayis, T., 2011. New species of click beetles from Turkey (Coleoptera, Elateridae). *Boletín de la Sociedad Entomológica Aragonesa*, 48: 207-215.

Platia, G., Öncül Abacıgil, T., Jansson, N., Kayış, T., Coşkun, M. and Varlı, S.V. 2014. Click-beetles (Coleoptera, Elateridae) from two oak forests in Turkey. *Boletín de la Sociedad Entomológica Aragonesa* 55:41-48.

Ranius, T. and Hedin, J., 2001. The dispersal rate of a beetle, Osmoderma eremita, living in tree hollows. *Oecologia*, 126: 363-370.

Ranius, T. and Jansson, N., 2000. The influence of forest regrowth, original canopy cover and tree size on saproxylic species associated with old oaks. *Biological Conservation*, 95: 85-94.

Sama, G., Jansson, N., Avcı, M., Sarıkaya, O., Coşkun, M., Kayış, T. and Özdikmen, H., 2011. Preliminary report on a survey of the saproxylic beetle fauna living on old hollow oaks (*Quercus* spp.) and oak wood in Turkey. *Munis Entomology and Zoolology* 6: 819-831.

Schillhammer, H., Snäll, S., Coşkun, M. and Jansson, N., 2007. The West Palearctic species of Hesperus Fauvel, 1874, with description of three new species from Turkey (Coleoptera: Staphylinidae: Staphylininae). *Koleopterologische Rundschau* 77: 123- 132.

Schülke, M., Jansson, N and Atay, E. 2013. Eine neue Art der Gattung *Sepedophilus* GISTEL aus der Türkei (Coleoptera, Staphylinidae, Tachyporinae). *Linzer Biologische Beiträge* 45/1: 905-912.

Speight, C.D., 1989. *Saproxylic invertebrates and their conservation.* Council of Europe, Strasbourg.

Türker, M.F., Pak, M. and Öztürk, A., 2005. *Turkey*. In: Merlo, M., Croitoru, L. (eds.) Valuing Mediterranean forests. Towards total economic value. . CABI Publishing, Wallingford and Cambridge, UK, 195-211.

Turkish Ministry of Environment and Forestry, 2007. *The National Biological Diversity Strategy and Action Plan.* Ankara, Turkey.

Uğurlu, E. and Oldeland, J., 2012. Species response curves of oak species along climatic gradients in Turkey. *International Journal of Biometerology* 56: 85-93.

Uğurlu, E., Roleček, J. and Bergmeier, E., 2012. Oak woodland vegetation of Turkey – a first overview based on multivariate statistics. *Applied Vegetation Science* 15: 590-608.

Uslu, E. Bakış, Y. and Babaç, M.T., 2011. A study on biogeographical disribution of Turkish oak species and their relation with the Anatolian diagonal. *Acta Botanica Hungarica*

53: 423-440.

Warren, M.S. and Key, R.S., 1991. *Woodlands: past, present and potential for insects.* In: Collins, N.M. and Thomas, J.A. (eds.). The conservation of insects and their habitats. Proceedings of the 15th symposium of the Royal Entomological Society of London. Academic Press, Imperial College, London, 155-211.

Westphal, C., von Oheimb, G., Meyer-Grunefeld, M., Tremer, N., Härdtle, W., Levanony, T., Dayan, T. and Assmann, T., 2009. Ya'ar Bar'am-an old *Quercus calliprinos* forest of high nature conservation value in the Mediterranean region of Israel. *Israel Journal of Plant Sciences* 57: 13-23.

Whitehead, P.F., 2003. *Current knowledge of the Violet Click Beetle Limoniscus violaceus (P. W. J. Müller. 1821) (Col., Elateridae) in Britain.* In: Proceedings of the second pan-European conference on saproxylic beetles. Royal Holloway: University of London, 25-27 June 2002, 57-65.

European Woodland History and Management: some concluding thoughts

Ian D. Rotherham, Alper H. Çolak, Simay Kırca

Many European wooded landscapes are eco-cultural being the result of long-term human interactions with nature. Often their origins were as various types of wood pastures - an expansive patchwork landscape of forest, wetland, grassland and other naturally occurring 'habitats' with large grazing herbivores. The descendants from these original ecosystems and landscapes may persist today as 'woods' and other 'unimproved' features. Many are now recognised as 'shadows' and 'ghosts' in the landscape. Across the continent, from Turkey in the continental east, to Great Britain in the Atlantic west, there is great diversity of landscape types, forms and histories, yet they share much in common.

In countries such as England for example, most 'woodlands' today are relatively small which makes them vulnerable to processes of clearance and neglect throughout their history. However, until industrialisation and the potential to power clearance by petro-chemical engines and to alleviate nutrient shortage by petro-chemically derived fertilisers, clearance often resulted in 'grubby landscapes' in which woodland plants and the like persisted in favourable refuges. From here, they could re-colonise the wider landscape when conditions became tolerable once more. Understanding these processes through the detailed study of specific sites and regions can prove enormously helpful in informing potential options for future management and for conservation.

By way of contrast, many European countries have more extensively 'forested' landscapes, and yet even these have been modified by the concepts of modern 'forestry'. Furthermore, many traditional and cultural uses have ended with major consequences for ecological, successional change. Turkey, Rumania, Scandinavia and the Baltic states, France, Germany and the Alpine regions, for example, all have extensive forest tracts. Yet these are frequently heavily modified and many have lost their ancient trees on the one hand, and their associated human communities on the other. The processes of 'cultural severance' (Rotherham, 2008) run deep across the continent.

Treescapes of forest and woodland reflect and influence community cultural history with multi-layered palimpsests of archaeology as testimony to human exploitation. Some uses were sustainable but others were not, and evidence of this cultural past relates to both woodland and non-woodland uses (e.g. Muir, 2005). Intensive studies in the UK show the depth of evidence and the diversity of interactions between people and their woods with a major output from focussed research being the Woodland Heritage Manual (Rotherham et al., 2008). Understanding of the nature of these landscapes and the drivers shaping them has evolved over recent decades with new concepts emerging to change perceptions. Key issues to emerge have included matters of traditional knowledge (Agnoletti (ed.), 2006, 2007; Parrotta and Trosper (eds.), 2012; Rotherham, 2007), of cultural severance (Rotherham, 2008), and more recently, of woodland shadows and ghosts (Rotherham, 2012a, b).

During the 1980s, interest in ancient woodlands in Britain and across Europe grew with the research and writing of woodland and forest enthusiasts. Particularly significant were Oliver Rackham (1980, 1986), George Peterken (1981, 1996), Charles Watkins (e.g. Kirby and Watkins, 1998), Richard Muir (2005) and Mel Jones (2009). This emerging literature triggered interest in the unique histories and values of forested or wooded landscapes.

The ideas and enthusiasms to emerge from this work have influenced much site management across the continent and beyond. There have been moves to reinstate native broadleaved tree species and to encourage demonstrations or targeted conservation programmes of 'traditional' management. These grew in parallel with increased recognition of the benefits that woods and forest landscapes bring to, for example, public health (e.g. Crowe, 2001), ecosystem services, and local economies (e.g. O'Brien and Claridge, 2002).

However, despite the increased interest in woods, and awareness of wooded landscapes, a steady loss of understanding and knowledge of their traditional management and cultural origins threatens long-term sustainability. In particular, the often complex and sometimes subtle impacts and influences of human management are frequently overlooked and 'restoration' may not lead to the desired outcomes. At the same time as interest in woods and forests has grown, there has been an emerging enthusiasm for trees themselves. This is reflected in, for example, the dramatic and influential growth of the Ancient Tree Forum and an associated network of researchers and practitioners. Significantly, from the 1980s onwards there has been increased a realisation firstly, of the importance of ancient parks and wood pastures, and more recently, of the potential overlooked resource of unrecognised pasture-woods. Now recognised as holding some of our most iconic and precious wildlife resources, medieval parks and similar habitats were for decades the 'Cinderellas' of conservation. Today, following in particular the writing of Frans Vera (2000), there is interest in not only the ecological history of such landscapes, but also in the potential for future 'wilder' treescapes.

Studies of environmental history demonstrate how the management of European woods and forests has changed dramatically over the centuries. With changing human influences and local factors, the balance between grazed wood-pasture, coppice woods and other uses has varied to produce local and regional character and distinction. In terms of understanding the spatial extent of the component communities and the balances, interactions, and drivers of change, there is much debate. However, a degree of consensus is emerging and over millennia, a primeval landscape was transformed over time to human-driven utilisation, with compartments, large and small. Various aspects of the ecology and landscape were driven by long-term, often traditional management. By medieval times, the rights and ownership were often vested in an individual, an estate (large or small), the Crown, or sometimes held in common (De Moor et al., 2002). The exact processes and mechanisms of such management were complex; varying over time and with location. Nevertheless, by the medieval period, wooded landscapes occurred in a number of clearly recognisable forms. These can be broadly divided into wood-pastures (including legally–designated hunting 'Forest'), and woods or coppice, with at least localised areas of natural, closed-canopy 'woodland', and more natural 'forest' particularly in rough or mountainous areas. More natural 'forest' would also have occurred extensively in the widespread wet landscapes of marsh, bog, fen, and flood-plain prior to large-scale drainage in the later medieval and early industrial periods. Some of these once widespread treescapes have now been all but eradicated from the European landscape. Also derived from ancient wood pastures, though generally significantly altered, were medieval landscape components such as meadows, pastures, heath, wooded common, and moor; and all may include treescape species. The scale of some of these changes and therefore the implications for future sustainability has not yet been widely recognised. It is also from these wider treed landscapes that many of the 'shadow woods' appear to have descended and the management processes now suggest exciting possibilities to regenerate or even to create new pasture woodlands.

Certainly since Rackham's ground-breaking book, Ancient Woodland (1980) and The History of the Countryside (1986), it has been clear that wood-pasture was once the most widespread and common wooded landscape in north-western Europe. Essentially a landscape or system of land management where trees are grown, but grazing by large herbivores (domesticated, semi-domesticated, wild, or combinations) is also permitted (Rotherham, 2007). Of course wood-pasture in England is well documented for over a thousand years; the Domesday Book (1086) recording a countryside where this is the predominant 'woodland'. Controversially, Vera (2000) then highlighted the importance of large grazing and browsing mammals in determining ecological successions in European primeval environments and their persistent influences into historic times. In this context, it has been suggested that managed wood-pasture evolved from grazed forest or a savannah as an ancient system of management in a multi-functional countryside where woodland (open and closed canopy) was relatively plentiful.

In this emerging medieval European countryside there was little need for formal coppice since there were generally few people and abundant resources. Coppice evolved from Roman systems of management, but was not widely adopted until much later since this is a labour intensive, rigorous system to ensure essential supplies of wood and timber in resource-limited landscapes (Fowler, 2002; Hayman, 2003; Perlin, 1989). Coppice woodland requires resources of labour and effective application of cyclical management together with control of grazing livestock. Pasture-woodland is an older and more 'natural' system, and is inherently less labour intensive. An important point too, is that most livestock, wild or domesticated, will take leaf-fodder or browse if available rather than grazing (Vera, 2000; Rotherham, 2012a, b).

Modern countryside with woods, parks and forests derive from a suite of medieval landscapes mixing trees and grazing or browsing mammals. As argued above, this medieval countryside included wood-pasture, wooded commons, heaths, moors, fens, bogs, forest, and Forests. These were the modified relicts of what was probably in prehistory a great wooded savannah with extensive wetlands, across much of north-western Europe. Alongside the main historic 'woods', and often embedded within them, were coppices (and for example, in England, holts, hags, heys, and hollins) managed in controlled and specialist ways to produce particular woodland materials (Jones, 2009; Rotherham, 2013). In more intensively managed landscapes, both wood pasture and coppice were characterised by 'working trees' including pollards, shreds, and stubs, and in the protected 'woods', coppice stools. The evidence for this persists today as 'ancient trees' and indicator plants in the landscape (Rotherham, 2011a).

In the 1700s and 1800s, three major drivers affected many of these woodland areas: 1) the imposition of formal estates and grand landscape parks for the aristocracy, reflecting status and offering opportunities for recreation such as hunting; 2) the development of intensive industrialised coppice wood production; and 3) the emergence of industrialised plantation forestry. In regions such as South Yorkshire in England, the changes were associated with the need to fuel the emerging industrial revolution (Perlin, 1999). These wooded landscapes produced massive amounts of wood for charcoal to smelt iron and other metals, and then later were harvested for pit props for coalmines.

The changes as described fragmented the earlier countryside and weakened, changed or removed the social systems and common rights relating to forest and woodland resources. But they also helped generate the wooded landscapes we experience today. However, as new technologies displaced the industrial demands, rural traditions lapsed too; the working forest or wood often abandoned.

Where woodlands and forest continued to be worked, the new scenario was of management intensified through twentieth century agri-forestry (Fowler, 2002; Hayman, 2003; Rotherham, 2011b). This swept across much of Europe as part of a rush to 'improve'. However, by the late twentieth century, in countries such as Great Britain, the economic driver for woods and forests no longer related to the primary production of timber and wood. Tourism and recreation have emerged as the new economic drivers (Rotherham and Jones, 2000), and are broadly welcomed. However, there are serious issues and implications for management and sustainability. At the heart of the problem is a shift in economic focus when benefits from such modern post-industrial landscapes bear little relation to the actual 'management' of wood and forest. The cost of care and management bears no direct relationship to the benefits provided, and in the time of new 'austerity', this does not bode well, though arguments are put forward about intangibles such ecosystem benefits. Many sites are effectively abandoned with management reduced to provision of access and recreational opportunities, (often including drainage and surfacing of footpaths etc), and basic safety work. Traditional and utilitarian management of vegetation largely ceases and there are consequential changes though ecological successions and the development of recombinant species communities.

Today it is often presumed by planners and others that the wooded landscape is a 'natural' backcloth that can be taken for granted and which will take care of itself. Indeed, abandoned, a woodland or forest cover will regenerate; however, this will have different structural and ecological characteristics and qualities from that of the ancient treescapes. To maintain or enhance the benefits and functions of ancient treescapes requires management interventions and we argue that these need to be best informed by knowledge of woodland and forest history.

A wider context

Many fundamental drivers of process in wooded landscapes have gone or changed, with woods and forests now valued for recreation and for tourism, not subsistence and survival. This is part of the process of 'cultural severance' and the breakdown of subsistence utilisation (Rotherham, 2008). Significantly, Rackham (1986) noted that woods were often lost when their economic importance waned but were maintained so long as they were important to local people.

Today's forests and wooded landscapes risk severance from their direct, local economic functions. In place of this, they provide a backdrop to tourism and leisure, to the visitor's gaze and the community's recreation (Crowe, 2001). This has real value (O'Brien and Claridge, 2002) and along with the value of ecosystem functions such as carbon sequestration, provides a real economic reason for forest maintenance. The problem seems to be, that in the past the economic value, management cost, and control of the resource and its management were placed or held, at least by the same community, if not by the same person. This is no longer the case and today's 'value' and 'cost' are generally separated. Furthermore, it was the day-to-day community impacts of management over centuries, that made the forest and woods what they are; they are not merely 'natural'. They are complex palimpsests of culture and nature. It is clear that with the loss of cultural memory and knowledge these landscapes are misunderstood. The woods are seen as ancient, natural and primeval on the one hand, and young and secondary on the other. To let nature take its course as is so often advocated (see Skeggs, 1999 for example) will lead inevitably to major changes and these may not represent sustainability.

Future vision

The issues and challenges discussed here become even more acute in the context of environmental change (particularly climate change and eutrophication). Their importance is also raised in the context of the 'Frans Vera debate' about forest origins and dynamics in Europe (Vera, 2000; Rotherham (ed.), 2012). For sustainability of future treescapes, our vision of wooded landscapes needs to be more dynamic and more fluid, yet at the same time resonating with cultural attachments and local values. This is a serious and complex challenge.

There are real causes to worry about the long-term future of the unique heritage and ecology of ancient treescapes. In some cases these areas represent the accumulated eco-cultural impacts of human activities over several thousand years have generated remarkable and rich palimpsests of landscape heritage and associated biodiversity. Cultural severance, urbanisation, and destruction management are now ever-present threats and it only takes one major adverse event to erase the heritage of centuries. Sadly, the abandonment of non-wooded countryside to trigger succession to secondary scrub and woodland, whilst potentially creating valuable (though often short-lived) habitat, is not a replacement. There are major challenges for future conservation and it is important to understand ecology and history in order to address these most effectively. It is hoped that this collection of essays by leading European authorities will contribute towards such understanding.

References

Agnoletti, M. (ed.), 2006. *The Conservation of Cultural Landscapes.* CAB International, Wallingford, Oxon, UK.

Agnoletti, M. (ed.), 2007. *Guidelines for the Implementation of Social and Cultural Values in Sustainable Forest Management. A Scientific Contribution to the Implementation of MCPFE – Vienna Resolution 3*. IUFRO Occasional Paper No. 19 ISSN 1024-414X

Crowe, L., 2001. *Fresh Air ..... Fitness and Fun*. Yorkshire Sports Board, Sheffield.

De Moor, M., Shaw-Taylor, L. and Warde, P., 2002. *The Management of Common Land in north west Europe, c. 1500-1850*. Brepols Publishers n.v., Turnhout, Belgium.

Fowler, J., 2002. *Landscapes and Lives. The Scottish Forest through the ages*. Canongate Books, Edinburgh.

Hayman, R., 2003. *Trees. Woodlands and Western Civilization*. Hambledon and London, London.

Jones, M., 2009. *Sheffield's Woodland Heritage*. 4th Edition (revised), Wildtrack Publishing, Sheffield.

Kirby, K. and Watkins, C. (eds), 1998. *Ecological History of European Forests*. CABI, Oxon.

Muir, R., 2005. *Ancient Trees Living Landscapes*. Tempus Publishing Ltd, Stroud, Glos.

O'Brien, L. and Claridge, J., 2002. *Trees are Company*. Social Science Research into Woodlands and the Natural Environment. Forestry Commission, Edinburgh.

Parrotta, J.A., & Trosper, R. L. (eds), 2012. *Traditional Forest-Related Knowledge: Sustaining Communities, Ecosystems and Biocultural Diversity*. Springer, New York.

Perlin, J., 1989. *A Forest Journey*. Harvard University Press, Massachusetts.

Peterken, G.F., 1981. *Woodland Conservation and Management.* Chapman and Hall, London.

Peterken, G.F., 1996. *Natural Woodland – ecology and conservation in northern temperate regions*. Cambridge University Press, Cambridge.

Rackham, O., 1980. *Ancient Woodland: its history, vegetation and uses in England.* Edward Arnold, London.

Rackham, O., 1986. *The History of the Countryside*. Dent, London.

Rotherham, I.D., 2007. The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: a UK case-study. *Forest Ecology and Management*, 249: 100-115.

Rotherham, I.D., 2008. *The Importance of Cultural Severance in Landscape Ecology Research*. In: Dupont, A. & Jacobs, H. (eds.) (2008) Landscape Ecology Research Trends. Nova Science Publishers Inc., New York, pp. 71-87.

Rotherham, I.D., 2011a. *A Landscape History Approach to the Assessment of Ancient Woodlands*. In: Wallace, E.B. (ed.) Woodlands: Ecology, Management and Conservation. Nova Science Publishers Inc., USA, pp. 161-184.

Rotherham, I.D., 2011b. Animals, Man & Treescapes – perceptions of the past in the present. In: Rotherham, I.D. & Handley, C. (eds.) (2011) Animals, Man and Treescapes: The interactions between grazing animals, people and wooded landscapes, Wildtrack Publishing, Sheffield, 1-32.

Rotherham, I.D. (ed.), 2012a. *Trees, Man, & Grazing Animals – A European perspective on trees and grazed treescapes*. EARTHSCAN, London.

Rotherham, I.D., 2012b. *Re-interpreting wooded landscapes, shadow woods and the impacts of grazing*. In: Rotherham, I.D. (ed.) (2012a) Trees, Man, & Grazing Animals – A European perspective on trees and grazed treescapes. EARTHSCAN, London (in press).

Rotherham, I.D., 2013. *Ancient Woodland: History, Industry and Crafts*. Shire Publications, Oxford.

Rotherham, I.D., Jones, M., Smith, L. & Handley, C. (eds.), 2008. *The Woodland Heritage Manual: A Guide to Investigating Wooded Landscapes*. Wildtrack Publishing, Sheffield.

Rotherham, I.D. and Jones, M., 2000b. *The Impact of Economic, Social and Political Factors on the Ecology of Small English Woodlands: a Case Study of the Ancient Woods in South Yorkshire, England.* In: Forest History: International Studies in Socio-economic and Forest ecosystem change. Agnoletti, M. & Anderson, S. (eds), CAB International, Wallingford, Oxford, 397-410.

Skeggs, S., 1999. Various Botanical and Social Factors and Their Effects on an Urban Woodland in Reading, Berkshire. *Arboricultural Journal*, 23(3): 209-232.

Vera, F.H.W., 2000. *Grazing Ecology and Forest History*. CABI Publishing, Oxon.

TÜBA

TURKISH ACADEMY OF SCIENCES

IUFRO

IUFRO Headquarters

Marxergasse 2
1030 Vienna, Austria

Tel: + 43-1-877-0151-0
Fax: +43-1-877-0151-50
Email: office@iufro.org

www.iufro.org