

Grazing as a Management Tool in European Forest Ecosystems

Edited by Jonathan Humphrey, Robin Gill
and Jenny Claridge



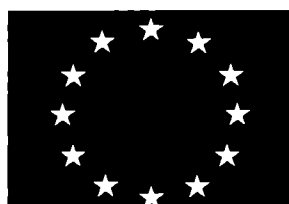
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Grazing as a Management Tool in European Forest Ecosystems

Edited by Jonathan Humphrey^a, Robin Gill^b and Jenny Claridge

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Front cover: Adult fighting bulls grazing on a Spanish dehesa with holm oaks. (*José Manuel Gómez-Gutiérrez*)

Back cover: *top* Red deer in birch woodland. Concern for conservation of semi-natural woodland has grown following recent increases in deer populations. (*Forest Life Picture Library: 1012416.030*). *Inset* Browsing by deer reduces tree seedling survival and stunts growth. (*Robin Gill*)
Bottom Alpine herb-rich meadow created by seasonal livestock grazing. (*Robin Gill*)

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Introduction

Jonathan W. Humphrey and José Manuel Gómez-Gutiérrez

The chapters in this Technical Paper are based on presentations made at a grazing workshop hosted by the University of Salamanca, Spain. The workshop and the editing of these proceedings was funded as part of a European Union AIR Programme Concerted Action: 'Grazing as a management tool in natural and semi-natural woodland ecosystems', co-ordinated by the Forestry Commission Research Agency.

There is a growing concern in many European countries that recent increases in the population densities of large herbivores is having a serious impact on the biodiversity, regenerative capacity and economic value of multi-purpose forests. However, the herbivores themselves are an important economic asset to many rural communities, be it domestic stock production in silvi-pastoral systems, or hunting of deer in high forests. There is a need therefore for a better integration of both ecological and economic objectives in forest ecosystems. The impetus for the concerted action is the belief that large herbivores can be used in management to achieve this integration. Although much is known generally about the impact of herbivores on various wooded ecosystems, there is still a lack of quantitative data on key aspects such as the effects of particular species, grazing regimes and seasonality of grazing in determining floristic and structural dynamics. Such information is needed if grazing impacts are to be properly understood and managed in the longer term. The main aims of the concerted action were to:

- Review information on the impact of grazers, current management problems, and specific research needs within each country.
- Identify common problems and research needs.
- Identify priority areas for future research and generate collaborative links between participating organisations.

The greater part of this Technical paper comprises chapters 1 to 8 which review grazing problems and research needs in the countries participating in the concerted action; chapter 9 then provides an overview of common problems and research priorities.

The workshop at Salamanca in central-west Spain provided a focus on the 'dehesas' ecosystems. These semi-natural silvi-pastoral systems are of great importance to both the economy and indigenous biodiversity of a large part of the mediterranean region. The proper management of herbivore populations is essential for the long-term survival of the dehesas, so the location of the workshop afforded an excellent opportunity to relate the theme and objectives of the concerted action to a real situation. A further workshop held in May 1997 in Edinburgh and hosted by the Forestry Commission Research Agency, focused on identifying appropriate methodologies for research on forest grazing. Proposals for future collaborative research aimed at providing the quantitative information needed by forest managers were developed at this workshop.

Chapter 1

The Fennoscandian perspective: grazing in boreal, hemiboreal and nemoral forest

Richard H. W. Bradshaw and Lars Edenius

Summary

This chapter describes the major forest vegetation types of Fennoscandia and their past and present disturbance and grazing regimes. We discuss the grazing problems associated with each forest type and what actions could be taken to resolve these problems. Fennoscandia is extensively covered with semi-natural forests and plantations. The current grazing regime is totally dominated by wildlife and densities are

very high when viewed from a historical perspective. Particular problems associated with the present high grazing pressure are reduced structural and compositional diversity of forests, and damage to tree crops. We argue that it is necessary to analyse present conditions in the context of the past when characterising current problems and developing appropriate management regimes. We conclude that a deeper understanding of the role of herbivory in different forest systems is a prerequisite for the development of management guidelines.

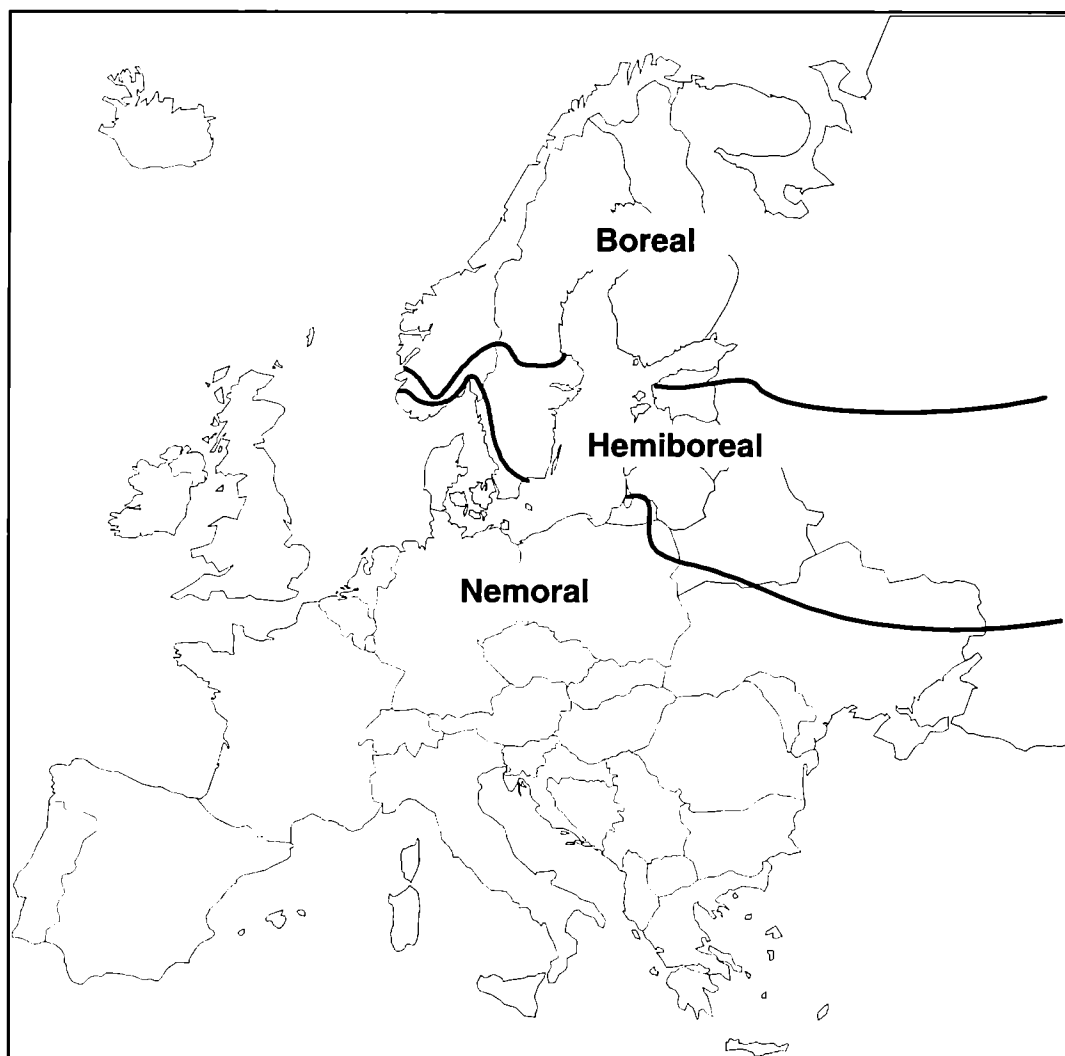


Figure 1.1 The forest zones of north-west Europe as defined by Ahti *et al.* (1968)

Introduction

Fennoscandia (Sweden, Finland, Norway) comprises three major forest types: boreal, hemiboreal and nemoral forest which all cover large areas in European terms (Figure 1.1). Many forests are natural or semi-natural, although most of the forest area is rather intensively managed for timber production. Wild herbivores are the dominant grazers and browsers. In the north, the herding of semi-domesticated reindeer is an important form of resource use. By contrast, woodland pasturage and other anthropogenic grazing systems that were once widespread are now almost completely abandoned.

This chapter gives an overview of the forest types found in Fennoscandia and the grazing regimes associated with each type. It is directed towards means of resolving current grazing problems, and addresses conceptual and scientific problems relating to this issue. We start by describing the vegetation types in each forest type and their respective disturbance and grazing regime. We then identify the grazing

problems and outline the information needs and research strategy necessary to address these problems.

Boreal forest

Natural and semi-natural boreal forest occupies more than 50% of the land area in Fennoscandia. Forests are often interspersed by wetlands, and natural forest-wetland mosaics form an integral part of the landscape. Domestic stock are no longer put out to graze in the forests, but some of the effects on vegetation of former forest-based grazing systems remain locally. Earlier forms of utilisation such as tar and potash production and selective felling have had considerable impact on current forest structure. Scots pine (*Pinus sylvestris*) has been extensively favoured in forest regeneration during the past 50 years at the expense of Norway spruce (*Picea abies*), leading to an increased proportion of pine in the landscape. The proportion of mature, mixed deciduous and coniferous forest has decreased due to intensified forestry. The main ecosystem types are described in Table 1.1.

Table 1.1 Main forest ecosystem types in Fennoscandia, and occurrence in forest zones

Forest type	Boreal	Hemiboreal	Nemoral
Coniferous forest			
Scots pine	✓	✓	
Norway spruce	✓	✓	
Mixed	✓	✓	
Swamp forest	✓	✓	
Plantations		✓	✓
Deciduous forest			
Mixed	✓	✓	✓
Birch	✓		
Spruce-beech		✓	✓
Pine-oak		✓	✓
Beech		✓	✓
Oak, elm, ash, lime		✓	✓
Alder		✓	✓
Abandoned meadows		✓	✓
Parkland with giant trees			✓

The vegetation of boreal forests is generally species-poor. Mid and northern subzones are characterised by a poorly developed shrub layer, except for dwarf shrubs, e.g. *Vaccinium myrtillus*. Fire, which was the dominant large-scale disturbance factor, has now been almost completely replaced in this respect by clearfelling. Small-scale gap dynamics is the main natural disturbance regime at sites protected from fire.

Strongly fluctuating microtine rodent populations and adverse climate affect tree establishment and population dynamics of established tree species in boreal forest. Trampling and grazing by semi-domesticated reindeer affect conditions for plant establishment and survival at the seedling stage. Moose and roe deer browse on established trees, particularly at the sapling stage (Table 1.2).

Hemiboreal forest

Semi-natural forest occupies more than 50% of the land area. Abandonment during the last 50–100 years of former management systems involving domestic grazing and pasturage has had considerable impact on current floristic composition and structure. Successional processes have resulted in a denser forest structure than before with few open areas remaining, and an increased proportion of certain late-successional forest trees on the landscape. Spruce and beech have increased in abundance, while species such as oak and hazel have experienced rapid and catastrophic population reductions. The altered grazing regime is one of a group of interconnected factors that have resulted in such changes (Nilsson, 1992; Bradshaw *et al.*, 1994; Table 1.2).

Hemiboreal forests are floristically richer and structurally more complex than boreal forests. They often have a well-developed shrub layer and ecotones between ecosystems. The complex mosaic of communities on the landscape is greatly influenced by former management history. Several forest types can be recognised (Table 1.1).

Fire was originally the single most important large-scale disturbance factor in these forests, where climatic conditions were suitable. Fire was less frequent in western Sweden than in the east. Even areas with a high proportion of deciduous trees burnt rather frequently. In the eastern part of the region (Figure 1.1) slash-and-burn agriculture has modified the natural disturbance regime during the last few hundred years. As with boreal forests, fire and slash-and-burn agriculture has recently been replaced by clearfelling. Windblow during windstorms has been of recent importance, particularly in western regions, and small-scale gap dynamics is important in deciduous forests. Moose and roe deer are dominant browsers on established trees. Selective grazing by roe deer affects ground-floor vegetation and tree seedling establishment (Table 1.2).

Nemoral forest

Semi-natural forest, plantation forest and open woodland systems occupy more than 50% of the land area. Domestic grazing and pasturage in the past, together with other forms of cultural and agricultural impact, have exerted a major control on floristic composition and structure of the forests. There is a patchy forest cover in the landscape, often with sharp land-management boundaries. The forest often has an open structure, except where grazing pressure has recently been reduced, and the ground flora can be extremely diverse. A range of forest types can be distinguished (Table 1.1).

Disturbance has largely been under human control for several centuries. Formerly controlled grazing regimes of domestic animals have now been replaced by unusually high pressures from roe deer and even moose in northern areas (Table 1.2). Fires are now a rare occurrence but wind-storms can be important particularly in western areas. Most older forest is managed for timber production, while unmanaged secondary successions show least signs of human impact. Gap dynamics are the most important disturbance regime in mature forest.

Table 1.2 Summary of grazing regimes, vegetation structure and commodity outputs for Fennoscandian forests

	Past	Present	Future
Boreal forest			
Grazing regimes	Moderate grazing pressure by domestic livestock, low browsing pressure by wildlife	Moderate – high browsing pressure by wildlife and semi-domesticated reindeer	Moderate browsing pressure
Vegetation composition and structure	High structural complexity, spatial heterogeneity of forest	Reduced structural diversity, shortage of large deciduous trees	Increased floristic and structural diversity
Outputs	Timber, potash/ tar, fuelwood, meat	Timber, meat, sport	Timber, meat, sport
Hemiboreal forest			
Grazing regimes	High grazing pressure by livestock, low - moderate pressure(?) by wildlife	Low grazing pressure by livestock, high pressure by wildlife	Low-moderate browsing pressure
Vegetation composition and structure	High floristic diversity, multi-layered forest canopy	High proportion of even-aged conifer plantations, reduced structural complexity of old forest	Larger proportion of deciduous trees in forest regeneration, high structural complexity
Outputs	Timber, tar, hay, fuelwood, meat	Timber, meat, sport	Timber, meat
Nemoral forest			
Grazing regimes	High grazing pressure by livestock, moderate browsing pressure (?) by wildlife	Low grazing pressure by livestock, high browsing pressure by wildlife	Low-moderate browsing pressure
Vegetation composition and structure	High floristic diversity, multi-layered forest canopy	High proportion of even-aged conifer plantations, reduced structural complexity of old forest	Larger proportion of deciduous trees in forest regeneration, increased structural diversity
Outputs	Timber, tar, hay, fuelwood, meat	Timber, meat, sport	Timber, meat, wildlife, recreation, sport

Identification of grazing problems and information needs

There are two major conceptual problems and a number of associated practical problems and constraints facing management of grazing regimes in Fennoscandian forests. Research will be useful in clarifying the scientific issues facing decision-makers and in proposing practical means to achieve any agreed goals. The conceptual problems are:

1. How to understand the legacy of the past.
2. The choice of future direction.

The legacy of the past

Present forest composition, structure and grazing regimes are a result of interactions

between past management (e.g. forest grazing by domestic stock) and natural processes such as climatic change. The variety and numbers of grazing animals in the past appear to have been one of the major factors in determining present conditions in southern Sweden (Bradshaw *et al.*, 1994). Currently available data suggest that changes in grazing regime within the last century have been particularly dramatic seen in the context of longer time periods (Figures 1.2 and 1.3). Some of these changes are a consequence of altered management patterns (e.g. reduction in numbers of domestic stock grazed in forested areas), while other changes arise indirectly through past alterations in land-use (e.g. increasing moose numbers associated with industrial forestry). An increased knowledge of former types and numbers of grazing animals will help place the present situation in the context of the past.

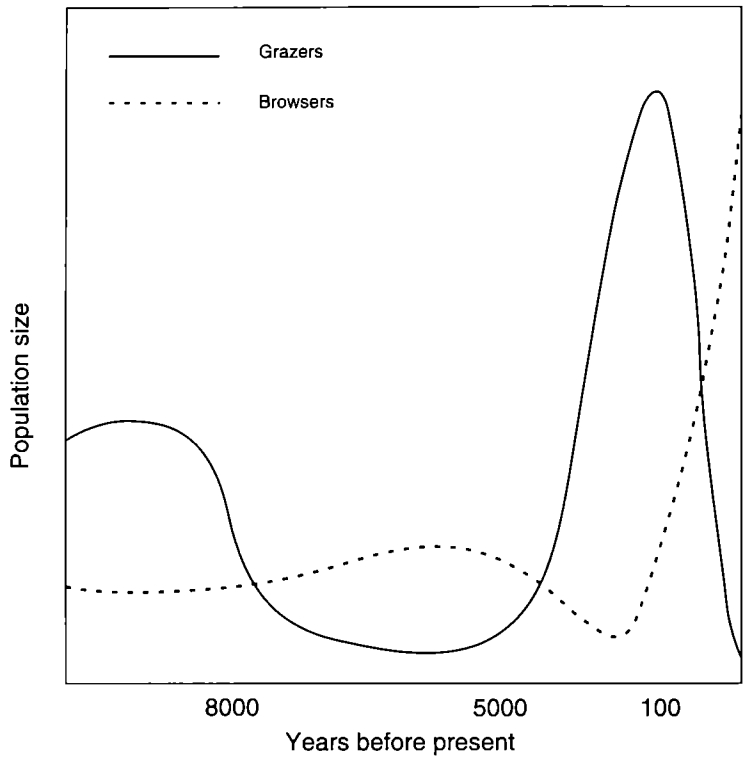


Figure 1.2 Conceptual model showing the probable relative changes in population size of large, grazing ungulates (e.g. aurochs, bison, domestic cow) and browsing ungulates (e.g. moose, roe deer) during the Holocene in southern and central Sweden. The time-scale is non-linear. Data taken from many sources

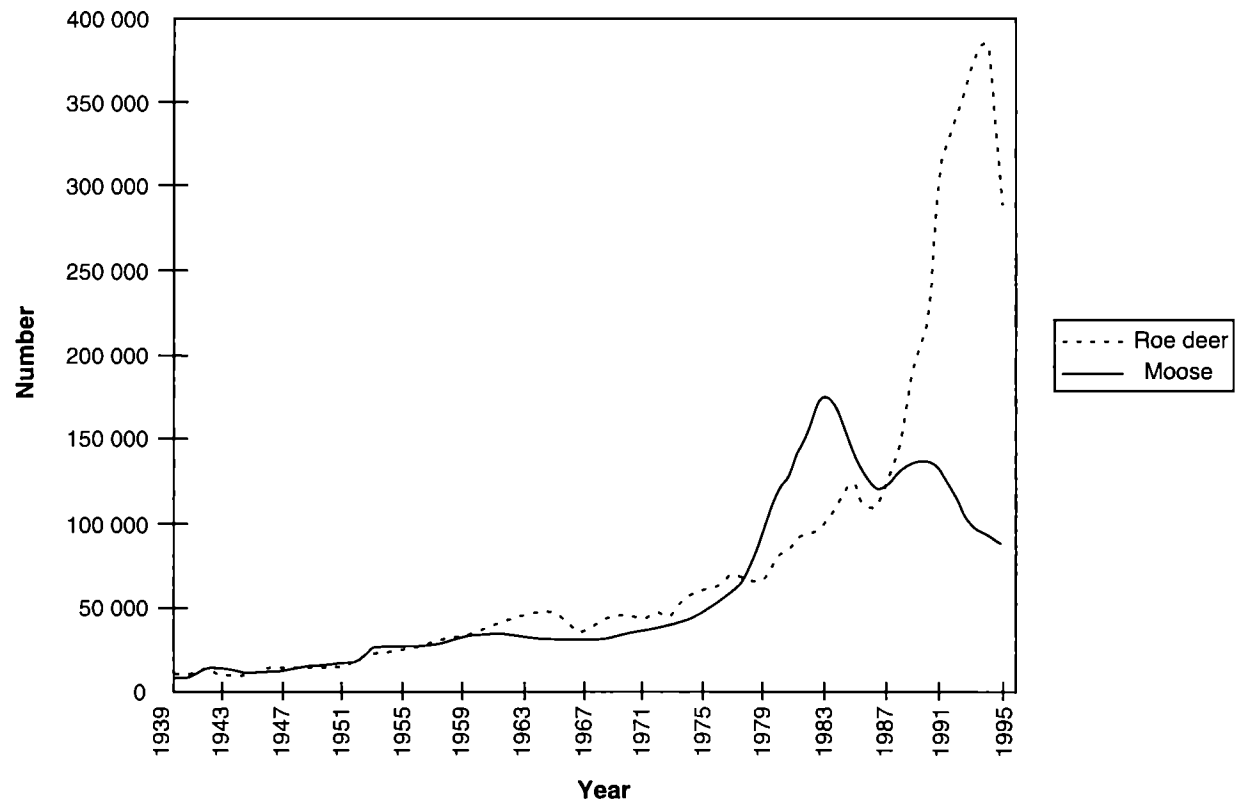


Figure 1.3 Numbers of moose and roe deer shot in Sweden 1939-1991. Source: Swedish Hunters' Association

Specific grazing problems that exist today (Table 1.3) which are direct or indirect consequences of former management decisions include:

- Decline in forest grazing by domestic animals during the last 100 years has led to a decrease in open areas in the landscape, and denser forest structure. Regeneration of certain deciduous trees has declined. Many light-demanding forest species are under increasing threat.
- Virtual disappearance of rooting animals from the forest (initially wild boar, subsequently domestic pigs) has altered the disturbance regime of the forest floor. This has had consequences for tree regeneration and soil processes such as accumulation of acid humus layers.
- Browsing pressure from super-abundant populations of wildlife ruminants (moose and roe deer; Figure 1.3) has shifted competitive advantage in favour of unpalatable tree and shrub species. Spruce has increased in abundance at the expense of more palatable deciduous tree species.

- Large populations of semi-domesticated reindeer have had a severe impact on lichen floras.
- High incidence of browsing damage to trees in forest plantations.
- Changed floristic composition, vegetation structure and successional pathways in the forest due to selective grazing/browsing by wildlife species.
- Negative impact on biodiversity in terms of reduced recruitment of deciduous tree species to old growth stages.

For the first two problems mentioned above, the recent collapse of traditional systems of agriculture has had consequences in the forest. One might imagine that the forest is returning to a pre-agricultural natural state, but this is not the case. Palaeoecological research suggests that domesticated animals replaced to some extent their natural precursors (pig and wild boar, cattle and aurochs; Figure 1.4). Loss of both the natural and domestic grazers is creating forests with no previous analogues. The developing forest is rather a new cultural product that is largely a consequence of recent techniques of industrial forestry.

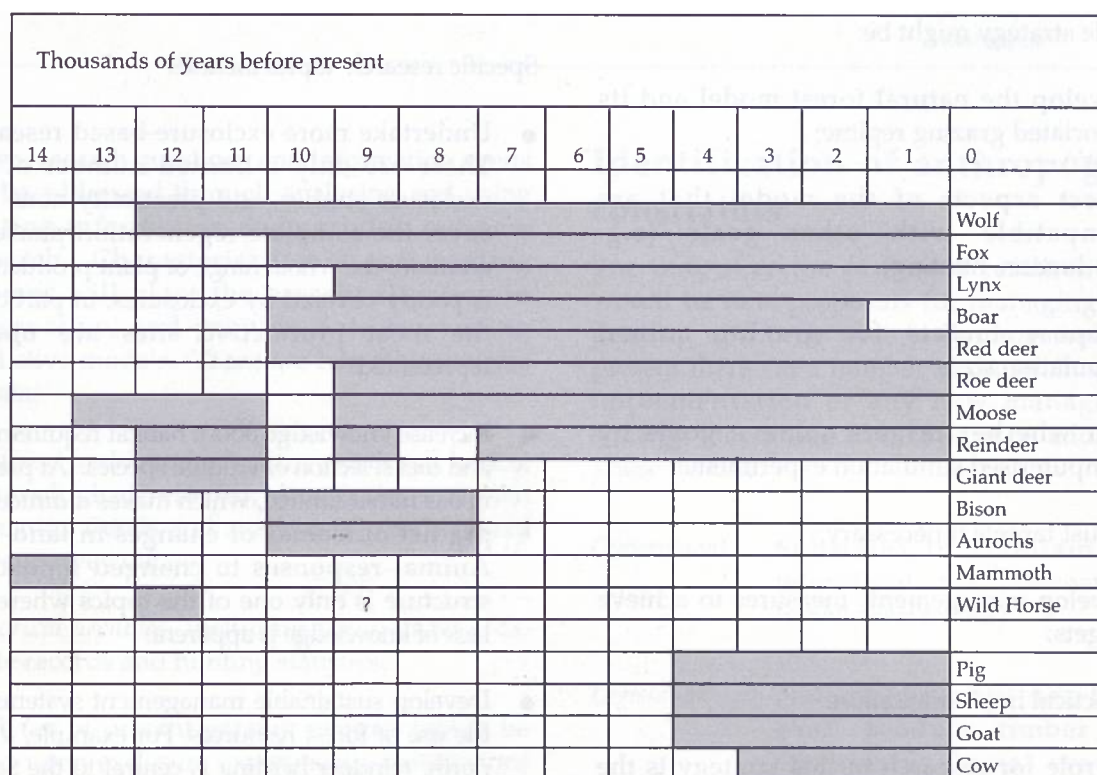


Figure 1.4 Summary of occurrence of certain mammals in Sweden during the last 14 000 years (after Liljegren and Lagerås, 1993)

Mention should also be made of some of the positive consequences of recent changes in forest management. These include enhanced opportunities for wildlife recreation and hunting, and enhanced conditions for species benefiting from herbivory.

The choice of future direction

Planning for the future has to begin from current conditions that are themselves a consequence of the past. This is particularly true in slowly responding systems such as the forest-grazing animal complex. The chief constraint on future directions is the wishes of society, and the main pressure groups in Sweden are the forest industry, the environmental movement and the hunting lobby. These three interest groups have partially contradictory aims, and there is much debate aimed at reconciling these aims. Recent forest legislation giving equal weight to production and environmental considerations in the forest coupled to green market pressures has led to the implementation of more nature-based forest planning. In the cultural landscape of central and southern Sweden this movement has created the need for a model of natural forest, and the natural grazing regime is an integral part of this model (Bradshaw, 1996).

A viable strategy might be:

1. develop the natural forest model and its associated grazing regime;
2. select aspects of the model that are compatible with other goals (e.g. production, hunting);
3. propose targets for grazing animal population sizes;
4. test whether targets achieve goals by computerised simulation experiments;
5. adjust targets if necessary;
6. develop management measures to achieve targets;
7. practical implementation.

A key role for research in this strategy is the development of the natural forest grazing model, and the simulation model for assessing effects of future management decisions.

Research questions and information needs

Research questions that include the longer-term perspective (see Table 1.3) are:

- What were grazing regimes prior to widespread, intensive human activities, e.g. Eemian times (100 000 years ago), and early-mid Holocene (10 000–5000 years ago)? Are there some baseline conditions for NW Europe (Davis, 1989)?
- How have baseline conditions been affected by human activities, particularly during the last 300 years?
- What trends are detectable in current grazing regimes, both directions and rates of change?
- What are the major long-term controlling factors of grazing regimes: climatic change, human activities, vegetational change?
- What are the impacts of these trends on forest ecosystems?

Increasing our data on herbivore densities in the past (both wildlife and domestic stock), will help forecast vegetational changes and model plant–animal interactions (Table 1.3).

Specific research topics include:

- Undertake more enclosure-based research. There are only a limited number of old enclosure studies, and practically none that cover the complete regeneration phase. In addition, the whole range of plant productivity is poorly covered by enclosures, in particular the most productive sites are under-represented.
- Increase knowledge about habitat requirements and diet selection of wildlife species. At present this is rather limited, which makes it difficult to predict outcomes of changes in land-use. Animal responses to changed landscape structure is only one of the topics where the lack of knowledge is apparent.
- Develop sustainable management systems for the use of forest resources. For example, in the north, reindeer herding is central to the Saami culture, but grazing conditions are affected by forestry and there is a need to reconcile these different land-use objectives.

Table 1.3 Summary table of grazing problems and information needs

	Problem	Important interactions to consider	Information available	Information needed
Boreal forest	High incidence of damage in forest plantations; reduced recruitment of deciduous trees to old growth stages	Effects of selective grazing on plant community dynamics; effects of forest management on animal behaviour (habitat and food plant selection); long-term effects of herbivory on successional pathways and soil productivity	National Forest Survey data 1920-present day; limited amount of experimental data on effects of grazing; some enclosure data a few experimental clipping studies; good hunting statistics for moose and roe deer	Species-specific responses to grazing; relations between damage, intensity of herbivory and herbivore density; long-term effects of grazing on biodiversity (plants and animals); effects of grazing in the past
Hemiboreal forest	High incidence of damage in forest plantations; reduced recruitment of deciduous trees to old growth stages; changed floristic composition and structure of shrub and forest floor vegetation; super-abundant populations of roe deer	As for boreal forest but additionally need to explore the role of grazers in the recent, dramatic shift from deciduous to conifer dominance	As for boreal forest, but additionally unique archived material on numbers of domestic grazing animals from 1500s onwards	As for boreal forest, but greater need for establishment of baseline conditions. How open were former forests?
Nemoral forest	High incidence of damage in forest plantations; changed floristic composition and structure of shrub and forest floor vegetation; super-abundant populations of roe deer	As for boreal forest, but additionally need to consider role of grazers in recent loss of tree species diversity and rise of pure stands, e.g. beech	As for boreal forest, but additionally excellent historical archives and an adequate fossil record of bones	As for boreal forest, but greatest need for clarification of goals for grazing management. What is natural? Is it worth moving the grazing regime towards this natural concept in extremely modified forest types?

These research questions and information needs can be addressed through analysing and using existing information and carrying out new research. Characterisation of past grazing regimes will place the present situation in perspective, and provide data for testing predictive models. There are two main sources of data:

Biological archives, including sub-fossil bones, archaeological remains, descriptions of past vegetation trends and analyses of past National Forest Survey data.

Historical archives, including taxation records, estate records and hunting statistics.

Analyses of present grazing regimes would be based upon enclosure experiments, observations and experimental manipulations, while prediction of future regimes would rely on the development of appropriate models.

Identification of anthropogenic constraints

The output of the proposed research effort would be new proposals for managing forest grazing and browsing in Fennoscandia. At present there are a number of constraints to the implementation of any new management strategy that would also have to be addressed. These include:

Government Subsidies to maintain open woodland for conservation (small areal extent).

Legislation National Forestry Act; forests shall produce timber on a sustainable basis, economic commodities and preservation of biological diversity shall have equal value.

<i>Hunting lobby</i>	Managing wildlife to maximise meat production; recognition of recreational and cultural aspects of hunting; recognition of wildlife harvesting as an integral part of forest resource use.
<i>Timber lobby</i>	Limits to herbivore population numbers to reduce forest damage.
<i>Land ownership</i>	Difficulties in co-ordinating measures in areas with many landowners and small land holdings.
<i>Tradition</i>	Requirements of good grazing grounds for reindeer herding.
<i>Conservation</i>	Desire to maintain old farming systems including woodland pastures for species conservation; negative impact of intense grazing pressure on recruitment of structures/ elements required for maintenance of late-successional specialist species.

Concluding remarks

Grazing regimes in Fennoscandian forests have been dynamic through time, and at present are in an unstable, unsustainable situation that demands new management initiatives to safeguard forest resources for the future. Both forest production and biodiversity are threatened by the unnaturally large ungulate populations of today. A research effort with due regard given to socio-economic and political

constraints could provide the basis for the development of management guidelines which would achieve sustainable yields of the desired outputs from the forest systems. Given the related grazing problems in most EU countries, and the dispersed nature of the research expertise, this area seems highly appropriate for a joint EU research effort.

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Chapter 2

Ungulates and forest management in the Netherlands

Loek Kuiters

Summary

The history of Dutch forests, their management and current grazing practices and problems, for both domestic and wild ungulates, are reviewed. Recent research on grazing by wild ungulates is detailed and future research priorities highlighted. Over-exploitation of forest since the Middle Ages by a combination of grazing, large-scale removal of litter and wood, and fire, has reduced current forest cover in the Netherlands to 9% of total land area. Over 70% of forest area is classed as multi-purpose plantations, comprised predominantly of Scots pine and oak. The remaining forest area is classed as semi-natural forest, and 'virtually natural' forest landscapes where nature conservation is prioritised over timber production. In multi-purpose forest, forest management policies favour the conversion of homogeneous single-species stands to those of heterogeneous composition and structure. Small gaps are created which attract high ungulate densities, and grazing hampers regeneration of native broadleaved species. Foresters need information on the maximum tolerable ungulate densities to allow suitable regeneration of timber-producing species. In semi-natural forests, cattle grazing has been applied as a management tool to prevent vegetation succession and to develop transition zones of high biodiversity between closed forest and open habitats. However, the precise grazing pressure needed to maintain this process is not known, and research is urgently needed. In virtually natural forest landscapes, grazing is considered a key process in ecosystem functioning, but little is known about the interaction between ungulate population dynamics and forest vegetation dynamics, and whether such systems can survive without management input. To quantify these interactions, a forest-ungulate simulation model has been developed (FORGRA) to describe long-term forest development within a forest-heathland landscape on sandy soils.

Interim management prescriptions for grazing regimes have been produced, but these need to be refined by the further development of FORGRA to incorporate soil processes and ungulate population dynamics. FORGRA also has to be parameterised for other forest types. The impacts of different grazing regimes on biodiversity also need to be quantified for a range of forest types.

Introduction: main forest ecosystem types

In the Netherlands, total forest area amounts to 334 000 ha, which is c. 9% of total land cover. By 1800, the forest area was at a minimum of only 150 000 ha (4%). Over-exploitation of forests since the Middle Ages by grazing of domestic animals, large-scale removal of forest litter, collection of wood and fire had resulted in the disappearance of most forests. Large-scale re-forestation on drift sands and heathlands, in particular during the second part of the 19th and the early 20th century, has increased total forest area since then. Consequently, present-day forests are predominantly man-made, rather homogeneous, and less than 1% is older than 150 years. About 7% of existing forests have developed spontaneously. Pristine forest is totally absent since the last old-growth forest, 'het Beekbergerwoud' (150 ha), was cut in 1870. In the next two decades forest area will be enlarged by 75 000 ha as a result of land-use changes.

Most forests are found on poor sandy substrates, with Scots pine (*Pinus sylvestris* L.) as the most common tree species (Table 2.1). Indigenous deciduous forest with European beech (*Fagus sylvatica* L.), sessile oak (*Quercus petraea* (Mattchuska) Lieblein.), pedunculate oak (*Q. robur* L.) or birch (*Betula* spp.) as the dominant canopy species forms only 30% of total forest cover. For timber production, non-indigenous species like Douglas fir (*Pseudotsuga*

menziesii (Mirb.) Franco), larch (*Larix* spp.), Norway spruce (*Picea abies* (L.) Karst.) and American oak (*Quercus rubra* L.) are widely used.

On rich soil substrates along Dutch rivers, typical riverine floodplain forest occurs only on a very small scale. This forest type, with elm (*Ulmus glabra* L.), poplar (*Populus canescens* L.), black poplar (*P. nigra*), black alder (*Alnus glutinosa* L.) and ash (*Fraxinus excelsior* L.) as characteristic species, has disappeared over the centuries due to clearfelling for agricultural purposes. At present, less than 500 ha of typical riverine forest remains. As a consequence of changes in land-use, this forest type has re-established at certain locations under the grazing influence of cattle and horses. Ecosystem restoration is promoted here on abandoned agricultural land. Nature conservation policy aims to promote an expansion of riverine floodplain forest beyond 3000 ha within the next decade.

Table 2.1 The most common tree species in Dutch forests (Probos, 1995)

Tree species	Percentage of total forest area
Coniferous species	
Scots pine (<i>Pinus sylvestris</i>)	39%
Larch (<i>Larix</i> spp.)	6%
Douglas fir (<i>Pseudotsuga menziesii</i>)	5%
Norway spruce (<i>Picea abies</i>)	4%
Deciduous species	
Oak (<i>Quercus</i> spp.)	16%
Birch (<i>Betula</i> spp.)	6%
Poplar (<i>Populus</i> spp.)	5%
Beech (<i>Fagus sylvatica</i>)	3%
Other species	16%

On the Pleistocene sandy soils, three natural forest ecosystem types are distinguished (Table 2.2).

Scots pine forest

Although Scots pine is the most common tree species in Dutch forests, typical Scots pine forest with a species-rich lichenous and mossy ground vegetation is rather scarce. Over the years, top soils have become enriched with nitrogen and sulphate through atmospheric deposition. Grass species like wavy hair grass (*Deschampsia flexuosa* (L.) Trin.) and purple moor-grass (*Molinia caerulea* (L.) Moench) have become the dominant species in the herb layer of this forest type.

Birch–oak forest

Birch–oak forest, with silver birch (*Betula pendula* L.) and pedunculate oak the most common species, is the characteristic forest type on dry, acid sandy soils. Most of the original forests have disappeared due to cutting, overgrazing and degradation to heathland and drift sand in the past, or by re-forestation with Scots pine. The remaining birch–oak forests have in the past often been exploited as coppice. Currently, this forest type occurs as plantations over large areas, often with a low structural diversity (Table 2.2). The understorey vegetation is dominated by wavy hair grass on dry sites and by purple moor-grass on moist sites. Spontaneous regeneration in these forests, especially of pedunculate oak, is vulnerable to grazing by ungulates. Consequently, open sites created by windthrow or clearfelling may develop with heather dominated vegetation persisting over a long period when grazing pressure is too high for oak regeneration. With mature trees of Scots pine close by, a development to Scots pine dominated forest is most likely.

Oak–beech forest

Oak–beech forest, with pedunculate oak, sessile oak and beech as dominant species in the forest canopy, occurs on loamy sandy soils and as planted forest on former agricultural land. Due to overgrazing, degradation to heathland and soil reclamation, pristine oak–beech forest has completely disappeared. Of the newly planted stands, a small part is grown on old-forest sites. Most planted oak–beech forests have low structural diversity, being composed of only a single age class. Understorey vegetation is often totally absent. In situations where sufficient light reaches the forest floor, the ground flora is dominated by bilberry (*Vaccinium myrtillus* L.) crowberry (*V. vitis-idaea* L.), bracken (*Pteridium aquilinum* (L.) Kuhn) or ivy (*Hedera helix* L.). At many locations, the forests on sandy soils occur mixed with heathland. Open, dry heathland with heather (*Calluna vulgaris* L., *Erica tetralix* L.), covered hundreds of thousands of hectares in the past, but only a few thousand hectares remain. These are maintained by an active management of sod-cutting, mowing, burning, and grazing with sheep, cattle or horses. Due to atmospheric deposition, soils have become enriched with nutrients, which has resulted in the spread of wavy hair grass and purple moor-grass. Without active management measures, heathland develops very rapidly by succession into Scots pine forest, particularly if seed trees are present nearby. Grazing by ungulates can only retard this process.

Table 2.2 Potential natural forest types on dry sandy soils in the Netherlands

Natural forest type	Main tree species	Percentage of total
Scots pine forest	Scots pine	5%
Birch-oak forest	Birch Pedunculate oak Scots pine	30%
Oak-beech forest	Beech Pedunculate oak Sessile oak	65%

Main grazing regimes

In most forests on sandy soils, ungulate densities (i.e. red deer *Cervus elaphus* L., wild boar *Sus scrofa* L.) have been kept artificially high during recent decades for hunting purposes. Up to 1985, densities of 5 red deer and 10 wild boar per km² were usual. In certain areas, additional species such as fallow deer (*Dama dama* L.) and moufflon (*Ovis musimon* L.) were introduced. Supplementary feeding and the presence of wildlife meadows in the forest supported these high densities. Consequently, many forests suffer from a lack of spontaneous regeneration of shrubs and trees.

Since 1985, forest management policy in the Netherlands, as in many other countries, has changed. Natural processes are given greater priority. Forests are cleared or thinned on a smaller scale, to avoid the forest microclimate conditions being strongly affected. Tree planting is no longer subsidised by the government and mixed forests are promoted. Spontaneous regeneration is therefore considered as a key process, which must guarantee a sustainable timber output. At many locations, indigenous deciduous species are promoted by natural regeneration and older trees are saved from being cut. These changes in forest management policy have consequences also for the management of ungulate populations (Kuiters *et al.*, 1996). At an increasing number of locations ungulates are no longer given supplementary feed over winter, and densities are more in accordance with local food supply levels. However, the food supply in forests on sandy soils has increased over recent decades, partly as a result of forest ageing and vegetation succession, increasing the carrying capacity for ungulates (Groot Bruinderink and Hazebroek, 1995a).

With respect to forest grazing regimes in Dutch forests, distinct forest categories can be distinguished related to the different management strategies applied (Table 2.3). In the **virtually natural forest landscapes** (management units of greater than 500 ha), nature conservation is the primary function. Self-sustenance of nature is maximised and human interference minimised. 'Naturalness' is the main objective. Active management is only carried out as transitional management to reach a situation with no interference, or to imitate or stimulate certain natural processes. Ungulate grazing is considered as one of the main components of the disturbance regime (with windthrow and fire) and assumed to play a key role in ecosystem functioning. In this respect, the introduction of semi-wild populations of cattle or horses qualifies as a way of achieving ecosystem restoration. The grazer species are assumed to play an important role in the development and maintenance of a semi-open forested landscape, with heathland and abandoned grassland.

In **semi-natural forest areas** (management unit 100–500 ha) nature conservation is generally the primary function. Active management measures are applied on a permanent basis, which is often related to certain land-use practices in the past such as coppice. Grazing by domestic ungulate species is applied as a management tool to prevent vegetation succession and to maintain and further develop species-rich transition zones between closed forest and open grass or heathland vegetation. Ungulate populations (cattle, horses, sheep, goats) are managed, and grazing is often not year-round, but seasonally applied. Park forests (which cover a total area of about 3500 ha) are an example of this. In coppiced forests (total area about 3000 ha) grazing is often applied as a management tool to maintain the species-rich ground flora.

Table 2.3 Main categories of forest areas as distinguished in the Dutch Nature Policy Plan (1990) based on different management strategies

Category	Forest type	Management unit (ha)	Ungulates	Percentage of total forest
Virtually natural forest landscape	Large-scale forest reserve	>500	Wild and semi-wild ungulates as integral part of ecosystem	1-2%
Semi-natural forest	Shrubbed and wooded heathland; park forest; coppice	100-500	Domestic grazers as management tool; wild ungulates	20-25%
Multi-purpose forest	Plantations with timber production	10-100	Wild ungulates; cattle grazing to reduce dense grass-mats	70%

In **multi-purpose forests** (management unit 10–100 ha) timber production is one of the main functions alongside nature conservation and other functions. Ungulates are mostly present only as wild species (roe deer, red deer, wild boar). Sometimes cattle grazing is used as a temporary management tool to reduce the dense grass-layer (i.e. wavy hair grass), which often forms dense root-mats in forests on poor sandy soils, and impedes spontaneous forest regeneration. Grazing is thus used as a 'curative' management tool against nutrient enrichment by atmospheric deposition. Wild ungulates in these forests are sometimes considered as a 'pest' causing damage to tree growth, and impeding spontaneous forest regeneration.

Identification of grazing problems in each forest ecosystem

Table 2.4 summarises the particular grazing problems for each forest category.

Conversion management for nature conservation purposes

At many locations, forests are no longer managed only for timber production. Nature conservation is an additional and sometimes even a primary function. Within the next two decades, about 20% of Dutch forests will be managed mainly for nature conservation purposes. Many forests are being changed from homogeneous, single-species stands into forests with a heterogeneous species and age composition. Forest managers have to deal with the problem of ungulate grazing, which hampers spontaneous regeneration of indigenous tree species like pedunculate oak, sessile oak and beech. For instance, in

oak–beech forest stands, forest managers try to accelerate a development towards a more varied age-composition by creating small gaps to improve the light conditions for spontaneous regeneration. However, these gaps are highly attractive to ungulates as they offer a good food supply which is often better than in the adjacent 'bare' forest. A grassy vegetation is promoted by grazing, thereby impeding forest regeneration. Since coniferous species are generally less preferred by ungulates, regeneration often consists mainly of species such as Scots pine and Norway spruce instead of indigenous, deciduous species like oak or beech.

Ungulates and forest dynamics in virtually natural forest landscapes

In large-scale forest landscapes, grazing by ungulates is considered as a key-process in ecosystem functioning. The question arises as to what extent natural food supply regulates ungulate population size and when additional regulation measures should be carried out. Also not much is known about the consequences for long-term forest regeneration of fluctuating herbivore densities compared to constant population levels. Information is needed on the relationship between forest dynamics and herbivore population dynamics.

Ungulate grazing and the diversity of floral and faunal species

In semi-natural forest areas, grazing is often applied as a management tool. For instance, in park forests the semi-open forest vegetation, related to certain land-use practices in the past, is actively maintained by grazers such as cattle

Table 2.4 Problems related to ungulate management and grazing in the different forest categories

Category	Problems related to ungulates
1. Natural forest landscape	<ul style="list-style-type: none">- impact of ungulate grazing on long-term forest/landscape development- population dynamics of ungulates in relation to forest dynamics- regulation of densities by human interference
2. Semi-natural forest	<ul style="list-style-type: none">- usefulness of ungulate species with respect to management goals- desirable ungulate densities- effects on vulnerable floral and faunal species- optimal grazing pressure in relation to biodiversity
3. Multi-purpose forest	<ul style="list-style-type: none">- maximum tolerable densities of wild ungulates, especially roe and red deer, allowing sustained natural forest regeneration and a stable species composition

and ponies. The relatively high grazing pressure that is often needed to attain management goals may have an impact on vulnerable plants and animals (e.g. reptiles, insects). Additionally, grazing is assumed to influence the diversity of species in an area by affecting habitat quality, in particular vegetation structure and spatial mosaic patterns. However, the grazing pressure needed to maintain biodiversity is still not known and research is urgently needed.

Stable forest composition for timber production

In multi-purpose forest, where timber production is one of the main objectives of forest management, natural regeneration plays an important role in sustainable timber production. Therefore, grazing pressure and related ungulate densities must be low enough to allow tree species to regenerate. Roe deer, red deer and wild boar are often seen as causing damage to forest regeneration. Forest managers need information on the maximum tolerable ungulate densities that allow natural regeneration of suitable timber producing species to occur at a sufficiently high rate. Therefore, research is needed into the way ungulate species like roe deer, red deer and wild boar interfere with forest stand composition in the long term.

What information do we have?

Forest grazing research

The Dutch Research Programme on Forest Grazing (1990-1996) has generated useful information concerning the problems raised in Table 2.4. The main aim of the Research

Programme was to investigate the role of ungulates, either wild or domestic species, in the maintenance and development of a semi-open forest-heathland landscape on dry sandy soils. Much emphasis was put on a quantitative description of the processes that play a decisive role in forest development in relation to ungulates. The programme was carried out as a joint research project of the Institute for Forestry and Nature Research (IBN-DLO), the Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO) and the Wageningen Agricultural University, Department of Terrestrial Ecology and Nature Conservation (WAU-TON). The following eight topics were explored in detail.

Diet choice of ungulates: a modelling approach

A model describing diet choice of different ungulate species in relation to natural food supply was developed. It was based on the hypothesis that ungulates maximise their energy intake rate (Van Wieren, 1996). The quality of main food items was assessed in indoor experiments, carried out with animals fed food items of different digestibility. The model is further based on detailed observations on the foraging behaviour of red deer, roe deer, Highland cattle and ponies in enclosures of 30 ha in Scots pine forests, where the seasonal variation in food supply was quantified.

Modelling the herbaceous layer

Forage supply in forest and heathland vegetations on poor sandy soils was also modelled. The model takes into account that during forest succession, the growth conditions for herbaceous understorey species are changing, thereby altering the

availability of food on the forest floor. The food supply model describes food supply of the herbaceous vegetation in relation to soil type, forest type and forest succession.

Forest–ungulate interactions: the FORGRA model

To describe the interactions between ungulate grazing and forest vegetation, an overall forest development model (a gap-model) was developed describing long-term forest development in the presence of ungulates. The growth and mortality of trees and natural regeneration were quantified based on physiological processes. Two modules, the food supply model and the diet choice model, are linked with the forest development model. Thus forest development under a certain grazing regime can be described with time-steps of one month, starting from a certain development stage, with a time-horizon of 50–100 years (Jorritsma *et al.*, 1993).

FORGRA is used for research purposes to assess the critical parameters in forest–ungulate interactions and as a decision-support system for the management of ungulates and forests. When applied to natural forest landscapes, model-outputs may help forest managers to take decisions with respect to the management of ungulate populations. For semi-natural forests, FORGRA is a useful management tool for the assessment of ungulate species and densities that are needed to attain certain management goals. If, for instance, one of the objectives is to maintain a specified balance ratio between open area and closed forest, guidelines can be provided for ungulate densities based on model outputs. In multi-purpose forests the Forest Grazing model can be used to assess the maximum tolerable densities for roe and/or red deer populations, to allow forest regeneration to occur at a sufficiently high rate to guarantee sustainable timber production and a stable forest composition.

Sustainable ungulate populations in poor habitats

Forest-heathland landscapes on poor soil substrates offer a sub-optimal habitat for ungulates. In situations where red deer, roe deer and wild boar were fully dependent on natural food supply, the physical condition and reproduction of individuals was monitored over a period of 7 years (Groot Bruinderink *et al.*, 1994, 1995b). Although the mineral status of

animal tissues (organs, bones, antlers) showed a negative trend when supplementary feeding was stopped, there were no indications then that certain essential minerals became deficient. Neither physical condition nor reproduction were negatively affected. Sodium, calcium and phosphorus appeared to be the critical elements. Reproduction of wild boar was found to depend strongly on the availability of mast in autumn and winter, unless wildlife meadows with 'high-quality grass' were present (Groot Bruinderink and Hazebroek, 1995b).

Fencing

As part of the Grazing Research Programme, 25 exclosures (40 m x 40 m) with unfenced control plots, were installed separately in several forest and heathland vegetation types. Information about the impact of ungulate species (red deer, roe deer and wild boar) on forest development, regeneration of woodland clearings and succession processes in heathlands will become available in time (Van Hees *et al.*, 1996).

Impact of ungulates on the soil mineralisation process

Most grazing research focuses on direct vegetational effects of grazing. Indirect effects on vegetational development through effects on soil conditions are scarcely investigated. During the past few years a field experiment has been carried out, investigating the effects of cattle grazing on soil mineralisation. In small fenced areas (1 ha) in a Scots pine forest, herbaceous vegetation was grazed each year for several weeks during the growing season. Effects on decomposition and mineralisation were established. Although the applied grazing pressure was rather high (5 to 10 times a moderate grazing regime), the experiment revealed how soil processes are affected by grazing. For instance, decomposition and nitrogen mineralisation were promoted and the productivity of the herbaceous grass layer was lowered (Kemmers *et al.*, 1993).

Wild boar rooting and forest regeneration

A 2-year study using 130 transects revealed that rooting by wild boar had a negative impact on the successful establishment of young deciduous saplings. Spring densities of wild boar in the study area amounted to 3–4 individuals per km². At this density the wild

boar not only create a favourable 'seed-bed' for germinating tree seeds but also return to these sites frequently, and sooner or later uproot most saplings, thus preventing successful establishment (Groot Bruinderink and Hazebroek, 1996).

Assessment of the carrying capacity for ungulates

Based on a seven-year study of the population dynamics of wild boar and a monitoring of their physical condition (body weight, fat reserves etc.), a model was developed for the assessment of the carrying capacity of forested areas on poor sandy soils for wild boar. Thus guidelines were provided for a more natural approach in the management of wild boar populations in forested areas based on the available food supply in the area (Groot Bruinderink and Hazebroek, 1995b). For other wild ungulate species like roe and red deer, such models are still missing.

Research priorities

Forest–ungulate interactions: a quantitative approach

It has been argued that ungulate grazing might positively contribute to the diversity of vegetation structure in nature reserves, especially in semi-open landscapes, i.e. forest–grassland–heathland systems. In order to provide guidelines for applying grazing as a management tool, a quantitative approach is needed that describes forest development under different grazing regimes. The simulation model FORGRA describes forest–ungulate interactions on a quantitative basis, but at present this model is only parameterised for forest–heathland landscapes on sandy soils. Grazing research in forest systems on other substrates will provide data that are necessary to parameterise FORGRA for other forest types as well. Due to a lack of knowledge the model does not deal with the effects of, for example, herbivore trampling on vegetation and soils. An extension of FORGRA with a module describing the effects of ungulates on soil dynamics is desirable. Furthermore, the model is just dealing with ungulate densities at constant levels and a homogeneous spread of habitat use. Future research should focus on the population dynamics of ungulates and on spatial heterogeneity in habitat use.

Ungulate grazing and trampling and soil processes

By grazing, trampling and dunging, ungulates affect the nutrient dynamics of forest soils. At low densities these effects might be negligible. However, beyond a certain density effects on soil organic matter decomposition and mineralisation may become manifest. Changes in soil microclimate conditions might accelerate the mineralisation process as has been found in the grazing experiment with the fenced plots. At rather high grazing pressure this might even result in soil degradation. More insight is necessary here, to predict effects at the ecosystem level.

Spatial models for habitat use of ungulates

To be able to develop scenarios for forest and nature development in large nature areas, a general applicable model is needed that describes temporal-spatial developments at a landscape level. This requires new types of models which translate forest dynamics from the patch-level to vegetation patterns at the landscape level. A prerequisite is the development of models that describe the behaviour of ungulates in relation to vegetation patterning. In this respect, it might also be relevant to compare situations with and without natural predators, such as wolves or lynxes, as predators have been found to largely affect the habitat use patterns of ungulate species in large forest areas.

Dynamics of forest regeneration and ungulate populations

In forest areas the population size of wild or semi-wild ungulates is maintained at a more or less constant level. Sometimes this leads to a constant high grazing pressure and natural forest regeneration is hampered. Therefore it would be useful to investigate population dynamics of ungulate populations under natural circumstances, where ungulates are fully dependent on the natural food supply and no supplementary feeding is given. How long will it take to reach peak densities before population size is reduced by a shortage in food supply? How long will it take until populations are built up again? Will periods of relatively low grazing pressure exist long enough to allow forest regeneration to occur successfully and

guarantee sustainable forest development? Insight into the relationship between forest regeneration dynamics and ungulate dynamics is useful for the management of large forest areas.

Biodiversity

Ungulates may severely affect the diversity of floral and faunal species, by having an impact on the forest vegetation structure. In particular the characteristic species of old-growth forests often have a low dispersal rate, which makes them rather vulnerable to changes in the mosaic pattern of forest developmental stages. Ungulate grazing interferes with the grain size of open and closed forest sites within a larger area. Whereas grazing may negatively affect the occurrence of certain species at a local scale, the impact of ungulates may be positive at the landscape level. From the viewpoint of conservation and promotion of biodiversity in forests, knowledge of forest–ungulate interaction (pattern-dynamics at different spatial scales) is urgently needed.

Current anthropogenic constraints to ungulate management

Virtually natural forest landscapes

Since no functions other than nature conservation prevail in virtually natural landscapes, there is no conflict between nature conservation and timber production. Although 'naturalness' is given the highest priority in these areas, wild ungulate populations are still regulated by hunting. Natural starvation of animals during periods of shortage in food supply as a result of temporally high densities is not yet generally accepted. Therefore, the natural dynamics of ungulate populations are not allowed to function as the main mechanism influencing forest regeneration dynamics. Supplementary feeding is no longer applied in most of these nature areas, and hunting is mainly carried out for regulation purposes.

For the introduced free-ranging ungulates like cattle and ponies, there is the issue of animal health and welfare. A Veterinary Committee has recently been installed by the (Dutch) Ministry of Agriculture, Nature Management & Fisheries to prepare a judgement on whether animals introduced into large nature areas are allowed to starve or die without any human intervention. They will also consider the issue of how to control contagious diseases.

Accidents between free-roaming cattle and visitors of nature reserves are possible, but fortunately injuries so far have been minor. Education is required here to make visitors act in a responsible way towards grazers.

Semi-natural forests

In semi-natural forests, grazing is carried out mainly with domestic ungulates such as cattle, horses or sheep. For instance, the National Forest Service (180 000 ha) and the Society for the Preservation of Nature (60 000 ha), the two biggest nature management organisations in the Netherlands, have many of their areas grazed by their own animals. Often, grazing is also carried out with animals from farmers in the neighbourhood. There are no other constraints with respect to hunting or recreation than those mentioned previously. Timber production in semi-natural forests is of a lower priority to nature conservation purposes.

Multi-purpose forests

In multi-purpose forests there is frequently a conflict between timber production and grazing pressure by wild ungulates. As described earlier, the Dutch government no longer subsidises planting of trees. Therefore, spontaneous forest regeneration has recently become an important process in the sustainable production of timber. In many forests, however, ungulate densities are still kept artificially high for hunting purposes, resulting in locally high grazing pressures which conflict with the prerequisite conditions for successful regeneration. The hunting and timber lobby have opposite interests here. A similar problem is met in the conversion of homogeneous forest stands into forests with a higher structural diversity and a more varied species and age composition. Here too, a high grazing pressure conflicts with a successful conversion management.

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Chapter 3

Forest grazing in Denmark: past, present and future

Rita M. Buttenschøn

Summary

A brief history of forest grazing in Denmark is presented together with a review of current grazing problems and research needs. In common with other Northern European countries, Denmark has suffered major deforestation over the last 1500 years due to overgrazing by domestic stock, and conversion of forest land to agricultural production. Stock grazing is now restricted in most forests, but high roe deer densities are maintained by landowners for hunting and have a detrimental effect on tree regeneration. Recent increases in roe deer population are attributable to a reduction in fox populations, increased use of winter crops, and woodland management for game. In recent years, increased public interest in forests has resulted in a number of new initiatives aimed at doubling the existing forest area from 12 to 24% of total land area, and protecting existing fragments of semi-natural forest. Grazing will be re-established as a traditional management tool in some forests, but there is little quantitative information on the likely effects of different grazing regimes on

successional processes and biodiversity. In particular, land managers need to know more about the interaction between domestic stock and large wild herbivores, and the impact of different herbivore species on forest structure, tree species composition and natural regeneration.

Introduction

By nature, Denmark is a forested country. From the late Stone Age, when agriculture was introduced in Denmark, animal husbandry was the main type of farming, while grain growing was only on a small scale. The natural forests which covered the whole country provided a stable supply of fodder, with only a small amount of labour needed to convert the forest into a woodland pasture. It is not known exactly when the forest in the different regions disappeared due to an increasing need for agricultural land, timber and fuel wood, but a growing population in the Viking Age certainly influenced the forest area. At that time two important agricultural tools appeared, the scythe and the mouldboard plough. The scythe

Table 3.1 History of the breakdown and conversion of the climax forest by animal husbandry (summarised from Jakobsen, 1973)

Type of farming	Landscape description	Forest description	Fodder production	Need for gathering winter fodder
First stage of animal husbandry	Closed forest	Atlantic climax forest; elm, lime, oak and hazel with herbaceous understorey	Grass lacking, use of forest products	None; twigs, roots etc. are available
Husbandry based on forest products and grass (woodland pasture type), grain production not widespread	Dominated by trees with small pasture areas	Elm and lime decreasing, pioneer trees immigrating, trees are pollarded, fruitbearing trees are protected, grassy understorey	Still possibility for sustainable utilisation of foliage, and grass production	Less forest left for winter feeding, therefore part of summer production must be harvested and stored
Animal husbandry based on grass areas, no forest	Common (heath/grassland)	No trees	Heavily reduced by conversion to rosette herbs and grasses; drought is calamitous	

was necessary for gathering grass for winter fodder, which was needed when the forest itself could no longer provide sufficient winter food (Table 3.1).

The reduction in forest area continued until only approximately 100 000 ha, about 2% of the total land area, remained by the year 1800. *Calluna* heathland developed on the impoverished soils and 70% of the whole of Jutland became low productive heathlands. The remaining forest was still mainly natural deciduous forest dominated by beech and oak. Most of these forests were situated in the Eastern part of Jutland and on the islands. The forest landscape was a mosaic of mixed pastoral landscapes with high forest, grazing forest and coppice forest. In 1805 the government found it necessary to create the Woodland Preservation Act which prescribed general woodland enclosure and cessation of all woodland grazing except pannage.

Cattle grazing, together with pig grazing, was still considered useful under controlled conditions for managing forest regeneration, reducing the competitive grass vegetation and reducing the number of mice. However, farmers were generally not interested in using the woods of lower productivity. The Woodland Preservation Act was preceded by similar attempts to check grazing impact and promote wood production and hunting; these were, however, unsuccessful in their aims, because of the lack of farmer interest. In the oak

Table 3.2 Breakdown of the present forest area in Denmark

	State Forests (ha)	Denmark in total (ha)
Total land surface		4 300 000
Total forest area ^a	197 000	493 000
Coniferous forest		269 000
Spruce	75 000	193 000
Pine and others		76 000
Deciduous forest	32 000	148 000
Beech		75 000
Oak		25 000
Ash and others		48 000
Natural forest	8 000	35 000
Mainly deciduous		

^a Including non-wooded areas with forest declaration and open state-owned areas, administrated by the State Forestry. The figures for natural forest are estimated.

coppice in western Denmark sheep grazing was common, while cattle and especially horses were common in the forests in eastern Denmark. Goat grazing was already restricted in the 14th century.

The present Danish forest area

Since 1800 the area of planted forest has been increased to approximately 12% of total land area, while the original natural forest has been further reduced to cover only 1% of the present forest area (Table 3.2). Only a few forests have been grazed continuously or for long periods. Today about 2000 ha of natural forest are grazed, including deer parks and grazed oak coppice (Table 3.3). In forest areas governed by the Forest Act, grazing is still restricted.

Table 3.3 Estimated distribution of natural forest in Denmark (Ministry of Environment, 1994b)

Forest system	Area (ha)
High forest	20–30 000
Oak coppice (including areas which are grazed)	4 000
Coppice (excluding oak)	1 000
Grazing forest (including deer parks)	1 500
Total (estimated)	35 000

Forests and wildlife

Roe deer are widespread throughout Denmark, and they can have a detrimental affect on young natural regeneration and new plantings. Fencings and repellents are often needed to protect the young trees. The high roe deer population density is generally accepted by the landowners, because they obtain a substantial income from leasing the hunting rights. The Danish roe deer population has grown very markedly since 1980. Measured in terms of roe deer bag record (shot roe deer) the number has risen from 18 000 head in 1941, to 35 000 in 1980, and to just under 100 000 in 1994. The population increase is due to:

- afforestation of new areas;
- change in the field crops towards a higher percentage of winter-growing crops such as rape, barley, wheat and rye;

- woodland management for wildlife;
- the reduction of the fox population due to scabies infection.

Similarly, the red deer bag record has risen from 500 to 2500 over the same period. This species is concentrated in western and central Jutland where the highest concentrations of forests are found.

Forest development and woodland grazing in the future

In recent years an increased public interest in forests and nature in general has resulted in a number of initiatives. In 1989 a new Forest Act with multiple-use objectives was implemented. According to this Act, not only forest production, but nature conservation and protection of the environment should be taken into consideration in forest management. The Act has been followed by a series of strategies and action plans which are part of the Danish contribution to the recommendations from The Rio Conference and the Ministerial International Conference in Helsinki. These are:

1. **Strategy for Sustainable Forest Management** (Ministry of Environment, 1994a)
2. **Strategy for Natural Forests and other Forest Types of High Conservation Values in Denmark** (Ministry of Environment, 1994b)

In state forests, areas for non-intervention forest reserves and for old management systems have now been designated. Through various subsidy schemes, the protection of valuable natural forest on privately owned land will also be promoted. Ten million DKK (equivalent to approximately £1 million) was granted for a subsidy scheme in 1996 and new national grants are expected in the coming years. Fourteen million DKK was granted by the EU-LIFE programme for a project 'Restoration of large areas of natural forest for the benefit of endangered birds, plants and biotopes' offering subsidies for protection of privately owned forests.

Measures to be taken up to the year 2000:

- Protection of at least 5000 ha of untouched forest, primarily natural deciduous forest, but coniferous forest/mixed forests will also be represented.

- Protection of at least 4000 ha of traditional management systems, primarily in natural forest.

Measures to be taken up to the year 2040:

- Areas of natural untouched forest, and traditionally managed forest amounting to 40 000 ha will be retained, equivalent to 10% of Denmark's present forest area.

3. Implementation of specific research programmes

Research programmes will be initiated to improve the basis for conservation of biodiversity in the forests, and provide more basic knowledge on forest ecosystems, their dynamics and development.

4. National afforestation programme

The objective of a doubling of the forest area in one tree generation is to be maintained, and the efforts are enhanced through financial support for afforestation on state owned as well as on privately owned land. Afforestation on state owned land is part of the main measures of the Nature Management Act of 1989 (now included in the Nature Protection Act of 1992). An annual sum of money (about 120 million DKK) is granted for nature management projects, to be distributed by category: 40% for afforestation, 40% for nature (establishment of new forest grazing projects can be included in this category), 20% for recreational activities.

5. Green forest management in state forests

The project 'Green forest management' will be implemented on state-owned areas from 1994 onwards. This project should ensure nature conservation and the development of more varied, stable and natural forests by, among other methods, conversion of plantations on poor, sandy soils and dunes.

6. Promotion of multiple-use forestry in private forest

Multiple-use management, use of broadleaved species and various other forest improvement measures will receive financial support through subsidy schemes.

7. Advisory boards for each state forest district

Advisory boards representing the local interests and forest users are to be established. Being of a

small scale, not many lobby interests are involved in forest grazing issues. However, according to The Nature Protection Act there is public access to all publically owned forests and all privately owned forests larger than 5 ha. In this connection larger fencings in forests which are attractive for recreational use may provoke protests.

Grazing problems

In re-establishing forest grazing as a traditional management system many questions arise concerning the former management, the resulting forest types, animal health problems and so forth. Knowledge of natural afforestation of open pastoral land is available; the process occurs in stepwise phases of colonisation in accordance with different plant strategies as outlined by Buttenschøn and Buttenschøn (1978, 1985) and Buttenschøn (1988). Grazing tolerant species establish as a first phase and provide shelter for subsequent establishment of climax woodland species. This process is governed by the availability of browse, the grazing pressure and the current growth conditions; imbalance of one influences the others, e.g. a reduction in grazing pressure may enhance the forest development. These dynamics are in part applicable to closed forest conditions, but there is a lack of concrete knowledge.

In Mols Bjerger, a study of the long-term effect of cattle grazing on forest structure, regeneration and forest floor vegetation in mixed oak and beech wood is continuing. Galloway cattle are used together with 'forestcattle', a special crossbreed developed for grazing on marginal soils. An ongoing site study in southern Jutland is investigating the history of woodland grazing and the relationships between nutrient turnover and the consequences for water supply.

Further research

Further study is needed on major subjects such as:

- The influence of grazing pressure and its relation to different edaphic conditions within the forest systems.

- The interaction between domestic stock and large wild herbivores, e.g. fodder availability, population size and dynamics.
- The impact of grazing by different domestic animal species and/or races on forest structure, species composition, forest regeneration and other faunal groups. A point for consideration in this connection is that the introduction of a low level of grazing with bovine species in woodlands may reintroduce more original conditions to the forests of the region, where these species were of overall importance for the structure in prehistoric and historic times.

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Chapter 4

Ungulates and forest management in Great Britain and Ireland

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Summary

Ungulate management within the main forest types in the British Isles is summarised in this chapter. The forests have been classified into three broad categories: semi-natural woodland (divided into upland and lowland), pasture woodland, and plantations. For each of these forests, we describe their structure and composition, their cultural and economic importance, the main grazing regimes, and the current grazing problems. Priority research topics are defined to enable comparison with those forest types of other countries represented in this publication.

Introduction

Woodland in the British Isles (UK and Ireland) comprises a diverse range of habitats which can be grouped together into three main categories: semi-natural woodland (upland and lowland), pasture woodland, and plantations. The current lack of control of wild ungulate numbers is probably the most significant management problem within these woodland types. In particular, heavy grazing by ungulates prevents regeneration and simplifies the structure of semi-natural woods. Until recently, there has been little apparent acceptance of the need to combine grazing with woodland management in either the literature or management policies. Grazing levels are often classified as of acceptable or unacceptable damage, for example, while ignoring the other impacts of grazing on the woodland ecosystem as a whole. This approach is starting to change, with active herbivore management policies to encourage woodland regeneration in the presence of herbivores being carried out by both Scottish Natural Heritage and the Royal Society for Protection of Birds on selected reserves in the Scottish uplands (Hester and Miller, 1995; Staines *et al.*, 1995). Semi-natural woods in Ireland, however, are seen largely as an amenity and conservation resource and as such there is apparently little incentive to tackle the grazing issue.

The aim of this chapter is to describe current management systems and grazing problems for each of these forest types, and to identify the main research requirements. This thematic approach is common to all the chapters in this book and the intention is to enable comparisons to be made easily between the different countries involved. The choice of forest categories was made to represent the main differences in requirement for grazing management.

Ungulates

The main woodland grazers in the British Isles are red and roe deer, sheep and, more locally cattle, sika deer, muntjac deer, fallow deer and feral goats. The distribution and densities of these different herbivores vary greatly between regions. In general, sheep are the most widespread domestic herbivores affecting woodland areas, whereas cattle and ponies are only locally important. All three can damage seedlings and saplings and affect ground vegetation. Cattle and ponies have a more marked trampling effect than sheep due to their greater live weight, and this effect can be beneficial for tree regeneration. Numbers of all of these domestic herbivores have varied through the years in different regions.

All species of deer tend to browse more than sheep, cattle or ponies, and their activities are much less easy to control than those of domestic animals. Red and roe deer have been present in Britain since at least the last ice age, but other deer species, e.g. sika, have been introduced more recently and tend to be local in their distribution. In Ireland, sika and red deer were introduced to some estates by land owners during the 18th century, with management practices generally maintaining high deer populations. The decline of Irish estates at the beginning of the 20th century led to the reduction of wildlife management, but high deer numbers (red and sika) have been maintained locally due to extensive open grazing land with

adjacent woodland providing shelter. There are no roe deer in Ireland and fallow deer have a restricted distribution. As forestry plantations have become more widespread in Britain, giving good habitat and cover for red, roe and sika deer, numbers and ranges of all these species have greatly increased (Staines *et al.*, 1995). In many upland areas the high density of red deer (often maintained by winter feeding) is causing overgrazing and a loss of woodland and scrub habitats. Roe deer are common in many areas and they also can have dramatic effects on woodland regeneration.

Rabbits, hares and small mammals are widespread throughout the British Isles, and have all been shown to damage seedlings and saplings. They generally have unhindered access to all semi-natural woodland areas. Goats are thought to have been brought to Britain during Neolithic times. In the uplands, feral populations have become established locally, with most found in the Scottish Highlands and Islands. Goats are primarily browsers and can have dramatic detrimental effects on woodland structure and regeneration, which has led to their control in some areas. Their great agility gives them access to tree seedlings that would be inaccessible to other herbivores.

Upland semi-natural woodland

Structure and composition

Upland semi-natural woodland occurs in the north-western parts of Britain and the west of Ireland, where annual precipitation is above about 1000 mm year⁻¹ and the terrain is generally rugged and mountainous. Very little semi-natural woodland remains in the uplands; in the UK it only covers about 2% of the land area (Roberts *et al.*, 1992) and in Ireland (the least wooded country in the EU) less than 1%. The current scarcity of semi-natural woodland in the uplands of Britain and Ireland is attributed primarily to many years of felling, burning and grazing since the arrival of man (Birks, 1988; McCracken, 1971), although climatic change (increased wetness) and increased peat formation have also been contributory factors in parts of the north and west. Rates of woodland disappearance have varied considerably both at different times and in different areas. Palaeoecological studies indicate that during the mid-Holocene (5000 years ago), over 80% of the land surface was covered by woodland (McVean and Ratcliffe, 1962; Mitchell *et al.*, 1996). As a result of man's

activities, the structure and composition of many upland semi-natural woodlands have been fundamentally altered, with a depauperate species composition dominated in many areas by relatively grazing-resistant species, and little or no shrub understorey or tree regeneration (Rodwell, 1991). However, climatic effects are still apparent, particularly between the drier east and the wetter west, with more diverse bryophyte and pteridophyte communities in western woodlands. Local soil and moisture differences are also reflected by both the understorey and canopy species composition.

In Britain, birch (*Betula pendula*, *B. pubescens*), Scots pine (*Pinus sylvestris*) and oak (*Quercus robur*, *Q. petraea*) are the most common tree species. Other locally dominant tree/scrub species include rowan (*Sorbus aucuparia*), ash (*Fraxinus excelsior*), holly (*Ilex aquifolium*), alder (*Alnus glutinosa*), sycamore (*Acer pseudo-platanus*), beech (*Fagus sylvatica*), juniper (*Juniperus communis* spp.), hazel (*Corylus avellana*) and willows (*Salix* spp.). Ireland's isolation and its limited range of habitats have resulted in a particularly depauperate native flora and fauna compared to the UK and the rest of Europe (Webb, 1983). Palaeoecological records demonstrate that Scots pine was widespread in Ireland until 4000 years ago but appears to have become extinct about 2000 years ago (Bradshaw and Browne, 1987). Scrub woodland communities are frequent in the uplands of both Britain and Ireland, dominated by species such as birch, willow and juniper with hazel on more base-rich sites (Kelly and Kirby, 1982; Hester, 1994).

Main grazing regimes

Many upland woodlands are unfenced and are therefore completely open to grazing by both large and small herbivores. Past upland woodland grazing regimes featured cattle and sheep in particular (but also pigs and goats). Rural human populations were substantially higher and the widespread free-range grazing of domestic livestock severely restricted tree regeneration in many woodland areas which were already being heavily exploited for timber products (McCracken, 1971; Watts, 1984). As a consequence, much previously wooded land was transformed into open rough-grazing. Some woodlands were managed more carefully for timber, with controlled grazing and managed regeneration or coppicing, and these woodland areas generally survived. Pollen analysis has demonstrated for Ireland how

differing grazing regimes in the past have influenced the woodland composition and dynamics (Mitchell, 1990). In recent years, sheep numbers in the British and Irish uplands have been strongly affected by European Union Common Agricultural Policy subsidies, resulting in increased densities in many areas and overgrazing of upland communities, including those woodlands open to livestock.

Outputs and uses

In the past, timber production, particularly for firewood and charcoal making, was important in many upland woods. The gradual decline in timber use from upland woods is variously attributed to declining rural populations, increasing use of alternative fuels, and more recently to increased availability of wood and wood products from plantation woodlands and from other countries. Today, most upland semi-natural woodlands are simply used for shelter and forage for stock grazing. Timber use, often constrained by felling licences, is now uncommon and is generally perceived to be of little economic value, as many of the trees are old, moribund and of poor form. Many upland semi-natural woods are probably of most value today for conservation and landscape reasons, which are becoming increasingly important factors.

Grazing problems

Herbivore control

Fencing to exclude herbivores. Enclosure studies have demonstrated that recent and current levels of grazing in most upland semi-natural woods are restricting natural regeneration and simplifying the woodland structure, particularly in the shrub and field layers. However, complete exclusion of larger herbivores also removes any potential beneficial effects, such as control of herbaceous vegetation by grazing and creation of regeneration niches by trampling and ground disturbance (Mitchell and Kirby, 1990). Domestic stock fencing is the cheapest way of excluding most herbivores, and is most useful when attempting to re-establish regeneration in moribund woodland or in open vegetation. Where deer are also present it may be necessary to resort to deer fencing although this has limitations (see 'plantation forests').

Promotional campaigns to increase farmers' awareness of the benefits of farm woodlands coupled with management grant aid (for example in areas designated for special

protection) are expected to result in more widespread stock and deer fencing. This will further restrict the access of free ranging stock and deer to woodland.

Fencing to control, rather than exclude, grazing within woodland. This option has great potential in many woodlands, both in terms of vegetation composition/structure and herbivore success (shelter and good forage in woodlands tend to produce larger, healthier animals). Stock densities and timing of grazing can be manipulated easily, although as yet we have insufficient information about the effects of these factors on damage to and regeneration of different tree species and other available forage to enable us to design 'optimal' grazing regimes for different herbivores (Kirby *et al.*, 1994). Control of wild herbivore densities within woodlands is particularly difficult. A severe example of this is in the Irish oakwoods where the widespread infestation of *Rhododendron ponticum* provides ideal cover for sika deer and frustrates efforts to control numbers (Cross, 1981).

More widespread reductions in densities of wild and domestic herbivores. The high sheep numbers in the uplands have resulted not only in woodland contraction but also reductions in forage on the open hill to the point of soil erosion in the west. Under these conditions, the few remaining woods come under increased grazing pressure and regeneration is almost completely suppressed. Widespread reductions in either domestic or wild herbivores will require changes in both EU agricultural policies and in current deer management systems. Change from the current system of headage payments, or removal of CAP subsidies altogether, could result in the reduction of upland sheep populations and grazing pressure in woodland areas. There are moves in the UK to encourage the widespread reduction of red deer numbers, but this has not yet been implemented, except locally. In Ireland, however, it is possible that deer stalking will be promoted in the future to increase revenues. If this is a successful venture then deer numbers are likely to be maintained at existing levels or even increased.

Incentives for one or more of the above options could be made by government policy, as follows:

1. Targeted government payments. Woodland grant schemes and ESA-related land management payments are now increasing

the areas of woodland protected to some degree from grazing, albeit still primarily by fencing. Such environmentally targeted grant aid has great potential for woodland management and grazing control.

2. Increased values of timber. Further encouragement of the increased use of both poor and good quality timber (e.g for production of compressed fibre board (MDF)) could increase the potential commercial value of most types of woodlands.

Control of tree regeneration to maintain non-wooded habitats

This will only be considered briefly because control, rather than encouragement, of woodland regeneration is currently only a problem in a few upland areas, for example where important open habitats such as heath are threatened by tree colonisation. However, if grazing management changes such that woodland does start to expand, it could become more important in the future. Generally speaking, browsers such as goats are considered most efficient at controlling regeneration of woody species, followed by deer, and less so, sheep, ponies and cattle. As with the above management problems, insufficient is known about the effects of different densities of these herbivores on tree regeneration to design 'optimal' grazing management schemes, although generally the control of regeneration can be easily achieved with high densities of any herbivore. Selectivity of different tree species can result in differential effects of grazing, and this needs to be considered when designing a scheme to encourage or control specific tree species.

Lowland semi-natural woodland

Structure and composition

Semi-natural woods are widespread throughout the lowlands of Britain, but particularly in the south-east of England. Most are relatively small (less than 10 ha) and are surrounded by farmland. They include both woods that have existed for centuries (ancient woods) and more recent colonisations of open ground. A wide variety of woodland types occur under this heading, but the most common fall within the lowland oak and mixed deciduous categories (*Quercus-Fraxinus*) woods. There are probably between 300 000 and 400 000 ha of woodland within this category in Britain. In Ireland,

lowland semi-natural woods make up a much smaller percentage of land than their upland counterparts, with a substantial proportion found on country estates, where woodland management policies in the 18th and 19th centuries were biased towards *Quercus* monocultures (Mitchell, 1988). Carr and other lowland wet forest types are also important in some areas of both Britain and Ireland. Their importance for conservation can be high, as some types have become increasingly scarce since agricultural intensification, drainage and river control. This section concentrates on ancient woodland where most of the concern arises over nature conservation, although in practice many of the grazing problems apply to younger semi-natural woodlands as well.

Most of the lowland woods were formerly managed as coppice, or coppice with standards. In the past, therefore, they were dominated by young-growth stands and much of the distinctive flora and fauna associated with them is linked to the young-growth stage. Restoration of coppice is often one option to be considered. Abandonment of coppicing during the 20th century means that an increasing number are acquiring a closed high forest structure and in some cases reasonable amounts of dead, old trees within them.

Main grazing regimes

Past coppice management implies that grazing levels within the woods must have been low, at least in the recently cut coupes. This was frequently achieved by fencing around the young growth. Limited grazing by stock did occur in older stands but was not always permitted, since with some crops even the older stems might be damaged. In addition, in well-managed coppice the degree of shade is such that the amount of vegetation on the forest floor is low and hence the potential for grazing is very limited. However, there would have been much more forage in any rides and open grassy trackways through the wood. It is likely, therefore, that even where grazing by stock did occur it was probably at low levels and fairly carefully controlled.

Deer numbers through much of the British lowlands have been low for the last few centuries (outside selected areas such as the royal forests where they were encouraged and protected) and do not appear to have been a major restriction on the management of lowland woods as coppice. Currently, domestic livestock

grazing in woods is not usual. In recent years there has been a substantial increase in the numbers of fallow, roe and muntjac deer, and they are spreading into areas where deer have not been for at least the last 200 years (Cooke *et al.*, 1995). Various factors have encouraged this spread, such as greater amounts of winter fodder in the surrounding fields (with the shift to more autumn sowing of cereals), minimal pressure from hunting, and in some instances, deliberate introductions. Hard winters may lead to heavy mortality locally, but it is not clear whether this is a real limiting factor. Deer numbers have only been accurately censused on a small proportion of sites, thus the information about overall deer densities is not reliable, particularly where they may be ranging across more than one land ownership.

Many of the Irish lowland woods are ungrazed. Some on farms are used as shelter and feeding sites for cattle. The concentration of cattle tends not only to prevent regeneration but also to damage existing trees.

Past management of lowland woods thus took place under very much lower and more controlled grazing regimes than today. In many woods coppice restoration (where desirable) is extremely difficult to achieve without extensive fencing, which makes it uneconomic, even with grant aid. Extra protection measures are needed to ensure regeneration under high forest production systems with the consequence that it is more difficult (often impossible) to work at small scales and to use natural regeneration in ways that mimic natural forest processes (Kay, 1993).

Outputs and uses

The main output from British lowland woods in the past was timber and other wood products (e.g. charcoal, bark). Other uses were secondary to wood production in the majority of cases. During the 19th and early 20th centuries the importance of wood production declined (except during the war years). Pheasant rearing and release became the primary woodland use in many cases. Over the last 50 years interest in wood production has increased but largely through replanting the woods with conifers. In the last 10 years there has been a revival in trying to restore former treatments, such as coppicing, and to devise modern systems that will allow the woods to be managed in ways that retain their semi-natural character. In Ireland, lowland woodland management aims are principally amenity and small game (i.e.

birds such as pheasant), but some sites support low deer populations.

The significance of semi-natural woods in lowland landscapes is widely appreciated; and their nature conservation value in a European as well as a British and Irish context is well documented. There is now good evidence that some of the features and species for which we value these woods are under increasing threat from the rising deer grazing pressures. Reductions in shrub layer communities, in the ground flora and in associated animal communities have been identified as consequences of overgrazing by deer. However there is also recognition that a low level of large herbivore activity within woods is desirable, both as a natural element in the woodland system and because of its effect in increasing species diversity.

The future 'outputs' of lowland semi-natural woods are likely to be varied. Wood and timber production will still be important and in some sites the primary use. The contribution of these woods to maintaining biodiversity is also likely to be critical in most cases. Recreation and landscape will be important in some sites, relatively unimportant in others, but for the most part are unlikely to cause serious conflicts if the other two objectives can be reconciled. Unless there is a big shift in attitudes to stalking deer among the majority of the population, stalking will remain primarily as a means to reduce deer populations sufficiently to permit other woodland activities to continue, rather than being a major output in itself.

Grazing problems

To date, most forestry-related deer research has been in the uplands and in plantation systems, with the main focus being on the effects of browsing on tree growth. Work on nature reserves and elsewhere is documenting examples of heavy deer grazing/browsing on the ground flora and shrub layers of lowland woodland with implications not just for the plants, but for associated animal communities as well. If lowland woods are to maintain their biological importance, future research should focus on these aspects. Interactions between herbivores and stand management are also a major area requiring study, at the landscape scale as well as within individual woods. Options for grazing control are as follows:

- *Culling*. Direct management of deer numbers (by shooting them) will frequently

be necessary but there are many circumstances in the lowlands where it will not be possible to adopt this approach.

- *Habitat manipulation.* In some areas it might be preferable to manipulate the structure of the woodland and/or the surrounding landscape, rather than cull the deer, to reduce the overall impact on the vegetation. For example, provision of alternative forage, such as pasture, could be used to attract the herbivores elsewhere, or additional open areas within the woods could be created, again as attractants for the deer away from the timber producing areas. Our knowledge of the outcomes of such options is currently poor and further research is required, as outlined later.

Pasture woodland

Structure and composition

Pasture woodland describes a variety of land-uses where trees coexist with either domestic livestock or deer and where both the animals and the tree products are or were of value to the owner (Harding and Rose, 1986). The density of large herbivores is higher than would normally occur for any length of time in a natural forest and the structure and composition of the woodland are largely determined by the impact of these grazing and browsing animals (Chatters and Sanderson, 1994). The woodland may be open with large gaps between the trees and a sparse or absent understorey. Long-established pasture woodland often contains old pollards, including some of the oldest and largest trees in Britain. The distinctive conservation value attached to these sites is linked particularly to the impact of prolonged grazing on woodland vegetation and/or the abundance of very old trees.

Pasture woodland in lowland Britain includes many long-established parks, old wooded commons and some of the former royal forests. Most parks are quite small (less than 50 ha) but some of the former commons and royal forests are among the largest blocks of semi-natural woodland in lowland Britain. The limits to pasture woodland are not, however, precise; any heavily grazed wood starts to acquire some of its characteristics; modern parks may be structurally similar to medieval pasture woods; old pollards survive outside of current pasture woodland systems, for example along riversides. Similarly, if the grazing in pasture woodland is reduced, allowing extensive

regeneration, then a more closed canopy high forest structure develops.

This woodland type is defined more by its open structure than by its composition, but in the majority of examples the main tree species are oak and beech. Many of the sites where pasture woodland survives were probably always poor in nutrients, but centuries of cropping both the trees and the animals will have further depleted the nutrient stocks. There are no national estimates of the area of lowland parkland and other pasture woodland because of the difficulties of defining it consistently for survey purposes. However, there is a consensus that there is unlikely to be more than about 20–30 000 ha in Britain, the majority of this being in England.

Main grazing regimes

There is very little quantitative information on the current grazing levels on many of these sites (except where grazing has stopped) and historical data are even more sparse. However some qualitative conclusions can be drawn. On many of the larger sites grazing by domestic livestock was common. Ponies and cattle are more common now than other animals although in the past a much wider range of herbivores was probably used. Grazing might have been regulated, but the incentives were for individual owners to have as many animals as possible. During the medieval period, when some of these areas were also major sources of deer (for food) to the crown or to nobles, this was frequently additional to the domestic grazing. Hence there was the tendency for high levels of grazing that lead to the characteristic structure of these sites.

Grazing levels were not static, at least on the larger sites. Major fluctuations in the grazing regime are believed to be the cause of the very marked gaps in the age structure in many pasture woodland sites. The best documented example is for the New Forest, where sudden drops in grazing appear to have occurred at intervals, either connected with major disease outbreaks, changes in the attitude to deer, or the economics of running livestock on common grazings (Putman, 1986). However we cannot guarantee, even if conditions change and grazing increases (where it is currently low) or reduces (where it is currently judged to be too high), that the associated plants and animal communities will be able to respond. The surrounding countryside has changed radically and most of these pasture woodland sites are now very isolated.

Outputs and uses

Lowland pasture woodland provided essential extensive grazing for livestock and deer for many centuries. There might also have been other common rights, for example to collect litter or turves. While medieval monarchs did sometimes hunt the deer in their parks and Forests, this recreational aspect was not the main reason for having the deer and most deer would have been killed by professionals. Wood was the second major product, primarily from pollard trees. Most of this was small timber cut during the pollarding process (which might also be used for fodder), but from time to time whole trees would be cut for special purposes. The value of the wood ceased to be a significant economic output on most sites 50–100 years ago although it is still collected locally. Grazing continues to be important in some cases, but has dramatically declined in many others in the last 50 years, since agricultural intensification.

From about the 17th century onwards the landscape value of pasture woodland, particularly parks, came to be increasingly appreciated. Old pollard trees attracted attention (and still do) because of their fantastic shapes and their age. Some of these woodlands have become major areas for recreation (the New Forest, Sherwood). Both recreation and landscape are likely to remain major uses of lowland pasture woodland and will influence their treatment through issues such as public safety (old trees), appearance of sites (removal of unsightly dead trees and wood), restrictions on grazing (worrying of livestock by dogs, difficulties of fencing, rustling).

Appreciation of the nature conservation value of these sites has built up over the last century but particularly in the last 10 years (Kirby *et al.*, 1995). Their importance for a wide range of organisms (not just lichens and saproxylic beetles, but also birds, bats, fungi) has become better known; the importance of the UK containing a much higher density of old trees than many continental countries has been stressed; and throughout Europe the significance of dead wood and veteran trees has acquired a higher profile (Kirby and Drake, 1993). There has also been a recognition that many of the biological values that are associated with pasture woodland depend on the grazing regime.

The future primary 'outputs' of lowland pasture woodland are therefore likely to be their contribution to maintaining biodiversity, their place in the landscape and as places for recreation. Grazing regimes need to be assessed

and if necessary redefined to be compatible with the above. Wood production from pollarding will be incidental and, because it removes material that may be of biological value, it is likely to be discouraged in many cases.

Grazing problems

The problem of grazing control is less common for pasture woodlands than control of tree regeneration, but nevertheless can occur. In these situations, as with the above, we have to know how many saplings need to become established to ensure continuity of the pasture woodland in a desirable form.

We know from theoretical and observational work that regeneration does not have to be continuous to maintain a population of trees and it rarely is (Shaw, 1974). To maintain the open character of pasture woodland, i.e. to maintain some significant pasturage, regeneration must inevitably be limited either in time or space. However, it is difficult to specify what spatial arrangement of regeneration patches we should seek in these sites, or what temporal regeneration patterns we should try to encourage. In addition, a better understanding of the economic consequences of any grazing regimes is needed.

Plantation forests

Structure and composition

Most conifer plantation forests in Britain and Ireland have been established over the last 20–150 years. They consist of uniform high forest with a structure that changes progressively with age. Broadleaved plantation forests have existed for at least 300 years and consist of uniform high forest except where old and/or heavily thinned (dense understorey), or where planted in mixture with conifers. Conifer plantations are now the most widespread woodland type making up 62% and 90% of the total woodland area of Great Britain and Ireland, respectively (Locke 1987; COFORD, 1994). Sitka spruce (*Picea sitchensis*) is the principal species planted, but lodgepole pine (*Pinus contorta*) is becoming increasingly important on western blanket bog. A number of other species are also planted, including Scots pine (*Pinus sylvestris*). The majority of the plantations in Ireland have yet to reach maturity, but many in Britain are well into their second rotation.

In the uplands, there is a tendency for conifer crops to have a relatively simple structure, generated by the patch-clearfell system of management most commonly in operation. There is an increasing number of small broadleaved (farm) woodlands, and pockets of broadleaved woodland in conifer forests. In most commercial forests and especially those that are heavily used for recreation, spatial diversity has been increased as a result of the adoption of forest design planning. Smaller felling coupes, irregular silviculture, use of broadleaved/conifer mixtures, etc. are contributing to improvements in overall diversity. On very exposed ground where economic return is marginal, forestry may be abandoned, leaving open areas where there were previously plantations. There are likely to be increases in small woods in agricultural and urban areas planted for landscape, wildlife, pollution or noise control. Short rotation coppice may become more extensive.

Main grazing regimes

In the past, livestock were completely excluded from plantation forests, but deer have progressively colonised many forests and densities are now extremely high. Currently, all species of deer are expanding their range and are still colonising plantations. More locally, browsing by rabbits can also have significant detrimental impacts on the establishment of new plantings and these animals are rarely excluded due to the high cost of rabbit fencing. In the future there are likely to be more deer species per forest, and possibly also livestock in restricted areas. Deer of all species cause serious damage to forest trees by browsing and barkstripping. This can result in losses due to growth delay, stem deformation, mortality or reductions in timber quality (Gill, 1992a,b; Lowe, 1995). Deer also have a marked impact on the composition of ground and shrub vegetation in forests, with the result that the value of plantation forests for other wildlife is threatened (Putman *et al.*, 1989; Gill *et al.*, 1995).

Outputs and uses

In the past, outputs were mostly timber, venison and stalking. Recreation, wildlife habitats and amenity uses are becoming increasingly important. In the future it is likely that forest management will become increasingly diversified, with timber, venison, stalking, recreation, wildlife conservation, amenity, energy and pollution amelioration playing a role in many woodland areas.

Grazing problems

Deer control to reduce damage to trees

Deer populations have proved to be difficult to control by culling in woodland habitats. One of the reasons for this in the past is that deer densities in woodland have been difficult to estimate (Gill, 1990); however recent advances in census methods should help to alleviate this problem (Gill *et al.*, 1997; Mayle *et al.*, in prep.). Where deer management is focused on trophy stalking there has been a reluctance to reduce the numbers of female deer. This coupled with the fact that deer become more secretive under culling pressure means that more effort needs to be applied to reduce densities in forest habitats (McIntosh *et al.*, 1995). An outstanding problem with deer management has been a lack of information relating the severity of deer damage to deer population density. There is therefore still uncertainty on just how much control is required to eliminate unwanted impacts, both to forest trees and ground flora.

Tree protection to prevent herbivore damage

Fencing is widely used to protect trees against deer during the establishing phase. Fencing, however, is costly and can force deer to move away, increasing damage elsewhere. It is also difficult to exclude deer from large areas (>1000 ha) and complete exclusion from entire forests is rarely achieved particularly where winter snowfalls are heavy. Individual tree protection is only economically viable on small areas (<2 ha).

Research requirements

Research is needed on several aspects of ungulate ecology before significant improvements in their management in woodlands can be accomplished. It is also important that results are communicated in a form that is useful to managers and policymakers as well as to scientists. Since herbivores are typically present at high densities as well as being poorly controlled, research directed at both assessing impact and improving control is urgently needed. There is, however, a need to direct research efforts towards the specific characteristics and management needs of each woodland type. The following key areas have been identified:

- *Quantification of the effects of different herbivores.* Research is required to quantify

the complete impact of a range of grazing regimes on the woodland ecosystem. For example, what damage do different herbivores do to different tree species, and how is this affected by herbivore density, time of year and other available forage? It is important to identify how different forms of impact vary in relation to ungulate density, to provide appropriate target densities for management.

- *Assessments of the patterns of habitat use.* Variation in the use of habitats is well recognised in ungulates, however the influence of this behaviour on various types of impact require further research. The amount of open space and the extent and type of adjacent farmland, for example, affect feeding behaviour within the wood and hence the level and perhaps nature of damage. It would also be valuable to quantify patterns of spatial variation in grazing pressure across sites and between years, and differences in the grazing patterns created when grazing levels are being reduced as opposed to when they are being increased (i.e. grazing restoration sites).
- *Herbivore-vegetation interactions.* Although it is well accepted that deer and other herbivores adversely limit tree regeneration, it is clear that there is considerable variation between years and sites in herbivore impacts that remains poorly understood. Factors that interact with browsing, such as competition between seedlings and other vegetation, or shading, deserve closer investigation. Data on the effects of herbivores on vegetation are available from a range of sources, including exclosures; however there is still a lack of information on the vulnerability of many plants, especially the rarer species, and it is not clear how changes in herbivore density and species complement affect different vegetation communities. The effects of competition between herbivores requires further research.
- *Grazing control.* Effective management requires control over the grazers, using appropriate combinations of fencing and shooting. Both measures require high inputs of resources. Current modelling work should provide a better understanding of factors such as ranging behaviour and seasonal diet selection of the main domestic

and wild herbivores (MLURI Annual Report, 1996) on which grazing control measures can be based. Site carrying capacity in terms of grazing also needs to be quantified in order to meet specific management objectives. This requires a full understanding of both the diet selection of the different grazers and the standing crop of available vegetation at different times of year. Data of this sort are not yet sufficient to achieve this for woodland based systems, as most UK work to date has focused on herbivore use of open ground communities. Modelling of herbivore impacts on the vegetation is again better advanced for open ground communities (C. Birch, personal communication) than for woodlands and there is a need to redress this balance with more research on woodland grazing issues. Development of both plant and herbivore based models of woodland grazing is important both as woodland management tools for the prediction of desirable animal species, densities and timing of grazing for specific woodland management requirements, and as tools to highlight gaps in our knowledge and to direct further research needs.

- *Cost-benefit analysis of grazing impacts on woodland systems.* More information is required on the economic aspects of ungulate management. Deer and other herbivores cause considerable economic damage in woodlands managed for timber production. However, excessive control, either through fencing or culling may prove equally costly. Assessment of the financial implications of both control and protection will help clarify appropriate management measures. To date, relatively little has been done on this, but research is now under way in relation to new native pinewood initiatives (D. MacMillan, personal communication). In plantation forests, more information is needed on the long-term consequences of browsing and bark stripping on tree growth and timber yield, before economic impacts can be fully assessed.
- *Modelling the long-term dynamics of woodland ecosystems.* This is an important requirement, as the current structure and composition of many woodland areas has been fundamentally fashioned by events in the distant as well as the recent past. More research is needed to address the long-term

impacts of a range of combinations of human disturbance, grazing and climate change on the dynamics of semi-natural woods. Grazing cannot be considered in isolation as these three factors become strongly interrelated over longer timescales, such as several hundreds or thousands of years.

- *Establish extent and needs for pasture woodland management.* There is a need to improve our knowledge of the extent and distribution of woodland types of special conservation significance, such as pasture woodland, particularly in view of its increased significance in a European context. Pasture woodland has been identified in Britain and Scandinavia as a habitat that should be considered for inclusion on the Habitats and Species Directive in any future revision of the legislation. The key interactions to address for pasture woodland are between herbivores and trees, and between herbivores and management (although account needs to be taken of the other elements in the system). The reason for stressing 'management' is that pasture woodland is very much a cultural landscape type; it can only be maintained in the lowlands through continued positive management decisions. The tree element is critical because much of the special conservation value of these sites and the system as a whole (and some of the other values too) are very strongly linked to the condition and survival of populations of old trees. There is a need to obtain basic data on the age structure of pasture woodland trees and to establish the minimum size of unit for which it is feasible to consider relying on natural regeneration and grazing control to maintain tree population structure, as opposed to planting and tree protection by fencing. There are likely to be benefits obtained from links with agroforestry research.

Conclusions

The three main forest types defined in this chapter give a good indication of the main grazing regimes and grazing-related management issues within British and Irish woodlands. In all systems, the impacts of grazing have been identified as important. Grazing by domestic stock is more easily controlled than by wild herbivores, but it is clear that our knowledge about the interactions between domestic herbivores and woodland

systems is still not sufficiently adequate to ensure appropriate management of stock within all types of forest. Timing and levels of grazing have been identified as key issues requiring research for all woodland types. For systems such as pasture woodland, economics of changes in stock numbers were also considered particularly pertinent, although economics are clearly important in any stock management system. This applies to changes in timing of grazing, not just changes in numbers; for example stock may require alternative grazing at certain times of the year due to removal from a woodland area.

Wild herbivores are generally considered to be too numerous within most woodland types in the British Isles. In semi-natural woodlands, the biggest problem identified is a lack of regeneration of new trees due to heavy grazing and browsing. Expansion of semi-natural woodland is considered to be particularly important within the uplands, where it is currently extremely limited in extent. In relation to plantations, the problem is one of herbivore damage to existing trees reducing their value as a timber product. Where semi-natural woods are coppiced, the biggest problem is also one of herbivore damage to regrowth reducing timber values.

In all forest types (although to a lesser extent in commercial forestry), conservation is identified as a key issue for woodland management. As conservation aims are many and diverse, compared to timber aims, our current state of understanding is clearly identified as inadequate, not just in terms of herbivore impacts on the woodlands themselves, but also the impacts on, and interactions with, surrounding vegetation types which are also important to consider in conservation terms.

For all the above reasons, grazing control is clearly a key issue in the management of almost all woodland types in the British Isles and it is essential that we develop a better understanding of the processes involved, and how to manage them. This must move forward both through consolidation of existing information, for example by synthesis and development of predictive models, and through development of further research programmes specifically designed to examine key areas relating to woodland grazing which are currently poorly understood.

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Chapter 5

Grazing problems in Germany: balance or imbalance between wildlife and habitat?

Rudi Suchant, Stefan Türk and Ralf Roth

Summary

Grazing problems in central Europe have changed dramatically as the transformation of natural landscapes to intensively utilised cultural landscapes has taken place over recent centuries. In the past, primary uses of forest resources included firewood (for charcoal), lumber and various forms of grazing. The reduction in forest regeneration, which occurred mainly due to grazing, led to the creation of an ordered forest management to secure the lasting usage of the forests. The forest manager's primary goal at that time was to ensure the continued production of wood. In order to meet this goal, large areas of devastated forest had to be re-forested and woodland pasture rights were revoked.

As economic efficiency gained a greater role in forest management during the 19th century, the high growth rate of Norway spruce (*Picea abies*) led to plantings over large areas. However, the effects of storms, bark beetles, and snow breakage made it clear that the cultivation of pure spruce stands only brought short-term economic success, and then only in those locations to which it was suited. At the turn of the century this led to a movement towards bringing forest management closer to nature. Although spruce and pine cultivation in the majority of central European forest areas was further intensified until the 1960s, 'close to nature' management was developing alongside this and has become an important factor in the last few decades, especially in publically owned forests. Large pure coniferous stands are being converted into deciduous or mixed stands; pure stands are no longer being established as such. This 'retro-conversion' to natural forest communities and their enrichment with associated tree species is heavily influenced by wild herbivore damage. Matters are further complicated by the frequent separation of property owning and hunting practices (i.e. the leasing of hunting rights to private hunters) as their goals are different. The hunter would like

a relatively large wildlife stock which he can sustain through moderate hunting and intensive feeding. The forest owner would like a relatively small stock which does not damage the forest regenerative process. Due to the many different private interests in Germany, there are a range of other conflicting goals in the arena of grazing in forest ecosystems (e.g. recreation/tourism). The forest-wildlife damage problems can therefore only be solved by finding an integral solution based on sound records of herbivore–forest interactions.

Types of forest utilisation in German forests

The present-day structure of most German woodland ecosystems is influenced by its silvicultural usage. There are three different silvicultural types in Germany today: high forest, coppice forest, and composite forest (coppice with standards) (Table 5.1). The high forest type plays the most important economic role as it comprises over 95% of the total forest area. The following three types of forestry utilisation are applicable to all three silvicultural types and have been categorised as follows:

1. Direct usage with significant removal
2. Direct usage without significant removal
3. Indirect usage.

Coppice forests

This silvicultural type is characterised by almost exclusive coppice shoot regeneration and dates back to the 10th century. These coppice forests were managed heavily in previous centuries by direct usage with significant removal as a source of:

- Firewood. As a consequence of firewood removal, the coppice forests are almost exclusively deciduous as the coppice shoot regeneration rate of trees is particularly

high, with a maximum rotation age of c. 40 years.

- Tannin from oak bark; both the wood and the bark were utilised.
- Willow to weave baskets.

It is only since the last century that direct usage without significant removal and indirect usage have played a role at all. The latter utilisation types were either unknown or impossible to implement due to the destruction caused by direct usage with significant removal. This has gradually changed since the beginning of the last century as those coppice and composite forest types remaining were not primarily utilised in order to produce raw materials, but rather appreciated for the significant contributions they could make to nature and landscape protection due to their characteristic structure and the diversity of species.

Composite forests

This utilisation type, dating back to the 10th–13th centuries, is characterised by a short rotation age and coppice shoot regeneration, but also by a core of trees which are left as topwood for consecutive rotation ages. As well as the uses described under coppice forests, composite forests also used the topwood for the following:

- to provide mast for livestock
- for hunting and wildlife
- as lumber and building material.

It should be noted that these usages hardly play a role nowadays.

High forests

The composite and coppice forests were particularly important in the Middle Ages, but lost their significance as other energy sources, particularly coal, became more important. This is the primary reason why these forests were converted largely to high forests as more modern forestry methods were gradually introduced. This forest type accommodates a spectrum of silvicultural types (Filion, 1993) and these are used directly for:

- the production of high-quality lumber and building materials
- secondary materials including firewood, honey, mushrooms and wildlife
- recreational utilisation for athletes and walkers
- ecological tourism, particularly in nature reserves and landscape conservation areas
- hunting.

High forests also provide indirect benefits:

- for the environment:
 - the removal of toxins and dust;
 - increased storage and filtration of ground water;
 - flood and soil erosion protection;
 - removal of atmospheric CO₂ and temperature stabilisation;
 - recycling of biological products.
- as habitat for wildlife and many other sorts of flora and fauna.

Structure and development of forest communities

By extrapolation one can presume that until the early stone age (c. 5000 BC) the whole of Germany was wooded, although not as thickly as today, perhaps amounting to approximately 25 million ha (in West Germany). Apart from the steep mountain ranges and alpine regions, which were populated by coniferous trees such as spruces and firs, other wooded areas were composed of various deciduous trees such as hazel, birch, oak and beech. Until the early 19th century there was a continued decline in forest cover. Probably the greatest change occurred between 1300–1700. During this time, up to 70% of the forest area was lost. Those areas that remained forested were shaped by livestock farming. The most important trees were the oaks and beeches which produced mast for livestock. Today the forest area in Germany (West) covers approximately 7.55 million ha, i.e. 33% of the total land available (Table 5.1).

Table 5.1 Forest area and utilisation in the former Federal Republic of Germany

Usage	Area (ha)	%
High forests (including selection forests)	7 250 000	96.0
Composite forests	36 000	0.5
Coppice forests	81 000	2.4
Total woodland area	7 547 000	100.0

The relative areas of coniferous and deciduous forests and the main tree species compositions are shown in Tables 5.2 and 5.3 according to the most recent state forestry census (Bundeswaldinventur) in 1990.

The Atlantic climate with its warm summers and relatively mild winters has a definitive

influence on the development of the beech, mixed beech forests and oak forests which predominate at lower altitudes. In the more mountainous regions, conifer forests of spruce, pine and fir are more common. The main features of these forest types are summarised in Table 5.4.

Table 5.2 Composition of German forests (Bundeswaldinventur, 1990)

Coniferous (million ha)	Mixture	Deciduous (million ha)
1.91	pure	0.45
1.22	up to 10% mixture	0.67
1.76	10% or more mixture	1.33
4.85 (66%)	total	2.45 (34%)

Table 5.3 Tree species composition of German forests (Bundeswaldinventur, 1990)

Tree species	Million ha	%	Tree species	Million ha	%
Spruce	2.74	37.4	Douglas fir	0.12	1.6
Fir	0.16	2.2	Oak	0.71	9.7
Pine	1.33	18.8	Beech	1.22	16.6
Larch	0.23	3.2	Other deciduous	0.82	1.1

Table 5.4 Summary descriptions of German forest types

Forest type	Main species	Soils	Past management	Current management
Chalk beech forests	beech (<i>Fagus sylvatica</i>), ash (<i>Fraxinus excelsior</i>), elm (<i>Ulmus glabra</i>), cherry (<i>Prunus avium</i>), limes (<i>Tilia platyphyllos</i> , <i>T. cordata</i>)	chalk moraines	coppice/composite	high forest favouring natural regeneration of beech
Acid beech forests	beech, oak (<i>Quercus robur</i> , <i>Q. petraea</i>)	acid brown earths	composite forest, wood pasture	high forest with shelterwood favouring beech
Brown soil beech forests	beech	calcareous brown earths	conversion to conifer stands	high forest with beech favoured by planting
Acid oak forests	oak (<i>Q. robur</i>), birch (<i>Betula</i> spp.), rowan (<i>Sorbus aucuparia</i>)	acid brown earths	coppice, wood pasture, conversion to heath/ scrub	high forest with conversion to mixed stands of birch and oak
Maple-ash-lime mixed forests	Norway maple (<i>Acer platanoides</i>) and sycamore (<i>Acer psuedoplatanus</i>), ash, elm, common lime	gravel slopes/ravines	conversion to spruce stands	'retro-conversion' to maple-ash-mixed forest
Floodplain forests	willow (<i>Salix</i> spp.), alder (<i>Alnus glutinosa</i>), oak, poplar (<i>Populus nigra</i>)	nutrient rich, high water table	coppice, composite forests	regeneration of forest to control inundation
Fir forests	silver fir (<i>Abies alba</i>), Norway spruce (<i>Picea abies</i>), beech	acid	'plenter' (selection) forests favouring spruce	continuation of plentering
Spruce forests	Norway spruce, rowan	acid	protective against erosion/avalanches	protective
Pine forests	Scots pine (<i>Pinus sylvestris</i>), birch	acid diluvial	high forest, overgrazed	high forest, increased broadleaves

Historical significance of grazing

Forest communities were significantly shaped by heavy agricultural usage, particularly in the Middle Ages, but also up to the late 19th century, i.e. loss of woodland area to farming. The conversion of deciduous and mixed non-coniferous forests into pure coniferous woods occurred as a result of woodland grazing. Often only conifers such as pine and spruce, which are not as sensitive to grazing as deciduous trees, can re-forest heavily damaged areas, which were previously wooded. However, these man-made coniferous forests are being converted back to original mixed deciduous forests — not only due to ecological considerations, but also due to economic factors (Hasel, 1985).

Mast utilisation

In the past, almost all deciduous forest communities were used as a mast source for

swine, which used to be the most important meat source. Mast from oak, beech, walnut and chestnut was often able to provide all the required autumn and winter food for swine. It was only after the introduction of the potato and raising livestock in stalls (beginning of the 19th century) that mast forests became less important. Nowadays, they hardly play a role at all.

Utilisation as pasture for cattle and horses

As there were few ways of producing fodder for livestock in the Middle Ages, it was necessary to drive the larger animals into the forest and use it as pasture land (Anon., 1988). This occurred during the warmer spring and summer months and utilised both deciduous and coniferous forests. Livestock trampling resulted in soil compaction (up to 15 cm), 'cattle paths' on slopes, heavy browsing, and the

destruction of natural regeneration. Since farmers often ignored the pasture prohibition rules, this form of utilisation was therefore very destructive. Forest pasturing often resulted in the complete destruction of the forest, which in turn led to erosion, and flooding in Alpine areas. Only after the agricultural system changed and a structured forest management was implemented, was it possible to reverse this damage by sowing and planting coniferous trees. Forest pasture no longer plays a role in livestock raising in Germany, with the exception of the Bavarian Alps which have retained forest pasture rights in certain areas. This is, however, strictly limited and controlled.

Utilisation as pasture for sheep and goats

Herds of goats and sheep were even more damaging to the forest than the cattle and horses. Among the reasons for the immense damage caused by the sheep and goats were extreme browsing and bark peeling of all woody plants, and the complete destruction of natural regeneration. This initiated processes of vegetation change. The development of the juniper heaths in acid soil oak forest areas of North Germany as well as in the poorer forest stands of the uplands can be traced back to sheep and goat pasture. Only through better provision for the general population, other means of agricultural production and better forest management was grazing damage eventually reduced. Today, it is forbidden to graze sheep and goats in Germany's forests. Controlled grazing plays a role in preventing unwanted scrub and re-forestation of the heather heaths.

Utilisation as hunting grounds

Large areas were used by the nobility solely for hunting, particularly in the 17th and 18th centuries. Their priority was to cultivate and maintain a high ungulate concentration (red, fallow and roe deer and wild boar). Due to wildlife overpopulation, the already heavily damaged forests were subjected to further stress as the wildlife destroyed natural regeneration and young stands through bark peeling and browsing new growth. Deciduous trees were most susceptible to wildlife damage. This was yet another reason why many deciduous forests were converted to conifers.

Present-day significance of grazing

Browsing by wildlife

Overpopulation of wildlife is currently the most important factor limiting the potential fulfilment of silvicultural goals. In the most recent German forestry census (Bundeswaldinventur, 1990) the damage was recorded on unprotected trees: 33% of deciduous and 16% of coniferous trees between 50 and 130 cm tall had been damaged by browsing or rubbing. In contrast, trees, both deciduous and coniferous, protected individually or through fences showed 0.5–1% damage. Trunk damage caused by bark peeling occurred on 24% of unprotected deciduous trees and 25% of unprotected conifers with a diameter of over 10 cm. As a rule, there are two different factors which can account for a balance or imbalance between wildlife and its habitat:

1. The population density of the wildlife (influenced by hunting, feeding, available food, etc.).
2. The quality of the habitat (influenced by forest edges, forest structure, seasonal variation in food supply, etc.).

In terms of evaluating wildlife damage, the term 'quality of habitat' can be substituted for 'disposition of the forest to wildlife damage' (Figure 5.1). If the maximum population density of wildlife which the forest can support is exceeded, this leads to the destruction of saplings and natural regeneration, seeds or plantings. Even if the forest is not completely destroyed by wildlife, a loss of mixed species stands and wood quality can occur (Reimoser, 1986). This is a problem, for example, in fir-beech-spruce forests in the higher uplands, where the fir disappears because it is browsed by wildlife, even though it would regenerate successfully under low browsing pressure. A similar problem can be seen with maple and ash in mixed beech forests. However, as not all wildlife species influence forest management goals in the same way, each species has to be separately appraised. Red and roe deer are potentially damaging and, in certain areas so are moufflon and chamois (Gossow, 1976).

Deer

Roe deer can be found in all forest ecosystems in Germany. This animal is a browser and feeds

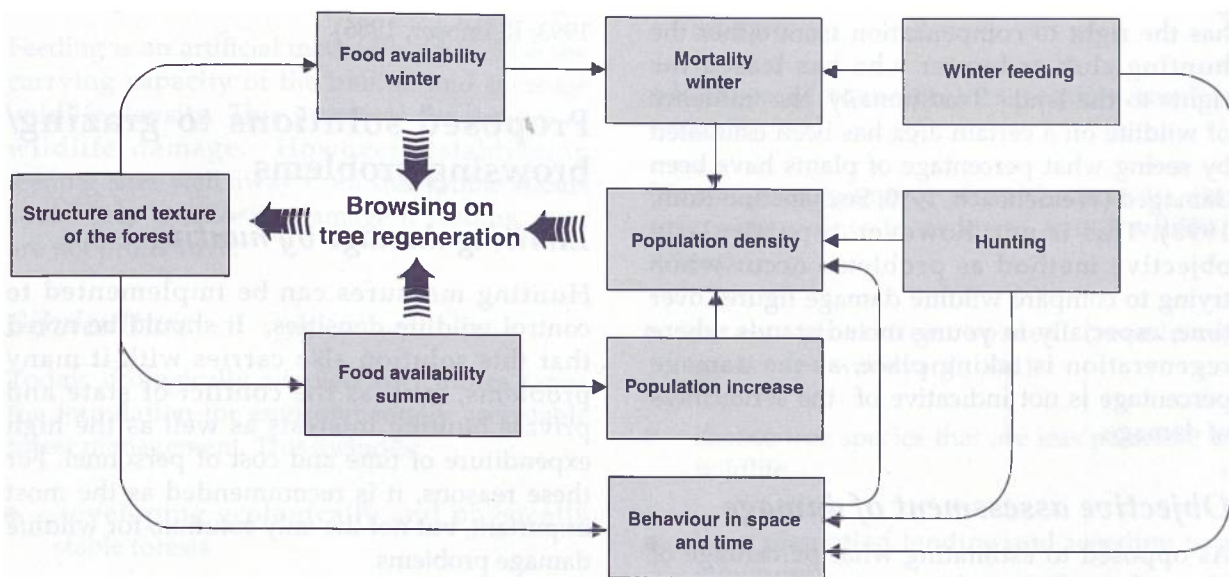


Figure 5.1 Simplified structure of the interrelationship between deer behaviour, population dynamics and management, and browsing damage to tree regeneration

selectively on shoots and buds of different trees and shrubs. Additionally roe deer require woody material which can only be found in shoots and bark. Due to this feeding behaviour and universal occurrence in Central Europe, roe deer can be labelled the most destructive wildlife species in terms of losses to forestry (Kech, 1993). Like roe deer, red deer also require adequate amounts of woody material. The bark peeling which occurs as a result of this has an economic impact, particularly in pole-stage stands. Due to the potentially serious damage that red deer can cause to forests, they are restricted to clearly defined areas through hunting.

Chamois

Chamois have much the same effect on forests as deer. As there are few chamois in Germany and these exist only in certain areas (parts of the Black Forest, Suabian Alp and main Alps), the frequency of damage is relatively small. Problems only occur when the chamois population rises above the level that the relatively scanty habitat in the uplands can support. Such cases can lead to severe damage in mountain and alpine protection forests.

Mouflon

The introduction of this wild sheep has the same effect on the forest as sheep and goats. Preventative measures must be taken to protect against browsing and bark peeling. Mouflon are found only in a limited area in Germany, but where they occur the damage is massive.

Legal foundation

The legal foundation for a solution to the forest-wildlife problem has resulted in many different laws and guidelines. For approximately a decade, German forest law and state forest laws, as well as silvicultural guidelines, have moved towards forest management close to nature with diverse species in mixed stands. An important principle of forest management is the establishment and development of forest communities which are adapted to their location and regenerated naturally. This principle has often met with difficulties including the overpopulation of wildlife, especially roe deer. Wildlife population densities should be appropriate to the landscape conditions and not hinder regular forest management. One of the reasons for the particularly high wildlife population density in Germany is its special hunting-lease system, which allows a separation between direct land usage and hunting, as the hunting rights may be leased to third parties. In order to help prevent such potential conflicts between the forestry administration and the private hunting lobby, most states have already produced guidelines for roe deer hunting which are binding for both parties.

Calculating wildlife density

In order to hunt effectively, the effects of wildlife on the vegetation must be assessed. As it is impossible to assess the number of deer in a forest to absolute accuracy, it must be decided whether the browsing damage is acceptable or not in any

given area. If damage is found, the landowner has the right to compensation from either the hunting club or hunter who has leased the rights to the land. Traditionally, the influence of wildlife on a certain area has been estimated by seeing what percentage of plants have been damaged (Weidenbach, 1990; Suchant and Roth, 1993). This is not, however, a particularly objective method as problems occur when trying to compare wildlife damage figures over time, especially in young mixed stands where regeneration is taking place, as the damage percentage is not indicative of the seriousness of damage.

Objective assessment of damage

As opposed to estimating what percentage of plants have incurred browsing damage, the systematic fence control method offers an objective assessment of the actual forest-wildlife problem (Reimoser and Suchant, 1992; Suchant and Roth, 1994). With this method the browsing damage to specific species and their terminal shoots can be compared to that within exclosures. The method allows the minimal needs for forest regeneration and survival to be assessed and provides an objective look at the actual damage occurring. Hunting practices can then be changed as necessary, with the result that forest and wildlife can co-exist.

Three step model for the evaluation of roe deer browsing

In 27 test areas the Forest Research Institute has investigated the influence of roe deer browsing on natural regeneration of mixed forest stands for about 18 years. The comparison between fenced control plots and nonfenced plots at the same site makes it possible to determine criteria which are essential for evaluating the influence of roe deer browsing. The following criteria have been developed: number of regenerated trees; species mixture in the top-height of the regeneration; relationship between browsing and height growth; and browsing rate.

To evaluate whether roe deer browsing causes silviculturally significant damage, a three step model has been developed. For this evaluation it is also necessary to define silvicultural goals at the outset. The examination of natural regeneration with the three step model shows that the browsing rate alone is not a suitable indicator of browsing pressure. A low browsing rate (<10%) for a certain species can cause silvicultural damage, a high browsing rate (>40%) can have no influence on the natural

regeneration (Roth, 1995; Roth and Suchant, 1993; Reimoser, 1986).

Proposed solutions to grazing/ browsing problems

Limiting damage by hunting

Hunting measures can be implemented to control wildlife densities. It should be noted that this solution also carries with it many problems, such as the conflict of state and private hunting interests as well as the high expenditure of time and cost of personnel. For these reasons, it is recommended as the most important, but not the only solution, for wildlife damage problems.

Game quotas

According to the guidelines in Baden Württemberg for the closed season for roe and red deer (Weidenbach, 1990), wildlife quotas should be introduced when:

- The establishment of mixed forests suited to the site is endangered. The principal tree species must be able to regenerate themselves without protective measures.
- Bark-peeling damage threatens the minimum number of trees necessary to ensure regeneration.
- The flora typical for the site has been significantly damaged by browsing and the diversity of species has diminished.

Disturbance through hunting activities

Wildlife fears man, especially the hunter. Therefore hunting seasons and methods must be adapted (Suchant, 1994) to include:

- short hunting times with long 'rest phases' even within the official open season
- hunting with decoys
- the use of favourable weather conditions
- intensive hunting at regeneration sites with browsing problems
- low intensity hunting in areas without browsing problems.

Feeding

Feeding is an artificial method used to raise the carrying capacity of the habitat and increase wildlife density. This increases the danger of wildlife damage. However, establishing feeding sites well away from susceptible stands could help ameliorate damage if feeding costs are not prohibitive.

Silviculture

Today, ecologically adapted silviculture forms the foundation for environmentally acceptable forest management. This includes:

- developing ecologically and physically stable forests
- retaining a large proportion of natural forest communities
- aiming for mixed habitats, with a diverse vertical structure
- taking advantage of the forest's potential to naturally regenerate
- care to avoid damage to ground vegetation and soils during forest operations
- pest control according to the principles of integrated forest protection
- taking into account nature preservation and landscape management aspects.

The link between forest and wildlife plays a definitive role in realising these goals. On the one hand, herbivorous wildlife can have a lasting effect on the forest system; on the other, the composition and structure of forests plays an important part in the influence that wildlife can have on the forest. Therefore, in solving wildlife damage problems, forestry management in its various forms must also be taken into account. The following factors are especially important:

1. The type and composition of the floor vegetation. This dictates the total browse supply (Suchant, 1994).
2. The structure and composition of the forest stands. This is important among other things as a source of camouflage and protection for wildlife.
3. Forest edges and spatial interrelations in the forest. These determine the spatial and

temporal behaviour of the dependent wildlife.

All three of these factors require further research.

Forest management should include the following points in order to avoid wildlife damage:

- retain stock-free spaces (meadows, grassways, woodyards, etc.)
- choose tree species that are less palatable to wildlife
- keep plantation tending and weeding to a minimum
- use the incident light along the edges of the forest and path borders to encourage vegetation development for browsing
- thin stands to encourage vegetation development
- favour trees which let sufficient light through to encourage understorey vegetation development
- promote the growth of naturally regenerated trees
- leave open spaces
- reduce the amount and duration of fencing.

Reducing damage by directing visitors

Recreation in the forest can also have a significant effect on wildlife distributions and behaviour, and hence forest damage. The following guidelines should be adopted to reduce the impact of people on wildlife:

1. Recreational traffic should be routed through sections that are composed of as little forest area as possible.
2. Summer and winter routes should be identical. This enables wildlife to become accustomed to people more easily and creates less damage.
3. People should be encouraged to use paths and cross-country skiing tracks by: creating high quality paths and tracks with

attractions such as panoramic views, etc. along the way; providing easy to read signs; providing links with facilities such as parking places, restaurants; designating quiet areas free of public traffic.

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Chapter 6

Forests and ungulates in Austria: problems, management strategies and research needs

Friedrich Reimoser

Summary

Forty-six per cent of Austria is covered by forest, consisting of 77% coniferous and 23% deciduous trees. Management objectives for these forests include timber production and environmental protection measures to reduce the risks of avalanches, rockfalls, torrents, erosion and wind damage. The forests provide a clean, healthy environment for residents and tourists, as well as provision of habitat for wildlife. Grazing by domestic animals (cattle, sheep, goats, horses) is common in certain areas of the alpine mountain forests. Some 13% of the total forest area is pasture, and parts are still being seriously damaged by these ungulates. Hunting is permitted throughout the whole forest area with the exception of a few wildlife preserves. Game damage by roe deer, red deer and chamois is a major problem in forestry, affecting up to one-third of the forest area per year, costing at least ECU 220 million per year (on average, ECU 220 ha⁻¹, with some 10 000 km² of forest damaged annually). The main reasons for wildlife damage are:

- Obstruction and fragmentation of wildlife habitat and disturbance of wildlife (e.g. by human settlements, highways, fences, tourism and hunting pressure).
- Over-abundance of ungulate wildlife, resulting from poor culling, incorrect winter feeding, shelter and cover provided by forest edges.
- Disadvantageous wildlife distribution (retreat areas in steep protective forests and in dense pole stands, particularly susceptible to wildlife damage).
- Existence of forests with a high predisposition to wildlife damage (e.g. strip clearcut systems with spruce afforestation).

Results of a study that sought to assess how experts viewed wildlife-damage control, its

implementation, and research needs, showed that 80% of the respondents sought better communication of existing research results, and actions to assure more effective implementation of the findings. Only 20% believed more basic research to be a priority. Obstacles hindering adoption of improved management practices reflect the complex nature of the problem at the biological, as well as the social and cultural levels. The need to involve all interested parties such as foresters, hunters, local communities, tourist administrations and conservationists at both the planning and implementation stages is highlighted. Implementation studies will require interdisciplinary research involving biologists as well as experts drawn from the social and management sciences. Some key areas for research are presented.

Introduction

The Austrian forests are cultivated landscapes, the product of centuries of human impact, and there are only small areas of virgin forests remaining. Despite cultivation, the forest for the most part has remained essentially semi-natural. Multiple use of land and forest has a long tradition, but was not planned systematically. Agriculture, forestry, hunting, tourism, traffic, industry and nature conservation, have all intensified their land-use activities in the same areas, but without sufficient consideration for, or co-ordination with, each other.

Consequently, a complex disruption of natural forest processes has occurred. Damage to wildlife, plants and animals is increasing, especially in forests, where the over-abundant ungulate wildlife results in twig browsing, bark peeling, and bark-fraying damage. In addition, there are problems caused by damage to the forest by domestic animals. This has been much reduced in recent decades, but it is still an important factor in some mountainous regions (e.g. the provinces of Salzburg, Tyrol and Vorarlberg). Many wildlife species are losing

their habitats as a result of human impacts; for example stocks of woodland grouse (capercaillie and hazel grouse) and cavity-using species have been rapidly decreasing in the last few decades.

Intense selective browsing of fir (*Abies alba*), maple (*Acer* spp.) and oak (*Quercus* spp.) by ungulate wildlife has resulted in a lack of regeneration of these tree species in several regions. So instead of stable mixed stands, unstable pure stands (e.g. only spruce) have emerged. This has been a problem not only in production forests of the lower altitudes or in the protective forests¹ of the alpine highlands, but also in the small nature conservation areas and national parks. This is especially true if hunting is prohibited (conservation areas are often retreats for ungulate wildlife during the hunting season).

Clearly the balance in forest ecosystems between animals, plants and the demands of humans is seriously disturbed, and these

systems must be managed if they are to be maintained to suit the diverse needs and wishes of humans. Consequently, there is a need for a better planned and active integration of animal species into cultivated landscapes to provide suitable habitat for plants and animals, and to reduce damage. As part of this, the natural interactions should be better utilised to achieve sustained regulation (Figure 6.1). The principles of a proposed integration strategy are:

- Define clearly the land-use aims for the various areas.
- Co-ordinate habitat and ungulate management (regarding content, area, time).
- Include wildlife as a site factor in planning tourism and forestry.
- Plan hunting and wildlife preservation to match the local capacity of vegetation (tolerable ungulate impact).

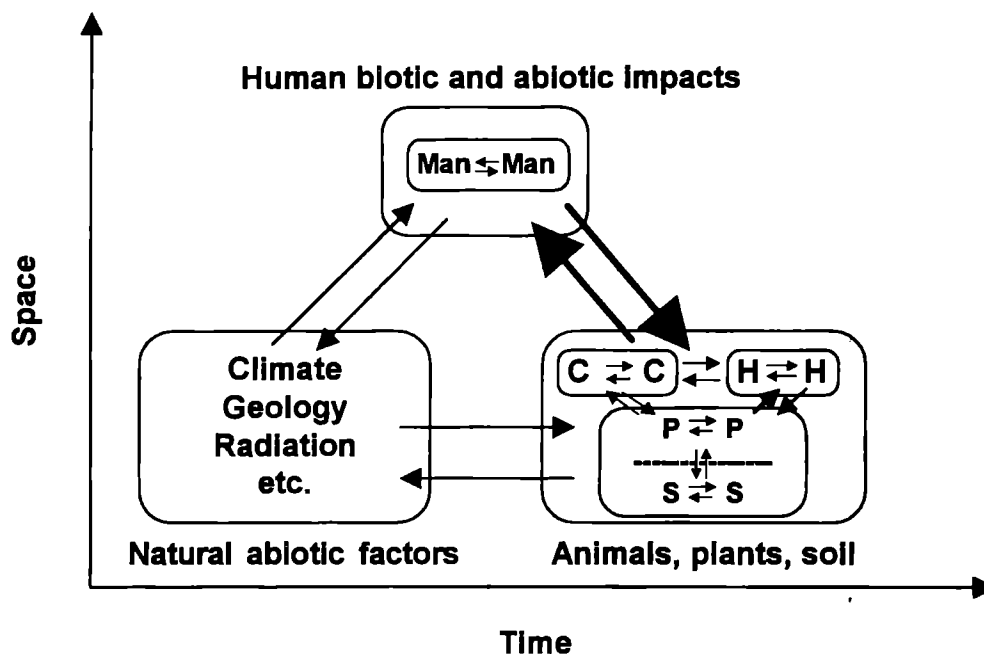


Figure 6.1 System of interactions (arrows) in forest ecosystems. The largest bold arrows show the interactions which are main research fields related to 'grazing as a management tool'. S: soil, P: plant, H: herbivores, C: carnivores

¹ Protective forests: forests preserved or planted to protect against avalanches, landslips, rockfalls, torrents, erosion, and wind damage etc., often vital to safeguard farms, communities and structures such as road or rail links.

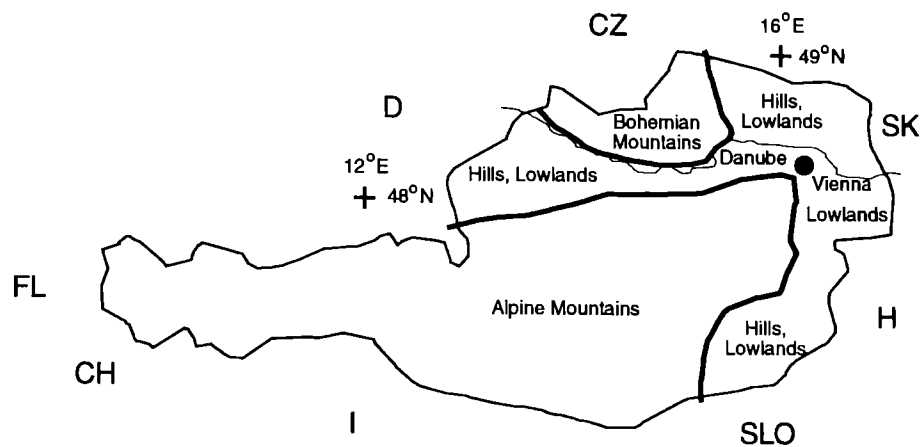


Figure 6.2 Regions of mountain forest (Alps; Bohemian mountains to the north) and lowland plains and hills in Austria. CH: Switzerland, CZ: Czechoslovakia, D: Germany, FL: Liechtenstein, H: Hungary, I: Italy, SK: Slovakia, SLO: Slovenia

The aspects presented below start with a short description of land-use, forests, and ungulate populations and related damage. The grazing situations of the past and the present, as well as the aims for the future, are summarised for the two main types of Austrian forest, that of the mountains and that of the lowland plains and hills (Figure 6.2). The impact of forestry on habitat quality and wildlife damage (a forest's predisposition to wildlife damage and aspects of damage theory), and suggestions for a flexible, integrated pattern of wildlife and forest management are considered in detail. Research requirements as determined in a separate study are also presented. The views of forestry, hunting, tourism and related regional authorities regarding the impact of research on practice are noted. The primary focus is on forest management practices in connection with ungulate wildlife and wildlife damage. In addition, forestry problems with livestock and a number of human impacts on the ungulate-vegetation interaction are considered.

Land-use, ungulates and forest

Austria covers an area of 84 000 km². It has 7.9 million inhabitants (mean population density 94 km⁻²). Forest covers some 46% of the area, with 0.5 ha of forest per head of population. Altitudes range from 150 m above sea level (Eastern Danube plain) to 3800 m (the Grossglockner). The average yearly precipitation lies between 500 mm (eastern areas) and 1500 mm (in the west), while the annual mean temperatures vary between 6 and 11°C, depending on region. The mountains are more humid and cooler.

Tourism

There is both summer and winter tourism, supported by a very varied landscape. The 7.6% share of the GDP is the highest of any European country. There are about 123 million overnight stays per year (16 stays per inhabitant), compared with only 16 million 40 years ago. Many tourist activities disturb the fauna and flora. The transport capacity of the lifts and funiculars is now more than 10 times as high as in the 1950s and together with forest roads have made alpine pastures above the forest line accessible to tourists, and so many wildlife animals have been displaced to lower altitude forests, giving rise to ungulate wildlife damage. Some 22 000 km of prepared ski-runs dissect the landscape, with additional problems arising from skiing outside the marked pistes (disturbing wildlife and damaging young trees). There are also problems caused by people hiking, mountain biking and paragliding. Thus in alpine areas wildlife is being disturbed and confined to its already scarce habitat. The animals take refuge in small areas, where browsing on young plants and bark peeling increases, to the detriment of the forest.

Agriculture

Approximately 43% of the total area of Austria is given over to agriculture, 24% to grassland (meadows, pastures, alpine grasslands), 18% to arable land and 1% to garden plots. In addition, some 13% of the forest area (especially alpine highland forests) is pasture, of which 5% is intensively damaged by cattle, sheep, goats and/or horses. The animals browse forest plants and cause trampling damage to roots and

soil. In many regions the upper forest margin has retreated 200 m down slope as a result of intensive exploitation of alpine pastures. This has proved particularly damaging to ecologically sensitive protective forests. A balanced perspective must be maintained; many summer tourists seek views, open scenery with free-ranging domestic animals. Conservation of such cultural landscapes is also needed to encourage this so-called 'rural tourism'.

The 'rights of forest pasture' date back to the Middle Ages. These were granted at a time when it was difficult to feed the population,

such that domestic animal grazing had to be given priority. These rights are no longer relevant under current conditions and procedures are being implemented to alter them to less problematical forms of land-use² (separation of forest and pasture, concentration on exclusive pastures, conversion into rights for wood utilisation, conveyance of land and property, etc.), while duly respecting the farmer's rights of redemption. The past and present grazing regimes in the two main types of Austrian forest are presented in Table 6.1, together with aims for the future.

Table 6.1 Austrian forests (closed and fragmented high forests): past, present and planned grazing regimes, vegetation structure and principal outputs (forest functions)

	Past	Present	Future
MOUNTAIN FORESTS			
Grazing regimes	High grazing pressure by domestic livestock (cattle, sheep, goats, horses) on forest with peak around 1850; fluctuating (low-moderate-high) browsing/bark peeling pressure by wildlife with highest peak around 1970	Moderate grazing pressure by domestic livestock; high browsing pressure by roe deer, chamois, red deer (also bark peeling)	Low grazing and browsing pressure
Vegetation	Conifer and conifer-deciduous mixed forest dominating; high floristic diversity; multi-layered forest canopy; many gaps	High proportion of even-aged conifer stands; shortage of deciduous trees; fewer gaps	Larger proportion of deciduous trees in forest regeneration; increased structural diversity
Main outputs	Fuelwood, hay, meat, timber, wildlife	Protection (against avalanches, rockfalls, torrents, erosion, wind); timber; environmental welfare (water balance, air filtration, CO ₂ fixation); wildlife (hunting); recreation (for population and tourists); sport; wildlife habitat; biodiversity	As at present, multiple use, sustainable in quality and quantity
LOWLAND FORESTS			
Grazing regimes	High grazing pressure by domestic livestock (cattle, sheep, goats, horses) on forest with peak around 1800; fluctuating (low-moderate-high) browsing/bark peeling pressure by wildlife, with highest peak around 1970	No or low grazing pressure by domestic livestock; moderate to high browsing pressure by roe deer and red deer (also bark peeling)	Low grazing and browsing pressure
Vegetation	Deciduous and mixed forest dominating; high floristic diversity; multi-layered forest canopy; many gaps	High proportion of even-aged stands; shortage of deciduous trees; fewer gaps	Larger proportion of deciduous trees in forest regeneration; increased structural diversity
Main outputs	Fuelwood, meat, hay, oak mast, tree litter, timber, wildlife	Timber; environmental welfare (water balance, air filtration, CO ₂ fixation); wildlife (hunting); recreation (for population and tourists); sport; wildlife habitat; biodiversity; protection against erosion and wind	As at present, multiple use, sustainable in quality and quantity

² It should be noted that forest pasturing seems to have a favourable effect on habitat for capercaillie, as does forest litter utilisation.

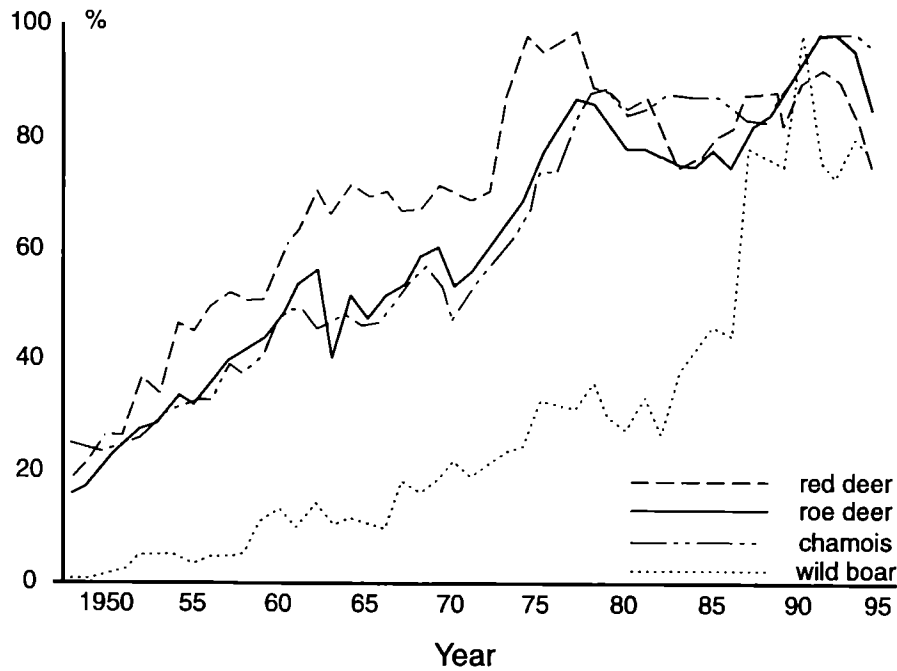


Figure 6.3 Yearly culling of wildlife ungulates in Austria since 1948, in relation to the maximum number for each species (= 100%). Maxima: roe deer 268 838 (1992); red deer 46 640 (1977); chamois 29 194 (1992); wild boar 13 205 (1990)

Hunting

Austria has 11 760 hunting districts (minimum district area of 115 ha). There are 111 000 hunters and 33 hunted wildlife species (16 mammals, 17 birds). The average annual bag of ungulates and woodland grouse (1993-94 data) was: 37 000 red deer, 247 000 roe deer, 29 000 chamois, 10 500 wild boar, 300 ibex, 600 capercaillie (*Tetrao urogallus*), 2400 black grouse (*Lyrurus tetrrix*), and 200 hazel grouse (*Tetrastes bonasia*). While the stock and culling of ungulate wildlife have strongly increased since the Second World War (Figure 6.3), the numbers of capercaillie and hazel grouse have decreased during the same period. In addition to the number culled, many animals were found killed by road traffic or dying from other causes (traffic/other causes ratios: roe deer 34 000/25 000; red deer 400/1000; chamois 50/1700; wild boar 100/70; ibex 0/40; capercaillie 0/30; black grouse 4/30; hazel grouse 2/25). These are recorded data; the actual figures may be significantly higher.

The hunting rights belong to the landowner. Each of the nine federal provinces of Austria has its own hunting law. These laws are to be amended to be more ecologically oriented. The fundamental principles for this have been developed by the Institute of Wildlife Ecology.

Two of the provinces (Salzburg and Vorarlberg) have already passed the new laws.

Forestry

Austria has 3.88 million ha of forest, of which 77% is coniferous (62% spruce) and 23% broadleaved trees. The average growing stock is 250 m³ ha⁻¹. The Austrian Forest Inventory lists the increment in production forests as 31.4 million m³ yr⁻¹ (stem wood), of which only 19.8 million m³ yr⁻¹ (63%) are felled. The annual quantity felled represents less than 2% of stocks. In recent years, the area covered by forest has increased by some 2000 ha yr⁻¹ on average.

Forest distribution

Forests are not evenly distributed over the federal territory. The mountain slopes in the alpine area are the most densely covered by forest (two-thirds of the total forest area). In areas well suited for agricultural purposes, forests were cut back in times gone by. Areas particularly poor in forest land thus lie in the east, where summers are warm, and in the high mountains, where the forest line has sunk as a result of exploitation of alpine pastures. The forest line in the Central Alps lies between 1900 and 2000 m above sea level, in the limestone Alps some 200 m lower. The tree line lies about 300 m above the border of the dense forest.

Coniferous forests mainly occur in mountain regions. In the plains and on hilly terrain, broadleaved forests dominate; mixed forests are to be found in the transition areas. Alluvial forests represent an ecological speciality in river basins or along major rivers where flooding occurs regularly.

The Austrian forest is dominated by conifers such as spruce and pine. This is partly because of the predominance of mountainous areas, where these trees grow well and partly because of their economic value. In order to eliminate the ecological drawbacks resulting from an over-emphasis on spruce and pine, Austrian forest policy has been endeavouring to enforce restoration of a natural species composition. Thus the share of broadleaved and mixed forests in the entire forest area has been significantly increased since the 1970s. The most popular tree species in the Austrian forest is spruce (*Picea abies*), with a 62% share. Further important tree species are pine (*Pinus sylvestris*, *Pinus cembra*), larch (*Larix decidua*), fir (*Abies alba*), beech (*Fagus sylvatica*), oak (*Quercus* spp.), maple (*Acer* spp.) and ash (*Fraxinus excelsior*). According to the Austrian Forest Inventory, the share of broadleaved and mixed stands is 33% and has increased from 31% since the 1970s. The change in vegetation structure with time is indicated in Table 6.1.

Ownership

Most of the Austrian forests are privately owned and are tended by silviculturalists within a very small-scale structure: 52% by area are small private forests (< 200 ha), 32% are large private forests (> 200 ha); only 16% are state-owned forests. The density of forest roads (suitable for lorries) comprises on average 34 running m ha⁻¹ (in 1990), compared with only 21 m ha⁻¹ in 1966. In production forests, forest roads reach a density of more than 40 m ha⁻¹. Persons gaining all or part of their livelihood from forestry in Austria include more than 214 000 owners plus 9000 working as foresters, forest wardens or professionally trained forest workers in private forest enterprises or with the Austrian Federal Forestry Commission. Game animals belong to the landowner and are an economic asset. However, they can also be a major problem when forest stands are being regenerated (twig browsing, bark peeling). Management aims to have enough wildlife to obtain an income from hunting leases and the sale of meat and trophies, while keeping populations low enough to allow forest stands to regenerate.

Forest law

Forests have been under strict legal protection for a long time. Sustainability has been the most important rule in the forest law for more than 100 years. Clearcuttings exceeding 0.5 ha require official permission and are prohibited in excess of 2 ha. Forest enterprises of over 500 ha must be supervised by appropriately certified personnel. Since 1975, the public have had access to forests for recreation. Only forest plantations, felling areas, areas of windblow, etc. are closed to the public. The picking of mushrooms and berries is limited in order to protect the forest ecosystem. Skiing is prohibited in areas adjacent to ski-lifts and ski-runs. Cycling and horse riding on forest roads is only permitted with the consent of the forest owner. Cross-country cycling is strictly prohibited, as are all forms of damage or contamination, particularly unchecked garbage disposal. All forest areas are supervised by the national forest authority.

Sustainable functions and outputs (Table 6.1) of a forest are considered to be:

- timber production (commercial efficiency);
- protection (against avalanches, rockfalls, torrents, erosion, wind);
- environmental welfare (water balance, air filtration, CO₂ fixation);
- recreation (population and tourists);
- provision of a secure habitat for wild plants and animals (this fifth function is not yet enshrined in forest law).

Initiatives and endeavours to solve forest and wildlife problems are regularly launched. Some of the federal provinces have made amendments to their hunting regulations so as to secure a well-balanced, harmonious coexistence of forest and wildlife. The future separation of forests and pastures is expected to minimise damage by trampling and browsing. The following five programmes were prepared by the Federal Ministry for Agriculture and Forestry with the aim of conserving and protecting the forests on a long-term basis.

- *Action programme for the protective forest.* In a mountainous country such as Austria, the protective function of the forest (see footnote 1) is of particular importance and improving such forests is a matter of great priority. One-third of all the Austrian forest area is

primarily protective in intent. The protective effect, however, is in many places jeopardised by the poor condition of the forest, and/or by an unsatisfactory or a complete lack of regeneration. Some 161 000 ha of forest with an immediate protective function for settlements, road and rail infrastructures, etc., urgently require improvement. Forest practices must be adopted that speed up regeneration in order to prevent local breakdown and to guarantee continued protection. The creation of regeneration areas and the suppression of damaging agents are just as much part of protective forest improvement as are the complementary reforestations at high altitudes and other technical protection measures. Practical implementation is effected by forest owners in co-operation with the Torrent and Avalanche Control Service. Since 1989, some ECU 90 million have been spent by the federal government on an area of more than 70 000 ha.

- *Regional forest zoning.* Regional forest zoning is carried out using the forest development plan and the danger zone map. The forest development plan is a planning framework showing actual forest conditions, pointing out key functions and listing future perspectives so as to assist optimal and sustainable maintenance of the functions of the forest (cf. Table 6.1). All operational measures required are indicated, and prioritised according to urgency. The forest development plan is used as a basis for making political decisions in respect of forests at a federal or provincial level. To an increasing extent it is also being used for general zoning and transport planning. Furthermore, the forest development plan provides the basis for reforestation that has become necessary in the public interest, above all in sparsely wooded areas. Clearly, in zoning, several different forest functions may be combined, but the implementation of at least one function is paramount. Danger-zone maps are prepared by the Torrent and Avalanche Control Service. These maps show areas where the risk of torrents and avalanches is high. They are basic documents for land development. The aim is to prevent settlements, houses and transport infrastructures from being erected in endangered areas.
- *The National Forest Inventory.* Since 1961, all important statistics concerning the structure

and development of Austrian forests have been registered in the National Forest Inventory. Assessments are made to obtain the following key data: type of enterprise and property; forest area; amount of wood stocked; increment and utilisation; ratio of tree species; damage; care measures; ecological characteristics. The forest inventory is updated every five years. The regular inventory of the entire Austrian forest is an important instrument for monitoring the forest industry with a view to ensuring sustainability, and for action to be taken by forest authorities.

- *Forest damage observation.* A comprehensive forest damage observation system has been set up in Austria. Changes in the developments within the forest affecting the forest environment are observed and documented. The system was developed by the Federal Forest Test Institute in order to obtain a closer approach to the cause-effect complex of 'new types of forest damage'. The condition of crowns and soil are assessed in 534 permanent observation areas, and infra-red aerial photos of selected problem areas are evaluated. Annual chemical analyses of needles and leaves are used to determine the effects of accumulated (hence concentrated) air pollutants and the nutritional condition of the trees.
- *Natural Forest Reserve Network.* Natural forest reserves are sections of forest dedicated to the natural development of an ecological forest system in the absence of any direct human intervention. They are left untended for the purpose of preserving biological diversity, permitting research and instruction, and a chance for the general public to 'come face to face with nature'. Game damage is a problem in most of the reserves. A unique, extensive research project has addressed the question: 'How natural are the forests of Austria?' (Grabherr *et al.*, 1997). The effects on domestic forests of wood cropping, forest pastures, hunting, and other forms of forest use were analysed. Of some 3.88 million ha of forest, more than 20% can be considered semi-natural or natural. These terms have been defined according to very strict criteria. *Natural* (3%) means 'without human impact' (though there might have been historical influences, which are no longer discernible today). These forest zones are located mainly in the inner Alps and the northern and southern limestone Alps. The remarkably high

proportion of zones classified as *semi-natural* (22%) comprises weakly exploited forests featuring a natural blend of tree species with low perturbations to ground vegetation and forest composition. *Moderately altered* forest zones (41%) represent the largest proportion. These forests are all exploited, however, at least some residual natural vegetation remains. The structure of the forest stand, i.e. stratification or age, has been distinctly altered by wood cropping and forest pasture practices. Lastly, about one-third of the entire forest area is considered as *altered* (27%) or as *artificial* (7%). These areas are heavily exploited and the composition of tree species no longer corresponds to natural conditions. These forests are often dominated by foreign tree species. The percentages of natural and unnatural forest areas vary greatly from province to province.

Wildlife damage – too many animals in a disturbed environment

Forests are the natural habitat of numerous animals and plants and they form a complex, interacting community. Some of these animals are hunted, and the unnatural promotion of wildlife species favoured by hunting, coupled with the constriction and disruption of the wildlife habitat, considerably affects the ecological balance. Grazing of regenerating forest stock by roe deer, red deer and chamois does not pose a problem as long as the growth of sufficient new trees can be realised. Where browsing becomes excessive, however, leading to a reduction in the diversity of regenerating species, or preventing regeneration altogether, the situation becomes ecologically unacceptable. Browsing damage is also a greater problem when seed trees die early as a result of pollution, since later regeneration when browsing impact has been diminished is no longer possible, as the density of seed trees will have been reduced too greatly.

The main currently accepted causes of wildlife damage are:

- Reduction and fragmentation of wildlife habitat and disturbance of wildlife (e.g. caused by human settlements, roads, fences, tourism and hunting pressure).

- Restricted wildlife distribution (retreat areas in steep protective forests and in dense pole stands particularly susceptible to wildlife damage).
- Over-abundance of ungulate wildlife, arising from poor culling and incorrect winter feeding, as well as by the wildlife remaining in and around forest edges and in areas with good shelter and cover (Reimoser, 1986; Reimoser and Gossow, 1996); a result of incorrect forest management.
- Existence of forests with a high predisposition to wildlife damage (e.g. strip clearcut systems with spruce afforestation).

An objective and realistic assessment of browsing damage is difficult, particularly in relation to natural regeneration (Reimoser, 1986, 1992). Different estimates have given different results. According to the reports of the regional forest authorities, forest regeneration is impossible without protective measures on 24% of forest areas, and the growing of mixed stands is prevented by browsing on a further 49%. An equilibrium between forest and wildlife (i.e. no regeneration problem) existed in only 27% of Austrian forest areas in 1993.

Browsing is particularly heavy on firs and broadleaved trees, and has led to a significant decrease, in particular, in sapling firs. Further heavy damage is caused by red deer peeling young and medium-aged trees. Bark peeling damage has been recorded on 8% of all trees in Austrian production forests.³ Peeled trees are invaded by fungi, which cause rotting of the stem. This in turn leads to a devaluation of the timber, a reduction in stand stability, and a reduction in the protective effect of the forest. However, attitudes towards browsing damage depend on the forest operator's view of economic priorities. Landowners are more tolerant of browsing damage if income from hunting is the priority, e.g. when timber prices are low or timber extraction costs are high.

A special wildlife-damage rating was undertaken in 1991 (Reimoser, 1991a). Game damage (browsing, peeling, fraying) was found to affect one-quarter to one-third of the forest area annually (in this study damage was

³ Assessed for trees with trunk diameter >5 cm at 1.5 m above the ground.

considered only to exist if ungulate wildlife made healthy forest development impossible in terms of site conditions and target growing-stock, i.e. not every browsed or peeled tree implies damage to target stock). The monetary rating of damage resulted in a figure of at least ECU 220 million per year (on average ECU 220 ha⁻¹; at least 10 000 km² damaged forest area). In protective forests, wildlife damage was found to be increasing; in production forests it was decreasing (the result of changing wildlife distribution caused by man). The browsing/peeling impacts of ungulate wildlife in the two main types of Austrian forest in the past and at present, as well as expectations for the future, are indicated in Table 6.1.

Impact of forestry on habitat quality and wildlife damage

Inadequate culling programmes for ungulate wildlife and other mistakes in wildlife management relating to hunting have been intensively discussed. However, the influence of forest management (especially of different silvicultural techniques) on the interrelations between forest, wildlife and wildlife damage has not been fully recognised or investigated by forestry or hunting authorities. Forestry practices are now changing, and in some areas wildlife habitat management is practised with the aim of reducing a forest's predisposition to wildlife damage.

Predisposition to wildlife damage

During the last 15 years, forest-ungulate interactions have been investigated in several areas of Austria. An attempt was made to determine the main factors responsible for wildlife damage and the most important silvicultural factors influencing a forest's predisposition to wildlife damage (Reimoser, 1988a, 1992). Some principal findings are briefly summarised below.

Game (wildlife) damage can be expressed as a function of a target, a pressure of wildlife on plants, and a predisposition of the forest to wildlife damage. If the target growing-stock for a forest is uniform, damage can result from browsing, peeling, fraying, and trampling pressure of wildlife (frequency of plants and trees damaged by wildlife) and from the predisposition of the forest habitat to wildlife damage. Game damage, GD , in forest stands increases with increasing frequency, F , of trees damaged by wildlife as well as with the

increasing predisposition, P , of the forest to wildlife damage:

$$GD = F \cdot P \quad (1)$$

F in turn depends on mean frequency of trees damaged per animal per day (F_m), the wildlife density (D), and the occupation period (t), in days:

$$F = F_m \cdot D \cdot t \quad (2)$$

The predisposition of a forest to wildlife damage (P) is a result of both settling attractiveness (settling stimulus) of the habitat for wildlife and available feeding. P increases with increasing habitat attraction (HA) and decreasing available food (AF):

$$P = \frac{HA}{AF} \quad (3)$$

The ratio HA/AF in equation (3) is crucial. Seasonal food composition and the regeneration density (Reimoser, 1986; Reimoser and Gossow, 1996) are important factors influencing AF .

The habitat attraction (HA) for ungulates, on which wildlife density and distribution as well as browsing intensity primarily depend, is determined by both food-independent settling stimuli and food supply. The former were found to play an unexpectedly important role (Reimoser, 1986). These food-independent factors include terrain conditions, climate, edge-effects, wildlife disturbance and competition impacts (intra- and interspecific, including man), and thermal and hiding cover availability.

The impact of forestry on food supply and food-independent factors affects habitat quality, the density, structure and dynamics of ungulate stocks, the predisposition of forest to wildlife damage, and the scale of wildlife damage that arises. Indeed, forests with a badly managed HA/AF ratio, i.e. ratio of settling stimulus to available food, act as 'ecological traps'. The limited supply of food is taken intensively by the over-abundant ungulate wildlife, causing heavy twig browsing and bark peeling of timber species. Thus wildlife damage is provoked (Reimoser, 1986; Reimoser and Gossow, 1996). It was shown, however, that wildlife density is only one factor that affects wildlife damage, and therefore the latter can arise at any wildlife density.

A rating of different silvicultural practices (on montane sites with spruce–fir–beech forests) in respect of wildlife-damage predisposition is given in Table 6.2. Each example is rated numerically for browsing and peeling disposition. A score of 1 shows lowest predisposition: for details see Reimoser (1986) and Reimoser and Gossow (1996).

Our study results and the theoretical consequences concerning predisposition to wildlife damage relate to montane and sub-alpine site conditions (in Austria above 700 m altitude). The consequences for lowland sites may be different (e.g. where regeneration growth is much faster, there is less snow in winter, etc.). In forests that are broken into many small areas incorporating meadows, arable fields and/or settlements, the various extraneous influences (e.g. agriculture), interfere with and weaken the habitat-determining effects of forestry practices. In extensive areas of unbroken forest, those practices exert the principal influence on the quality of a habitat for wildlife and on the wildlife's impact on the forest.

Effects of different wildlife species

Roe deer, as selective browsers, tend to be solitary animals, especially within a forest. Thus, for these animals, habitat assessment in terms of biotopes and forest structures gives useful information (e.g. Reimoser, 1986). However, red deer and chamois are longer lived and more social, and they react more sensitively and adaptively to disturbances, habitat changes and disturbance, as well as to changes in

resources. The effects of hunting and tourism (as a re-enforcer of long-term hunting pressure) make a simple, solely vegetation-based evaluation of habitat suitability and carrying capacity less meaningful (Fischer and Gossow, 1987). This also applies to supplementary feeding.

Some aspects of wildlife damage theory

Foresters have difficulties in assessing objectively the damage done by wildlife (e.g. Mayer and Ott, 1991; Donaubaue, 1994), as the importance of wildlife damage to any particular forest or stand of trees is specific to the management objective for that forest or stand. Operational targets need to be set, but quantification of damage is difficult because 'Not every twig browsed represents damage to a tree; not every tree damaged represents damage to a stand' (Reimoser, 1994). So when does a disturbance of vegetation by ungulates become damage? To ascertain objectively the existence of wildlife damage, the following must be specified:

- *Is there a need for stand regeneration?* For example, after a pole stand has regenerated for an appropriate period after tending, it has no further need for regeneration. Browsing cannot then be counted by the forester as 'damage' because any regeneration would, even without browsing, die off as stand cover increases again. In other words, the browsing impact is now included within 'compensatory mortality' and therefore does not affect the further

Table 6.2 Rating of predisposition to browsing and peeling damage of different silvicultural systems for a complete forestry working cycle

Silvicultural system	Predisposition to damage ^a	
	Browsing	Peeling
Small clearcuts, reforestation	5	5
Large clearcuts (> 2 ha), reforestation	2 (3)	5
Shelterwood felling, natural regeneration	1	4 (3)
Shelter-strip-group felling, natural regeneration	1	3 (2)
Group selection felling, natural regeneration	2	3 (2)
Single tree selection, natural regeneration	4 (5)	2

^a Index 1 = lowest/best; 5 = highest/worst. Numbers in parentheses indicate tendency of index.

development of the stand. Some decades later, when the stand needs to regenerate again, the same browsing impact may truly be 'damage'. The concept of compensatory mortality is usually discussed in connection with animal populations, but it is at least as important for plant populations. Because of this effect, when assessing wildlife damage, the mortality of trees is less important than the number that survive.

- *The operational regeneration target.* A target set at the planning stage might be, for example, 3000 young trees per hectare undamaged with a distribution of at least 20% spruce, 10% fir, 20% beech, the remainder being of the same or other tree species. If, after disturbance by wildlife, there are still enough undamaged trees to fulfil the target, the browsing will not have reached the level of 'damage'. Thus, when calculating wildlife damage, the first step is to focus on the number of undamaged trees.
- *The response of trees to browsing.* The effect of browsing depends on the tree species, site conditions, time and intensity of browsing, etc. Again, not every twig browsed qualifies as damage to the tree.
- *Determination of the damaging species.* Is the impact truly being inflicted by wildlife or by other species (e.g. cattle, sheep, mice, humans)? Only wildlife can effect 'wildlife damage', but there are many causes of damage to trees, often with very similar symptoms.

These concepts have been incorporated into methods for browsing-damage assessment in Vorarlberg (Reimoser, 1991c, 1996b) and in Baden-Württemberg, Germany (Reimoser and Suchant, 1992 ; Roth, 1995).

Promotion of a flexible, integrated pattern of wildlife and forest management

Studies have confirmed that forest management practices have a profound influence on the settling and feeding of deer (e.g. Reimoser, 1986; Reimoser and Gossow, 1996). Thus, to limit wildlife damage, the forest manager will have to recognise that forest management is essentially habitat management, and the interplay between damage and habitat management must be investigated more

effectively if a better balance between wildlife and forest is to be achieved.

To date, reduction of ungulate wildlife damage has been the most important driving force for taking wildlife ecology into account as part of forestry management. However, a more wildlife-oriented silvicultural system is needed. Forestry measures will have to include fewer clearcuts and the adoption of new forest use and regeneration strategies. But forestry measures alone cannot solve the problem; they must be combined with measures that recognise the aims and targets of all stakeholders, e.g. foresters, hunters, farmers, tourist authorities, with plans co-ordinated over large enough regions to be relevant for the wildlife species of interest. Game (especially red deer and chamois) do not remain within one area (e.g. seasonal migrations) and can, therefore, only be managed expediently by planning control for sufficiently large areas. A concept for landscape-scale planning, with integrated management of deer and chamois as well as their habitats, has been developed and realised in two Austrian federal provinces, Salzburg and Vorarlberg (Reimoser, 1988b, 1996a).

The primary aims of planning efforts are to reduce forest damage by achieving a better wildlife distribution, as well as by reducing stress on wildlife caused by man. Forest managers must collaborate with the representatives of farmers, hunters, tourist boards and the local communities to ensure an understanding of each other's needs and problems; this will result in an effective, co-ordinated management programme, supported by all concerned.

The monitoring and evaluation of successful projects have shown that to realise integrated management planning the sociological dimension must be taken into account (Reimoser, 1989). Implementation of measures to assure a more harmonious balance between different interests (Table 6.3) requires that socio-economic and politico-administrative aspects as well as ecological aspects be taken into account. The measures themselves will depend on the aim, either to minimise or to optimise the impact of ungulate grazing on forest vegetation (grazing control or grazing use). In support of this, objective methods of wildlife-damage control have to be developed, e.g. systematic establishment of control enclosures (Reimoser and Suchant, 1992; Reimoser, 1996b). Some aspects of forestry and hunting control

measures are discussed briefly below. A more detailed discussion of these and other measures may be found in Crawford (1984), Gossow (1986), and Reimoser (1986, 1988a).

Choice of silvicultural system

Crawford (1984) put the question: '*Is good forestry good wildlife management?*' Investigations as well as practical experience have shown that silviculture that is 'close to nature' and properly planned often results in three distinct benefits: (1) good, i.e. more profitable, forestry; (2) good resistance to wildlife damage; and (3) a good wildlife habitat with greater wildlife species diversity (e.g. Eiberle, 1979; Loidl and Reimoser, 1980; Crawford, 1984; Reininger, 1987). While many foresters are still of the opinion that clearcutting is always the more profitable form of management, a steadily growing number are beginning to recognise its disadvantages. Indeed, it appears that what may be lacking is access to valid information and further training

to improve the standards of knowledge and qualifications of foresters and hunters alike.

Wildlife-damage prophylaxis should be considered and integrated into the planning and practice of forest operations more frequently. Unfortunately, Central European foresters have long been, and often still are, of the opinion that these forest-wildlife problems are primarily a matter of wildlife-density reduction. Yet often, where hunting efforts and culling have been intensified, the reduction of wildlife damage has not turned out to be as effective as planned (Gossow, 1986).

Choice of tree species: ratio of conifers to broadleaves in mixture

It is important to achieve a proper balance between deciduous and evergreen tree species. If there are only evergreen species such as spruce and fir, food supply in the dark stands is poor. While there may be excellent shelter and

Table 6.3 System of measures for a more harmonious balance between plants, animals and humans (minimising both damage to forest plants and disturbance to animals)

<p>1. Forestry measures</p> <p>1.1. Silvicultural system (harvesting method, regeneration technique, regeneration period, etc.)</p> <p>1.2. Choice of tree species (mixing ratio)</p> <p>1.3. Forest tending (technique, intensity)</p> <p>1.4. Forest accessibility (forest roads, extraction lines)</p> <p>1.5. Objective result control (monitoring), wildlife-damage control system (control fences, etc.)</p> <p>1.6. Technical protection against wildlife damage (single trees, areas)</p> <p>2. Hunting measures</p> <p>2.1. Hunting system, area limits, dividing lines</p> <p>2.2. Regulations for wildlife shooting (culling)</p> <ul style="list-style-type: none"> ● regional wildlife planning (central, peripheral or free area for a wildlife species – different measures) ● culling quantity (number of animals) ● technique and strategy of hunting ● seasonal distribution of shooting ● spatial distribution of shooting <p>2.3. Game feeding, winter enclosures</p> <p>2.4. Habitat improvement by hunters</p> <p>3. Touristic measures</p> <p>Establishment of areas protected against man</p> <p>4. Agricultural measures</p> <p>Especially regulations controlling forest pasturing</p> <p>5. Co-ordination measures</p> <p>Integrated area and land-use planning</p>
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cover, the ratio of settling stimulus to available food, HA/AF , is out of balance and the predisposition of the forest to wildlife damage (P), is increased, i.e. wildlife damage is encouraged. In central Europe, large areas naturally dominated by deciduous trees were afforested only with spruce. Increasing the proportion of deciduous species within these forests will take several decades. Problems regarding re-establishment of indigenous tree species are evident, because the replanting (without protection for the young trees) is very susceptible to selective browsing.

Thinning

Thinning of thickets and pole stands allows more light to reach the ground; the food supply increases, while shelter and cover are reduced. Thinning brings about a more balanced ratio between available food supply and food-independent settling stimulus, and hence the disposition to wildlife damage is reduced.

Stand edges

Visually striking stand edges should be avoided to reduce wildlife damage. Indeed in the 1930s, Leopold (1933) had referred to an 'edge effect' and pointed to the increased presence of certain wildlife species at boundaries between different habitats. He believed this effect was linked to the overlapping of habitat types (simultaneous availability of the benefits of more than one habitat element) and/or the greater richness of vegetation in the edge zone. For roe deer, which typically frequent hedgerows and forest stand edges, it became clear from investigations by Gossow (1986) and Reimoser (1986, 1994) that edge zones play an important role. However, it appeared that it was the separation of habitat types that was important for roe deer, not the overlapping as postulated by Leopold. It was noted that roe deer did not feel at ease in forests with irregular and diffuse, eye-level vegetation, even where such areas offered the most varied and best supply of food. They preferred visually striking edges, which appeared to assist their orientation, probably a function of the physiology of the roe deer eye (Reimoser, 1986, 1994). If differentiated habitat types bounded by sharp edges were in close proximity, this unnatural, visually attractive habitat provoked deer over-abundance and, hence, wildlife damage.

Aspects to be considered in the change to be 'closer to nature'

In Austria there is an increasing public demand that forests be restructured into more 'natural' ecosystems. This is matched by an obvious readiness to do so on the part of many foresters. In connection with the reduction, in particular, of wildlife damage, such 'restructuring' requires carefully planned implementation. A forest plantation often starts with reforestation of a clearcut area or an afforestation of an abandoned meadow. Thus there is no pioneering phase of a typical initial succession of brush and non-timber trees, herbs and perennials. It is noted that this type of vegetation also offers a very suitable food base for ungulates and serves as a helpful buffer against deleterious browsing of timber tree saplings growing in the wake of this succession. In this connection, elder stands (*Sambucus* spp.) should be supported as a source of food for herbivores, especially by upgrading the understorey and ground vegetation layers through improved and better directed thinning and clearing operations (cf. Loidl and Reimoser, 1980; Reininger, 1987; Reimoser, 1988a).

Hunting strategies

There are currently no laid down procedures to highlight best hunting techniques and strategies to use in a particular situation, such as stalking, waiting in a hide or battue, interval hunting and focus hunting (Reimoser, 1991b). Optimising culling success without high hunting pressure is necessary to control timid wildlife species. This would effect a better wildlife distribution, less wildlife damage, easier culling and less disturbance by tourists. Inefficient hunting strategies and increasing tourism cause several wildlife species to be restricted to less accessible forest areas. The resulting wildlife damage, caused primarily by roe deer, is fairly well distributed throughout re-afforestation areas. Thickets, pole stands and young tree stands are particularly affected by the bark stripping of roe deer but also increasingly now by chamois. These animals, which prefer areas at or above the timberline, react to increased hunting pressure and to the increasing and reinforcing impacts of tourism with avoidance strategies that have caused them to move into forests (the so-called forest chamois). They prefer forests with cleared areas, e.g. with forest roads, clearcuts, clearings for ski-runs, and also storm

damaged areas (e.g. Hamr, 1988; Gossow, 1992). More detailed research is needed to clarify how problems resulting from hunting and tourism can be avoided.

Protected areas

Increased public access to forests in Austria (a result of the 1975 forest law), together with the continuing development of tourism (in particular affecting the alpine highland pastures above the forest line) and greater hunting pressure, have significantly added to human disturbance of wildlife. This has resulted in an increasing call for zones protected against man's intrusion (Gossow, 1986). Present-day tourists show a greater readiness to accept the need for wildlife protection and related rules, e.g. keeping strictly to paths in conservation areas. Providing protection for deer and chamois habitats outside the forest (e.g. on highland pastures) is also of great importance. This will reduce human pressures that force them into the forest, where the resulting high wildlife density aggravates wildlife damage. Further research is needed to see how protected areas may be used to steer wildlife into areas less sensitive to damage.

Winter feeding and winter enclosures

Supplementary feeding of red deer (less necessary for roe deer) results in wildlife markedly changing their avoidance and habitat-use strategies. Such feeding serving as an overwintering strategy is an important steering instrument in alpine red deer management, but is not equally effective everywhere and at all times (e.g. Gossow, 1986, 1987; Schmidt, 1992, 1993; Schmidt and Gossow, 1991). However, winter feeding can increase as well as decrease wildlife damage. Provision of such feeding sites have often been found to be counterproductive if judged by their effectiveness in preventing browsing and bark peeling (e.g. Gossow, 1985; Gossow *et al.*, 1987; Sackl, 1992). Key problems are incorrect use and a need to increase the annual cull, an aspect usually forgotten (Reimoser, 1990).

A further management tool for red deer is to provide fenced winter enclosures around a feeding station (about 10 to 50 ha enclosures with 30 to 150 head, respectively). This is a kind of 'makeshift' non-ecological solution which, nevertheless, eliminates wildlife damage outside the enclosure during winter and spring and disturbance by tourism inside (Reimoser

and Onderscheka, 1987). With limited use, this technique might be tolerable in heavily cultivated landscapes but it is much better to provide safe, ecologically sound winter habitats.

Tourism

The impact of tourists on the environment is well recognised. Ryan (1991) gives a good overview of recreational tourism from a social science perspective. The impacts of tourism are currently being studied. The World Tourism Organisation (1983) has highlighted alteration of the ecological balance and an increase in activities producing irreconcilable land-use conflicts as two main impacts. Phillips (1988) sets out six principles to guide tourist activity. The relevant principles here are: promotion of enjoyment of the countryside should primarily be aimed at those activities which draw on the character of the countryside itself, its beauty, culture, history and wildlife; and those who benefit from rural tourism should contribute to the conservation and enhancement of the countryside. Echoing these principles, it is clear that the representatives of the tourist trade at local and regional levels have an interest in sustainable management of the countryside, and hence the forests. Thus they should be involved in land-use planning, and the funding of conservation measures, even related research.

Research needs

A study was undertaken to assess how different experts with an interest in wildlife-damage control in forests viewed the problem and characterised the difficulties in implementing control measures (cf. Reimoser and Völk, 1988, 1990). Over 400 questionnaires were distributed throughout all provinces and political districts of Austria. The responses were analysed with respect to the concern about wildlife damage and the disparity of opinions between individuals and groups having different fields of interest (public forest administrations, forestry professionals, torrent and avalanche control organisations, hunters, rambler associations, conservationists, etc.).

The results of the analysis clearly showed a need for research into methods of implementing current management recommendations as well as more biological/behavioural research. The complex nature of the wildlife damage problem was recognised (interaction between the various biological, ecological, sociological, cultural, economic, political and administrative factors).

Table 6.4 Austrian forests (continuous and fragmented high forests): principal grazing problems, important interactions and available information

	Problems	Important interactions	Information available
Mountain forest	High incidence of forest damage by over-abundant roe deer, chamois and red deer (browsing, fraying, peeling); in some regions also heavy grazing by cattle and/or sheep; reduced recruitment of fir (<i>Abies alba</i>) and deciduous trees to old growth stages (often labile pure stands, particularly of spruce)	Effects of selective browsing on plant community dynamics and soil productivity; effects of forest management on animal behaviour (habitat and food plant selection), and predisposition of forest to damage; effects of tourism on animal distribution and wildlife damage (chamois and red deer escape from open alpine areas into forest); interactions between different ungulate species	National Forest Inventory data since 1961; good hunting statistics for deer and chamois since 1948; monitoring data of the provinces; long-term monitoring data from some forestry enterprises; limited amount of experimental data on ungulate-forest interactions; enclosure data (effects of ungulates on forest development depending on plant community and silvicultural impacts)
Lowland forest	Wildlife damage; reduced recruitment of deciduous trees to old growth stages; changed floristic composition and structure of shrub and forest-floor vegetation; over-abundant population of roe deer and, locally, also red deer	As for mountain forest; additionally habitat fragmentation and habitat use	As for mountain forest; good hunting statistics for deer and wild boar

The analysis also showed that 80% of the respondents sought better communication of existing research results and studies to ensure effective implementation of the findings; only 20% believed more basic research to be the priority. Clearly, the overwhelming demand is that 'we bridge the gap between research and practice'. The derived research priorities in each area, biological and implementational, relating to ungulate wildlife and wildlife damage are listed below (for details see Reimoser and Völkl, 1988, 1990). Principal grazing problems, key interactions in the ecosystem and indications of what information is available are summarised in Table 6.4 (see also Table 6.1).

Biological research priorities

- *Standardised terminology/nomenclature*: a precondition for more efficient research (better communication, avoidance of misunderstandings).
- *Bibliographies*: annotated compilations of available literature and translations.
- *Physiological fundamentals*: physiological limits of mammals in respect of energy, nutrients and time in changing and fluctuating environments (project in preparation at the Research Institute of Wildlife Ecology, Vienna).
- *Genetics of ungulates*: 'ecotypes', genetic potential, post-glacial distribution, impact of hunting, habitat fragmentation.
- *Ecological fundamentals*: analysis of forest regeneration dynamics, with and without ungulate impact (role played by animals in different forest ecosystems); control mechanisms acting on ungulates in various *natural* environments (e.g. the Carpathians); responses of plant and animal species to grazing; long-term effects of grazing/browsing on biodiversity (soil, plants and animals, etc.).
- *Impacts of different animal species*: clear differentiation between impacts of wildlife and domestic ungulates, hare, mice, etc. to improve effectiveness of control measures.
- *Impacts of forestry, agriculture, hunting/feeding and tourism on habitat quality, wildlife distribution, population dynamics, wildlife*

damage predisposition and wildlife damage: habitat management in forestry (damage prevention and therapy); hunting methods (planning, implementation); feeding (natural and supplemental); effect of stress (behaviour, metabolism, etc.).

- *Landscape ecology:* evaluation and mapping of habitats, biological inventory (local, regional, national, cross-border; including non-forested areas).
- *Technical fundamentals:* possibilities for remote sensing.

In Austria, the greatest lack of information relates to the subalpine regions (those over 1400 m above sea level). For lowland plains and hills, research is needed to explore the role of habitat fragmentation in population dynamics, genetics, habitat use and wildlife damage.

Research priorities supporting the implementation of basic findings

- *Long-term, large-area field research:* field research in different landscapes, interdisciplinary studies, model testing.
- *Output-target setting and monitoring:* establishment of practical methods to set measurable targets and assess browsing damage in forest stands.
- *Historical development of forest damage by ungulates:* provides an understanding of the current situation.
- *Regional planning:* incorporation of wildlife-ecological factors in planning decisions (mechanisms, co-ordination, integrated management concepts, long-term follow-up).
- *Complementary research:* sociological research into factors facilitating and hindering practical application of research findings, including studies of related laws and legal concepts, studies of economic factors (e.g. cost benefit analyses of different management strategies) and political and administrative aspects; studies of methods to develop collaboration between the various stakeholders (from foresters and hunters to representatives of local communities, tourist administrations and conservationists).

Factors that were identified as hindering implementation of existing research results in practice included:

- Poor implementation of existing, often excellent, laws and regulations.
- Resistance of foresters and hunters; each group having a long tradition and powerful lobbies in Austria.
- Poor communication of research results to these two groups.
- Poor co-ordination between the aforementioned groups and stakeholders involved in agriculture, tourism, regional planning, etc., with the result that there is a poor understanding of each other's needs.
- Biological/ecological models not tested in practice and therefore not accepted by the parties involved.
- Results from a case study in one locality often not being transferable to another.
- No clear regional planning goals in relation to preferred grazing regimes.

Conclusions

The main obstacles to implementation of improved management practices are the complexity of the interactions between plants, animals and humans, and the lack of co-operation between all stakeholders. As a first step, it is believed that better progress requires better communication of existing research results to all interested parties, in a form that ensures that the practical aspects and impacts can be clearly understood. It will be necessary to study the factors that hinder the incorporation of the new insights into management practices, recognising the role played by tradition and community culture. Models will then have to be developed to promote implementation of research findings. These will need to include ways of involving all stakeholders, so that the forest and ecosystem management regimes will have been collaboratively developed and will consequently be assured of general support, the only way to ensure long-term success and sustainability. Such studies will require interdisciplinary work involving those who have undertaken the biological research as well as experts drawn from the social and management sciences.

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Chapter 7

Grazing and woodland management in the dehesas: a silvi-pastoral system in central Spain

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Summary

The dehesas are a silvi-pastoral system characteristic of central-west Spain, occurring as ownership units in the range of 100–1000 ha. The traditional exploitation of natural agribiological resources in this system is considered sustainable for the Mediterranean semi-arid climates with poor soils and fragile ecosystems. The management of dehesas is ecocompatible; respecting its natural components while obtaining the maximum economic benefit. However, it is not perfect, since there are many ecological processes which need to be further investigated and management practices improved upon. In particular more information is needed on tree–herbivore compatibility, optimum tree cover density, types of livestock and types of exploitation.

In this study we briefly review the elements and subsystems constituting the dehesa system (soils–grass–trees–herbivores–predators), as well as the traditional methods of management and modifications introduced recently under current economic and political pressures. We stress the economic and ecological importance of conserving the traditional management methods. There is pressure to adapt management practices to suit modern market requirements, but this could be detrimental to the survival of the dehesas, and the effects of any new practices should be thoroughly evaluated prior to their implementation. The optimised dehesa system should be the model to follow for the recovery of marginal lands. Its extension to the marginal lands, abandoned by farmers through emigration and also recently under the pressure of the European Union Common Agricultural Policy directives, would be an ideal way to encourage ecological recovery. The physiognomy and ecology of these marginal areas and the social and economic situation of the inhabitants are in a poor state. We are certain that there is no better future for them than their transformation into

silvi-pastoral systems which mimic the dehesa model. The historical evolution of the dehesas and the effects of the different management systems can provide extremely valuable information which will help current decision-making aimed at mitigating the effects of inappropriate management practices. In this respect, a number of ecological and socio-economic studies proposed here must be completed as a matter of urgency.

Introduction

Many characteristic plants of the dehesas can survive browsing because they have developed strategies allowing them to defend themselves and subsist in the face of herbivore pressure (Begon *et al.*, 1987). For example, holm oaks (*Quercus ilex* subsp. *ballota* Desf. Samp) and Pyrenaican oaks (*Quercus pyrenaica* Willd), the dominant tree species of the dehesas, have different characteristics. The former resist the high pressure of herbivores better than the latter. Holm oak shrubs can survive in a dwarf form, whereas Pyrenaican oak shrubs die. When the outer leaves are consumed, the terminal sprigs of the holm oak, which are more lignified and dense, dry and form a barrier of spikes which defend the innermost leaves; the shrub may not grow in size, but it gains reserves. If herbivore pressure is very high and persistent, even holm oak shrubs eventually die. The survival of the dehesas depends on the delicate balance between grazing pressure, pasture quality and tree growth. Changes in animal husbandry practices, climatic change, and disturbance events, can upset this balance. In particular there are considerable differences between the primitive stock management practices of prehistoric times and modern systems. Also little is known about the behaviour of wild herbivores before domestication by man. However, it necessary to obtain adequate information on the circumstances in each case, in order to fully inform current management practices. The aims of this chapter are to describe the components of

the dehesa system in relation to traditional and modern management methods, highlight grazing problems and solutions, and outline further research needs relating to the dehesas and other similar habitat types.

Origins of the dehesas

The dehesas operated historically within an almost closed cycle of self-sufficiency, with very few inputs or outputs. Their isolation conferred a very peculiar character on these systems and their exploiters. The dehesas originated as Roman estates or farms. The land underwent variations and fluctuations according to the character of the different invaders: Phoenicians, Carthaginians, Romans, Visigoths, Moslems, Christians. The dehesas were consolidated as extensive properties of a single owner or organisation (bishops, religious orders, etc.) towards the end of the Reconquest in the 15th and 16th centuries (García-Martín, 1992). Labour was very cheap and abundant, within a medieval-type feudal situation which remained in effect until the 1960s. The absenteeism of landlords (nobles, the rich or religious orders) was very frequent. They lived in the cities and exploited the estate through tenant farming and sharecropping, or they simply left it and protected their property with guards and 'montaraces' (García-Martín, 1992; Gómez-Gutiérrez, 1982).

Components of the dehesas

Climate

The climate is semi-arid to subhumid. Precipitation is 400-700 mm per annum, strongly seasonal with very irregular rainfall not only throughout each year, but from year to year. Frosts occur from November to April, and occasionally in October and May. Summers are very dry and hot, winters are cold and humid. The mean annual temperature is 11–12 °C, with the maximum temperature around 40 °C and the minimum -20 °C. Climatic change is becoming evident; there are fewer frosts, more dry months, and rainfall is less frequent but more intense (Luis-Calabuig and Montserrat-Recoder, 1979; Oliver-Moscardó and Luis-Calabuig, 1979).

Soils

Soils are oligotrophic, acid and sandy and categorised as distric and humic cambisols (autochthonous) over granites, slates and quartzites. Scanty pluviosols and luvisols as well

as some sedimentary soils (allochthonous) occur over sandstone (García-Rodríguez *et al.*, 1979; Jimenez and Arribas, 1979).

Vegetation

The dehesas occupy an ecotone between Mediterranean and Atlantic–Central European climates. The vegetation associations are dominated by oaks: *Quercus ilex*, *Q. pyrenaica*, *Q. faginea*, *Q. suber* occur in monospecific or mixed formations. *Fraxinus excelsior* occurs in the more moist depressions. Along river banks there are *Salix* spp., *Populus* spp. and, exceptionally, with sufficient persistent humidity in summer, *Alnus glutinosa*. *Ulmus nigra* has almost disappeared as a result of Dutch elm disease. Tree densities are highly variable and range from 2 to 100 trees ha⁻¹. The dehesas are also an important habitat for shrub species such as *Cytisus multiflorus*, *C. scoparius*, *C. striatus* and *Genista hystrix*. There are also some smaller shrubs which are very frequent such as *Echinopartum barnadesii*, *Lavandula* spp., *Thymus* spp., *Fumana* spp. and other lesser *Cistaceae* spp. Some of these species have been studied because of their possible value for energy generation (both electric and thermic power) among other economic uses (Gómez-Gutiérrez *et al.*, 1988; Fernández-Santos and Gómez-Gutiérrez, 1994). Herbaceous species are the most important component of the dehesas. Leguminous species of the genera *Trifolium* (some 21 annual and perennial species), *Medicago* and *Lotus* (also with annual and perennial species) etc., are very frequent and are important for the quality of the pastureland (protein and palatability). Grasses are highly abundant; among the tallest are *Agrostis castellana*, *Festuca rubra*, *Festuca arundinacea* and *Dactylis glomerata*; among the shorter are *Vulpia* spp., *Anthoxanthum* spp., *Poa* spp. These species are important for the overall biomass of pasture. The families Compositae, Umbelliferae, Fabaceae, Juncaceae, Cruciferae, etc., are represented by species of many genera. There are also many other very well-represented families, outstanding among which are the Boraginaceae and the Plantaginaceae, for example the genera *Borago* and *Plantago*, responsible for maintaining the mineral status of the dehesa herbage (Rico-Rodríguez *et al.*, 1982).

Pastures

The dehesas are made up of a mosaic of different herbaceous pasture communities which is governed by topography and soil type. Some land is devoted to the cultivation of

cereals used for fodder. Both pasture and arable land occur with or without a scattering of oak forest. The topography is the determining factor for soil quality, the retention of moisture and hence the composition of herbaceous communities. The landform is composed of alternating 'thalweg' or valleys and peneplains of varying extent in the interfluves. The plant communities show adaptation to the varying conditions of the small valleys, along the moisture gradient from the lower, more moist part to the upper drier part. The gradient of soil depth and moisture retention is responsible for the establishment of the most productive communities in the lowest areas. The production of these areas can exceed 4000 kg ha⁻¹ of hay, although normally it does not exceed 2000 kg ha⁻¹. The further up the slope, the lower the production; however, the quality does not always decrease, since quality is a function of the abundance of leguminous plants (mainly the *Trifolium* and *Medicago* genera) which may be plentiful.

The botanical composition may be partially modified through use. Cattle promote the development of gramineous plants; sheep promote the development of leguminous plants; reaping favours the gramineous plants, to the detriment of the leguminous plants. Excess concentration of livestock favours the nitrophilous gramineous species (such as *Ordeum* spp., *Lolium* spp., *Bromus* spp.) but, above all, other, non-palatable species (Cruciferae and Boraginaceae). Thus, livestock management comes to be the determining factor in the evolution, production and quality of the pasturelands. It is possible to find dehesas of very diverse types, from the well-utilised to those that have been abandoned or very poorly managed.

Cereal growing

Since the dehesas were self-sufficient systems it was necessary to produce cereals, and to this end the areas of the estate with the best soils were cultivated, mainly with wheat, barley, rye and legumes. Cultivated land alternated with pastureland, with rye sown in the first year followed by legumes to enrich the soil for the subsequent growing of wheat, barley or rye. Sometimes land was cultivated to rid it of shrubs. Cereals were used as food for humans, and for livestock fattening. The surplus, usually scant, was sold. Today the amount of cultivated area has decreased and the produce is reused on the same estate for animal food.

Tree cover

An essential and defining element of the dehesas is the thinned or sparse oak forest. Apart from the normal biological elements of any tree cover that affect the micro-climate (Clinton, 1993) and the soil (Escudero-Berián, 1985), the tree cover in the dehesas also provided firewood, charcoal for the home, wood for construction and farm tools, leaves (as forage) and acorns for herbivores and for human consumption. Cork trees provided cork for various uses. Trees were subjected to regular pruning every 7 to 10 years and a more drastic pruning, or pollarding, was carried out every 15 to 20 years. Tree cover is an essential element in the functioning of the self-sufficient system. Tree cover was severely reduced due to felling and excess use in order to facilitate the activity of farm machinery from 1950 to 1985 (Gómez-Gutiérrez and Pérez-Fernández, 1992).

Domestic herbivores

The indigenous domestic herbivores are animals which are well adapted to the harsh conditions of the environment and to the traditional systems of extensive exploitation. A counterpoint to their stamina is their aggressiveness, which makes them difficult to manage. Three thousand years ago wild herbivores migrated between suitable pasture areas. Migration allowed the system to recover and survive without spoilation or input. This is the basis for the great interest in 'transhumance' (the traditional transfer of livestock). Some herds are still transhumant (e.g. from Castilla-León to Extremadura). Traditional management of herbivores has positive effects on the soil and can impede the development of shrubland, in some cases to the point of elimination. Today there is a tendency to maintain excessive concentrations of livestock, with the following consequences: soil erosion, formation of paths, deterioration of the grass, exhaustion of water in ponds and streams, total incompatibility with reforestation and a high feed input which raises the price of the final product (meat).

Until the 1960s all the domestic livestock were indigenous breeds (Morucha salamantina, Morucha avileña, Retinta extremeña, etc.) with the exception of the Friesian cow imported for milk production. The desire for economic improvement led to the importing of stud cattle from Central European breeds for cross-breeding with the native stock. These hybrids are generally less well adapted to the environment, they require greater medical care, more

complementary food and more costly systems of transportation (by lorry rather than walking). They also place the permanence and conservation of the indigenous breeds in serious danger. This situation has given rise to the creation of associations of stockbreeders for the defence of indigenous breeds which obtain government aid.

The management of bullfighting cattle (Bravo breed) requires specific techniques and care that does not allow any modifications or variations from the traditional approach. The efforts of the animal protection societies to put an end to the debatable practice of the national 'fiesta' would cause great economic damage and the loss of a cultural manifestation that may be questionable but is deeply rooted in Iberian culture. Traditional sheep breeds are very sturdy and fertile and they respond well to improvements in health care and food. Several selected foreign breeds have been introduced, with no definitive results. Many flocks are still transhumant. In summer they are transferred to cereal growing zones in order to take advantage of the residue or remains of cereal after harvesting.

Factors which are common to the indigenous breeds of cattle and sheep are: adaptation to the environment, great resistance and stamina, and medium to low productivity. No serious structured programmes for genetic improvement have been carried out.

Systems of exploitation and pasture management

The grazing method is based on the production cycle of natural pastureland. This productivity is strongly seasonal, with maximum production in spring and some production in autumn, but no production in summer or winter. Topographic, climatic and soil heterogeneity is very marked; hence it is not possible to establish pasture systems that are sequential, progressive or rotating. There are no regulated or standardised systems of pasturage. The pressure on the tree cover can be great. Shrubby phases rarely occur due to the pressure of herbivores in times of drought when pasture is scarce, and diseases or attacks by xylophagous insects can be intense, favoured by drought (Hosking, 1993; Pérez-Fernández and Gómez-Gutiérrez, 1995). Cattle density is excessively high today and does not permit tree regeneration.

Trees affect the specific composition, the production, and the quality of the herbaceous species of the pastureland. The ground flora under the tree canopy (a radius of up to 5 m) consists of nitrophilous species of low quality for livestock (e.g. *Ordeun*, *Bromus*, etc.) or species which are more resistant to grazing (e.g. *Dactylis glomerata*, *D. hispanica*) dominate. Just outwith the tree canopy there is a zone of influence in which production and quality are considerably greater than in the completely treeless areas. It is therefore important to know what the optimum tree cover density should be (Puerto-Martín *et al.*, 1980). The leaves of the lower tree branches, all the leaves of the small shrubs (up to 2 m high) and acorns are consumed by domestic herbivores.

The productive cycle of the pastureland is frequently slowed down by low temperatures or the scarcity or irregular distribution of rain. In more benign years there may also be primary production in autumn (October or November), but this is scanty and irregular. The soil benefits from the inputs of organic material from the trees, shrubs, pasture herbs and faeces, but deteriorates if there is excessive density of herbivores. Conversely, if herbivore densities are too low, pastureland is encroached by shrubs. The presence of a high shrub cover decreases the livestock load; the fewer the livestock the more shrubland, which in turn leads to a further decrease in the livestock load. The solution is to increase the density of animals in the shrubby zone, specially at those times when it is necessary to give them complementary feed because grasses are scarce. This feed can be located in the shrubby zones to increase the concentration of livestock that would then destroy shrubs by trampling. The following cycle can be established in the herbivore-tree cover relationship:

<i>Winter</i>	Hungry cattle consume the leaves of the holm oak and tender stems of the Pyrenaican oak, eliminating a large amount of leaf buds and therefore slowing down development and placing the tree in danger.
<i>Spring</i>	Grazing pressure on woody species ceases. The cattle consume herbaceous species.
<i>Summer</i>	The intensity of the attack on woody species has an inverse relationship

with the availability of residual herbaceous species from the spring. If spring production is scarce and the cattle density high, the effects of grazing on the woody species is usually lethal for the Pyrenaican oak shrubs and very damaging for the holm oak shrubs. Three straight years of drought, and therefore scarcity of grass, can be catastrophic for shrubs and for any tree species in the young stages, which are consumed intensely.

Autumn The attack of late summer (August and September) increases in October and November if there is not enough rain to facilitate new shoots and germination of grasses.

The stockbreeders prune or lop the oaks and ashes at the end of summer or beginning of autumn, and the holm oaks in February or March, to provide food (leaves) for hungry animals. The dimensions of the pasturage plots vary widely, from a few to several hundred hectares. According to the traditional system, cattle are preferred over the other species, with sheep in second place. The cattle load that these systems can support is typically 3 to 7 head ha⁻¹. Some of the norms of traditional pasturage of cattle include:

1. Removing cattle from the depressions or the most productive parts of pastureland from winter (January) to June, for reaping and hay storage to cover the lean periods of summer and winter. In practice this is only possible when the climatic conditions are favourable (not every year).
2. Ensuring that gestating females graze in the areas with most grass and receive complementary feed.
3. Keeping studs apart from June to December so that the birth of calves coincides with the most favourable time of year for weaning and fattening (the hot months).
4. Ensuring that the animals are vaccinated and de-wormed regularly.
5. Ensuring that calves are weaned at 6-7 months. They are either sold to be fattened or fattened directly.

In the areas grazed mainly by sheep there is low forage with *Poa bulbosa* and *Trifolium*

subterranean as the dominant species. Goats feed preferentially on the most abandoned and least productive areas which are covered with shrubs of *Genista* spp. or *Quercus* spp. in their shrubby phase, or in closed forest. Horses live together with cattle or with sheep and goats. Horses are generally the 'cleaners' and consume the plants or parts of plants left by the cows, goats or sheep because of their hardness or lack of palatability. Pigs are herded together in autumn for slaughter or to be sold after being fattened up with acorns.

Cultural and economic importance of the dehesas

The systems of extensive stockbreeding in the dehesas are many centuries old. Such deeply rooted systems have given rise to the formation of an extremely rich cultural heritage which has affected not only the customs of western Spain, Portugal and southern France, but also Mexico (the Mexican 'charro' or cowboy comes from the original 'charro' from Salamanca) and the American West. Knowledge has been handed down from one generation to the next, and systems of stockbreeding that best suit the fragile ecosystem of the dehesas have evolved gradually over hundreds of years (Gómez-Hernández *et al.*, 1992). These systems have been adapted to the harsh environmental conditions and it is very difficult to improve on them. However, they are now being subjected to the profound effects of dramatic economic, social, cultural and ecological change. That is why for the first time they require very special attention and in-depth studies to guarantee their future.

Firstly, a good knowledge is needed of the potential of each vegetation community in order to establish grazing cycles. Some plots, because of their orientation, height, richness of soil, etc., attain maximum production before others; some have a more rapid turnover of species, which in turn is a result of the system of exploitation and even of the type of livestock grazed; others are suitable for mowing because of their location in depressions; in some there is a predominance of grasses because they were traditionally used for feeding cattle (cattle pasture or 'vaqueril') whereas in others there is a predominance of leguminous plants, due to sheep grazing (sheep pasture or 'majadal'), etc. Therefore, the correct use of the primary production, on which the future of the farm depends, can only be carried out under the direction of real experts with a knowledge of the territory and traditions. These experts (herdsmen and shepherds) were nearly

always illiterate. Attempts have been made to incorporate modern methods through large investments, but these were never recovered as it was necessary to sell the dehesa, or part of it, to meet the debts. In these fragile, poor, but notably resilient systems, the economic margins, both of man and nature, are very narrow. Investment has to be exactly right. If it is high it is not recovered, if it is low it has no effect and is lost.

The dehesas: past, present and towards the future

Past

The systems for extensive exploitation of stockbreeding resources in the past, before the economic development of the 1960s, were based on the following characteristics:

- They were closed self-sufficient systems with minimum input and scanty agricultural and stockbreeding surplus as output.
- Stockbreeding was highly diversified and permitted the organisation of exhaustive exploitation of all the resources with ecological disturbances that were well tolerated by the ecosystems.
- Abundant and very cheap labour (food for service) which, together with the absenteeism of the landlords, caused economic, social and cultural stagnation.
- Very difficult environmental conditions, with highly fluctuating primary production determined by the harshness and fluctuations of the climate and the poor soil.
- Stockbreeders had a profound ancestral knowledge of the possibilities of their natural resources. This knowledge was acquired from centuries of using the same system and by oral transmission of the techniques for the utilisation and management of livestock.
- The lack of selection of livestock breeds and the absence of systems for improvement.
- Minimum economic development and very rich cultural heritage.
- Grazing systems that interfered with the regeneration of tree cover but did not impede it completely.

Present and towards the future

- Climatic conditions evolving towards desertification.
- Scarce and expensive labour force.
- Drastic simplification of species diversity (only cattle, or only sheep).
- Increase in mono-specific density of domestic livestock.
- Deterioration of the system: soil, pasture, tree cover.
- Absorption of indigenous breeds by imported ones.
- Artificial fattening of calves.
- Increase in inputs and outputs.
- Livestock health situation acceptable or good.
- Demoralisation of the stockbreeders due to market fluctuations, lack of information and of a clearly defined agrarian policy, economic confusion.
- Irreparable loss of an extremely rich cultural heritage.
- Disappearance of the transhumance system that facilitated the correct integral exploitation of the stockbreeding resources of several regions.

Identification of grazing problems and solutions

Disappearance of the tree cover and its regeneration

Systems of forest protection must be tested, such as the use of organoleptic characters that produce rejection in herbivore consumers. The optimum tree density needs to be defined as a function of the effects of intraspecific and interspecific competition with pastureland. Pruning and care that will benefit the survival of the tree cover and acorn production should be improved. Attempts at fertilisation, drip irrigation and inoculation with mycorrhizae to facilitate the establishment and growth of tree cover and the production of acorns and truffles (*Tuber* spp.) are needed. The available

information on these subjects is minimal and very dispersed.

Loss of indigenous livestock

Indigenous livestock is disappearing due to cross-breeding with foreign breeds. It is necessary to study the yield and adaptation of cross-breeds and the remaining indigenous breeds. The information available is that learned by experience; there is a lack of bibliographical information.

Suitable stocking levels

Studies and evaluation of inputs–outputs are needed, such as: effect on pastures and tree cover; effect on the soil (water and tracks caused by movement); distribution of hay, straw and concentrates and their effects on the pasture and shrublands. The information on these subjects is sparse and dispersed.

Improvement of pastureland

Studies are needed on the economic and ecological effects of fertilisation, introduction of species, diversion of streams and increases in seasonal irrigation. Quite a lot of information is available on these subjects, but it is very dispersed.

Grazing systems

New systems should be compared with traditional systems. Information on new systems is scarce and dispersed.

Commercialisation

Two options are possible for the marketing of cattle and sheep:

1. Sell as soon as weaned: this is ecologically desirable but its economic viability is doubtful.
2. Fatten: this option is economically convenient, but requires large inputs.

To establish the best option, better information and organisation of the markets is required with networks that guarantee pick-up and payment. Stockbreeders need to be able to monitor demand in order to decide on the type of

production needed. Unless there is stability in the marketplace, it will not be possible to make any improvements. Information is limited and based on experience; there is scant written information.

Agrotourism and recreation

Possibilities for horseback riding, trail hiking, hunting, amateur bullfighting, etc. can be studied. Information on the economic viability of these options is lacking.

Other problems and information needs

Other problems and areas where more information is needed include:

- Lack of funding to carry out studies and co-ordinate dispersed groups of researchers.
- Campaigns for disseminating research information.
- Transhumance system: study of its viability and possibilities for reintroduction.
- Pasture quality.
- Biodiversity.

Research priorities

In dehesas that are already established, a good approach is to focus the problems from the perspective of the interactions of the three subsystems involved: soil–tree–pasture (Figure 7.1).

The following research objectives and experiments are proposed.

Research objective 1: Optimise production-quality of herbaceous species

Proposals: (a) Experiments on the introduction, improvement and selection of herbaceous species.

(b) Experiments on fertilisation.

(c) Optimisation of exploitation (livestock management).

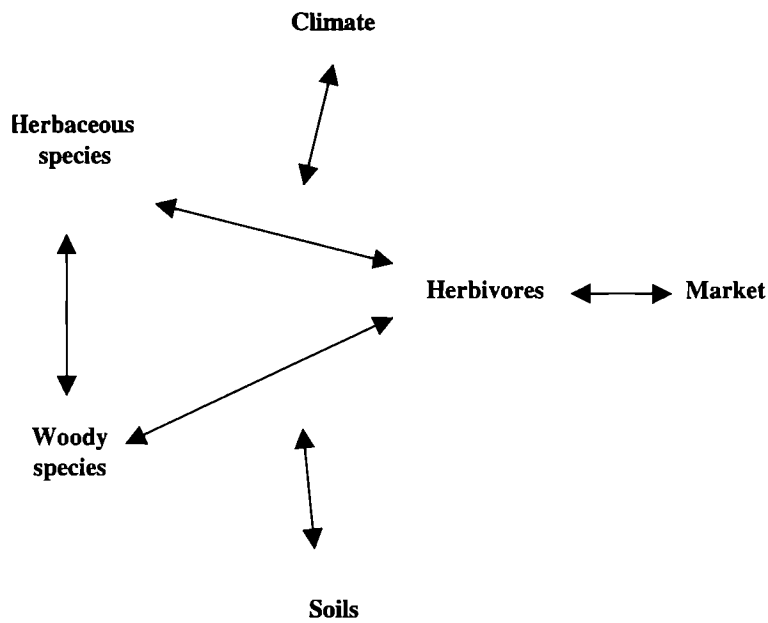


Figure 7.1 Interactions of the three dehesas subsystems: soil–tree–pasture

Production and quality of the herbaceous species are affected by competition with the trees.

Research objective 2: Define optimal tree cover density

Proposal: A study of the intensity of pasture–tree interaction by quantifying the factors affecting them (radiation, moisture, temperature, contributions of organic matter, etc.). This will be achieved by establishing transects from the trunk to open pasture and recording vegetation species, cover, diversity, quality, for example.

Research objective 3: Prevent herbivore attacks on trees

Proposals: (a) Assessment of the physiological effects of the attack and the response of seedlings, shrubs and trees.

(b) A study of natural systems for recovering tree cover (resowing and resprouting).

(c) Biochemical and chemical defence systems for seedlings and shrubs (selection of species or varieties which livestock do not like, use of repellents, etc.).

(d) Protection systems for seedlings and shrubs (evaluation of different types of fences, tubes or other kinds of protection).

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Chapter 8

Forest ecosystems of Greece and their relation to grazing animals

Thomas G. Papachristou

Summary

In Greece the total forest area represents 49% of the total area of the country. Twenty-five per cent of the country is covered with closed forests while the remaining 24% is covered by shrubs or trees in shrubby form. Grazing animals have been an integral as well as controversial part of forests and shrublands for many centuries. At present livestock grazing within forest lands is regulated by complex legislation which raises conflicts between stock managers and forest authorities. In this study, experience with domestic animals grazing within forest lands in Greece is briefly reviewed. Grazing within closed forests is considered as a management tool because it reduces ground forage production and vegetation cover, favours the growth of trees and reduces fire frequency. However, additional research is needed to clarify whether or not grazing could be integrated within all types of forest lands. At present this integration may be implemented in shrublands where small ruminant grazing is the only profitable use.

Introduction

All EU countries have developed forestry policies, although with different priorities or objectives (Kula, 1988). The forestry policy developed in Greece is to expand the forests by reforestation and to protect them against wild fires and other risks. Soil protection, wildlife conservation, rangeland management, production of industrial wood and improvement of the economic situation of the people living in mountainous areas are included among objectives of the national forest policy. Because forests have suffered serious damage by overgrazing or by clearing for grazing lands in the past, grazing animals are currently considered as one of the causes that prevent the fulfilment of forestry policy goals. However, there is evidence that grazing

animals and forest production could be integrated under a proper management regime (Liacos, 1980; Papanastasis, 1984; Nastis, 1993). This study presents the grazing activities within forest lands in Greece and examines the interactions between grazing animals and vegetation.

Forest ecosystem types

Some of the most degraded forest ecosystems in the EU are in the Mediterranean countries where they are of low productivity, timber production is deficient and the expected services (e.g. soil erosion protection) are not ensured. Human activities such as over-harvesting, irrational felling, wild fires and overgrazing have contributed to the forest ecosystem degradation. Forest lands occupy a great part of the land area of Greece, about 6.5 million ha or 49.3 % of the country's total area (Table 8.1). The majority is state owned (73.2%), 12% is communal, while the remaining 14.8% is privately owned.

Twenty-five per cent of the land area in Greece comprises productive forests (Table 8.1), yielding at least one cubic metre of timber per hectare. This productivity is low and certainly below their potential, especially for the broadleaved oak forests which are mainly coppice: 75% of the total oak forests covering 23% of the forest area (Smiris and Dafis, 1988; Radoglou, 1994).

The remaining forested area consists of land covered by shrubs and trees mainly in shrubby form. These woodlands do not produce commercial wood products but they have multiple uses because they provide firewood, soil protection, water production, landscape and aesthetic values, wildlife habitat and forage for grazing domestic and wildlife animals (Liacos, 1982; Papanastasis, 1984; Greek Ministry of Agriculture, 1992).

Table 8.1 Type of forest lands in Greece (adapted from Greek Ministry of Agriculture, 1992)

Forest type	Area (000s ha)	%
Closed forests	3359	25.4 ^a
coniferous	1430	21.9 ^b
broadleaved	1929	29.6 ^b
Woodlands	3154	23.9 ^a
evergreen oak shrublands	460	13.3 ^b
other species	2694	35.1 ^b
Total forested area	6513	49.3 ^a

^aPer cent (%) of the total area of the country.

^bPer cent (%) of the total forested area.

Grazing on forest lands

Animal husbandry was one of the first economic activities of man which also affected the natural environment (Liacos, 1980), and the survival of animals depended on the spontaneously growing vegetation. However, pastures dominated by herbaceous species produce forage for only a short period in Mediterranean climatic conditions. Therefore new forage resources had to be discovered that produced green material in periods when herbaceous species were mature and of low quality (summer). Forest lands were an obvious target. At the same time agricultural activities expanded on the most productive pasture lands. As a result forest lands were overstocked or converted to grazing lands by thinning when tree density limited the available forage. During harsh periods in the winter months, livestock were fed indoors with felled branches of forest trees such as oaks. This irrational use of forest lands resulted in a hostile attitude towards the compatibility of forests and livestock husbandry.

Today the relevant legislation for the high closed forests which are under proper management suspends or prohibits grazing in thinned or cleared forest stands in order to facilitate natural or artificial regeneration. In addition, grazing is prohibited in artificially regenerated forest lands and in wild burned forests until the vegetation is restored. The same grazing right is applied to wild burned shrublands. The prohibition time may range from 5 to 10 years depending on whether sheep, cattle or goats are involved. At present, domestic animals, especially goats, are considered as enemies of the forests in Greece

and in other Mediterranean countries (Papanastasis, 1984); therefore, they should be kept out of them. However, Greek forests are still subjected to grazing, contrary to the forest law and mostly through opportunism on a local basis by shepherds. In a relevant work for the Mediterranean countries, Papanastasis (1984) reports that the policy of excluding grazing animals from the forest lands was not successful because it was designed without taking into account the needs and habits of the local people. According to Liacos (1980) any effort for forest development with elimination of grazing by domestic animals is not possible because at the same time the demand for better food of high quality (meat, milk, etc.) is increasing.

However, forest lands may be integrated with livestock husbandry when proper forest management is applied appropriate to the particular bioclimatic and socio-economic conditions related to each forest type and area (Liacos, 1980). The ideal situation for the achievement of this integration would be a forest with high amounts of herbage biomass of high quality, which herbivores would preferentially forage, rather than damage natural regeneration or canopy trees. Forage production under tree canopy and the reaction of forest trees to grazing vary according to forest type and tree species. Liacos (1980) classified forest lands according to plant ecology and the grazing problems within them (Table 8.2); he suggested a realistic model for the coexistence of grazing animals with forest lands. Although this suggestion was made 16 years ago, the present grazing problems within the forest lands have not changed. More specifically, he suggested that grazing activity within forests of light demanding coniferous species such as Aleppo

pine (*Pinus halepensis* Mill.) and Calabrian pine (*Pinus brutia* Ten.), deciduous oak (*Quercus* spp.) and *Carpinus* and *Fraxinus* species is justified as a silvicultural tool which favours the growth of trees. Grazers have to be excluded from forests comprising fir (*Abies* spp.), black pine (*Pinus nigra* Arn.), beech (*Fagus* spp.) and chestnut (*Castanea* spp.), because of the extensive damage they can cause.

The most important forest lands for livestock production are those covered by evergreen shrub vegetation (shrublands; Table 8.2) with kermes oak (*Quercus coccifera* L.) as the dominant species. The main use of these forest lands in the past was livestock grazing; their use for firewood production was also quite common. At present, their vegetation (browse and herbage) generally serves as the year-round forage resource for small ruminants, especially for goats (Papachristou and Nastis, 1993a,b). The importance of these resources for livestock production is well established (Tsiouvaras, 1987). A series of grazing management experiments has been carried out aiming to investigate the plant–animal interactions.

Table 8.2 Classification of Greek forest lands according to species ecology and the similarity of grazing problems (adapted from Liacos, 1980)

Forest land groups	Area (000s ha)
Light demanding coniferous species	528
Deciduous oak species	1034
Mediterranean firs and black pines	509
Beech and chestnut species	262
Shrublands	743
Others	5

Plant–animal interactions in the grazed forest lands

Closed pine forests

The light demanding coniferous species (Table 8.2) constitute the most typical forests in the Mediterranean zone and occupy a large part of the forested area in Greece. The most common species of these forests are Aleppo and Calabrian pines which even after canopy closure allow the development of understorey vegetation. This vegetation, composed of shrubby and herbaceous species, competes with

young trees for soil water, which is the limiting factor for plant growth in Mediterranean climatic areas. Moreover, the herbaceous and woody understorey plants are accumulated as fuel on the ground. During summer, this fuel creates a fire danger due to its flammability. Grazing animals can reduce this fuel load. It has been found that the risk of fire is decreased after grazing because of the decreased flammable material on the ground of forest stands (Liacos, 1980; Papanastasis, 1984; Nastis, 1993), in particular the reduction in herbaceous understorey vegetation (Liacos, 1977; Nastis *et al.*, 1991; Braziotis and Papanastasis, 1995). Natural regeneration of pine is favoured by the reduction of ground vegetation by grazing. However, Koukoura *et al.* (1993), investigating the effects of the combination of prescribed burning and goat grazing on pine re-generation of a 55-year-old *Pinus brutia* stand, found where stands were burned, protection from grazing benefited seedling survival (Table 8.3).

Table 8.3 Seedling survival (number ha⁻¹) of *Pinus brutia* after burning and grazing (from Koukoura *et al.*, 1993).

Burned		Unburned	
Grazed	Ungrazed	Grazed	Ungrazed
7	160	10	13

Pine plantations

One of the goals of forest policy is to increase wood production. This will be achieved in part by reforestation and in part by improving the productivity of existing forests. However, most of the time reforestation is carried out on grasslands or shrublands (e.g. kermes oak) that are typical grazing or browsing areas. These plantations are protected against grazing animals thus resulting in depression of livestock production and the rise in conflicts between animal husbandry and forest authorities. Another problem with these plantations is that they are threatened by frequent and devastating wild fires because herbaceous species grow abundantly on the ground surface and this material becomes dry and flammable during summer. There are, however, indications (Papanastasis, 1982) that pine plantations of black pine and maritime pine (*Pinus maritima*) over 5 years old can be effectively grazed by cattle under a controlled grazing system. An interesting finding of this study was that the herbaceous vegetation was significantly reduced by grazing, but no damage

was recorded to the pine trees. Cattle did not indicate an interest for tree foliage even when the herbaceous material was mature and depleted in nutrients. The reduction of herbaceous material resulted in a decrease in water competition thus favouring tree growth as well as reducing wild fire hazard.

The evidence from these experiments, therefore, is that grazing animals can be used as a silvicultural tool, by reducing the herbaceous material present in the understorey, reducing fire risk, and encouraging pine regeneration. Secondary income for local people is provided by the livestock grazing. However, since the existing experimental data are limited, and in some cases conflicting, grazing within pine forests needs further investigation before any conclusions can be drawn.

Deciduous oak forests

The forests dominated by deciduous oak species and species of the genera *Carpinus* and *Fraxinus* (Table 8.2) have suffered more from overgrazing and excessive timber extraction than any other forest type in the past. These activities were uncontrolled and resulted in the destruction and deterioration of the forest. Soil degradation is still a common characteristic. In addition, low rainfall and its irregular distribution, low humidity and high air temperature also limit the growth of oak forests (Radoglou, 1994). The deciduous oak forests in Greece are classified into six site classes (Dafis, 1966), of which only two and part of a third type provide economically productive stands. In an attempt to increase the productivity of the remaining sites, it has been proposed (Dafis, 1966) that they should be converted to high forests after clearcutting and reforestation with coniferous species. The protection of these forests against grazing is considered as a necessary management tool. However, reforestation efforts of these forest lands has failed because oak sprouts and the spontaneous herbaceous species prevented coniferous growth (Liacos, 1980) and the most suitable coniferous species were not used (Radoglou, 1994).

For these forest lands Liacos (1980) proposed that the oak sprouts and herbaceous material could be controlled by grazing with domestic animals. This application is regarded as a silvicultural tool that favours conifer tree growth. However, no information exists on how such grazing activities could be integrated with

conversion practices. Such information is needed for the development of the management strategies appropriate for the deciduous oak forests.

Shrublands

Shrublands (Table 8.2) dominate the landscape of the low elevation zone of Greece, covering 13% of its total forested area. These forest lands are a degraded state of former productive high forests, mainly deciduous oaks; their most profitable use at the present is for grazing domestic animals. Past studies (Liacos *et al.*, 1980; Papanastasis and Liacos, 1983; Papanastasis *et al.*, 1991; Papachristou and Nastis, 1993a, b) have suggested management schemes for the evergreen kermes oak shrublands. A combination of kermes oak pastures of varying cover (mosaic of vegetation types) over the total shrubland area has been suggested as the best management scheme for these grazing forest lands (Liacos *et al.*, 1980; Liacos, 1982; Tsiouvaras, 1987). This scheme has the advantage of producing several products and services by improving water yield, increasing forage production, improving wildlife habitat, protecting the soil, producing woods (e.g. firewood, fence posts) and providing aesthetically attractive landscapes that have a reduced fire hazard. A number of forage production and herbivore studies have been undertaken in this forest type.

One such study evaluated a management scheme which aimed to maintain both a mosaic of vegetation types and an increase in livestock production. An area of kermes oak shrubland was converted to grassland by the use of prescribed burning and sowing with a range of grasses and legumes; another area was manipulated to improved shrubland by the reduction of brush cover (elimination of woody species with low productivity and low herbivore preference index) and shrubs within the grazing height of goats (0.8 m). These improvements (Liacos *et al.*, 1980), resulted in an increased meat production compared to dense shrub stands (80 vs 25 kg ha⁻¹) while the landscape was more attractive, with a decreased wild fire hazard. Likewise, Papachristou and Nastis (1993a,b) investigated the diets of goats grazing on kermes oak shrublands of varying brush cover (50–70%) and shrub height less than 1 m. Results of this study indicated that goat diet composition averaged 60% browse, 17% grass and 23% forbs. Browse appeared to be the most important class of dietary forage almost all year

round. The goats ate large amounts of kermes oak and selected other woody species present such as rock-rose (*Cistus incanus* Rchb.). Goats selected grasses and forbs in relatively high proportion during spring (April–June), when their availability was high. In this period, goats consumed almost equal percentages of browse and herbage species. Dietary levels of crude protein approached or exceeded maintenance requirements for goats during all grazing periods. However, during August–October the nutrient content of diets was insufficient to meet gestation requirements. Thus, supplementation is clearly needed during this critical period. During this time, the nutritional status of goats is elevated when they graze in forest lands dominated by deciduous broadleaved species such as *Carpinus orientalis* Mill. and *Fraxinus ornus* L. (Papachristou and Nastis, 1996).

Kermes oak forest lands will continue to be used for grazing by animals in the future since this use appears to be the most profitable land-use. For this reason further research is needed concerning management techniques for improving forage and livestock production. Maintaining the role of kermes oak shrublands in soil stability, watershed protection and ecological value of the landscape may also be served by the proposed management schemes. The integration, however, of grazing goats within the forest lands dominated by deciduous broadleaved trees in shrubby form, such as *Carpinus orientalis* and *Fraxinus ornus*, needs further investigation before it becomes common practice.

Implications

A large part of the productive forest lands in Greece have been damaged as a result of irrational uses in the past. Among these have been uncontrolled grazing, irrational felling and wild fires. It is also well established that on forest lands dominated by shrubby species, namely shrublands, the most profitable use is domestic stock grazing. Forage demands of the grazing herbivores are catered for by maintaining a mosaic of pasture and wooded vegetation types, where the shrub cover is around 70 % of the total forest/pasture area (Liacos, 1982). Such management ensures these forest lands continue to offer goods (e.g. firewood) and services (e.g. soil protection). Moreover, the shrub component is complementary to the herbaceous understorey, resulting in a maintenance of forage quality the whole year round. However, more research is

needed to indicate economically and ecologically acceptable ways of reducing shrub cover in dense woody stands. Various classes of grazing animals (e.g. goats and sheep) may be used as a tool for maintaining the desired pasture composition. Results of a study (Papachristou, 1997) which examined the grazing behaviour of sheep and goats on shrublands of varying cover suggest that when brush cover is down to 40%, the bite rate (bites min^{-1}) of both sheep and goats is higher when compared to areas with greater shrub cover (55%). Sheep have a tendency to select more herbaceous plants while goats use shrub species more intensively. This suggests that sparse kermes oak shrublands could be used by both goats and sheep.

The grazing problems associated with other categories of forest lands (pine and deciduous oak forests) are more complex than those on shrublands. The benefits for the forest ecosystem and tree growth have been discussed in detail by Liacos (1980). In addition, the integration of forestry and livestock may also be favourable to the economy of the resident population. This integration in the remote and more disadvantaged regions of the country will encourage the population to stay there, thereby maintaining the social coherence of these regions. At the same time, the animal raisers will realise that forest lands must be maintained by providing additional goods and services to livestock products. In other words the inhabitants of these areas have to be regarded as the tool for protection of forest lands from risks such as fires. Sheep and goat husbandry in such remote areas could have a significant role to play in maintaining the landscape by preventing fires through vegetation modification.

The environmental and ecological impacts of grazing activity need further research. The social, cultural and economical conditions of each area have to be taken into account for successful integration. New techniques on animal foraging behaviour (Provenza, 1995) have to be tested under grazing conditions within forest lands. There is evidence that the potential impact of learning upon diet selection is high but it has been overlooked until now. The possibility also of manipulating animal preferences with a goal of increasing livestock production by exploiting particular plant species in a community has to be examined. Accordingly, Provenza and Balph (1987) suggested that through aversive conditioning grazing animals might be trained to avoid

desirable plant species such as seedlings in forest plantations. This is an important suggestion because livestock grazing in forest plantations could benefit tree seedling survival, by reducing the fire hazard and the competitive effectiveness of associated herbaceous species (Liacos, 1980). However, this suggestion needs further investigation.

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Chapter 9

Grazing as a management tool: a synthesis of common research needs

Jonathan W. Humphrey

Summary

This chapter identifies grazing research priorities which are common to all the forest ecosystems described in Chapters 1-8. Over-grazing is a major concern in all forest types, and the main problem facing managers is how grazing regimes can be modified to achieve a better balance between ecological and economic objectives. While there are socio-economic constraints to achieving these objectives (e.g. stock subsidy systems, land-use policies), basic information on the biological interactions between herbivores and other components of forest ecosystems is required in order to formulate herbivore management regimes matched to site characteristics and management objectives. It is proposed that a research approach integrating the disciplines of ecological modelling, experimental investigations and forest history studies can address these information needs and produce management guidelines in a form readily acceptable to end-users.

Background

Grazing by domestic and wild herbivores has a major impact in most European forest ecosystems. There is consistent evidence across a range of different forest types that high herbivore population densities can severely restrict the regeneration potential of forests of significant conservation value, and reduce floristic, faunal and structural diversity (Putman, 1996). In addition, many silvo-pastoral systems where low-intensity domestic herbivore management practices have, in the past, sustained a balance between ecological and economic outputs are now under threat through either neglect or inappropriate herbivore management (Pérez-Fernández and Gómez-Gutiérrez, 1995). However, grazing herbivores are an integral, natural part of woodland and forest ecosystems in Europe (Mitchell and Kirby, 1990; Kuiters *et al.*, 1996) and many ecological processes within forests and partially wooded systems, such as nutrient cycling and vegetation succession, are

profoundly influenced by herbivore impacts (Putman, 1996). Herbivores can be used as a management tool with which to manipulate ecosystems for a balance of desired outputs, such as timber production, pasturage, nature conservation, and hunting (Kirby *et al.*, 1994), but the quantitative information required by resource managers to make site-specific management recommendations is currently lacking for a number of systems.

Research is needed to provide a basic quantification of the effects of herbivores on forest ecosystems as well as to help tackle implementation issues which accompany any recommendations on changing grazing regimes. Thus there are socio-economic as well as ecological problems to tackle. Many of these problems are common to a range of countries within the European Union (EU), and are set within the context of legislative frameworks governing forestry and agricultural production which are now firmly established at the EU level. It makes sense therefore to seek solutions to grazing problems at the EU scale to take advantage of cost savings in centralising research efforts, to make the most of available skills and expertise, and to ensure that research results are readily transferable between countries and adaptable to local conditions.

The objective of this concluding chapter is to identify priority areas for future research. The material for this synthesis comes largely from discussions at the grazing workshop held in Salamanca, Spain (see Introduction) and from the papers presented at that workshop (Chapters 1-8). The assembled group of foresters, vegetation and animal ecologists and land managers put together a broad synthesis of common research needs. These cover a wide spectrum of research areas, and there will inevitably be gaps in coverage and a focus on those areas where most expertise was available. This chapter should be viewed therefore as a *discussion document*, and only the first step in the process of clearly defining target areas for future herbivore/forest research in Europe.

Description of forest types in Europe

European forest ecosystems can be divided into three structural types (Figure 9.1): continuous, fragmented, and savannah. This classification can be used as a framework for identifying relevant grazing research needs. The classification is based primarily on differences in ecological functioning at the landscape scale and cuts across geographic and political boundaries.

Continuous forest occurs predominantly in Scandinavia, central Europe and parts of the Mediterranean, where forest cover is often in excess of 50% of total land area, and there are large tracts of uninterrupted forest blocks (usually > 50 ha) where non-wooded habitats form a relatively minor component.

Fragmented forest occurs in countries such as the UK, Ireland, Denmark and The Netherlands, where forest cover is more broken up due to past clearance for agriculture and urban development; small woodland blocks (usually < 50 ha) are isolated and scattered within an essentially non-wooded landscape matrix.

Savannah woodland encompasses ecosystem types such as the Spanish Dehesas, kermes oak shrubland in Greece, and wood pasture in the UK, Denmark and the Netherlands where an open landscape containing scattered individual trees is maintained for pasturage (wood pasture also occurs locally in Scandinavia and central Europe). Fuller descriptions of the woodland types are given in the respective country chapters.

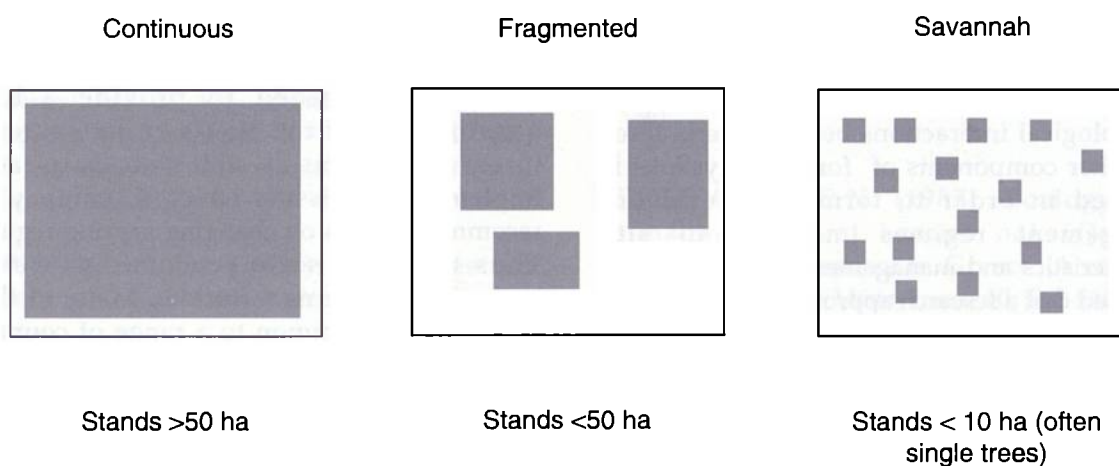


Figure 9.1 Stylised representation of European forest and woodland ecosystem types in relation to surrounding landscape. ■ = forest/tree canopy. The boxes represent hypothetical landscapes

Process used to identify research priorities

The majority of forest and woodland ecosystems in Europe have been modified by man in some way, either through direct destruction of habitat or by more subtle forms of management and habitat manipulation (Peterken, 1993). This cultural legacy has important implications for the present day structure and composition of woodland ecosystems, and past patterns of herbivore management have been an essential element within this process. Throughout the ages herbivore densities have been managed to provide particular outputs. For example, ancient

landscapes such as the dehesas in Spain have evolved due to the need to balance timber production with pasture outputs (see Chapter 7). Within the three forest ecosystem types, the interrelationship between forest structure and herbivore densities can be best understood within the context of a *temporal framework* (Figure 9.2). When we recommend how best to manage herbivores for the future, we have to consider the effects of past practices on forest structure. This will provide a starting point in determining the scope for future outputs from forest ecosystems (e.g. timber, recreation, hunting) and the type of grazing regime required to produce the desired structure and composition which could meet these outputs.

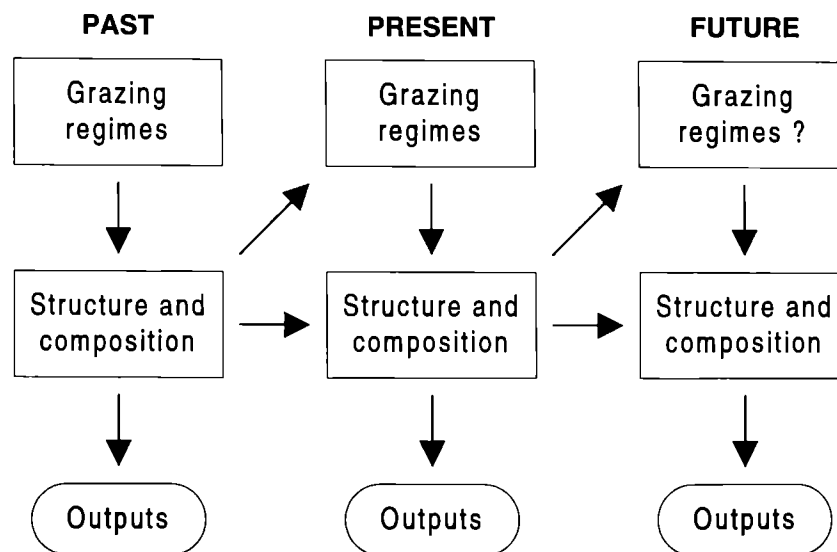


Figure 9.2 Temporal framework to illustrate the relationship between forest structure and composition and grazing regime

The next step in the process of identifying research needs is to focus in more detail on current and likely future outputs from the forest ecosystems represented within each country. A decision process has been developed to aid this task and also to provide a mechanism for identifying key grazing problems, knowledge gaps and research needs in a logical manner (Figure 9.3). The decision process helps to illustrate instances where enough biological information may be available to recommend changes in grazing management, but the potential to make these changes might be limited by political constraints, or lack of socio-economic knowledge. The decision process was adopted as a pro-forma for each country and aided in the completion of the review papers (Chapters 1-8).

Research priorities

The information provided by the pro-formas has been summarised for the main forest types in Table 9.1. In general, European forests fulfil similar functions regardless of country or forest type. Timber production, recreation, and biodiversity conservation are all primary outputs. In alpine and Mediterranean regions, forests also have a protective function against soil degradation and erosion. In terms of herbivore management, the main differences lie between the central European/Scandinavian continuous forest types and savannah forest types. In the latter, research into the management of domestic livestock is a priority, whereas in continuous forests, management options for wild herbivores are a more important consideration. Fragmented forests provide the

most complex situation where both domestic and wild herbivore management are important issues.

One issue that emerged as being of key importance in all European forest systems where herbivores are a significant component, is that densities of both domestic and wild herbivores are simply too high at present, to the detriment of other forest products such as timber production and biodiversity. Ecosystem sustainability, particularly biodiversity, depends on each forest type having particular structural and compositional attributes, such as diverse tree age structure, occurrence of natural regeneration, and temporal and spatial variability at both the landscape and stand scales. There are of course key structural components of forest ecosystems which can be equated with higher biodiversity, such as the presence of ancient trees, dead and dying wood, and a higher proportion of broadleaves (Ratcliffe, 1993). Over-grazing can have a disproportionate effect on these ecosystem components and hence has a disproportionate impact on biodiversity.

Two central questions arise from this. How can herbivores be managed to ensure a better balance between economic and ecological objectives? What information is needed to make these management decisions? Table 9.2 provides a synthesis of research priorities common to all forest types. These are divided into biological research priorities and socio-economic priorities. In addition, there is a list of recommended grazing and forestry policy changes which currently restrict the effective application of existing ecological knowledge.

Figure 9.3 Flow diagram illustrating process used to identify research needs

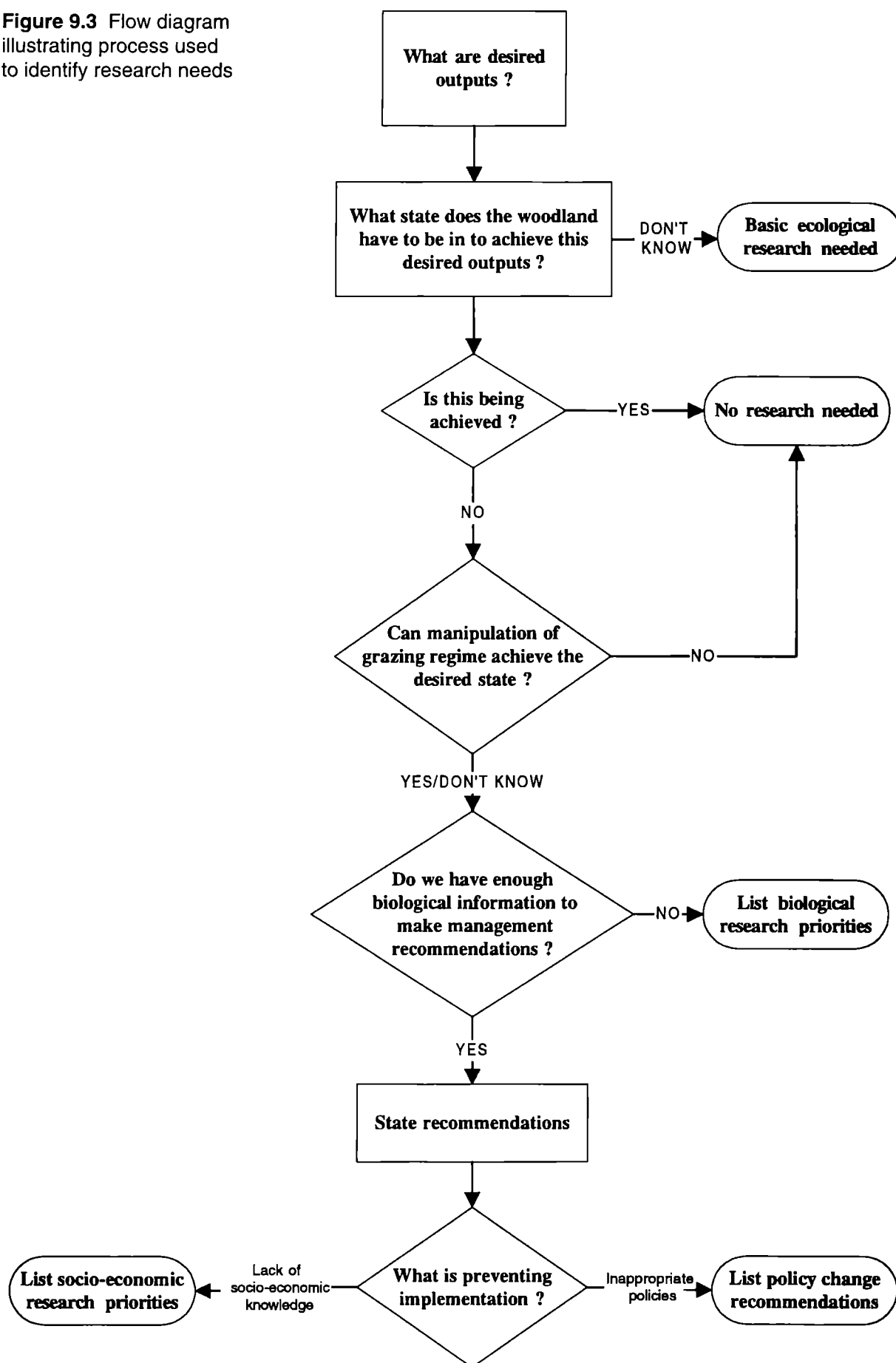


Table 9.1 Summary of contributors' judgments on forest outputs, forest condition, biological and socio-economic research priorities, and management and policy change recommendations relating to grazing management in European forests

Country/ region of contributor	Fragmented forests	Outputs	Condition	Biological research priorities	Management recommendations	Socio-economic research priorities	Policy change recommendations
The Netherlands	Multi-purpose high forest	Timber production; biodiversity	Heterogeneous tree age and species structure; more native broadleaves	Collation of historical records on forest development and changes in ungulate densities; modelling grazing systems; impact of grazing on biodiversity; modelling impact of food supply on ungulate populations	In development		
	Natural forest	Enhance biodiversity; improve landscape	Self-regulating populations of herbivores; partially forested landscape	Interactions between spatial layout of habitat and herbivores, and as above	In development		
Denmark	Lowland forest (dry and wet)	Biodiversity; fuel wood; recreation; cultural heritage	Heterogeneous tree age and species structure; dead wood present; species and management variety	Long-term impact of grazing on tree species composition; collation of historical information on impact of grazing; modelling impacts of grazing on all forest components	Reinstiate coppicing and controlled cattle grazing to wetter sites; develop management skills	Methods of communicating science research to land owners; environmental and economic cost benefits of different management systems	Adapt forest law to allow grazing or coppicing in woodlands; change tax and EU incentive system to encourage appropriate management
Britain/ Ireland	Fragmented upland semi-natural woodland	Biodiversity; recreation; small-scale timber production; wildlife; livestock; landscape	Active regeneration; temporally and spatially heterogeneous; expanding	Modelling and experimentation: herbivore impacts (density and species) on woodland dynamics; collation of long-term information on grazing impacts on woodland dynamics; modelling and experimentation on the impact of habitat type and spatial distribution on foraging behaviour; prediction of wild herbivore population dynamics	Reduce deer populations	Economic and environmental cost-benefit analysis of different woodland use systems	Modify EU sheep subsidy system (current headage payments encourage high sheep densities); provide incentives to ensure reductions in deer densities (red and roe deer hunting interests actively encourage high deer densities); promote small scale timber production and use (lack of markets currently a factor limiting management)
	Plantation forests	Timber; biodiversity; recreation, landscape, wildlife	Homogeneous age structure at stand scale, heterogeneous at landscape scale; diverse tree species	Modelling/experimentation of impact of silvicultural systems on foraging behaviour; methods of reducing tree damage by herbivores, and as above	Reduce deer populations; introduce controlled grazing by non-browsing stock to ungrazed woods	As above	
	Lowland semi-natural	Biodiversity; recreation; timber; wildlife; livestock; landscape	Active regeneration; temporally and spatially heterogeneous; expanding; variety of management systems	As for upland semi-natural	Reduce deer populations; introduce controlled grazing by non-browsing stock to ungrazed woods		

Table 9.1 continued

Country/ region of contributor	Savannah forests	Outputs	Condition	Biological research priorities	Management recommendations	Socio-economic research priorities	Policy change recommendations
All countries where these systems occur	Wood pasture: including Spanish dehesas, Greek kermes oak, traditional olive landscapes, English park land	Charcoal / wood from pollards; cork; truffles; biomass energy; domestic and wild animal products; bio- diversity; wildlife; medicinal plants; recreation and eco- tourism; landscape and cultural heritage; soil protection; micro- climate effects	Regenerating trees and shrubs (including replacement of ancient trees); plant species variety maintained; sustainable resource use; appropriate tree manage- ment (pollarding / cork stripping)	Clarify and quantify the ecological services provided by these systems; model / predict / experiment on impact of changes in system management, and balance between wild and domestic animals; interactions between herbs, trees and animals including tree damage, nutritional cycles etc.; effect of spatial habitat mosaics on herbivore densities; model eco- system function under different conditions	Involve and educate local people in system management and decision making	How can owners be persuaded to accept management recommenda- tions?	Subsidise systems which encourage appropriate manage- ment, and fund education through management demonstrations
Country/ region	Continuous forests	Outputs	Condition	Biological research priorities	Management recommendations	Socio-economic research priorities	Policy change recommendations
Central Europe Austria/ Germany	Continuous high forest	Timber; protection from erosion / avalanche/ rockfall; environmental welfare (CO ₂ fixation, air filtration etc); recreation; biodiversity (genetic / habitat)	Depends on desired outputs	Genetics of ungulates ('ecotypes'); ungulates in fluctuating environments; interactions between forest dynamics and ungulate impacts; control mechanisms acting on ungulates; impacts of silviculture, tourism, hunting on habitat quality and ungulate population dynamics		Historical development of forest damage by ungulates; methods of changing views of hunting lobby and foresters	Regional planning on a wildlife- ecological basis; enforce current laws
Fennoscandia	Continuous high forest	Sustainable timber; berries; fungi; recreation; biodiversity	Composition and configuration of habitats / stand and landscape scale that allows maintenance of spatially structured populations and maximises biodiversity	Identify where grazing is the critical controlling factor in short and long term; model forest grazing parameters to assess critical parameters to assess critical parameters	Reduce grazing pressure; increase diversity of grazers; restore natural predator prey relationships	As above	Policies to reduce conflicting interests; incentives to ensure reductions in deer density on farmland; promote small scale timber; production and use; education on woodland manage- ment for biodiversity
Mediterranean	Continuous high forest	Timber; wildlife; domestic and wild animal products; recreation; biodiversity; soil protection; honey, resin, fruit	Adequate regeneration; fire control; sustainable timber harvest; continuous cover forestry may be necessary	To recommend controlled grazing regimes need information on: interactions between climate / soils / plants / animals at different animal density and species; relationship between grazing and fire control; seasonal use of the forests		Cost benefits for stock owners and state owners of allowing domestic stock to graze the forest; to what extent do existing state forest regulations contribute to rural emigration?	

Table 9.2 Summary of grazing research priorities and policy change recommendations which are common to all EU countries

Modelling	Biological research			Socio-economic research	Policy change recommendations		
	Experimental and historical research to calibrate models	Impact studies	Methods to implement research findings				
Modelling the relationship between mammalian herbivore population dynamics, and forest structure, composition and dynamics	Past and present interaction between herbivores and vegetation succession	Impact of herbivores on biodiversity	Develop practical management regimes that are based on the concept of using herbivores as a management tool	Potential for land ownership change where at present this is a constraint	Manage wild ungulates within carrying capacity of ecosystem, linked to a new subsidy system		
	Past and present interaction between silviculture systems and herbivores	Impact of herbivores on micro-climate / soil condition	Develop methods for tree protection				
	Interaction between herbivore foraging behaviour and habitat quality / diversity	Impact of herbivores on different tree species	Develop methods of assessing herbivore damage			Potential for alternative hunting practices	Review EU afforestation programme in Mediterranean countries to base it on existing biological information
	Past and present interaction between spatial and temporal arrangement of wooded and non-wooded habitats and herbivore population dynamics		Develop methods of assessing herbivore densities			Ecological vs economic cost benefit analysis for different grazing options	Change EU subsidy for domestic stock to reduce damage and increase environmental benefits
			Defining common nomenclatures for terms such as silviculture, grazing, browsing, semi-natural, high forest	Economic impact of reintroduction of transhumance systems			

Biological research priorities

In Table 9.2, there are four main categories of biological research priorities. The first of these categories is ecological modelling. Results from experimental research alone can only provide partial answers to management problems (e.g. Hester *et al.*, 1996) as the scope for such work is limited by cost, logistics, complexity of confounding ecological factors, and the long

time scales needed to monitor successional processes. Kuiters *et al.* (1996) have shown that many of these problems can be surmounted by adopting an ecological modelling approach. For all systems there is a requirement to model the relationship between herbivore population dynamics, and forest structure, composition and dynamics. These interrelationships can be generalised in a functional model which is common to all ecosystem types (Figure 9.4).

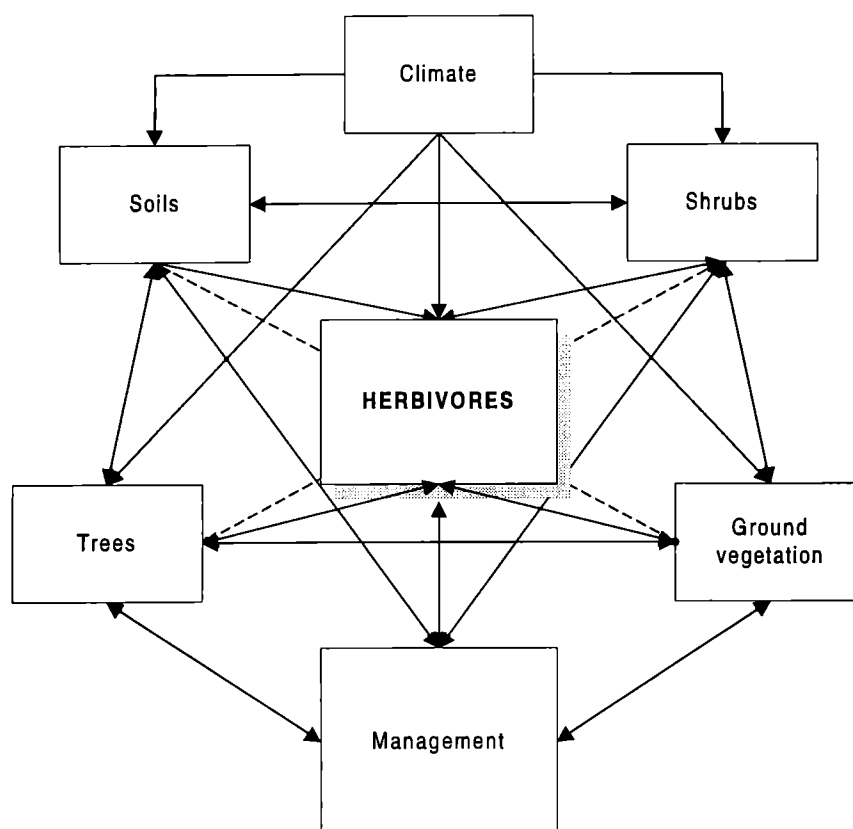


Figure 9.4 Generalised, functional model illustrating the interrelationship between herbivores and other ecosystem components

This conceptual model illustrates the main interactions between herbivores and the forest environment. Climate and soils are the main factors determining ecosystem composition, but management can have a major effect on the composition, structure and function of forest ecosystems by directly altering tree, shrub or ground vegetation components or indirectly through manipulation of herbivore densities and behaviour. These interactions and effects are common to all of the forest systems under study. Conceptualising the relationship between herbivores and forest ecosystems is only the first step in developing a quantitative and testable modelling approach. A quantitative approach is necessary if management recommendations are to be expressed in the numerical terms necessary to set management goals.

Dynamic models of forest development based on growth, population dynamics and mortality of individual trees have been developed in recent years. Such models relate forest succession to tree species properties, ecosystem structure and composition, and environmental factors such as soil and climate. Recently, these forest development models have been extended to incorporate herbivores and grazing (Kuiters *et al.*, 1996). One example is FORGRA, a simulation model developed by IBN-DLO to predict the impact of different grazing regimes of wild (red and roe deer) and domestic herbivores (cattle, horses) on forest development. The model describes the growth and development of individual trees within stands over long time periods, and is built up of sub-modules for tree growth and development, food supply, and seasonal digestibility of

understorey vegetation and for the feeding behaviour of herbivore species. By scenario analysis the consequences of different herbivore grazing regimes for long-term forest development can be evaluated.

While models such as FORGRA have aided our understanding of the mechanisms of several specific systems, it is imperative that this approach be extended to the other European forest types described in this chapter. Once these models are constructed it is then easier to see where additional information is needed to calibrate relationships amongst model parameters. The type of information can be obtained by targeted experimental research (Table 9.2): for example, data on interactions between herbivore foraging behaviour and habitat quality. The relationship between modelling and experimental research activities is essentially iterative, where data obtained from experimental research feed back information to the models, the models are further refined and additional areas for experimental research to improve model predictive ability are identified.

It is essential, however, that grazing scenarios generated by models should be validated on a practical basis, and this can be achieved by obtaining information on the influence of past grazing regimes on forest structure and composition such as historical archives, pollen and macro fossil analyses (Bradshaw, 1996). Together with current experimental data, these historical data can provide temporal reference points for the calibration of ecological models.

Once appropriate grazing regimes are identified through modelling, the next problem is one of implementing proposed grazing regimes. Research is needed here on methods of tree protection, herbivore assessment and herbivore damage assessment (Table 9.2). This research is also vital to provide methodology for carrying out effective experimental research, and herbivore population and range management. For example, standardised methods for assessing herbivore densities are essential if experimental results and derived recommendations are to be compared between ecosystems.

Socio-economic research priorities and policy changes

The expertise within the group is largely biological/ecological, so discussion on socio-

economic research priorities was limited to the production of a list of potential study areas (Table 9.2). Similarly, proposed policy changes are very broad in scope, and detailed investigations are required to ascertain their specific application to individual countries. However, some common themes can be identified. In many countries there are conflicts between different interest groups such as hunters and timber growers. This particular problem is most acute in those countries with high forest cover such as Scandinavia (Chapter 1) or Germany and Austria (Chapters 5 and 6). New legislation or land management policies are required to reconcile the needs of these two interest groups, perhaps linked to new subsidy systems. In most EU countries, where forest regeneration and biodiversity is threatened by overgrazing by domestic stock, e.g. the *dehesas* (see Chapter 7) and upland UK and Ireland (Chapter 4), there is an urgent need for adjustments to the EU grazing subsidy system. A more flexible system is needed which will support grazing regimes suited to local conditions which are not based primarily on headage payments, but on the carrying capacity of the environment.

A future research approach

The biological research priorities discussed above can be synthesised into a targeted research approach. The framework for such an approach is illustrated in Figure 9.5 which combines the *temporal* and *spatial* elements described previously. On a landscape scale the relative proportions of different types of forest stand changes over time. The aim of herbivore management is to use grazing to help direct the course of forest succession to provide a better balance of commodity outputs. Information on the distribution and composition of forest stands in the past can be elucidated by historical research. This information can then be fed into the modelling processes, together with present day information from mechanistic research on forest and herbivore interactions to produce forest succession scenarios for the different ecosystem types. It is therefore proposed that such an *integration of ecological modelling, experimental investigations and forest history research* can be used to quantify the effects of herbivores on forest dynamics to generate management guidelines for integrating multiple functions in key forest ecosystems in Europe.

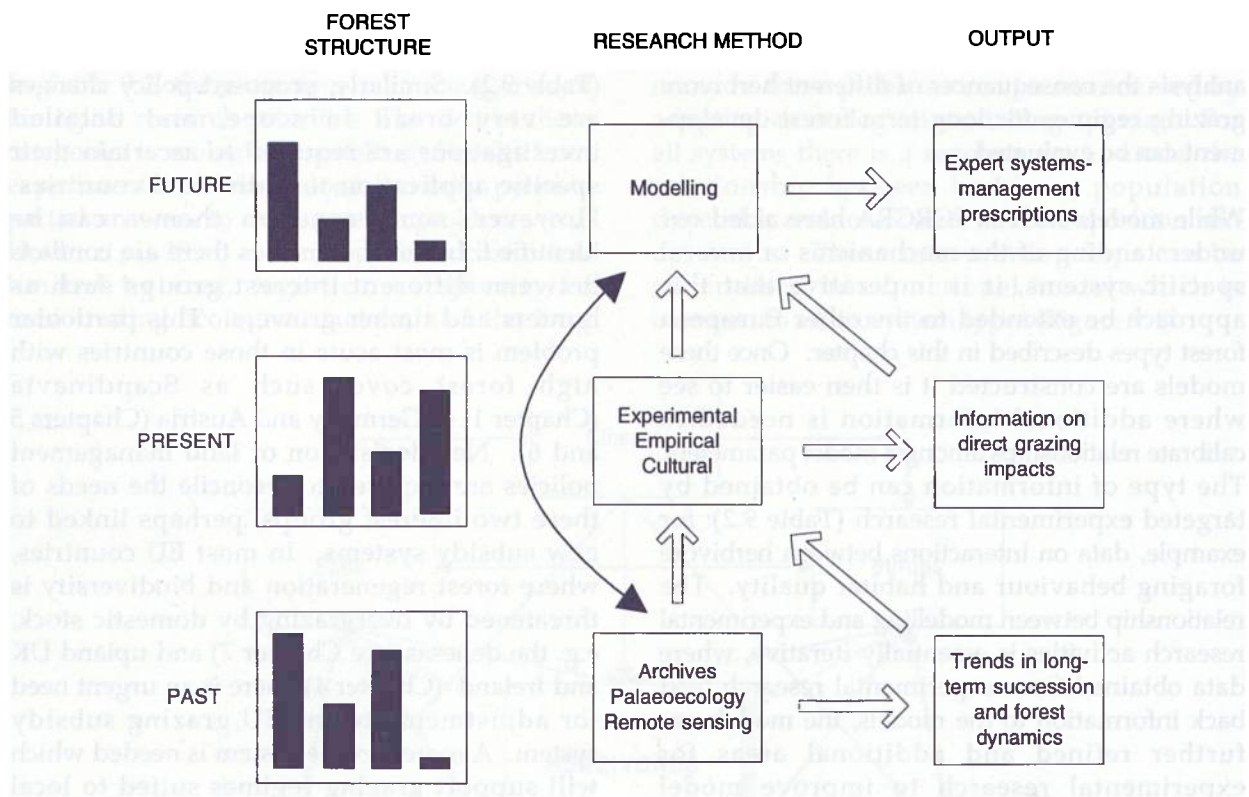


Figure 9.5 Research framework, integrating spatial and temporal scales. The forest structure boxes are a diagrammatic representation of forest landscapes; the vertical bars indicate relative proportions of different stand types within these landscapes. Modelling will predict the effects of grazing on the future composition and structure of forest stands and landscapes

The end-users for these guidelines would be *resource managers* (forest managers, wildlife managers, land managers, farmers) and *research scientists* (forest ecologists, ecological modellers, landscape and wildlife ecologists).

Within this context a future research proposal might involve six specific work tasks.

1. Develop a generic model of forest herbivore interactions based on the conceptual model in Figure 9.4.
2. Develop customised models: (a) for each of the three structural forest types (continuous savannah, and fragmented), and (b) parameterise the models for target ecosystems within each of the three categories of forest structural type.
3. Collate experimental data for: (a) customising the generic model for the three structural forest types, and (b) parameterise the model for target ecosystems within each of the three categories of forest structural type.
4. Test the customised models on real examples (case-study sites) taken from each

of the target forest ecosystems, where sufficient long-term information is available for validation (e.g. historical data on herbivore densities and forest development).

5. Generate optimal grazing scenarios from the models for each case-study site and evaluate their relative benefits for sustaining biodiversity within the context of multiple uses of these forest types.
6. In consultation with end-users, produce guidelines for the sustainable management of herbivores in multifunctional forests of particular conservation value.

Development of the generic model will be based on the conceptual model (Figure 9.4) and will comprise a number of modules used by the Dutch grazing model FORGRA (Jorritsma *et al.*, 1993). The structure of these modules may be modified to customise them for each of the three forest structural types. These forest structural types will be further stratified into ecosystem types of particular biodiversity value (Table 9.3). Existing, abiotic and biotic data will be collated for these target ecosystems to parameterise the models.

Table 9.3 Proposed target forest ecosystems for grazing modelling research within the three forest landscape types (see Figure 9.1)

Continuous forests	Fragmented forests	Savannah forests
Scandinavian boreal <i>Picea abies</i> forest	Scandinavian southern boreal forests	Lowland English wood pasture
Central European alpine mixed <i>Picea abies</i> – <i>Abies alba</i> – <i>Fagus sylvatica</i> forest	Upland <i>Quercus petraea</i> woodland in western Europe	Spanish <i>Quercus ilex</i> – <i>Q. pyrenaica</i> – <i>Q. faginea</i> dehesa
Mediterranean <i>Quercus</i> <i>pubescens</i> forest		

In the third phase of the proposed project, specific case-study sites might be selected as examples of each ecosystem type where sufficient historical data could be assembled to test the models on real situations. These data will be assimilated for the case-study sites to 'validate' the model generated scenarios, by examining the linkages between past herbivore densities and forest structure and composition.

In the final phase of the project, optimal grazing scenarios will be generated from the model for each case-study site and their relative benefits for biodiversity will be evaluated. This will also involve an appraisal of the implications of management recommendations for other forest outputs such as timber production and hunting. Grazing management guidelines will then be produced for each target forest ecosystem type in consultation with end-users. User fora could be convened for this purpose.

In time, once the models are running effectively, they could be used as a basis for the development of 'expert systems' which could be utilised by land managers as a predictive tool for managing herbivores. By using current technology, these decision support systems which incorporate expert or knowledge systems could make powerful management tools.

Acknowledgements

This chapter is based on discussions generated at the second workshop of the EU funded project: 'Grazing as a Management Tool in Natural and Semi-natural woodland Ecosystems', and subsequent collaborative meetings between participants. Most of the ideas and concepts presented in this synthesis are

attributable to the workshop delegates (see list). The author would like to extend his thanks to the delegates for permission to use some of these ideas in this concluding synthesis.

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At a time when wild herbivores have been increasing and causing widespread damage to forest habitats in Europe, traditional systems of woodland management involving livestock have fallen into decline. However, there is a growing awareness that if carefully managed at appropriate stocking levels, both wild and domestic herbivores can enhance woodland biodiversity.

To bring together the views of European ecologists, a workshop was held in 1996 in Salamanca, Spain with the focus on the impact of grazers and their management and the identification of common problems and research needs.

This Technical Paper provides comprehensive coverage of the workshop presentations and includes an overview of grazing problems and research priorities.

