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Forestry Commission
Bulletin 14

Forestry Practice

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Forestry Practice

A summary of methods of establishing, maintaining and harvesting forest crops, with advice on planning and other management considerations for owners, agents and foresters

Edited by

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FRONT COVER

An aerial view of part of Alice Holt Forest, Hampshire. The mature oak was planted early in the 19th century to replace trees cut for shipbuilding timber in the Napoleonic wars. Some of the later felling coupes have been restocked with conifers to produce supplies of commercial softwood timber. Other compartments have been replanted with oak and in some of the most recent plantings the establishment of these is being aided by the use of plastic tree shelters.

Public access is encouraged, and facilities provided include picnic areas, car parks (one of which is beside a lake), a visitor centre, forest trails and bridleways. A range of recreational activities can be enjoyed in the forest and a variety of wildlife is to be seen. (*23331*)

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Foreword

Forestry practice has proved to be one of the Forestry Commission's most popular publications. It is of value not only to practising growers and owners but also to planners, students and all those concerned with the care and management of trees. To produce a publication which covers the whole range of forestry in Britain is a daunting task and inevitably this Bulletin must often be treated as a guide to further information, leading the reader into the greater depth and detail obtainable from more specialised publications. The Bulletin's chief value is in providing a practical account of current forestry activities, and each revision of the Bulletin has to take account of changes in attitudes and the growth of knowledge in forestry. This, the 10th edition, in tune with the times reflects the fact that today's forester has not only timber to produce; he has also to ensure that as far as possible his woods enhance the landscape and provide an enriched habitat for wildlife.

In this Bulletin each chapter concentrates on a particular aspect of forestry but it should be remembered that forestry practice means the weaving together of them all.

Acknowledgements

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General Reading

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TANSLEY, A. G. (1949). *Britain's green mantle – past, present and future.* Allen and Unwin, London.

TAYLOR, W. L. (1945). *Forests and forestry in Great Britain.* Crosby Lockwood, London.

Further Reading

A list is to be found at the end of each chapter. The content of each list does not provide a comprehensive coverage of the specific area of forestry covered in the chapter – but will hopefully guide the reader into a particular area of interest. Forestry Commission publications which are now out-of-print are denoted by an asterisk. These may well be available in forestry college/departmental libraries for reference. A catalogue of Forestry Commission publications in print can be obtained from Publications Section, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH. Tel. 0420 22255 ext. 305.

CHAPTER 1

Seed

The choice of seed source is one of the most important decisions faced by the forest manager; an error in judgement can lead to unthrifty crops with poor stem and branch form, or prone to pests and diseases. Within the genetic constitution of the seed is the potential of either good or poor tree growth, and since even small increases in growth rate or improved timber quality can lead to a much enhanced return on investment, the advantages of using the best available seed from which to grow the planting stock are considerable.

The production of trees with good vigour, health, stem form and crown habit depends upon two interacting factors, the genetic constitution of the seed and the environment in which it is planted. Accordingly the forest manager must do his utmost to ensure that the seed he uses is of superior genetic quality for his purposes and that it is planted in the environment to which it is best suited. These considerations and the regulations governing the sale and purchase of seed are the main subjects of this chapter. FC Bulletin 59 *Seed manual for ornamental trees and shrubs* provides detailed information on the more specialised aspects of ornamental broadleaved tree seed, such as collection, storage, processing, testing, dormancy and pretreatment. A companion manual is shortly to be published in the same series, dealing with species used in plantation forestry. Raising seedlings is an aspect dealt with in the next chapter and in FC Bulletin 43 *Nursery practice*. Table 1 summarises most of the important information on seed production for the more widely used forest species.

SEED SOURCES

Provenance and origin

Tree species which occur over wide geographic areas develop sub-populations with slightly different characteristics which may, for example, be related to altitude and day length. These populations are usually not physically distinguishable from one another but each one is just a little better suited to its own particular environment. Seed from these populations (or ecotypes as they are called) is usually better adapted to grow in a similar environment to that in which its ancestors grew. In order to realise a tree's maximum potential growth it is clearly wise to plant seedlings on a site to which they are best suited and this is why information on the seed source is so important. The place from which a seed lot has been collected is called the *provenance*; the *origin* is the original native source.

Seed orchards

The Forestry Commission and some private estate owners have established seed orchards in which trees are exclusively managed for seed production (see FC Bulletin 54 *Seed orchards*). They are composed of individuals selected from parents with highly desirable attributes, grown either by grafting or by raising seed derived from controlled parental crosses. They are called respectively 'clonal' or 'seedling' seed orchards. Seed obtained from an orchard is more likely to be superior in genetic quality than that from plantation sources.

Seed stands

Early in their rotation young conifer stands selected for their good quality or perhaps rare origin are heavily thinned to keep only the best trees for seed production. Depending upon species and tree quality these may be entered into the National Seed Register of Seed Stands (see page 4). Seed collected from a local registered seed stand, where the origin is known to suit the planting environment, is the next best source after orchard material. But if locally produced seed is unavailable, or even the best local stands are of inferior quality, then seed collected from a high quality source growing on a broadly similar site elsewhere in Britain is a good alternative. When imported seed is the only source available caution must be exercised and, if there is a choice, an origin known to produce trees which will grow well in the region to be planted should be used.

Table 1 Seed production of trees in Britain

Common name	*Age of first good seed crop (years)*	*Age of maximum production (years)*	*Average interval† between good seed crops*	*Recommended time of seed collection‡*			*Notes*	*Notes on seed collection*	*Average number of cones per hectolitre*	*Average yield in grams of clean seed per litre of cones*
				Earliest	*Normal*	*Latest*				
BROADLEAVED										
Ash*	25–30	40–60	3–5	Aug.(1)	Oct.(2)	Nov.	(1) For immediate sowing (2) For stratification for 16–18 months			
Beech**	50–60	80–200	5–10	Sept.	Oct.	Nov.	Flowers sometimes damaged by late frosts			
Birch*	15	20–30	1–2	Aug.	Aug./ Sept.	Sept.	Good seed producers in Britain. Some seed most years, though sometimes empty			
Chestnut, Horse**	20	30	1–2	Sept.	Oct.	Nov.				
Chestnut, Sweet**	30–40	50	1–4	May	June	June	A warm late summer is required to ripen nuts. Collect biggest nuts only			
Oak,** Sessile and Pedunculate	40–50	80–120	3–5	Sept.	Oct.	Nov.				
Sycamore	25–30	40–60	2–3	Sept.	Sept./ Oct.	Oct.	Some seed most years			
Wych elm**	30–40	40	1–2	May	June	June				
CONIFERS										
Scots pine	15–20	60–100	2–3	Nov.	Jan.	Feb.	Some seed borne every year	Some seed retained in cones until early spring	5500	6
Corsican pine	25–30	60–90	3–5	Nov.	Dec.	Jan.	Most seed produced in SE & E England		2800	9
Lodgepole pine	15–20	30–40	2–3	Mid-Aug.	Late Aug./ early Sept.	Late Sept.			4500	4

Table 1 Seed production of trees in Britain (*continued*)

Common name	*Age of first good seed crop (years)*	*Age of maximum production (years)*	*Average interval† between good seed crops*	*Recommended time of seed collection‡*			*Notes*	*Notes on seed collection*	*Average number of cones per hectolitre*	*Average yield in grams of clean seed per litre of cones*
				Earliest	*Normal*	*Latest*				
European larch	15–20	40–60	3–5	Nov.	Feb./ March	April	Flowers often damaged by frost	As for Scots pine	10 000	10
Japanese and Hybrid larch*	15–20	40–60	3–5	Sept.	Sept.	Nov.	Flowers often damaged by frost	Also during November in Scotland in some years. Collect before European	9500	14
Douglas fir	30–35	50–60	4–6	Sept.	Sept.	Oct.		Collect when cones a light golden brown or yellow colour	3000	5
Norway spruce	30–35	50–60		Oct.	Oct.	Nov.	Rarely seeds heavily	As for Scots pine	1000	13
Sitka spruce	30–35	40–50	3–5	Sept.	Sept./ Oct.	Dec.			3600	9
Grand fir	40–45	—	3–5	Aug.	Aug./ Sept.	Sept.	A poor seed producer	Collect immediately the scales loosen and the cone softens, otherwise seed will be lost	700	26
Noble fir	30–35	40–60	2–4	Aug.	Aug./ Sept.	Sept.			2200	22
Western hemlock	30–35	40–60	3	Aug.	Sept.	Sept.		Collect as soon as cones change colour from bright green to yellow and the tips of the seed wings are visible and a light brown colour	58 000	13
Western red cedar	20–25	40–60	2–3	Aug.	Sept.	Sept.	A good seed producer		190 000	14
Lawson cypress	20–25	40–60	2–3	Aug.	Sept.	Sept.	A good seed producer		107 000	44

Notes: † The figures refer to the intervals between good seed years. In Scots pine, for example, 2–3 years of relatively poor production will generally follow a good seed year.

‡ *Sept./Oct. means at the end of September or beginning of October.* *Collect by special felling. **Collect fallen seed from the ground.

NATIONAL REGISTER OF SEED AND PLANT SOURCES

Since 1973 the Forest Reproductive Materials (FRM) Regulations, which arise from our membership of the EEC, have required the Forestry Commission to maintain a National Register of seed stands, seed orchards and poplar stool beds. These sources must have been inspected and found to meet certain criteria. Under the Regulations this register is required only to cover the following 13 species and one genus: European silver fir, European larch, Japanese larch, Norway spruce, Sitka spruce, Austrian and Corsican pine, Scots pine, Weymouth pine, Douglas fir, beech, Sessile oak, Pedunculate oak, Red oak and poplar. An owner wishing to have registered a plantation of one of the listed species or a poplar stool bed should contact his nearest Conservator of forests for advice. An inspection fee is charged whether or not the stand meets the criteria prescribed by law.

REGULATIONS GOVERNING THE SALE AND PURCHASE OF SEED

Under the FRM Regulations, seed of the 13 species listed, may not be marketed within the EEC unless from a source approved and registered by the Forestry Commission in Great Britain, or by the relevant authority in another member state of the EEC or Northern Ireland. (Exceptions are seed or cones to be used in tests for scientific or non-forestry purposes under the written authority of the Forestry Commissioners.) Seed of EEC species originating from outside the EEC countries must have been specially authorised for marketing in Britain by the Forestry Commissioners. Furthermore, seed of the 13 species, from wherever it originated, may only be marketed if it has been tested at an Official Seed Testing Station during the same seed testing year (1st July–30th June) as that in which it is marketed. Seeds of EEC species intended for export to non-EEC countries are not covered by the FRM Regulations; however they may be covered by alternative similar regulations of the importing country.

For species not covered by the FRM Regulations, seed from recommended sources is still to be preferred to seed from 'unknown' sources but only the normal consumer legislation protects the purchaser.

FURTHER READING: SEED

Forestry Commission publications

BULLETINS
43 *Nursery practice.*
54 *Seed orchards.*
59 *Seed manual for ornamental trees and shrubs.*
In preparation: *Seed manual for commercial forestry species.*

MISCELLANEOUS
The Forest Reproductive Material Regulations 1977 – An Explanatory booklet.

Other publications

McMILLAN BROWSE, P. D. A. (1979). *Hardy woody plants from seed.* Grower Books, London.

CHAPTER 2

Nursery practice

The raising of young trees in nurseries is the first stage in planting a forest and the Forestry Commission has had long experience of this work backed by years of research. The subject is fully covered in FC Bulletin 43 *Nursery practice* and anyone concerned with the management of forest nurseries is advised to consult that publication.

OBJECTIVES

The principle objective of the forest nursery is to produce good quality plants in uniform batches as cheaply as possible. In this context 'good quality' can be taken as meaning a sturdy plant, with a well balanced root and shoot, and with a well developed root system.

METHOD

Plants of the required standard are usually raised by a two stage process. Seed, given the appropriate presowing treatment (chilling where dormant, etc.), is sown on prepared seedbeds, designed to ensure maximum germination of the seed and good growth of the seedlings in their first growing season. The seedlings are then lifted when dormant and transplanted into lines where they have enough space to grow into well shaped plants fit to go into the forest at the end of a further growing season, referred to as '1+1 transplants'. This is the basis of the process but there are modifications. Less favoured nurseries or slower growing species may not produce usable plants in 2 years, and longer periods may have to be allowed in seedbeds and lines.

NURSERY SOILS

Both seedlings and transplants of conifers, and most broadleaved species (there are exceptions, e.g. ash and poplar), grow best in acid soils. Soils in the range pH 4.5 to 5.5 are the most suitable for forest nurseries; pH levels under 4.5 are too acid and those above 5.5 are too alkaline. Soil texture is also important because nursery work involves soil cultivations in winter and early spring. At these seasons, soils with a clay plus silt content exceeding 15 per cent are often too wet to cultivate, a factor which delays the nursery operation so that valuable growing time is lost. Although the clay or silt fraction in soil is valuable for its water and nutrient retaining characteristics, the factor of 'workability' is more important in the nursery and the nutrient retention problem is overcome by the addition of fertilisers. The best nursery soils therefore are the sandy loams or even sands which have the additional merit that they tend to be sufficiently acid.

Seedbeds

Successful seedling production depends on a number of factors, of which the two most important (provided good quality seed is available) are usually correct preparation of the seedbed and time of sowing. A properly prepared seedbed with a good tilth, well consolidated, is essential. If sowing is delayed beyond the optimum date (normally March in the south and April in the north) the time available for growth in the summer will be reduced and may result in seedlings too small to transplant. Sowing density is also important, and depends on the species being sown and the viability of the seed. A seedlot which has a high proportion of viable seeds has to be sown at lower density to give adequate growing space to the seedlings, the normal aim being to produce 600 usable seedlings per square metre.

Transplants

Correct spacing is important to allow plants to develop to the required size, but the success and cost of transplanting are very dependent on the workability of the soil. Light sandy soils are both easy to work and quicker to dry out in the spring. Lining-out is generally carried out using machines that place seedlings in position and firm the soil round the roots. The seedlings are fed into the planting mechanism by hand. The machines most widely used produce five or six rows of transplants with a density of 100–150 plants/m^2. Careful plant handling is essential for ensuring good survival after transplanting.

Plant nutrition

Successful nursery production depends very much on correct fertiliser application for both seedbeds and transplant lines. Suitable fertiliser regimes for both seedbeds and transplant lines have been developed from many years' research, and experience has shown how local knowledge, soil analysis and foliage analysis (of the crops) can be used to modify the general recommendations to suit a particular nursery. Most nutritional regimes are based on the use of both organic and inorganic fertilisers, although the inorganic material supplies the major part of the crop's nutritional requirement. Organic fertilisers are used mainly because there are indications that they help to maintain soil organic matter levels, thus preventing deterioration in moisture holding capacity and workability. Results of experiments suggest that inorganic fertilisers alone will give satisfactory results over long periods of time, and whilst soil organic matter levels have fallen, there has been little evidence of a fall in productivity. However, some soils, particularly heavier soils, have tended to become markedly more difficult to cultivate after continuous inorganic fertiliser application.

Weed control

Uncontrolled weeds will result in substantially reduced growth of seedlings, and to a lesser extent, of transplants, and as weeds quickly produce fertile seeds the aim is to keep a weed-free nursery. The inadvertent introduction of weed seeds in composts, organic fertiliser, imported seedlings and even tractor tyres or workers' boots should be guarded against. Acid soils have an advantage in that they have a more restricted weed flora than the more alkaline soils.

Modern herbicides give the nurseryman a much more effective armoury against weeds than was available previously using hand and cultivation techniques. Diphenamid is used as a standard pre-emergence spray on seedbeds of all species except birch and alder. The most widely used herbicide for weed control in transplant lines is simazine. With all herbicides, careful adherence to dosage rates and timing is essential. There is no universal answer to the wide range of weed species in the different phases of nursery work, and the nurseryman has to apply the appropriate technique for each set of circumstances. The subject is covered in Chapter 10 of FC Bulletin 43.

Irrigation

Most nurseries can expect a dry spell at some stage in the growing season. Lack of available soil moisture can reduce germination and survival of seedlings, and limit growth of transplants. In addition, many nursery herbicides and granular fertilisers require moist soil to be fully effective. For these reasons a good irrigation system is an important tool in nursery management.

OTHER PLANT PRODUCTION TECHNIQUES

There are a number of alternative techniques to the main nursery method of seedbed and transplant lines outlined above. They are:

Small containers

Seedlings can be raised in small containers in unheated polythene greenhouses and planted out at 12 to 25 weeks old. To minimise root disturbance seedlings are planted either in biodegradable containers or in plugs of growing medium held in re-usable containers. These techniques have been widely used in Scandinavia and North America. However, under British conditions costs of production tend to be slightly higher than for transplants. Containerised stock is generally smaller and less robust than normal stock. Trials in upland Britain have generally shown that containerised stock does not establish in the field as quickly as transplants. However, in East Anglia, container-grown Corsican pine, a species sensitive to root damage, has proved more successful than conventional nursery stock. An integrated establishment system combining intensive site preparation and mechanised planting and weeding has been developed in this region to back up the use of container-grown stock.

Seedbed cloches

Improved germination and first season growth of pines can be obtained by covering seedbeds immediately after sowing with clear polythene tunnel cloches. In northern nurseries this technique can make the difference between being able to produce a transplantable seedling in one year and having to hold seedlings over for a second growing season. To prevent weed competition it is advisable to sterilise seedbeds where cloches will be used. Sowing densities should be reduced (compared with normal seedbeds) to ensure seedlings do not become spindly. Cloches are removed 12–16 weeks after sowing and thereafter normal nursery methods apply.

Undercutting

Instead of transplanting seedlings their roots can be severed in the seedbed by drawing a sharpened steel blade through the bed at the appropriate depth. The effect of this is to cut the main root and stimulate the formation of a branched and fibrous root system. Seed has to be sown at a lower density to give greater growing space, and this involves controlling weeds on a larger area of seedbeds and into a second season of growth. However, undercutting has the important advantage of eliminating the costly transplanting operation. The technique has been successfully applied in New Zealand for large scale pine production.

Vegetative propagation

Traditionally, few forest trees have been grown from cuttings with the exception of poplar, willow, London plane and elm, and amongst the conifers Lawson cypress, Leyland cypress and Western red cedar. However, recent research shows that cuttings of a range of coniferous and broadleaved species can be propagated successfully from stem cuttings provided that these are collected from young (less than 4 years old) parent trees. Cuttings are raised under an intermittent mist irrigation regime in a polythene greenhouse. Species successfully propagated under such conditions include Sessile oak, Gean, Lodgepole pine, Sitka spruce and Hybrid larch. This technique is of particular interest where highly productive material can be identified that is too scarce to allow use of conventional nursery techniques. The use of rooted cuttings of superior Sitka spruce has proved promising and large scale trials are now under way to mass produce such material for field planting in upland Britain.

NURSERY PROTECTION

It is normal practice to net seedbeds for about 12 weeks after sowing to prevent birds taking seeds and small seedlings. Nurseries should be fenced against the risk of damage from rabbits, stock and deer where necessary. Damage from fungi, insects and climatic factors (e.g. frost) will occur in most years and the nurseryman needs to be able to diagnose the problem and take appropriate remedial action. Further details can be found in Chapter 4.

COLD STORAGE

A cold store is an essential tool in modern nursery management. A small store can be used to hold seedlings temporarily prior to transplanting should weather or soil conditions prove unfavourable. Similarly, a larger store may be used to hold lifted transplants in a dormant state until forest planting conditions are suitable. Several types of cold store are available, and handling and packaging systems must be adapted to the particular store used.

SITE SELECTION

It will be clear from the above that the selection of a suitable nursery site is the foundation of the successful nursery. Summing up, the requirements are:

a sandy or sandy loam soil of acidity between pH 4.5 and 5.5;
a gently sloping, free draining site which avoids frost hollows;
availability of labour, supervision and management;
an adequate water supply on site;
buildings for storage and mechanical equipment.

TRENDS IN NURSERY MANAGEMENT

During the last 20 years the trend has been to concentrate production in larger nurseries where skilled labour and management, specialised equipment and favourable site conditions can be brought to bear on a large output, and so result in lower production costs.

FURTHER READING: NURSERY PRACTICE

Forestry Commission publications

BULLETINS
37 *Experiments on nutrition problems in forest nurseries. Vols. I & II.**
43 *Nursery practice.*
53 *Production and use of tubed seedlings.*

BOOKLET
52 *The use of chemicals (other than herbicides) in forest and nursery.*

FOREST RECORDS
60 *Procedures used for progeny-testing in Britain with special reference to nursery practice.**
67 *Effect of fertiliser and density pretreatment on spruce seedling survival and growth.*
88 *Cold storage of forest plants.*

LEAFLETS
43 *Keithia disease of Western red cedar.*
50 *Grey mould in forest nurseries.*

RESEARCH AND DEVELOPMENT PAPERS
46 *A review of research and development in forest nursery techniques in Great Britain (1949–1966).**
85 *A plan for the improvement of Sitka spruce by selection and breeding.*
87 *Production and use of ball-rooted planting stock in Sweden and Finland.**

103 *Survey of losses of first-year conifer seeds and seedlings in Forestry Commission nurseries 1972.**

109 *Fertiliser effects on the growth and composition of Sitka and Norway spruce nursery transplants and on the composition of a podzol profile after 15 years cropping.*

RESEARCH INFORMATION NOTES

80/83/SEED *Overcoming dormancy of tree and shrub seeds.*

90/84/SILN *Vegetative propagation of conifers using stem cuttings. I. Sitka spruce.*

91/84/SILN *Vegetative propagation of conifers using stem cuttings. II. Hybrid larch.*

92/84/SILN *Vegetative propagation of conifers using stem cuttings. III. Commercial conifers other than Sitka spruce and Hybrid larch.*

Other publications

BIGGIN, P. (1983). Tunnel cloches – development of a nursery technique for growing conifers. *Forestry* **56**(1), 45–60.

LAMB, J. G. D., KELLY, J. C. and BOWBRICK, P. (1975). *Nursery stock manual.* Grower Books, London.

STANLEY, J. and TOOGOOD, A. (1981). *The modern nurseryman.* Faber and Faber, London.

TINNS, R. W. and McDONALD, S. E. (1979). *How to grow tree seedlings in containers in greenhouses.* General Technical Report RM–60. USDA Forest Service, Rocky Mountain Range and Experiment Station.

CHAPTER 3

Establishment and tending

OBJECTIVES

The first essential before starting establishment operations is to decide on the objectives. Failure to make these clear from the outset will create difficulties and mistakes in all subsequent operations. Most forestry planting will have as its main objective the production of timber but there will be other subsidiary objectives of landscape, conservation, recreation, sporting and shelter which are likely to result in some reduction in timber producing capacity. Occasionally such objectives will be paramount but rarely to the entire exclusion of timber production.

Timber production

It is necessary to consider the type of timber required, the length of time it will take to produce it and the potential markets, matters which are discussed in greater depth in Chapters 9, 10 and 12. With these in mind, it is possible to select species which will give the best yield for the sites concerned. In most cases both quantity and quality of timber produced will be important. Obviously problems will arise if substantial quantities of low grade (and therefore low value) material are produced, unless there is a suitable market in close proximity. Good quality saw log material, whether coniferous or broadleaved, is much more likely to find a satisfactory market. In upland areas and on less fertile lowland sites, use of coniferous species will almost invariably give the best return. Good quality broadleaved timber can only be produced on the more fertile lowland sites. Coppice has had a major influence on broadleaved woodlands in the past and is still practised extensively with Sweet chestnut. Coppice is discussed at the end of this chapter.

Landscape

There are occasions when landscape improvement or maintenance will be an overriding objective; tree planting on motorway and trunk roadsides is one example. Usually however, landscape will be a subordinate although still important consideration. In recent years our predominantly urban population has become increasingly interested in the appearance of the countryside and there have been justifiable objections to unsympathetic changes in landscape caused by afforestation or clear felling. Changes due to forestry activities can usually be blended into the landscape by paying proper attention to the shape of plantation edges, the location of different species and the retention of existing broadleaves. The principles are well explained by Dame Sylvia Crowe in FC Booklet 44 *The landscape of forests and woods*.

Wildlife conservation

This is discussed in greater detail in Chapter 14. It is important to give attention to conservation when setting overall objectives. The level of priority necessary will vary greatly, from the site of unique conservation value which may impose considerable constraints on forestry – e.g. ancient woodland whose history can be traced back to medieval times and further – to simple conservation measures involving little or no sacrifice of timber potential, such as keeping trees back from stream edges or mowing ride and road sides alternately in successive years. Conservation will often have some influence on choice of species.

Recreation

This also is discussed in greater detail in Chapter 15. Like conservation, it needs to have a defined place in the objectives so that decisions on planting layout and choice of species can take into account present and possible future recreational needs.

CHOICE OF SPECIES

Correct choice of species is essential if the selected objectives are to be met. Where timber production is important there is no point in planting species which are incapable of growing usable timber on the sites involved. In Britain, climatic conditions are generally favourable for tree growth and a wide range of species will grow well. Before considering the influence of site factors it is useful to examine the species available to the forester.

Native tree species

These are the trees which colonised Britain unaided by the influence of man after the last Ice Age, about 10 000 years ago. This natural re-invasion of trees ceased when the English Channel opened some 6000 years ago. Trees which are regarded as native number about 30, depending on whether certain larger shrubs are considered to be trees. They are listed in Table 2. Of this total only a few are suitable for commercial timber production, although a few more have wood of some interest for craft work and decorative purposes. Generally these trees do not have the ability to produce high yields of timber although individual values may still be high for timber of good quality (see Chapter 12).

The classification 'native trees' does present some problems of definition because some species which clearly came into Britain through the influence of man are well established and sustain themselves naturally – sycamore and Sweet chestnut being good examples. English elm is another, although this is now surviving only as hedgerow suckers because of the effect of Dutch elm disease on mature trees. There are also difficulties because some trees have a limited natural distribution in Britain. Beech, for instance, is not regarded as having spread naturally into Scotland.

Table 2 Native tree species

The trees generally accepted to be truly native are, in an approximate order of arrival here:

Common juniper	*Juniperus communis*
Downy birch	*Betula pubescens*
Silver birch*	*Betula pendula*
Aspen	*Populus tremula*
Scots pine*	*Pinus sylvestris*
Bay willow	*Salix pentandra*
Common alder*	*Alnus glutinosa*
Hazel	*Corylus avellana*
Small-leaved lime*	*Tilia cordata*
Bird cherry*	*Prunus padus*
Goat willow	*Salix caprea*
Wych elm*	*Ulmus glabra*
Rowan	*Sorbus aucuparia*
Sessile oak*	*Quercus petraea*
Ash*	*Fraxinus excelsior*
Holly*	*Ilex aquifolium*
Common oak*	*Quercus robur*
Hawthorn	*Crataegus monogyna*
Crack willow	*Salix fragilis*
Black poplar	*Populus nigra* var. *betulifolia*
Yew	*Taxus baccata*
Whitebeam	*Sorbus aria*
Midland thorn	*Crataegus laevigata*
Crab apple	*Malus sylvestris*
Wild cherry*	*Prunus avium*
Strawberry tree	*Arbutus unedo*
White willow	*Salix alba*
Field maple	*Acer campestre*
Wild service tree	*Sorbus torminalis*
Large-leaved lime*	*Tilia platyphyllos*
Beech*	*Fagus sylvatica*
Hornbeam*	*Carpinus betulus*
Box	*Buxus sempervirens*

* Trees that produce timber

There are two other features of this native group of trees. Firstly they include only three conifers, Scots pine, yew and juniper. Only Scots pine is an important timber tree, though the wood of yew is extremely decorative and valued for this reason. Secondly, the number of broadleaved native trees capable of producing timber for industry is small, and in comparison with many non-native species their yields are low. The average volume yield of all broadleaves in Britain is about 5 cubic metres per hectare per annum, whilst that for the conifers is about 11.

The category of native trees is helpful in the context of the conservation of ancient woodland. However, any attempt to confine forest planting to these species would affect forestry adversely by preventing the use of valuable timber trees which are not necessarily harmful to conservation interests.

Exotic species

Apart from sycamore, Sweet chestnut and English elm (which have in fact become naturalised) there are no exotic broadleaved species with a major forestry role at present. There are some promising candidates which may become more widely planted, e.g. the Southern beeches (*Nothofagus* species) and possibly *Eucalyptus*, particularly if seed origins of more hardy genotypes can be identified.

In the case of coniferous species the position is very different because, with the exception of Scots pine, all the timber producing conifers used in British forestry have been introduced to this country. The introduction of exotic tree species into Britain has been stimulated by two factors. Firstly the climate in Britain is favourable to tree growth because of relatively mild winters and rainfall distributed throughout the year. Spring frosts and summer droughts may have a severe effect on newly planted trees but do not usually affect trees seriously after the establishment phase. The second factor is historical; land owners were interested in establishing exotic trees in their arboreta and gardens, and vied with one another to import and grow the latest discoveries as various countries were explored.

Varieties and cultivars

Although the numbers of varieties and cultivars of ornamental trees are very large, only cultivars of poplar have any present significance in forestry. European and American poplars have been successfully crossed to produce a number of fast growing disease resistant varieties which have been successfully planted in lowland Britain. Cultivars of other species may assume more importance in the future as results of tree breeding are applied to forestry through the medium of vegetative propagation. This is already happening with Hybrid larch and Sitka spruce.

Provenance and seed origin

The process of determining which species were suited to conditions in Britain and which site factors influenced their growth was, in the early stages, a process of trial and error. Later systematic experimentation, testing species and provenance on a range of different sites, has given a better understanding of species performance in relation to site factors. Some species have a very wide natural distribution covering a range of climatic and site types, and it is important to choose appropriate races and provenances within that range to suit British conditions. Sitka spruce is a good example. It has a natural north-south distribution of some 1500 miles from Alaska to Oregon (from latitude 39° to 61°N). Its east-west distribution is restricted to coastal areas, and it is not tolerant of low humidity, low rainfall or drought. The more northerly origins are adapted to a short growing season with long day length and in Britain are slow growers (although tolerant of spring frosts). The southern origins are more vigorous but because they start to grow early in spring they are susceptible in Britain to spring frost damage. In practice Sitka spruce seed origins from the middle of the range are well suited to most conditions in Britain, Queen Charlotte Islands being amongst the best.

Distribution of species

The Forestry Commission's 1979–82 Census of Woodlands shows that there has been a tendency to concentrate on a small number of species in Britain. In coniferous high forest Sitka spruce, Norway spruce, Scots, Lodgepole and Corsican pine account for 80 per cent of the area. The principal broadleaved species are oak, beech, sycamore, ash and birch which together make up 77 per cent of the total broadleaved area of high forest.

Site factors

Factors which have a marked influence on tree establishment and subsequent growth are soil, local climate and topography. Different tree species are adapted to different conditions and within species, differences in races or provenances are important. However, there is a risk of making the process of matching species and site over-complicated and maximising yield through use of a wide range of species is likely to introduce management and marketing problems. Some species, Sitka spruce for example, can grow reasonably well on a wide range of site conditions.

Soil

Classification of soil for forestry is concerned with the physical properties which influence root development and hence tree stability, and with the chemical properties which affect nutrient availability. General purpose or pedological classifications of soils have therefore been modified by foresters to place emphasis on physical factors such as depth of soil, soil water regime and aeration, and the presence of compact or cemented layers which limit downward rooting. These factors not only control root growth but they may also affect root function, i.e. the ability to take up water and dissolved nutrients and to survive extreme conditions such as drought or waterlogging. The ability of the soil to provide nutrients therefore depends on these factors as well as on the mineral composition of the soil material, whether this be derived from the bedrock itself or a drift material deposited by ice, water or wind.

The most recent soil classification for forestry purposes is that of Pyatt (1982) in Research Information Note 68/82/SSN. The 1:250 000 soil maps and accompanying reports of the Soil Survey of England & Wales and the Soil Survey of Scotland cover the whole country for the first time and give some useful information for forestry.

Table 3 summarises species choice according to a simplified soil classification. Brief descriptions of these soils follow.

Brown earths

Freely drained, usually loamy textured soils that are slightly or moderately acid in reaction. They are fertile and usually provide favourable rooting conditions but are liable to encourage strong weed growth of bramble or bracken.

Podsols

These are also freely drained soils with good rooting conditions but are strongly acid and less fertile than brown earths. Textures are usually sandy and it is convenient to include in this group other sandy textured brown earths and coastal soils. Heather vegetation is typical of this group.

Ironpan soils

These are mainly upland soils with a perched water-table above the thin cemented ironpan and often with a peaty surface layer. Aeration is readily improved by cultivation and by tree growth itself, but fertility is usually rather low. Heather, Mat grass or Purple moor grass are typical.

Table 3 Soils and species choice

Soil	*Soil codes (Pyatt)*	*Conifer species*		*Broadleaved species (sheltered sites only)*	*Remarks*
		Sheltered	*Exposed*		
Brown earths (loams)	1, 12t	Douglas fir Larches	Sitka spruce	Beech	Most tree species will grow well on this soil type.
Podsols and other sandy soils	3, 15	Scots pine Corsican pine Larches Sitka spruce	Sitka spruce (Lodgepole pine)	Birch	Sitka spruce and Douglas fir may suffer heather check unless planted in mixture with pine or larch.
Ironpan soils	4	Sitka spruce	Sitka spruce	Birch	Mixtures of spruce and pine or larch may be used.
Lowland gleys	5, 7	Corsican pine Norway spruce	Corsican pine Norway spruce	Oak Alder Birch	
Upland gleys and peaty soils		Sitka spruce Norway spruce (where non-peaty)	Sitka spruce Norway spruce (where non-peaty)	Birch Oak (where non-peaty)	
Peatlands and flushed basin bogs	8, 9	Sitka spruce	Sitka spruce	Birch	Birch for amenity and conservation only.
Peatlands, raised, flat or blanket bogs	10, 11	Sitka spruce Lodgepole pine	Sitka spruce Lodgepole pine		Mixtures of Sitka spruce with pines or larch may be used.
Calcareous soils	12a, 12b	Corsican pine	Corsican pine	Beech Norway maple Sycamore	Where free calcium carbonate is present in the topsoil most species will suffer lime-induced chlorosis.

Lowland gleys

These are mainly heavy clay soils, often calcareous in the subsoil, but also included are groundwater gleys of lighter texture. Poor aeration in winter restricts rooting to the topsoil except for well-adapted species such as alders and oak. The soils are usually fertile and very weedy especially after clear felling. Grassy vegetation, especially Tufted hair grass, is usual.

Upland gleys and peaty gleys

Textures are clays or loams in which the high rainfall maintains a shallow water-table for much of the year. A shallow (<45 cm) peat layer forms on the wettest sites. Rooting is restricted in depth. Nutrition is usually adequate on non-peaty gleys, though the application of phosphate may be beneficial, especially on peaty gleys. Tufted hair grass is characteristic of non-peaty gleys, with Purple moor grass on peaty gleys.

Peatlands; flushed and basin bogs

These are sites with an impermeable substrate where peat has accumulated under the influence of water seepage from nearby higher ground. This flushing water brings nutrients which become incorporated into the peat via the bog vegetation. The vegetation contains the tall species of rush and usually Purple moor grass.

Peatlands; raised, flat or blanket bogs

Peat which accumulates in the absence of flushing has a low nutrient content and carries a 'bare ground' vegetation which is tolerant both of the waterlogging and poor nutrition. Such species include Deer sedge (*Trichophorum*), Cotton grass (*Eriophorum*), heather, Cross-leaved heath and several *Sphagnum* moss species. Characteristically, Purple moor grass is absent from these sites, although on blanket bogs unflushed and flushed areas often occur in close proximity.

Calcareous soils

These are found on the chalk and limestone rocks mainly in lowland England. When shallow to bedrock and calcareous to the surface they provide difficult conditions for tree growth because of lime-induced chlorosis. Deeper soils with high pH restricted to the subsoil behave similarly to non-calcareous brown earths.

Exposure

This is related to elevation but topography plays a major part. Hillsides are more exposed than valleys at the same elevation whilst low ground with no shelter by hills or trees can also be extremely exposed. On exposed sites, early establishment of trees may be difficult. At a later stage, tree crops may be susceptible to windthrow and this can be a serious problem on upland areas with shallow soils which inhibit root depth. Exposure problems close to the sea are exacerbated by salt-laden storm winds.

Table 3 is an attempt to produce a simplified guide to species choice by grouping the main soil types from Pyatt's classification, showing for each soil group only the species most commonly planted on a commercial forestry scale.

The individual characteristics of a range of tree species, in relation to site, timber qualities and yield, are given in the appendix to this Chapter.

ESTABLISHMENT METHODS

If bare land is being afforested the only practical method available in most circumstances is the planting of young trees raised in a nursery. Very rarely direct sowing or the insertion of unrooted cuttings may be used. If there is an existing tree crop then two other alternatives are available for establishing a new crop – the use of natural regeneration or (with some broadleaved species) coppice.

Successful direct sowing with pine seed has been achieved on heathland sites, particularly with Scots pine. Good weed control, typically by burning and ploughing beforehand, is essential. Direct sowing of acorns has also resulted in successful establishment. However, the risk of heavy losses from predation by birds and small mammals is high, frost lift on mineral soils can be a problem with small conifer seedlings and the control of weed competition is difficult. On balance, direct sowing is regarded as unreliable in most circumstances and is an extravagant use of valuable seed.

The use of nursery transplants, which typically spend 1–2 years in the seedbeds and 1–2 years in transplant lines, is the usual practice in Britain. If such stock is properly handled and planted success rates are high and there is the opportunity to introduce improved genetic material. Only with poplars and willows is the use of unrooted cuttings a practical proposition and their use must be accompanied by ground cultivation. Unrooted cuttings are a very cheap form of planting material.

Where a tree crop is to be replaced natural regeneration is a possibility and with broadleaved species coppicing is an option. However, there are two main disadvantages. Firstly, seed years are intermittent and unpredictable with most species, typically 5 years or so with oak and beech and rather less infrequently with conifers. This makes relying on natural regeneration difficult in most situations where the timing of the felling programme is controlled by market factors. Secondly, natural regeneration and coppice provide no opportunity for change of species or the introduction of improved genetic stock.

However, establishment costs are low when advantage can be taken of natural regeneration. It is important to ensure that dense thickets of natural regeneration have their stocking reduced at an early stage otherwise heavy snow falls may cause high losses due to stem breakage.

The cost of establishment is the main one in the whole sequence of operations in managing a plantation and methods therefore need to be critically appraised. Each operation can be appraised in order to ensure that the right intensity and timing of each job is chosen.

GROUND PREPARATION

Clearance

Much depends on the amount of lop and top on the ground and what cultural operations are planned. If there is heavy branchwood arising from felling broadleaves then it is advisable to cut and remove the larger material for firewood and burn the remainder. This work should be carried out as felling and should be part of the felling operation. Leaving lop and top to be cleared later invariably leads to a much more difficult and expensive operation, and if no cleaning is done subsequent weed control becomes almost impossible. Conifer tops and branches are lighter and it is usually possible to plant through them without further treatment (particularly if they are left to decay for a season), although extra planting costs will usually be incurred and a good standard of planting can be difficult to maintain. In upland areas with peaty soils the brash which is often accumulated in windrows to assist the harvesting operation may seriously impede replanting. In the pine woodlands of East Anglia clearance of lop and top by heavy-duty brush chopper is carried out partly to facilitate use of a planting machine which makes a shallow furrow, but also because bare ground reduces the incidence of radiation frosts in the spring.

Drainage and cultivation

Soils which suffer from excessive water are usually in this condition because they are fine textured or very compact in the subsoil and movement of soil water through them is very slow. It follows that drains on such soil types (most peats and gleys) will only remove substantial amounts of water from the upper more permeable layers. Where there is restricted horizontal movement of water through the soil deeper drains at closer spacing are unlikely to be beneficial. The spacing between drains should vary with the slope, from 20 m on deep peat with slopes of less than 3° to 50 m on steep loamy gleys. However, it is important to have a drainage system which removes surface water and does not allow it to accumulate in hollows or in plough furrows. The layout of a main drain system must take into account the catchment area it will serve. If the catchment is too large heavy rainfall will overburden the drain causing erosion, if too small then the drain will not have sufficient flow to keep itself clear of blockages. The optimum slope along a drain is about 2°, which is steep enough to ensure rapid water movement and minimise silting, but not so steep as to cause serious erosion. Drains should run towards the head of the valley when draining slopes; this gives the shortest length of drain for a given catchment area and allows better control of the slope of the drain as it approaches the water course.

Successful tree planting on many peaty soils was achieved in the 1920s and 30s by planting on upturned turves which provided an adequately dried microsite on which the tree could establish itself. Ploughing to provide a raised turf for planting is now the most common form of forest cultivation. Once establishment is achieved tree roots are an effective way of drawing moisture out of impervious peats and clays and this can result in a drying and cracking process which is not reversed even in the winter. Unfortunately after felling the presence of tree roots makes it very expensive to plough restocking sites and so provide raised furrows for replanting. The alternative of making planting mounds (or dollops) with an excavator or digger is effective but also expensive and the forester has frequently to replant without cultivation by making use of raised positions, usually beside tree stumps.

On sites with inadequate slopes where disturbance has occurred for mineral working, open-cast coal for example, artificial ridges 30 m wide with height at centre of 1.5 m have proved very effective in inducing both surface run off and, provided compaction has been relieved by ripping, some water movement through the soil.

Many potential forest soils are impervious to water and root penetration because they are either heavily compacted by the effect of the last Ice Age or have developed a pan resulting from deposition of iron compounds at depths between 10 and 40 cm. Deep ploughing using a specially designed plough was found to be an answer to this in the late 1930s. Modern ploughs for mineral soils usually have a deep subsoiler or ripper combined with a shallow mould board which produces an upturned ridge and hence a well-drained weed-free planting position. Complete ploughing is seldom used in forestry but may have a place on highly indurated soils.

FENCING AND TREE PROTECTION

Both farm and wild animals can seriously damage young plantations and fencing is one way of preventing this. However, fencing is expensive; careful planning is required to ensure that it is only used where essential and that the most economical and effective specification is adopted. Protection of the young plantation may not be the only consideration; although the owner of farm animals is required by law to keep them under control and to fence against his own stock, many conveyances include clauses which require a woodland owner to maintain a stock fence on the boundary. There may be other legal constraints such as rights of way, both public and private, though usually these can be overcome by gates, stiles or cattle grids at the appropriate places.

Clearly there will be situations where fencing is unnecessary because there are no damaging animals present or because numbers can be reduced to levels causing little damage; rabbits are a case in point. There will also be instances when the cost of fencing would be so high that it is cheaper to provide individual protection for each tree than to fence the whole area. Each case will vary depending on the area, length and type of fence involved and the number and cost of individual tree protection. In Figure 1 the costs per hectare of fencing areas between 1 and 10 hectares are compared with the cost of protecting either 500 or 1000 trees/ha against deer and rabbits (from Burdekin, 1982). The cost per hectare of fencing a 6 hectare block is similar to that for protecting individual trees planted at 500 trees/ha. If protection were provided for 1000 trees/ha the cost would be similar to fencing a 1.5 ha block. Additional advantages of individual tree protection include less interference with game bird management and a possible revenue from roe deer.

Individual tree protection can take the form of a wire or plastic mesh cylindrical guard which prevents damage by rabbits and roe deer. Alternatively a transparent plastic tree shelter can be used which not only protects the tree from mammal damage but also enhances early growth of the tree by the shelter and greenhouse effect. These shelters also facilitate weed control because trees are easily found and the plastic prevents accidental herbicide damage to the young tree. Further details can be found in Arboricultural Leaflet 10 *Individual tree protection.*

Fence specification

Spring steel wire is now recommended for all forest fences and mild steel is not used. Spring steel has the advantage that once tensioned in a fence it has the ability to accept further accidental tensioning from animals or humans or trees without deforming; consequently it returns to its original position and tension once the accidental load is removed. Multiple

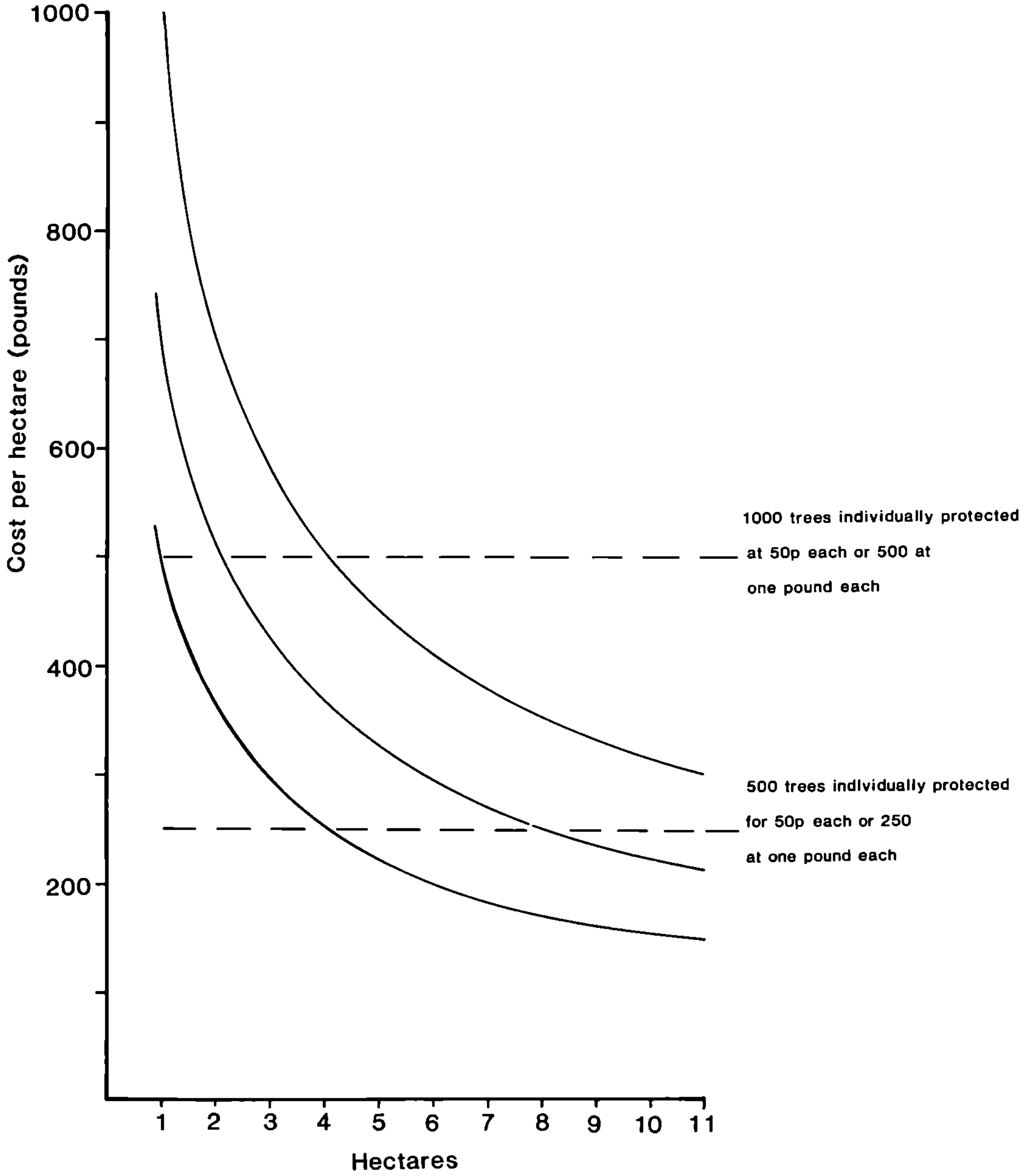

Figure 1. Cost of rabbit/roe fence compared with individual tree protection. Outer curves delineate the maximum and minimum range of the cost of fencing, whilst the central curve represents the average cost.

wires are not used in spring steel fences but netting of various sizes, depending on the animals constrained, is used instead. Because spring steel fences retain tension well the spacing of the supporting fence posts can be increased substantially, thus reducing both material and erection costs.

The fencing specification must match in height and strength the animals it is wished to constrain. Figure 2 illustrates a typical deer fence; this and other designs are given in FC Leaflet 87 *Forest fencing*. Expected fence life is a further consideration. Wooden posts and rails must be pressure treated with preservative if the fence is to be permanent but untreated wood can be used for a temporary fence.

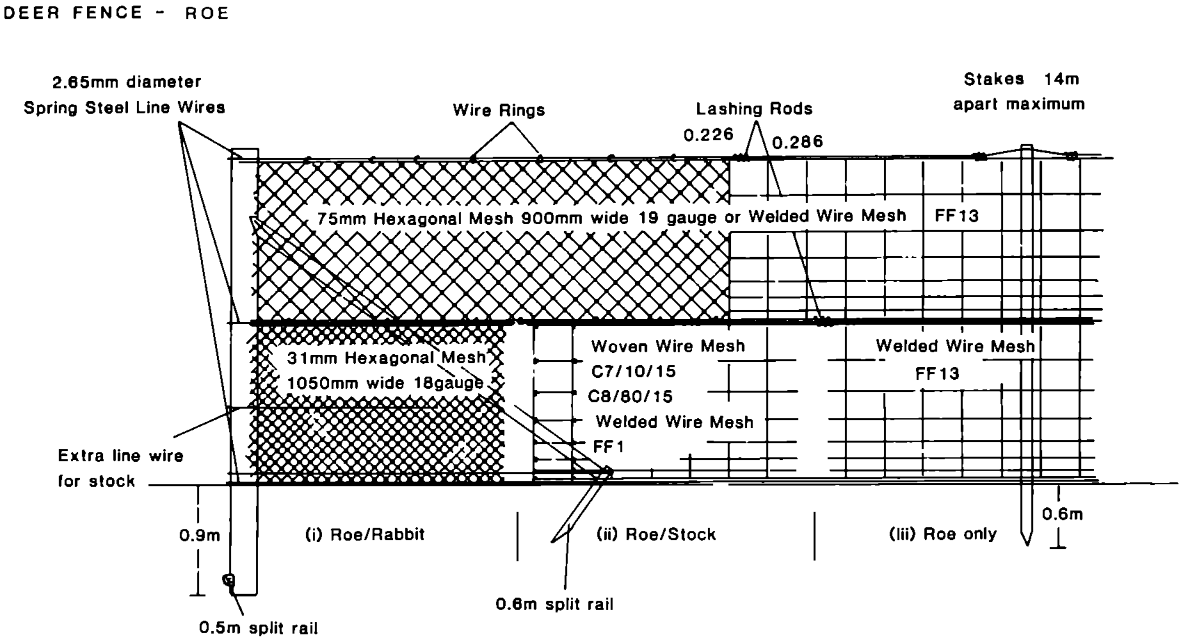

Figure 2. Designs of typical deer fencing (for protection against roe deer).

PLANTING

Spacing

A number of factors influence the decision on spacing at time of planting and over the post-war period there has been a steady trend to widen spacing from 1.4 m to between 2 and 3 m. However, for Sitka spruce recent wood quality studies have shown that it is probably unwise to exceed 2 m spacing if structural quality sawnwood is to be produced.

The advantages of using a wide spacing compared with a closer one are:

- reduced costs of cultivating, plants and planting.
- increase in tree size thinned.

The disadvantages of increasing spacing are:

- losses of plants cause large gaps.
- canopy closure and full site utilisation takes longer, hence time of first thinning is delayed.
- branch suppression is delayed, leading to larger knots and reduced timber quality.
- more rapid diameter growth results in wider annual rings and greater taper with consequent reduction in recovery of sawnwood.
- smaller numbers allow less intensive selection of good quality stems.

The spacing adopted must be a matter of judgement on the part of the forester after taking these factors into account for the site and crop involved.

Plant type

There are several plant type possibilities. The tradition in Britain is to use a bare-rooted transplant, raised from seed, spending 1 or 2 years in seedbeds, then being transplanted for a further 1 or 2 years. Transplants are described as 1+1, 2+1, 1+2, etc., depending on the years spent in seedbed and transplant lines. Typically such plants are 20 to 40 cm in height with a root system in balance with the crown and a sturdy stem diameter.

The effect of transplanting in the nursery is to stimulate the production of a compact fibrous root system. Undercutting in the nursery seedbeds is an alternative to transplanting and if correctly carried out is a satisfactory method. Two-year-old and 3-year-old undercut plants are referred to as 1 u 1 and 1 u 1 u 1 respectively.

Generally smaller plants are preferred for planting in exposed localities, whilst larger ones are used on the more fertile sites where weed growth is greater and exposure less. The use of seedlings (i.e. 1+0 or 2+0) which have not been transplanted or undercut incurs the risk of severe losses due to the small size, low reserves or imbalance between root and shoot in these plants.

Plants raised in small containers, typically the Japanese paper pot, have been extensively tested. The main species such as Sitka spruce, Lodgepole pine, oak and beech do not perform any better as container plants than they do as bare-rooted stock so there are no strong reasons for using the more expensive plants. Container-raised Corsican pine is used in East Anglia because the system fits in well with mechanised planting and because the use of containers extends the planting season. Corsican pine is a difficult species to plant and survival can be poor, although the use of container plants does not always overcome this difficulty. Container-raised *Eucalyptus* have been very successful in trials.

TENDING

Beating up

Some losses after planting are almost inevitable due to accidental mammal, insect or fungal damage. However, if a standard initial spacing of say 2 m has been adopted then scattered losses up to 20 per cent may well be tolerated and no replacement or beating up need be attempted. However, with a wider spacing of say 3 or 3.5 m any failures will leave substantial gaps which will take a very long time to close, leading to heavily branched trees on either side, and beating up is desirable. Inevitably plants used in beating up are at a disadvantage, being at least one year younger than the rest of the crop and although this may be mitigated to some extent by using larger plants, long-delayed beating up may be ineffective as trees run the risk of being suppressed by their neighbours. In these circumstances it will be better if one replacement plant is substituted for two failures. It should be remembered that delayed beating up will extend the period over which weeding will be necessary. The conclusion is that the best course is to adopt high standards of plant handling and initial planting so as to minimise or better still eliminate the need for beating up.

Weed control

Traditional forestry practice has been to cut any weeds which might shade the crop trees too strongly or which could cause physical damage by collapsing on them in winter. Before the advent of herbicides weed cutting was the only practical way of controlling weed growth after planting. In recent weeding experiments, however, it has been found that cutting weeds does little to reduce competition for moisture and nutrients and may even increase it. Root competition reduces tree growth. On dry sites or in dry years, it actually reduces the survival of newly planted trees. Competition is most detrimental if the trees have already been stressed, for example by poor planting or desiccation during transport from the nursery.

On many upland sites where new planting is undertaken, weed reinvasion after ploughing is sufficiently slow to allow satisfactory crop establishment with no further weed control, but herbicide control will be needed on many unploughed restocking sites. Most lowland sites, even when ploughed, will require chemical weed control.

Mechanical weeding with a tractor-mounted swipe or with a clearing saw prevents woody weeds getting too large. However, the strong growth of herbaceous weeds that usually follows is extremely competitive. A weed-free area of about 1 m diameter around the tree is a convenient size, obtainable by the use of a suitable herbicide, and it will give a good degree of relief from competition. As competition is most serious during spring and early summer, weeding in mid-summer or later will have little effect in that growing season, although it will help the trees in the following year provided there is little weed reinvasion.

There are many herbicides available which will control weeds in forestry. They work in a variety of ways, some entering through the leaves of weeds, others through their roots. They must be applied before the trees are planted or when the trees are at a non-vulnerable stage, or else the trees must be guarded. An alternative which is proving popular in forestry practice is to use direct applicators (weed wipes) to place the herbicide on to the weeds. It should be remembered that a successful herbicide application is often followed by a change of weed species, requiring a different chemical at the next weeding.

The large number of weed and crop species and the variety of herbicides and application methods make the subject a complicated one. The reader is directed to FC Booklet 51 *The use of herbicides in the forest* where detailed advice can be found. In practice it is likely that for any particular forest area a range of, say, three herbicides and application methods will cope with the various weeding situations encountered.

Fertilising

There are two situations in which the use of fertilisers needs to be considered. Firstly, many soils used for afforestation are phosphate deficient and an application of ground mineral rock phosphate at, or shortly after, planting will make the difference between successful establishment and the development of the condition known as check. These soils are the podsols and deep peats, found mainly in the uplands but also on lowland heaths. Brown earths, surface water gleys and intergrade soils do not usually require fertilisers. Secondly, crops that are well established and have closed canopy may respond to the application of fertilisers. However, it is unusual for trees in this condition to be unhealthy through lack of nutrients – a closed canopy forest recirculates its available nutrients efficiently. There is growing evidence that on poor sites (podsols and peats) mixtures of trees are efficient at acquiring nutrients. Thus Sitka spruce mixed with Scots pine or Japanese larch will grow better than Sitka spruce pure. Although broadleaves have not been tested to the same extent there is no evidence to suggest that additional growth responses are obtainable with fertilisers applied to broadleaves on the majority of sites to which they are suited.

Cleaning

The cutting of unwanted woody growth may become necessary in a young plantation after weeding has ceased and it is properly established. Typical problems are birch amongst conifers and, in lowland woods, the presence of woody climbers such as honeysuckle and old-man's beard. Areas regenerated by direct sowing or natural regeneration may have to be cleaned to reduce stocking and at the same time remove unwanted species. If cleaning is not done at this stage a drawn-up unstable stand can develop, which will be difficult to treat later. However a judgement always has to be made on the effectiveness of the operation relative to likely crop losses and the high cost of cleaning.

Brashing

This comprises the removal of lower branches up to a height of about 2 m to facilitate access for thinning. Nowadays brashing, which is very labour intensive and costly, is not normally undertaken as a separate operation but is carried out at time of thinning at the minimum intensity needed for access.

Pruning

The removal of branches is undertaken to improve the quality of timber in the lower stem of a tree. The work should be done in stages when the stem is small in diameter so that subsequent growth produces a cylinder of knot-free timber around the knotty stem core.

In conifers only dead branches or exceptionally the lowest living whorl should be removed; removal of part of the green crown will slow growth which may lead to the pruned tree becoming suppressed. Wounds resulting from pruning live branches may decay. Pruning of conifers destined for sawlogs is unlikely to be an economic proposition.

Pruning is most justified on trees such as broadleaves capable of producing high value timber of veneer quality. The operation should then be done to 5–6 m over a limited time scale of 5–6 years. This will necessitate removal of live branches but these are likely to contribute little to the economy of the tree. Furthermore, in broadleaved trees there appears little difference in the susceptibility of green or dead pruning wounds to decay.

Thinning

Thinning has the twin purposes of providing income and improving, by selection, the quality of the remaining trees. The improvement takes two forms: firstly, deformed and unthrifty trees are removed thus allowing their growing space to be used by good quality trees; secondly, removal of a proportion of the growing trees will increase the diameter increment of the remainder, thus reducing the time taken for trees to reach the valuable sawlog size and increasing the proportion of sawlog material.

Removal of the deformed and unthrifty trees requires the thinning to be selective and this increases harvesting costs. In stands of reasonable form, line thinning can be carried out, which simplifies harvesting but is arbitrary in removal of trees and does not reduce the proportion of defective trees.

In a recently thinned stand the remaining trees have greater freedom of crown which means that movement in the wind is greater. Recently thinned crops are therefore vulnerable to windthrow (particularly if line thinned) and this is a serious risk in the uplands where soil types restrict rooting depth and the incidence of wind is greater than in the lowlands. The serious danger of windthrow following thinning operations has led to the adoption of 'no thin' regimes in some upland areas. High costs of thinning and poor markets for small conifer roundwood may also restrict thinning programmes. With broadleaves, conversely, a rising demand for fuelwood has led to a revival of thinning.

Coppice

Coppice is a crop raised from shoots produced from the cut stump (called stools) of the previous crop. All broadleaves, except for beech, can be worked in this way to produce small roundwood products – sticks, firewood, pulpwood, fencing materials – on rotations of 6–30 years depending on species (Table 4). Coppicing can generally be resumed even after a period of 60 years neglect, except in the case of hazel for which there is a poor market anyway.

Coppicing has many wildlife and sporting benefits as well as being a low cost system of management. Unless some trees are grown among the coppice to large size (standards) no timber will be produced.

For many small lowland broadleaved woods (often known as coppices or copses) resumption of coppicing will be the simplest way of bringing them back into management and producing some worthwhile material.

Except for woodlands of less than 2 ha, it is best to divide the whole area by the number of years in the coppice rotation and cut this amount each year. In this way a constant annual yield of produce is obtained. For very small woods it is probably best to coppice at intervals working at least 0.2 ha each time.

Table 4 Coppice practice

Species	*Rotation years*	*No. of stools per hectare*	*Products*
Sweet chestnut	15	800–1000	Stakes, fence paling, hop poles
Oak	30	600–800	Fuelwood, tan bark, charcoal
Other hardwoods and mixed coppices	20–25	600–1200	Fuelwood, pulpwood, turnery
Short rotations Mixed species	7–10	about 2000	Pea and bean sticks, hedge-laying stakes
Hazel	6–9	about 2000	Spars (thatching), hurdles

Coppice working

Stems are cut in the normal way using a chainsaw but with extra care not to tear or damage the bark at the base of the stump below the point of cut. Cutting may be done at any time between August and April. Care must be taken in extracting the cut stems in order to prevent damage to the stumps (also called stools). Similarly if lop and top is burned on the site this must be done well away from any stumps.

It is generally not necessary to protect young coppice shoots against browsing damage, since their growth is vigorous and the damage usually confined to peripheral shoots. Initially in the life of a coppice crop large numbers of shoots grow up but these rapidly thin themselves and no formal thinning is necessary.

At each coppicing a few stumps usually die and when this loss creates a large gap (more than 6 m across) it is necessary to establish a new tree for future coppicing. This may be done either by planting or bending down to layer a shoot from a neighbouring stump which has been left specially for the purpose.

Coppice with standards

In many woodlands trees are grown to timber size with the coppice as underwood; such trees are called standards and generally occupy 30–40 per cent of the area. Their crowns must be far apart and never touching so as to allow plenty of light on to the coppice crop below. In a fully functioning coppice with standards system the standards will consist of from three to six different age classes with the numbers of trees as shown in Table 5. Standards are almost always oak.

Table 5 Traditional stocking for standards

	Age class/coppice rotation 1	2–3	3–4	4–6
Name of 'standard'	Teller	2nd class	1st class	Veteran
No. of stems per hectare	50	30	13	7
Maximum percentage of area occupied	10	10	10	10

At each coppicing trees in the oldest age class of standards are felled and a few new ones established. Standards among coppice may either be planted, recruited from suitable natural regeneration, or occasionally allowed to develop by encouraging one shoot on a coppice stool to develop into large size, a practice called storing coppice.

Converting coppice to high forest

Much coppice woodland is already past the normal age of cutting and is becoming a form of high forest. This can be aided and the quality of the stand improved by removing all stems except the best one (straightest, most vigorous) on each stump. The operation is called 'singling' coppice and the stems that are grown on to large trees are known as 'stored coppice'. Once the operation is done, subsequently treat as a normal forest stand for thinning, felling, etc.

Appendix: Notes on individual species

1. MOST COMMONLY USED CONIFERS

The figures quoted for the yield of various species are the range found in Britain, followed by the average in brackets. In an even-aged stand the cumulative volume production, including dead trees and thinnings, divided by the age of the stand is referred to as the mean annual increment (MAI). After planting, MAI increases during the early years of vigorous growth, reaches a maximum, and then declines with increasing age. The point at which the MAI curve reaches a maximum is the maximum average rate of volume increment which a particular stand can achieve, and this indicates the yield class. For example, a stand with a maximum MAI of 14 cubic metres per hectare has a yield class of 14.

Scots pine, *Pinus sylvestris* (L.)
British Isles and Northern Europe

SITE: An adaptable tree which succeeds over a wide range of conditions. The easiest tree to establish on dry heather sites. Thrives on light or sandy soils and at low or moderate elevations. Very frost hardy. A strong light demander. Does well in low rainfall areas. A useful nurse species.

Avoid soft ground and sites exposed to sea wind. Not easy to establish on moorland country under high rainfall. Unsuitable for chalk or limestone soils except as a nurse for beech. Not a tree for high elevations, except in north-east Scotland, where it thrives up to 450 m (1500 ft) in glens.

TIMBER: A general purpose timber with good strength properties. It works, nails and finishes well. Takes preservatives readily so is easily treated for outdoor use. Its wide range of uses includes fencing, joinery, building, flooring, box and packing case manufacture, railway sleepers, pitwood, fibreboard, wood-wool and chipboard manufacture, and telegraph poles. The 'redwood' of the imported timber trade.

YIELD: 4–14(8)

REMARKS: Although growth is rather slow and volume production is not high compared with the more exacting species, generally it is a 'safe' tree to plant.

Corsican pine, *Pinus nigra* var. ***maritima*** (Ait.) Melville
Corsica

SITE: Low elevations, particularly sandy areas near the sea. Light sandy soils and also heavy clays in the Midlands and south and east England; low rainfall areas. More successful on chalky soils than Scots pine. Tolerates smoke better than other evergreens.

Avoid high elevations. Not suitable for the northern and western uplands of Britain.

TIMBER: The timber resembles that of Scots pine but is somewhat coarser in texture, has a higher proportion of sapwood, and has slightly lower strength properties. Readily treated with preservatives. Its other uses include box manufacture, pitwood, fencing, fibreboard manufacture, pulpwood and wood-wool. It is the preferred species for wood-wool slab manufacture.

YIELD: 6–20(11)

REMARKS: It is important to obtain plants of true Corsican provenance — that is, plants raised from seed collected in Corsica, or their descendants. Produces timber faster than Scots pine. More difficult to establish than Scots pine.

Lodgepole pine, *Pinus contorta* Dougl. ex Loud.
Western North America

SITE: After suitable ground preparation Lodgepole pine grows relatively well on the poorest heaths, sand dunes and peat where no other tree will survive. Stands exposure better than most other species. Fairly tolerant of air pollution. For optimum results the choice of correct provenance is important (FC Research and Development Paper 114 *Pinus contorta provenance studies*, 1976). Tends to grow very coarsely on moist fertile sites.

TIMBER: Home-grown timber is used in the round for pitprops and fencing. The sawn timber has similar properties to Scots pine and can be used for the same purposes.

YIELD: 4–14(7)

REMARKS: Is probably the best pioneer species in Britain and is now being widely planted, especially in the west and north. Coastal provenances generally have higher yield than inland provenances but are of poor form. Vulnerable to Pine beauty moth in north Scotland.

European larch, *Larix decidua* Mill.

Mountains of Central Europe

SITE: Site requirements are exacting. Does best on moist but well-drained moderately fertile loams. A strong light demander. A good nurse tree. Has some tolerance of air pollution.

Avoid damp, badly drained or very dry sites, frosty places, shallow soils over chalk, poor sands, peat soils, leached soils, exposed sites at high elevations or near the sea, areas carrying a dense growth of heather.

TIMBER: The timber is heavier and stronger than most other softwoods. The heartwood is naturally durable but any sapwood needs preservatives for outdoor use. It is widely used for fencing, gates, estate work and pitwood. Other uses include telegraph poles, rustic work, garden furniture and chipboard. Selected material is in demand for vat making, boat building, and waggons.

YIELD: 4–14(7)

REMARKS: Canker is a danger and it is essential to select really suitable sites for planting. Choice of origin of seed for plants is most important; home collected seed (particularly Scottish), from a good stand, is the most reliable; seed from the high Alps (over 1100 m/3500 ft) must be avoided. Sudeten and Polish provenances are promising. Not a high yielding species.

Japanese larch, *Larix kaempferi* (Lambert) Carr.

Japan

SITE: Thrives over wide range of conditions including the high rainfall districts of the west and north. Suitable for upland sites including grassy and heathery slopes. Of great value in coppice areas and in fire belts as it quickly outgrows and suppresses adjoining vegetation. A valuable pioneer species and useful nurse with some resistance to air pollution.

Avoid dry sites and areas where the annual rainfall is low (under 750 mm/30 inches); also badly drained sites, frost hollows and very exposed situations.

TIMBER: The timber is strong and resembles that of European larch. Grade for grade it can be used for the same purposes.

YIELD: 4–16(8)

REMARKS: Resistant to larch canker. Gives a higher yield, up to middle age, than European larch or Scots pine.

Hybrid larch, *Larix* x *eurolepis* Henry

First raised in Scotland

SITE: Of special value on sites which are at the limits for the use of European or Japanese larch. Hardier and more resistant to disease. On good sites can grow even more quickly than Japanese larch. Shows some tolerance of smoke pollution.

Avoid dry sites and areas where annual rainfall is low (under 750 mm/30 inches); also badly drained sites, frost hollows and very exposed situations.

TIMBER: Resembles the timber of European larch and grade for grade can be used for much the same purposes.

YIELD: 4–16(8)

REMARKS: Characteristics are intermediate between European and Japanese larch but depend on the particular parents of the hybrid. First generation hybrid from selected parents is outstanding; second generation hybrid is also valuable, but third generation is poor.

Douglas fir, *Pseudotsuga menziesii* (Franco) Mirb.

Western North America

SITE: Requires a well-drained soil of good depth and of moderate fertility. A tree for valley slopes. Particular care is needed in site selection. A moderate shade bearer for a few years.

Unsuitable for exposed situations, heather ground, wet soil and shallow soils. Liable to windblow on soft ground except where drains are well maintained. Suffers from frost damage when young.

TIMBER: An excellent constructional timber with a high strength to weight ratio in compression and bending. Takes preservatives reasonably well. It is used for fencing, pitwood, flooring, joinery, building, packing case manufacture, telegraph poles, flag poles, chipboard, fibreboard and pulpwood.

YIELD: 8–24(14)

REMARKS: On suitable sites Douglas fir grows rapidly and produces a high volume of timber. Thinning at too late a date can render crop unduly susceptible to windblow. Good drainage is important.

Norway spruce, *Picea abies* (L.) Karst.

Europe

SITE: Moist grassy or rushy land, and shallow, less acid peats. Succeeds on old woodland sites and most soils of moderate fertility including heavy clays. Can withstand light shade for a few years. Somewhat sensitive to exposure.

Fails on heather land and does poorly on dry sites, particularly on eastern side of Britain. May be checked by frost in hollows and by occasional grazing by roe deer and sheep, but eventually grows away from this.

TIMBER: A good general purpose timber with a clean white colour. It works and nails well, and has a wide range of uses. It is stable during changing conditions of humidity and is therefore particularly suitable for building. Its other uses include joinery, kitchen furniture, boxes and packing cases, pulpwood. chipboard, pitwood, fencing, fibreboard, wood-wool, ladder poles and scaffold poles. The 'whitewood' of the imported timber trade. Seldom used out of doors as the heartwood is hard to treat with preservative, but small poles take enough preservative in their sapwood to fit them for fencing.

YIELD: 6–22(12)

REMARKS: Norway spruce produces a high volume of timber. Good drainage is essential if windblow is to be avoided. The young trees, and often tops of thinnings, can be sold as Christmas trees. Choice of provenance is important. East European origins have grown well.

Sitka spruce, *Picea sitchensis* (Bong.) Carr.

Western North America

SITE: Damp sites generally, including exposed high land. Stands exposure better than any other common conifer, very suitable for high rainfall districts especially on the west coast.

Avoid all dry sites. Honey fungus is a risk in some scrub and coppice areas. Not a tree for the dry east nor for southern and midland England. Can suffer severe damage from frost when young.

TIMBER: Properties and uses are similar to those of Norway spruce. A first class pulpwood and readily accepted for chipboard, boxboards and many building jobs but not for high grade joinery.

YIELD: 6–24+(12)

REMARKS: A faster grower than Norway spruce and a very large volume producer. Wide provenance variation. Queen Charlotte Islands (BC) is a safe choice but on southern sites Washington and Oregon are preferred.

Western hemlock, *Tsuga heterophylla* (Raf.) Sarg.

Western North America

SITE: No well marked climate preferences. Does well in the west. May be highly productive in quite low rainfall areas. Acid mineral soils and the better peats. A strong shade bearer and excellent for underplanting. Most competitive with other shade bearers on dry brown earths. Rather difficult to establish pure on bare ground, and does better with a nurse.

Dislikes heather competition and is slow to establish on heaths, where it may eventually grow well. Sites where previous conifer crops have suffered from *Fomes annosus* and *Armillaria mellea* should be avoided, as hemlock is prone to butt rot from these fungi.

TIMBER: Home-grown hemlock has good prospects as a building timber and – if graded for the purpose – as a joinery timber. Also for pitprops and general estate work. A good pulpwood.

YIELD: 12–24+(14)

REMARKS: Is best established under some shade.

2. PRINCIPAL BROADLEAVES

Oaks: Pedunculate oak, *Quercus robur* L., and **Sessile oak, *Quercus petraea*** (Matt.) Lieb.

British Isles and Europe

SITE: Well-aerated deep fertile loams. *Q. robur* grows well on fertile heavy soils and marls. Strong light demanders. Sessile oak tolerates less rich soils than does Pedunculate oak.

Avoid all shallow, ill drained or infertile soils, and exposed areas. Timber liable to 'shake' on very free draining soils.

TIMBER: Oak is hard and resistant to abrasion. It has a naturally durable heartwood, but the sapwood needs preservative treatment when small poles are to be used out of doors. Prime clean oak is used for veneers, furniture, gates, flooring and barrel staves for tight cooperage. Lower grades of oak are used for fencing, weather-boarding, engineering, waggon construction and repair, sawn mining timber. Round oak is used for hardwood, pulpwood and chipboard. Small poles are valued for cleft or round fence stakes.

YIELD: 2–8(4)

REMARKS: Both species are very windfirm. Bark is still harvested as tanbark in southern England.

Beech, *Fagus sylvatica* L.

Southern England, South Wales and Europe

SITE: Tolerant of chalk and limestone soils provided free calcium carbonate is absent from surface layers. Good loams of all types if well drained. Likes a mild sunny climate. A good shade-bearer.

Avoid frost hollows, heavy soils on badly drained sites and leached soils.

TIMBER: Beech has a wider range of indoor uses than any other home-grown hardwood, but is rarely employed out of doors. It is strong, works well to a good finish, and is easily stained. Its uses include furniture, particularly for kitchens and schools, turnery, flooring, veneers, bentwood and pulpwood. It is a good wood for charcoal making and firewood.

YIELD: 4–10(6)

REMARKS: Benefits from a nurse on exposed areas; Scots pine is a suitable species. Useful for underplanting. Grey squirrels can be very destructive to young beech. Stem form often poor. Dense planting gives better chance of selecting individuals for final crop.

Ash, *Fraxinus excelsior* L.

British Isles and Europe

SITE: A most exacting species which demands good soil conditions. Likes sheltered situations and deep calcareous loams, moist but well drained. Thrives on chalk and limestone but only where soil is deep.

Benefits from shelter in youth. Not a suitable species for large-scale planting or for use on open ground.

Avoid dry or shallow soils, grassland, heath or moorland, ill-drained ground, heavy clays. Frost hollows and exposed situations are also unsuitable.

TIMBER: Ash has a high resistance to shock and is thus used for oars, hockey sticks and other sports equipment, vehicle framing, tool handles and turnery and furniture. Also for pulpwood.

YIELD: 4–10(5)

REMARKS: It is no use planting ash unless there is local evidence that first-class timber can be produced. It is rare to find suitable conditions except in small patches, and it is necessary to choose these sites with great care.

Sycamore, *Acer pseudoplatanus* L.
Central Europe

SITE: Requires a moderately fertile freely drained soil, it is tolerant of calcareous soils. Fairly frost hardy. Stands exposure and smoke pollution very well. Not a suitable species for large-scale planting or for use on open ground.

Avoid dry or shallow soils, heath or moorland, ill-drained ground, heavy clays and frost hollows.

TIMBER: A white timber especially suitable for use in contact with food (kitchen utensils, butchers' blocks, bread boards, etc.). A good turnery timber; used for textile rollers and bobbins. Figured sycamore is much sought after for veneer and furniture manufacture. Also for pulpwood.

YIELD: 4–12(5)

REMARKS: A useful windfirm tree, suitable for mixture with conifers in shelterbelts. Grey squirrels can be very harmful.

Sweet chestnut, *Castanea sativa* Mill.
Mediterranean

SITE: Needs a moderately fertile light soil, and it does best in a mild climate. Profitable as coppice in the south of England.

Unsuitable for frosty or exposed sites, badly drained ground or heavy clays.

TIMBER: Coppice-grown material is used for cleft fencing and hop poles. Sawn timber is used for furniture and coffin boards.

YIELD: 4–10(6)

REMARKS: When grown for timber, should not be left to reach large size owing to risk of shake.

Poplars: Black hybrids, *Populus* x *euramericana* (Dode) Guinier
P. 'Eugenei', *P.* 'Gelrica', *P.* 'Heidemij', *P.* 'Robusta', *P.* 'Serotina'
Europe and North America

SITE: Very exacting; suitable sites are limited. Loamy soils in sheltered situations. Rich alluvial or fen soils, both well-drained and well-watered. Banks of streams.

Avoid high elevation, exposed sites and shallow soils. Stagnant water is fatal but occasional floods do no harm. Avoid acid peats and heathland.

TIMBER: Large clean poplar is peeled for veneer packages (chip baskets and vegetable crates). Used for mining timbers including waggon and barrow bottoms because of its high resistance to abrasion. Good pulpwood. Many other local market uses.

YIELD: 4–14

REMARKS: Poplar growing is a specialised job and is dealt with in FC Leaflet 27 *Poplar cultivation* and in FC Research Information Note 64/81/SILS.

Balsam poplars: *P. trichocarpa* Torr. & Gray, *P. tacamahaca* x *trichocarpa* hybrids.
North America

SITE: Often susceptible to a bacterial canker and only clones generally resistant in practice should be used, e.g. *P. trichocarpa* 'Fritzi Pauley' and 'Scott Pauley' and the *P.* 'Balsam spire'. They withstand slightly more acid soils than the Black hybrids and are more suited to the cooler and wetter parts of Britain.

Avoid high elevation, exposed sites and shallow soils. Stagnant water fatal but occasional floods do no harm. Avoid acid peats and heathland.

TIMBER: Large clean poplar is peeled for veneer packages (chip baskets and vegetable crates). Used for mining timbers including waggon and barrow bottoms because of its high resistance to abrasion. Good pulpwood. Many other local market uses.

YIELD: 4–16

REMARKS: Poplar growing is a specialised job and is dealt with in FC Leaflet 27 *Poplar cultivation* and in FC Research Information Note 64/81/SILS.

FURTHER READING: ESTABLISHMENT AND TENDING

Forestry Commission publications

BULLETINS

30 *Exotic forest trees in Great Britain.**
32 *Afforestation of upland heaths.**
34 *Chalk downland afforestation.**
48 *Weeding in the forest.*
49 *The potential of Western hemlock, Western red cedar, Grand fir and Noble fir in Britain.*
52 *Influence of spacing on crop characteristics and yield.**
57 *The safety of the herbicides 2,4–D and 2,4,5–T.*
62 *Silviculture of broadleaved woodland.*

BOOKLETS

15 *Conifers.*

20 *Broadleaves.*

33 *Conifers in the British Isles.*

40 *Chemical control of weeds in the forest.*

41 *Fertilisers in the establishment of conifers in Wales and southern England.*

44 *The landscape of forests and woods.*

50 *A key to Eucalypts in Britain and Ireland.*

51 *The use of herbicides in the forest.*

52 *The use of chemicals (other than herbicides) in forest and nursery.*

FOREST RECORDS

69 *Guide to site types in forests of north and mid Wales.*

73 *Ploughing practice in the Forestry Commission.*

88 *Cold storage of forest plants.*

97 *Forest site yield guide to upland Britain.*

114 *Terrain classification.*

122 *Nothofagus.*

127 *Fertiliser experiments in established conifer stands.*

LEAFLETS

27 *Poplar cultivation.**

57 *Replacement of elm in the countryside.*

61 *Tubed seedlings.*

62 *Ultra low volume herbicide spraying.*

63 *Fertilisers in the forest: a guide to materials.*

64 *Control of heather by 2,4–D.*

70 *Forest ploughs.*

71 *Ploughing of forest soils.*

72 *Forest drainage schemes.*

76 *Nutrient deficiencies of conifers in British forests – an illustrated guide.*

77 *Line thinning.*

83 *Coppice.*

84 *Guide to upland restocking practice.*

85 *Windthrow hazard classification.*

87 *Forest fencing.*

88 *Use of broadleaved species in upland forests – selection and establishment for environmental improvement.*

ARBORICULTURAL LEAFLET

10 *Individual tree protection.*

RESEARCH AND DEVELOPMENT PAPERS

76 *Bibliography of international provenance experiments begun in 1938.*

98 *International Norway spruce experiment at the Bin, Huntly Forest, Aberdeenshire: results up to 25 years.*

99 *Inventory provenance test with Norway spruce in Britain: first results.*

105 *Summary report on the IUFRO 1938 provenance experiments with Norway spruce.*

108 *Tree growth on the South Wales coalfield.*

109 *Fertiliser effects on the growth and composition of Sitka and Norway spruce nursery transplants and on the composition of a podzol profile after 15 years cropping.*

110 *Initial spacing in relation to establishment and early growth of conifer plantations.*

114 *Pinus contorta provenance studies.*

132 *Reclamation of mineral workings to forestry.*

136 *Tree planting on colliery spoil.*

139 *IUFRO Abies grandis provenance experiments – nursery stage results.*

141 *A guide to the reclamation of mineral workings for forestry.*

RESEARCH INFORMATION NOTES

64/81/SILS *Poplar cultivation.*

66/81/SSS *Reclamation of surface workings for trees. I. Landforms and cultivation.*

67/81/SSS *Reclamation of surface workings for trees. II. Nitrogen nutrition.*

68/82/SSN *Soil classification.*

70/82/SILS *Sweet chestnut coppice.*

71/82/SILN *Site preparation for restocking on wet soils.*

76/83/SILN *The effect of fertiliser and herbicide applications on Sitka spruce on mineral soils with a dominant grass/herb vegetation.*

84/84/SILN *Scandinavian scarifiers and their potential for site preparation in British forestry.*

89/84/SILN *Phosphate fertilisers in upland forestry – types, application rates and placement methods.*

96/84/SILN *The use of 'tatter' flags for exposure assessment in upland forestry.*

98/85/SILS *The effects of weed competition on broadleaved tree establishment.*

101/85/SILN *Rough handling reduces the root growth potential and survival of barerooted conifer transplants.*

102/85/SILS *Natural regeneration of broadleaves.*

ARBORICULTURE RESEARCH NOTES

5/83/WILD *Plastic tree guards.*

17/83/SILS *Nothofagus.*

21/80/SILS *Coppice.*

27/83/SILS *Herbicides for use with broadleaved amenity trees.*

29/81/SILS *The native and exotic trees in Britain.*

40/84/ARB *Tree staking.*

50/83/SSS *Nutrition of broadleaved amenity trees. I. Foliar sampling and analysis for determining nutrient status.*

52/84/SSS *Nutrition of broadleaved amenity trees. II. Fertilisers.*

53/84/WS *Chemical weeding: hand-held direct applicators.*

ESTABLISHMENT AND TENDING

54/84/SILS	*Control of epicormic shoots on amenity trees.*
59/85/ARB	*The effects of weed competition on tree establishment.*
63/85/SILS	*Tree shelters.*

OCCASIONAL PAPERS

3 *Tree planting on man-made sites in Wales.*
7 *Establishment of trees on regraded colliery spoil heaps.*
10 *Research for practical arboriculture.**

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CHAPTER 4

Diseases

Diseases in woodland are best controlled by avoidance. Over the years such control has to some extent been achieved, not as a result of knowledge of tree diseases, but simply by the commonsense planting of tree species which have been found to thrive, in preference to those that have not. No tree is immune from all disease, and it is obviously useful to know something about diseases and their control.

Some tree diseases can be classified as being caused either by non-living agents or by pathogens. In many cases however non-living and living factors interact to bring about disease.

DISEASES DUE TO NON-LIVING AGENTS

Damage due to climatic factors

Low temperatures cause various forms of injury to trees, including death. Extreme winter cold can be very damaging to exotic trees which are not fully hardy in Britain. Symptoms may show up quickly or they may be delayed until the onset of the growing season or even later. Early frosts in autumn may damage shoots or needles that have not hardened off, some species, for example Sitka spruce, are very susceptible to late frosts in spring. Early and late frosts occur mainly on clear still nights when plant and ground surfaces are cooled by radiation. Small plants are more likely to be damaged where there is a grass mat or some similar cover than where there is bare soil. Heat lost by radiation from a bare soil surface is replaced by heat from the underlying soil, providing it is moist (dry soil lacks thermal conductivity), whereas grass insulates the soil and has no large store of heat to replace that lost from its surfaces by radiation.

In summer the heat of the sun sometimes scorches seedlings at soil level, causing them to collapse and wither. It can also kill patches of bark on the stems of thin-barked species such as beech if they are suddenly exposed to full light after having been shaded. Drought may cause cracks in the stems of fast-growing conifers, and also wilting and dieback of trees, especially on sand, gravels and very shallow soils over rock.

Wind, snow and the weight of ice can cause breakage in trees, leading to the entry of decay-causing fungi. Lightning, as well as shattering individual trees, can commonly kill groups of trees in woodland. Sometimes, but not always, one or two trees in such groups show spiral scars on their stems. It is typical of lightning damage that the roots remain alive for some time after the top of the tree has died.

Damage due to site factors

Tree roots require oxygen and are liable to be killed where soil aeration is poor, as in boggy ground, or where aeration has been drastically reduced. Such reductions occur where soil becomes waterlogged after flooding or blockage of drains; where the surface layers of soil are compacted by machinery or by trampling by man or animals; or where thick layers of heavy soil or impervious covers such as concrete are laid down over the rooting area of trees.

Deficiency in phosphorus and to a lesser extent potassium can have a great effect on tree growth on certain poor wet acid sites. Available nitrogen may also be lacking in some cases. This matter is dealt with in more detail in Chapter 3. On limestone and chalk soils, where the high lime content prevents the absorption by roots of certain minerals, notably iron, deficiency in some minor elements is liable to cause yellowing, dieback and death of trees.

Damage due to chemical factors

Industrial and domestic pollution of the atmosphere with smoke and fumes can damage and sometimes kill trees. Where acute injury occurs after severe exposure to fumes in the vicinity of the source of pollution, the cause is fairly obvious, but the extent to which trees are harmed by relatively low concentrations of pollutants well away from sources of pollution is problematical. In the latter situation, damage and poor growth caused by other agents is quite often wrongly attributed to pollution when the cause is biotic or climatic. In general, conifers are more susceptible to pollution injury than broadleaves.

A nationwide survey of tree health in Britain's forests, with special emphasis on the possibility of air pollution damage, was completed by the Forestry Commission in 1984. The survey, the most comprehensive of its kind ever undertaken in this country, was stimulated by growing concern about air pollution and damage to forests in Europe, and fears that such damage may be occurring in Britain. The survey found no signs of the damage seen in West Germany nor any unexpected abnormalities; it did however provide a base line for measuring changes in tree health, should these occur. (FC Research and Development Paper 142 *Forest health and air pollution - 1984 survey*.)

Salt from roadside dumps, for use on icy roads, often kills trees where it is carried to their roots by rainwater, and, in summer, salt-laden gales from the sea sometimes cause conspicuous browning of foliage for several miles inland. Damage to trees by weedkillers mostly occurs where recommended precautions have been ignored. Seedlings may be injured in the nursery after top dressing with granular fertilisers.

A notable example of abiotic damage is top dying of Norway spruce. Initial damage appears as a reddening of the foliage in part or all of the crown and affected needles fall. Repeated injury to susceptible individuals leads to crown decline. Death of scattered trees or small groups of trees may occur throughout affected crops. Investigation of the problem has revealed that trees with foliage symptoms have shown poor growth for a number of years previously, and this poor growth is associated with mild winters. Changes in the crop which have lead to increased air movement (e.g. thinning or the removal of side shelter) have often taken place just before the foliage symptoms develop.

FUNGAL AND BACTERIAL DISEASES

Nursery diseases

While protective control with fungicides would in most cases be prohibitively expensive in woodland, it can often be justified in the nursery or greenhouse. Precise details on application rates for the various chemicals mentioned below can be found in FC Booklet 52 *The use of chemicals in forest and nursery.*

Damping-off

Various soil-inhibiting fungi cause losses at a very early stage of germination (pre-emergence damping-off), and they also infect the roots and cause the death of young seedlings (post-emergence damping-off). Post-emergence killing usually occurs before the end of June and is most serious in dense seedbeds under warm moist conditions. Once damage has begun treatment may have little effect, though captan drenches may check its spread if applied early enough and repeated at 10–14 day intervals until deaths cease. Captan itself can temporarily retard the growth of seedlings. Drenching cannot be unequivocally recommended for seedlings in containers in greenhouses because of the risk of waterlogging in the conditions of poor drainage and low evaporation which often prevail. In greenhouses damping-off is unlikely to occur if a sterilized medium and clean irrigation water are used and good greenhouse hygiene is practised. Mains water is preferable and spring or artesian well water is usually safe but, whatever the source, storage tanks must be kept covered and clean. If the disease is a recurrent problem in open nurseries, pre-sowing chemical sterilization with formalin or dazomet should give good control.

Grey mould

The aerial parts of conifer seedlings may be attacked by *Botrytis cinerea* usually in late summer, autumn and early winter. The disease is recognisable by a typical 'grey mould' that develops on killed tissues. Spraying at about 10 day intervals with thiram or captan gives protection and should be a routine measure with seedbeds of *Sequoia, Sequoiadendron, Cryptomeria* and *Cupressus* species as these are very susceptible. Benomyl is a very effective treatment for grey mould in horticultural practice but should not be used routinely against this or other diseases lest fungicide-tolerant strains of the pathogen develop.

Various conifers, notably Japanese larch, Sitka spruce, Western hemlock, Douglas fir and Lodgepole pine may be attacked under dense humid seedbed conditions or following damage by autumn frosts or granular fertilisers. Spraying should be instituted at the first sign of infection. In containers in greenhouses grey mould damage is likely to be more severe than in the open. Regular inspections must be made, especially of low hidden foliage in dense blocks of plants.

Lophodermium needle cast of pine

The fungus which causes this disease is called *Lophodermium seditiosum* (formerly *L. pinastri*). Infection leads to needle discoloration and defoliation in winter or early spring. Both Scots and Corsican pine may be affected but serious problems only arise when nursery stock is being raised in the vicinity of older pines which act as sources of infection. In such cases routine protective spraying with zineb or maneb may be necessary. It is unlikely that spraying after damage will arrest the disease in infected plants.

Leaf cast of larch

This is caused by the fungus *Meria laricis* which infects the young needles causing them to turn yellow and to wither. European larch is susceptible, Japanese larch resistant and Hybrid larch occupies an intermediate position. Infection begins at the base of the shoots and proceeds upwards, with needles remaining green at the shoot tip. The disease rarely kills plants but it may weaken them and reduce growth. Leaf cast is best avoided by raising larch in nurseries remote from standing larch, which acts as a source of infection. Plants which have been in seedbeds or transplant lines for 2 years are particularly susceptible to a build up of infection. In vulnerable nurseries, spraying with colloidal sulphur or zineb gives good control.

Keithia disease of Western red cedar (FC Leaflet 43)

This disease is caused by the fungus *Didymascella (Keithia) thujina*. Infection causes browning of individual scattered scale-leaves and, where infection is severe, death of whole shoots. The fructifications, which are small, round or oval structures produced on the scale-leaves, are slightly swollen and olive-brown when mature, but when moribund appear as blackened cavities. The fungus can cause very heavy losses in Western red cedar nursery stock. Disease is rarely seen on first-year seedlings, but rapidly increases in severity on older stock. Spraying with cycloheximide at the end of March and a month later gives good protective control in areas of low rainfall; in wetter areas a third application should be made in mid-June.

Oak mildew (FC Leaflet 38)

This is caused by the fungus *Microsphaera alphitoides* which grows mainly on the outside of succulent leaves and shoots covering them with a white bloom. It causes distortion, poor growth and dieback of lammas shoots rather than death. The fungus overwinters between bud scales, and the shoots emerging from these buds are the first affected in spring. Later, the disease is spread by wind-dispersed spores. Spraying with colloidal sulphur or dinocap at the start of flushing, and later at intervals of 2 or 3 weeks if secondary infections appear, gives good control.

Verticillium wilt (Arboricultural Leaflet 9)

In tree nurseries this disease is usually caused by *Verticillium dahliae*, and infrequently by *V. albo-atrum*, both soil-inhabiting fungi. It can cause severe losses of various broadleaved trees, especially species of *Acer*. In summer the leaves on some or all of the branches of infected trees wilt, and usually the wood of wilted branches shows a green to brown stain. Laboratory techniques are required for detection of the fungus. Infested soil can be cleaned by sterilization with chloropicrin or dazomet. Ground previously used for potato crops is particularly liable to be infested.

Phytophthora root rot (Arboricultural Leaflet 8)

This rather misleadingly named fungal disease – on woody species it kills roots and does not decay them – is caused by various soil-inhabiting species of the genus *Phytophthora*. Although it is uncommon in forest nurseries it can cause heavy losses among plants of various species including Lawson cypress, Douglas fir, Sweet chestnut, beech and *Nothofagus* spp. Roots are infected by spores that are free-swimming in water, and development of the disease is dependent on wet soil conditions in summer. The damage may easily be mistaken for that caused by waterlogging, particularly as the fungus cannot be detected without the aid of laboratory techniques. As yet no simple means of control has been found, although complex measures have been devised for nurseries specialising in the propagation of susceptible ornamentals.

Diseases of general importance

Honey fungus (Arboricultural Leaflet 2)

Honey fungus (*Armillaria* spp.) attacks the roots of a wide range of coniferous and broadleaved trees. Infection is by means of brown to black bootlace-like strands (rhizomorphs) that grow through the soil from infected wood, often that of broadleaf stumps. Rhizomorph tips can penetrate the bark of live roots with which they come into contact, after which disease development may vary from gradual and limited root decay to fairly rapid death of roots and, consequently, of trees. Where trees are killed, white or cream coloured sheets of mycelium, sometimes streaked with brown or black, can be found beneath the bark and wood of the bases of their stems. Later on, rhizomorphs may develop under this bark. Honey fungus often invades trees killed by other agents, so its presence is not necessarily proof that it was the cause of death. In autumn, clusters of honey coloured toadstools are produced at the bases and above the roots of infected trees and stumps.

In their early years conifers are particularly liable to be killed on sites which formerly carried broadleaved trees. Usually deaths are so scattered that appreciable gaps are not formed, but if they occur it may be necessary to replant them with more tolerant trees such as most broadleaves and Douglas fir or species of *Abies*. With increasing age, commonly planted conifers become more resistant to killing by the disease, but root decay may render them liable to windthrow. In some conifers, particularly spruce, decay progresses a little way up the stem but does not cause much loss of utilisable timber. Such decay has a characteristic wet stringy appearance.

Honey fungus is ubiquitous but rarely troublesome in broadleaved woodland. It is, however, a destructive pathogen in gardens, ornamental plantings and arboreta, where many of the more susceptible species are likely to be planted and where individual trees are of great value. In such places the stumps and large roots of felled trees should never be left in the ground to act as sources of infection, and any infected trees should be removed with all their major roots. Commercially advertised claims that stumps can be destroyed or that the disease can be controlled by chemical means alone should not be accepted without proof that the claims have been impartially verified.

Recent research has shown that there are a number of species of *Armillaria* in Britain, each with its own ecological and pathological attributes. This knowledge is likely to lead to improvements in disease prognosis and control.

Wound-associated stem decays

It used to be thought that stem decay occurred entirely within dead heartwood in the centre of the tree. It is now known that much decay is initiated when wounds allow fungi and bacteria to enter living sapwood. There are wound-associated stem rots of both conifers and broadleaved trees. Some are initiated through extraction damage, as with *Stereum sanguinolentum* decay of spruce and larch, and it is clearly of great importance that this kind of damage is avoided.

Other decays develop from pruning wounds. If possible, pruning should be carried out while the branches are still small enough for the wound to callus over completely within a short period, say 1 or 2 years. When making a pruning cut the branch should not be removed flush with the trunk but in such a way that a small amount of branch tissue remains. Currently available wound treatments are of little value in protecting against decay.

Diseases of conifers

Fomes root and butt rot (FC Leaflet 5)

The fungus now known as *Heterobasidion annosum* (formerly *Fomes annosus*) is the most serious cause of disease in British forest plantations. It can attack virtually all coniferous species, usually through their roots. Once in a root, it may progress through the heartwood to the stem and cause butt-rot. The larches and spruces are very liable to butt-rot, and Western hemlock and Western red cedar are the most susceptible species of all.

The decay is dry, stringy and fibrous. It is light brown with conspicuous white pockets which are filled with fungal tissue. The disease may also cause death of trees by killing their roots. The pines, which are resistant to butt-rot, are particularly susceptible to root killing on high pH soils and on former arable land. Douglas fir and species of *Abies* which are not particularly susceptible to butt-rot or to extensive killing of roots may be rendered liable to windthrow by partial decay of their roots. The fruit bodies of the fungus are perennial. They occur as brackets on stumps and at the base of killed trees, usually at soil level and often under fallen needles and vegetation. They are reddish-brown above with a conspicuous white margin, the underside being white and perforated by minute pores.

The disease is present in most areas that have previously carried coniferous crops. In new plantations on previously treeless ground the fungus is nearly always introduced by means of airborne spores deposited on freshly cut stump surfaces. It then invades the stumps and spreads to standing trees through root contacts. Infection spreads from tree to tree in the same way. The development of the disease in first rotation crops and its further development in the second rotation can be greatly retarded by the prompt treatment of freshly cut stump surfaces with a solution of urea. Pine stumps, but not those of other conifers, can be treated with commercially produced spore suspensions of another fungus *Peniophora gigantea*. *Peniophora* prevents the entry of the pathogen and decays the stump without posing any threat to living trees.

Phaeolus schweinitzii (FC Leaflet 79)

Butt-rot of conifers caused by the fungus *Phaeolus schweinitzii* is of low incidence and occurs mainly on sites that have previously carried broadleaves or pines. In Sitka spruce, the species most frequently attacked, decay may extend 3 m or so up the stem of 30 to 40-year-old trees. Douglas fir, Scots pine and the larches are also attacked, but in these extensive decay tends to develop later when the trees are mature or nearly so. Decayed wood is dry, brown and possesses a turpentine smell. It cracks radially and across the grain forming roughly cubical blocks. The fructifications are annual, appearing either as brackets at tree bases, or on the ground above infected roots, when they have a short central stalk. A fully grown specimen is about 30 cm across and has a deep rusty-brown upper surface with a yellow margin. The underside is yellow-green, and has angular irregular pores. The fungus enters through the roots and then spreads up the stem. It does not appear to attack healthy roots but invades roots weakened or killed in some way – especially by *Armillaria* spp.

Group dying of conifers (FC Forest Record 46)

This disease is caused by the fungus *Rhizina undulata* the spores of which readily germinate in the soil after they have been heated. In plantations the fungus appears where fires have been lit and spreads through the litter and upper soil damaging or killing roots as it progresses. With a susceptible species like Sitka spruce this spread may continue for 6 or 7 years before the fungus dies out. By this time large groups of dead trees may have developed. In turn these give rise to gaps which provide an opportunity for windthrow. The fructifications of *Rhizina* are annual, shallow, inverted cup-like structures, dark brown above, appearing mainly around the periphery of groups. In plantations the disease can be prevented by prohibiting the lighting of fires. Some loss of coniferous planting stock can result where fires have been lit during ground clearance, but usually the damage is slight, and the fungus does not persist for more than 1 or 2 years.

Larch canker and dieback (FC Leaflet 16)

Larch canker is a bark disease of European larch caused by the fungus *Lachnellula willkommii (Trichoscyphella willkommii)*. In winter the fungus advances and in summer it is checked by the renewal of cambial activity. Over a number of years a perennial canker is formed. Fruit bodies appear on active cankers; they are small saucer-shaped discs, the concave upper surface being apricot-orange to light buff, with a white rim. Susceptibility to canker is related to the origin of the larch, high alpine provenances being the most susceptible and Carpathian provenances, such as Sudeten larch, the least. Hybrid and Japanese larch are generally resistant. Where cankers girdle twigs, branches or stems, dieback and occasional deaths ensue, but a much more damaging type of dieback follows severe infestations by the insect *Adelges laricis* whether canker is present or not. As high alpine provenances are those most susceptible to this dieback as well as to canker, these two disorders often occur together.

Pine diebacks

Corsican pine in the north and west of Britain is very susceptible to a disease called Brunchorstia dieback caused by the fungus *Gremmeniella abietina*. Infection occurs as the young shoot expands in May and June, but symptoms do not develop until the following winter when resin bleeding occurs from the buds and the needles turn brown from the base. These affected shoots fail to flush in spring. Damage may vary from scattered shoot dieback to death of entire trees. In recent years this disease has also been serious on Scots pine in certain upland sites in north-east England and south Scotland.

A very similar disease occurs on Lodgepole pine although a different fungus is involved. This fungus *Ramichloridium pini* has so far proved most damaging in south-west England, south Wales and the Isle of Man. Elsewhere it principally takes the form of an apparently random death of scattered shoots.

Resin top disease of Scots pine (FC Leaflet 49)

This is caused by the fungus *Peridermium pini* and is most prevalent in east England and north-east Scotland. It is characterised by the presence of resin-soaked cankers on the stems and branches of trees aged 30 years and upwards. It is rare on young trees. In contrast to some other bark cankers the cambium is not killed immediately and many years may elapse between the first development of a lesion and the death of the top of the tree or of the branch. During May and June large numbers of blister-like fructifications are produced on the cankers and these open to release masses of orange spores.

Unlike many rust fungi *Peridermium pini* does not require an alternate host and can spread directly from pine to pine. Diseased trees should be removed in the course of thinning.

Needle-cast of pine

Several fungi can cause needle cast in pine plantations. The most spectacular damage is caused by *Lophodermella sulcigena* which attacks the current year's needles, particularly those of Corsican pine. By the end of October the needles are killed to within about 1 cm of the sheath, the dead parts being first brown and later pale grey. Severe outbreaks are normally confined to western and northern parts of the country, and are usually too infrequent to cause lasting injury.

From time to time, probably as a result of favourable climatic conditions, various *Lophodermium* species can cause significant defoliation of young pine plantations. This is usually associated with the presence of older trees in the vicinity, or of fairly recent 'lop and top' or brashings.

Diseases of broadleaved trees

Beech bark disease (FC Forest Record 96)

This disease affects beech from the pole-stage onwards. It develops where bark first infested by an insect, the Felted beech coccus (page 38), is subsequently invaded by a fungus, *Nectria coccinea*. Large vertical strips of bark may be killed and severely affected trees may decline and die within a few years. Once bark has been killed fungi that can cause rapid decay of the underlying wood usually gain entry and the stems of affected trees that remain alive are rendered very liable to snap. The minute, red, globular fruit bodies of *N. coccinea* appear in clusters on more recently killed bark. Prompt felling of affected trees is required if their timber is to be utilised. Recently infected trees and those markedly infested by the insect should be removed during thinnings. On specimen trees the insect can be controlled by the thorough application of a tar-oil winter wash. Beech bark disease can be described as a stress-related disease, with the effects of heavy coccus infestation providing the stress which enables *Nectria* to become damaging. Other forms of stress, such as drought, can have a similar effect.

Dutch elm disease (FC Forest Record 115)

This disease is caused by the fungus *Ceratocystis ulmi* which invades the xylem vessels of the current annual ring. Extensive wilting of foliage results and the tree may die within a few weeks. The disease is spread by elm bark beetles in the genus *Scolytus* which breed in the bark of killed trees. Infection occurs when newly emerged adults, carrying spores of the fungus in and on their bodies, fly to feed on the twigs of healthy trees. Local transmission of the fungus can also occur via the roots where trees have grafted together, or have arisen as suckers on a common root system. In Britain the elm has traditionally been considered more a hedgerow than a woodland tree. However with the depredations of the current epidemic of Dutch elm disease the hedgerow populations have been greatly reduced, and a significant proportion of the elm which remains is in woodland, largely as wych elm. Control programmes against the disease rely upon vigorous 'sanitation' campaigns to reduce the beetle breeding grounds in dead trees, but there are few woodland areas where such programmes are practised, or indeed are feasible. However there are a number of factors which together seem likely to result in a less rapid rate of disease increase in the woodland elm of north and west Britain than has been the case in the English elm hedgerows of the south and east. These include the somewhat higher resistance of the wych elm than of the English elm, and a series of natural constraints on the breeding and flying activities of the bark beetles.

In parts of southern Britain through which the disease has passed, vigorous regrowth of English elm is occurring from root suckers. This can offer a relatively cheap means of regenerating a woodland, but it must be remembered that the young trees are genetically identical to their predecessors and must be considered vulnerable to a new wave of infection.

Bacterial canker of poplar

This, the most important disease of poplars in Britain, is caused by the bacterium *Xanthomonas populi* which gains entry through fresh leaf scars and wounds in the bark. The first signs of the disease are splits in the bark of twigs, branches or young stems, from which a whitish bacterial slime oozes in spring. According to the variety of poplar, cankers varying from rough, blackish excrescences to open, smooth sided 'targets', may develop on branches and stems, and extensive dieback may occur. In recent years losses have been greatly reduced by the use of approved varieties, and by removing all older cankered trees on or next to ground that is to be planted with poplars.

FURTHER READING: DISEASES

Forestry Commission publications

BULLETIN

60 *Research on Dutch elm disease in Europe.*

BOOKLETS

4 *Rusts of British forest trees.**
13 *Principal butt rots of conifers.**
52 *The use of chemicals (other than herbicides) in forest and nursery.*

FOREST RECORDS

54 *Decay in standing conifers developing from extraction damage.**
96 *Beech bark disease.** (Revision in preparation.)
111 *Some important foreign diseases of broadleaved trees.*
115 *Dutch elm disease.** (Revision in preparation.)
116 *The EEC Plant Health Directive and British forestry.*
129 *Forest pathogens of N.W. North America and their potential for damage in Britain.*

LEAFLETS

5 *Fomes annosus*
16 *Larch canker and dieback.*
38 *Oak mildew.*
43 *Keithia disease of Western red cedar, Thuja plicata.*
48 *Needle-cast of pine.*
49 *Resin-top disease of Scots pine.*
50 *Grey mould in forest nurseries.*
53 *Blue stain of coniferous wood.**
65 *Group dying of conifers.*
79 *Common decay fungi in conifers.*

ARBORICULTURAL LEAFLETS

1 *The external signs of decay in trees.*
2 *Honey fungus.*
3 *Sooty bark disease of sycamore.*
4 *Virus and virus-like diseases of trees.*
5 *Common decay fungi in broadleaved trees.*
8 *Phytophthora diseases of trees and shrubs.*
9 *Verticillium wilt.*

RESEARCH AND DEVELOPMENT PAPERS

125 *International plant health controls: conflicts, problems and co-operation – a European experience.**
131 *Acid rain and forest decline in W. Germany.*
134 *Acid rain and forestry.*
142 *Forest health and air pollution – 1984 survey.*

RESEARCH INFORMATION NOTE

100/85/PATH *Beech health study.*

ARBORICULTURE RESEARCH NOTES

2/84/PATH *Breeding elms resistant to Dutch elm disease.*
8/79/ARB *Damage to broadleaved seedlings by desiccation.*
16/82/PATH *Decay and disintegration of dead elms.*
18/82/PATH *The detection of decay in trees with particular reference to the use of the Shigometer.*
20/82/PATH *Bacterial wetwood.*
25/80/PATH *Canker stain of plane.*

28/81/PATH	*The treatment of tree wounds.*
39/84/PATH	*Coryneum canker of Monterey cypress.*
45/83/PATH	*Cobweb fungus – Athelia.*
46/83/PATH	*Anthracnose of London plane.*
47/83/PATH	*Crown damage to London plane.*
51/84/EXT	*Ash dieback survey: summer 1983.*
58/85/PATH	*Phytophthora root disease.*
61/85/PATH	*Ceratotect – a fungicide treatment for Dutch elm disease.*

Other publications

EDLIN, H. L. and NIMMO, M. (1956). *Tree injuries – their causes and their prevention.** Thames and Hudson, London.

PEACE, T. R. (1962). *Pathology of trees and shrubs.** Clarendon Press, Oxford.

PHILLIPS, D. H. and BURDEKIN, D. A. (1982). *Diseases of forest and ornamental trees.* Macmillan Press Ltd., Basingstoke.

CHAPTER 5

Insect pests

The afforestation programmes of the past 60 years or so have been completed in Britain without major limitation by insects. From time to time there have been outbreaks of moth, sawfly and aphid defoliators, bark beetles and weevils with resulting economically important damage, but these have been local in occurrence. The underlying reasons for our relative freedom are as likely to have stemmed from the youth, vigour and extent of these new woodlands as to any special character of our environment inimical to insect outbreak. It is certainly true that as the estate has grown older and larger so have some indigenous forest insect species found conditions in our new forests compatible with population increase and have changed their status from forest inhabitant to forest pest. Similarly there are foreign insects, which may or may not have arrived on these shores before, that now find conditions congenial for settlement and increase. Visitations of these alien species should in no way come as a surprise to British foresters since, as exotic tree planters, it is from exotic pests that one might, on general principles, expect the more difficult and important problems to arise.

Often in forestry, quite evident insect damage has to be tolerated because control action would be uneconomic, or ecologically undesirable. Artificial control becomes urgent where crop survival is in jeopardy, and examples may be found in the nursery, during the establishment phase of new crops and in older crops. The abundance of many insects and the damage they do is often directly related to the general health condition of the crop. By observing the rules of good silviculture and maintaining the crop in a sound condition, the scale of damage inflicted by many pests can be considerably reduced. A very important example may be found in pine woods where the correct planning of thinning and felling operations does much to restrict damage by bark beetles and weevils. It should not be thought that good silviculture alone, embracing correct choice of species and careful subsequent tending of the crop, will result in immunity from all insect troubles. Such measures may well help to ward off 'secondary' pests whose increase is dependent upon the appearance of some predisposing factor. But a number of insect pests, including some of the most harmful species, are capable of attacking and seriously damaging if not destroying apparently healthy and well tended stands. The latter type of insect is commonly referred to as a 'primary' pest.

Different insect pests are associated with different ages of the host crop, and it will be convenient therefore to consider in this section the main enemies which are of common occurrence in the various stages of crop development. Obviously in such a brief review it is possible to do no more than quote a selection of examples and indicate which species of insect are of importance.

Within the Forestry Commission it is standard practice to use insecticides which have been fully cleared as to composition and usage through the Pesticides Safety Precautions Scheme (PSPS).

Insects attacking tree seed

Many insects live in the developing seeds and cones of forest trees and their attacks can sometimes result in appreciable losses. One particularly damaging species is the chalcid seed wasp *Megastigmus spermotrophus* whose larvae hollow out the seeds of Douglas fir (FC Leaflet 8). Infestations by this insect are sometimes very heavy and can cause near total loss of the seed crop. It is therefore advisable to make an assessment of the seed to determine its soundness before cone collecting is carried out. Other species of *Megastigmus* infest Silver fir, larch and Norway spruce seeds.

The caterpillars of a number of moth species such as *Dioryctria abietella*, *Cydia strobilella* and *C. conicolana*, the larvae of the weevil *Pissodes validirostris*, and the maggots of some dipterous (two winged) flies, feed upon and destroy the seeds of various conifers. Their attacks, however, are not often serious. The Knopper gall wasp *Andricus quercuscalicis* can destroy large numbers of acorns by transforming them into gross galls. The grubs of the weevils of the genus *Curculio* attack and hollow out acorns, whilst beech nuts are similarly infested by the caterpillars of the moth *Cydia fagiglandana*. Again the attacks are not usually of a serious nature, but they may on some occasions affect the success of natural regeneration schemes or the economics of seed collection.

Other types of insect infestation can produce an indirect effect on seed production. For example the defoliation of oak by the Oak leaf roller moth *Tortrix viridana* or of the Winter moth *Operophtera brumata* may result in marked reduction in acorn yield.

Nursery pests

The most important nursery pests are soil inhabiting insects and sap suckers. Leaf eating insects are not usually troublesome in the nursery, but occasionally some moth and sawfly caterpillars and species of leaf beetle damage broadleaved stock. These pests can easily be controlled with insecticides applied at the rates recommended in normal horticultural practice.

Cutworms and chafer grubs

Two important groups of soil insects are cutworms and chafer grubs. Cutworms are the caterpillars of various species of noctuid moths which remain in the soil during daytime and emerge at night to feed upon the seedlings. The damage consists of gnawing at the root collar region, usually resulting in the young tree being girdled or cut off at or about soil level. When damage is detected the identity of the pest can be confirmed by digging up the caterpillars or looking for them on the surface of the soil at night with the aid of a torch. The caterpillars are dirty grey-green in colour and measure about 25 mm in length; their reaction to handling or disturbance is to roll themselves up into a coil. Another check on the identity of the pest is the presence of holes – the entrance to the burrows – in the surface of the seedbed. A practical control can be achieved by using gamma HCH applied to the seedbed.

Chafer grubs are white, curved and wrinkled and measure up to 40 mm in length when full grown. They are the larvae of various species of scarabid beetles of which the best known is the large May bug *Melolontha melolontha*. A smaller species, *Serica brunnea*, is common in the north. The grubs live in the soil for from 1 to 4 years and during this period feed on the roots of seedlings and transplants. The roots are either stripped of bark or chewed through. The first obvious symptom of attack is browning of the foliage, and the death of the plant is a common result of attack. Chafer grubs used to be the most important pests in old agricultural-soil nurseries, but with the change to the heathland type and with annual cultivation they do not appear to be so troublesome. Control is effected by gamma HCH as a dust or solution, which is either worked into the top few inches of the soil between the rows or incorporated during the last cultivation before planting or sowing.

Springtails

The collembolon (springtail) *Bourletiella hortensis*, another soil dweller, can cause heavy losses amongst conifer seedlings. The attack takes place on the hypocotyl apical points and cotyledons. Death of the seedlings can occur before emergence from the soil or, where damage has not been great, the shoot and needles may be deformed. At the end of the growing season the surviving plant has a normal stem (often showing brown specks of dead tissue), on top of which is a bush of swollen distorted needles. After a second year's growth the small trees appear perfectly green and healthy but bear four or five leaders – the kind of plant which will normally be rejected without thought by the nurseryman. It is possible that collembolon damage on a small scale may be quite common and could account in part for the wide differences between laboratory-determined germination percentage and survival in the field. These tiny jumping wingless insects are easily controlled by spraying with malathion. The use of gamma HCH or other chlorinated hydrocarbons, often recommended for control of springtails in pot plants, will in the field result only in a temporary depression in numbers and the population will be found to have recovered within a short time if not actually to have increased.

Sap sucking insects

Aphids and adelgids are fairly common in nurseries, and their attacks may check and stunt the growth of plants. Adelgids are restricted to coniferous trees and their presence can be detected by the patches of white wool which they produce to cover themselves. *Pineus pini* on Scots pine, *Adelges cooleyi* on Douglas fir, *A. abietis* on spruce and *A. laricis* on larch are perhaps the most common and sometimes damaging. *Cinara pilicornis* feeds on the new shoots of spruce and sometimes causes local needle loss and a degree of distortion. *Phyllaphis fagi* on beech and *Myzus cerasi* on cherry are also often found feeding on the leaves of their hosts and bring about leaf curl and stunted growth. Another interesting aphid species, *Stagona pini*, may be found on the roots of nursery pine and is often associated with poor and dry conditions of growth; plants grown in clay pots tend to be particularly prone to infestation by this species. Most of the aphid species are controlled by the use of either malathion or gamma HCH sprays such as are used to combat the attacks of green or black fly in gardens. In the case of the adelgid species, however, which protect themselves under wool and have spring and summer egg stages, some difficulty may be experienced in reducing damage to an acceptable level. Careful timing of treatment and a suitable prevailing temperature are critical factors in adelgid control; a warm period in late autumn, winter or early spring provides optimum conditions for spraying.

The Conifer spinning mite *Paratetranychus ununguis* can be a serious pest of young conifers, particularly the spruces in rather dry growing conditions. This tiny relation of the spiders sucks the sap from the needles causing them to turn a dirty brown colour and leaving them netted with fine silk. Good control can be obtained through the use of Kelthane (dicofol).

Occasionally small weevils such as *Otiorhynchus*, *Phyllobius* and *Barypithes* cause damage in the nursery by feeding upon roots, leaves and stems. These insects are controlled by the use of gamma HCH sprays or dust.

Insect attacks in young woods

Root and bark feeders

Generally speaking the first few years in the growth of a conifer crop are much more critical from the point of view of insect damage than in the same period in the life of a broadleaved stand. This is particularly true when the new conifer crop is a replacement for another one recently removed. In such a case pests which have multiplied in the stumps and roots of the previous crop emerge to feed upon the young trees and may bring about heavy mortality if no protective measures are taken. The insects concerned in such situations are the well known Large pine weevil *Hylobius abietis* and the Black pine beetles *Hylastes* spp. (FC Leaflet 58). The Large pine weevil breeds in conifer stumps and roots. The grubs, which burrow beneath the bark of the roots and stump buttresses, measure 2 cm in length when full grown and are white, curved and legless. Development from egg to emergence of young adults takes between 1 and 2 years, depending on local climatic conditions. In particularly cold sites it may even take longer than this. On emergence the weevils, which can live in the adult stage for two or occasionally more years, feed by gnawing the bark above soil level of newly planted conifers. When the stem bark of young transplants is ringed the tree dies. Total loss of the crop is not an uncommon result of neglect to carry out protective measures. All of the commonly grown conifers appear to be susceptible to attack by this weevil.

Damage by the Pine weevil was traditionally avoided by allowing the site to lie fallow for a period of 3 or 4 years after felling. The time lag between felling and replanting allowed the weevil population to breed-up and exhaust the available breeding material; this was followed by intensive billet-and-spray trapping, intended to mop up the vastly increased population and return it to normal level prior to replanting. The method has disadvantages in that the ground was lost to use for the period, soil deteriorated, and weed growth often became rank. In modern terms the cost of trapping alone, in any case, would be prohibitively expensive.

Insecticidal control has replaced the old method throughout Europe and where this weevil is to be found as a forest pest. In Britain gamma HCH, a water-suspension rather than the emulsion formulation, is normally used and it is applied by dipping the whole plant in a tank for the joint control of Large pine weevil and Black pine beetle, or as a dip of aerial parts only for Large pine weevil control. Gamma HCH emulsions may be used as topical sprays of already planted crops, against either one or both of the two pests mentioned above, when sudden outbreaks of them occur and no prior protective measures have been taken, or when such measures have not been fully effective.

The Black pine beetles also breed in conifer stumps and later emerge to attack young coniferous trees. Damage is caused by these small bark beetles burrowing beneath the bark at and below the collar region of the young tree. The attack frequently causes the death of trees through girdling. Symptoms of attack are externally not so obvious as that by Large pine weevil, but it is an easy matter to carefully lift and examine obviously unhealthy and dying trees to determine if Black pine beetle is responsible. Pine appears particularly prone to Black pine beetle attack and, somewhat less so, spruce. Serious outbreaks are most common where annual or continuous fellings take place in contiguous coupes.

The Clay-coloured weevil *Otiorhynchus singularis*, like the Large pine weevil, can also bring about serious loss in new plantings. The larvae feed on the fine roots of various herbs and the adults upon the aerial parts of forest trees and other plants. Western hemlock seems particularly prone to attack. The adults not only eat triangular chunks from the needle, but also remove the bark from the finer twigs and branches in a manner similar to that of Large pine weevils feeding on the main stem. The creatures are dormant during the daytime but may be found just under the soil surface at the base of the stem. Adult activity usually starts at the end of April or early May and continues throughout the summer months into September. Almost identical damage, particularly to larch, is sometimes caused by the small brown weevil, *Strophosomus melanogrammus*. Indeed these two very often work together. Effective control of both species may be obtained by spraying with gamma HCH or DDT.

Defoliators

In the first decade after establishment a number of insect pests make their presence felt, especially in coniferous crops. The sap sucking adelgids (FC Bulletin 42 and FC Leaflet 7) are usually conspicuous on Douglas fir, the larches and the spruces. Although such attacks can be demonstrated to bring about a reduction in growth it is seldom economically worthwhile to attempt control artificially. One species, however, *Adelges nordmannianae*, so severely cripples the Common silver fir *Abies alba* that the planting of this tree species has seldom been attempted on a forest scale in this country (FC Bulletin 26). The so-called

Pineapple gall forming species *A. abietis* is a noteworthy pest of Norway spruce grown as Christmas trees. Here, winter or early spring treatments with gamma HCH emulsions can provide effective control (FC Forest Record 104).

Pine sawflies, *Diprion pini* and *Neodiprion sertifer*, are conspicuous on young pines and occasionally defoliation may be almost complete (FC Leaflet 35). Defoliation seldom brings about death of the tree although there may be a noticeable decrease in height increment. Outbreaks seldom persist on pine for more than two or three seasons before they collapse naturally, through parasites in the case of *Diprion pini* and a nuclear polyhedrosis virus (NPV) in *Neodiprion sertifer*. Artificial dissemination of the virus gives an extremely efficient and worthwhile control of *N. sertifer*. A preparation of the virus is now available commercially. This is known as Virox and is marketed by Microbial Resources Ltd (formerly Tate and Lyle Research and Development Ltd). Extensive testing of this virus for both efficacy and environmental safety has been carried out by scientists at the NERC Institute of Virology and recently by entomologists at the Forestry Commission. Virox has received limited clearance under the PSPS. It can be applied using most forms of insecticide sprayers (except thermal foggers) but ultra low volume application at 1 litre per hectare gives the best results. Full instructions for application are supplied with the preparation. The aim is to spray larvae soon after hatch (normally around mid to late May) thus reducing damage to the trees to a minimum. Maximum impact is achieved if populations can be sprayed during the first or second year of infestation so that, having killed the relatively low population present, enough virus persists from the virus killed larvae to exert control for at least 2 years.

In broadleaved crops of up to 10 years of age, defoliation by leaf beetles and by the caterpillars of moths and sawflies is sometimes encountered. Serious damage is rare and recovery is normally very good. Exceptions to this rule are the attacks made by the leaf beetles *Phyllodecta vitellinae* and *P. vulgatissima* on poplar stool beds. In the interests of increasing productivity of propagating material, sprays of gamma HCH are commonly applied. Aphid attacks, too, may occur, but again they do not seriously interfere with the growth of crops.

Insects in older woods

Many species of leaf feeding insects cause damage of varying degrees of severity in older woods of all types. Some of the most harmful forest pests are included in this group and although crops in Britain have, by comparison with similar ones in other countries, remained fairly free from serious outbreaks in the past, it is essential to appreciate that some species have by no means yet reached their full potential as pests. The list of insects having achieved pest status has grown as the forest estate has increased in size, and the crops have become older. Since 1953, at least two species on spruce and three each on pine and larch have, without obvious reasons, found conditions ecologically suitable for outbreak. It is wise to remember, therefore, that we are still very much a developing country as far as plantation forestry is concerned, and our quickly expanding, largely exotic, forest holdings must still be considered vulnerable to ecological change and to chance import.

Defoliators

The most important forest defoliators in old crops are the caterpillars of moths and sawflies, but some examples also occur in groups other than these. For instance, beech leaves are often damaged by the weevil *Rhynchaenus fagi*, the adults of which eat holes in the leaves whilst the larvae mine the interior of the leaf.

Sitka spruce is frequently defoliated by the aphid *Elatobium abietinum*, but, although recovery from attack is normally good, that is unless site conditions are particularly adverse, considerable loss of increment may result from severe defoliation. Outbreaks are invariably associated with mild winters −8°C being a threshold low temperature for winter survival (FC Forest Record 84). Control measures against this aphid have never, in fact, been recommended, partly due to difficulties of forecasting severe attack, and thus of taking timely action, partly for the doubtful economics of such action, and partly for ecological objections to wholesale insecticide applications. In the nursery and in research plots malathion has given good control.

Adelges laricis is now recognised as not only responsible for wholesale canopy discoloration and degrade, but may also be the prime factor in bringing about the condition known for many years as 'dieback of European larch.' Alpine provenances of larch are found to be particularly susceptible to this malaise, whilst Carpathian provenances and Hybrid larches are less so, and the Japanese larch is virtually resistant. The grey aphid-like creature may easily be spotted on the needles of larch often accompanied by white waxy wool. This, together with the sooty mould blackened honeydew produced by the species, is often conspicuous, and causes the foliage to appear a bluish-green by midsummer.

Examples of defoliators among the moths may be found in the Pine looper *Bupalus piniaria* (FC Leaflet 32); *Zeiraphera diniana* on larch, pine and spruce; *Coleophora laricella* on larch; the Winter moth *Operophtera brumata* on oak, many broadleaved trees and the spruces; and the Oak leaf roller moth *Tortrix viridana* (FC Leaflet 10). The Pine beauty moth *Panolis flammea* (FC Forest Record 120), though long known as a pest on the continent, reached infestation level for the first time in 1976 on Lodgepole pine in the north of Scotland. Outbreaks have since led to severe defoliation and death of trees. The organophosphorus insecticide fenitrothion, applied by aircraft, has given satisfactory control – generally about 98 per cent mortality. The material was chosen for good contact action against larvae and low toxicity to mammals and fish. A virus has been isolated from dead larvae and its use as a suitable pathogen is being investigated with the aim of ultimately obtaining biological control of the insect.

The sawflies on pine have already been mentioned as has the fact that their attacks occur usually in young stands. Larch and spruce also carry a varied sawfly fauna with seven species occurring on the former tree and eight on the latter. These species on larch and spruce are of particular interest since they must all be foreigners to Britain, all being specific to exotic tree hosts.

Space allows only brief reference to the forest status of the above insects. Most of them occur in some numbers in woodlands containing their host tree but will indicate their presence through visible damage in restricted areas only. The Winter moth and Oak leaf roller moth are well known pests which periodically cause damage to older oak woods. The trees usually recover fairly well, assisted by heavy lammas shoot production, but a distinct loss of timber increment results. It is interesting to note that the later flushing Sessile oak is less susceptible to heavy infestation than is Pedunculate oak. The Pine looper, also known as the Bordered white moth, was regarded as of little importance until 1953 when the first serious epidemic requiring artificial control occurred. Since then the moth has had to be controlled from the air on eight separate occasions. On larch the Larch web-spinning sawfly *Cephalcia alpina* caused widespread damage of Japanese larch for the first time in 1972, having been first recorded in Britain only in 1954. Among the spruce sawflies *Gilpinia hercyniae* (FC Forest Record 117), first recorded in Britain in 1906, made its debut as a serious pest of Sitka and Norway spruces in 1968 in north and central Wales. The Small spruce sawfly *Pristiphora abietina* for a longer time recognised as a pest in Britain, has also the capacity to cause quite serious defoliation and die-back of shoots, with consequent crown distortion following. Two other larch feeding species, *Anoplonyx destructor* and *Pristiphora westmaeli*, also occasionally cause heavy crown browning and needle loss. In general the control of defoliators is a complicated operation, since usually fairly large areas are affected, and special equipment has to be used. The best advice that can be given is that when trouble arises expert guidance should be sought. The Forestry Commission Research Division is always grateful for reports of outbreaks and will readily offer advice.

Bark and wood feeders

Bark and Ambrosia beetles and weevils are, in the main, secondary pests whose numbers are dependent on the provision of suitable breeding sites in the form of debilitated or damaged trees or felled produce. Multiplication normally takes place beneath the bark. When numbers of these insects are high they can under certain circumstances attack and damage healthy growing crops. The most important British problems are connected with bark beetles on spruce, pine and larch, and also weevils on the pines. The insects concerned are the weevils *Pissodes* spp. (FC Leaflet 29), and the bark beetles *Dendroctonus micans* the Great spruce bark beetle (FC Bulletin 38), *Tomicus piniperda* or Pine shoot beetle (FC Leaflet 3), and *Ips cembrae* the Larch bark beetle. The last is a fairly recent introduction to this country, having first been recorded in 1956, and is so far confined in distribution to east and central Scotland.

The young adults of *Tomicus piniperda* and *Ips cembrae* feed by boring into twigs or branches. In the case of *Tomicus* they bore up the centre of young, usually one-year-old, shoots and in *Ips* in the cambium and wood, girdling branches up to 4 years old. These damaged parts break off and, since the leading shoot is often involved, permanent and serious distortions of the main stem can result. Control can be achieved by maintaining a good standard of forest hygiene, and it is thus a managerial rather than a strictly entomological problem. As a general rule it is wise to ensure that stems which are felled in thinning and clearing operations are not left in the forest long enough for a brood to be produced from them. Material, therefore, should not be left in the forest for more than 6 weeks from the time of felling, during the period from April through to July, in the case of *Tomicus*, and rather later in the year for *Ips*. If removal within this time limit is not feasible the bark beetle brood should be destroyed, either by debarking the timber or by spraying it with gamma HCH. FC Leaflet 3 gives further details of the methods which should be employed. Good forest hygiene is also effective in controlling numbers of *Pissodes* weevils.

The Great spruce bark beetle *Dendroctonus micans* is a serious pest throughout Europe and is now well established in Britain, having been discovered here in 1982. It breeds under the bark in extensive chambers and all stages of the beetle can often be found at any time of the year. All species of spruce are susceptible and attacks can cause not only death of large patches of bark resulting in severe damage and distortion to the trunk but also death of the tree. Attacks are generally signalled by abnormal resin bleeding with obvious tubes of resin exuding from the stem. These may even be produced from roots just below the litter. If attacks by bark beetles to spruce are suspected to be by this beetle, rapid action is necessary and advice on identification and control will readily be given by the Forestry Commission Research Division. From 1984 the Entomology Branch of this Division has been rearing the predatory beetle *Rhizophagus grandis* for use in a biological control programme against the Great spruce bark beetle.

Stem feeders

Another category of insect which may be the cause of direct or indirect loss is made up of those that feed on tree stems. The more important species belong either to the family of so-called scale insects or to the woolly aphids or adelgids. The Felted beech coccus *Cryptococcus fagisuga* (FC Leaflet 15) may produce unsightly quantities of waxy wool on the stems and branches of forest and amenity beech trees. Its association with the fungus *Nectria coccinea* is well known. A joint attack of these two organisms can cause a serious canker and die-back condition in beech crops (FC Forest Record 96). The Ash scale *Pseudochermes fraxini* is associated with, and may be a contributory cause of, a debilitated condition of ash. Among conifers conspicuous stem infestation may be seen on *Abies* spp., particularly on *A. grandis* by *Adelges picea*, as well as on *Pinus strobus* by *Pineus strobi*. Infestations on *Abies* sometimes lead to a form of timber degrade or reaction wood termed Rotholz. Infestation on *Pinus strobus* appears to have no noticeable direct effect although stems affected are often also attacked by the pathogenic rust fungus *Cronartium ribicola*.

INSECTICIDES

Advice on the choice and use of insecticides in forest and nursery is given in FC Booklet 52.

Approved products for farmers and growers is an annually prepared list of chemicals sanctioned for use under the Agricultural Chemicals Approval Scheme of the Ministry of Agriculture, Fisheries and Food.

It is important to follow closely the advice given by the makers on the containers or in associated literature for each product. *The insecticide and fungicide handbook* published by the British Crop Protection Council is a mine of information as to prescription and treatment of specific pest species.

FURTHER READING: INSECT PESTS

Forestry Commission publications

BULLETINS
26 *Adelges insects of Silver firs.**
38 *The Great spruce bark beetle Dendroctonus micans.**
42 *Conifer woolly aphids (Adelgidae) in Great Britain.**
43 *Nursery practice.*
58 *Conifer lachnids.*

BOOKLETS
52 *The use of chemicals in forest and nursery.*
53 *A catalogue of phytophagous insects and mites on trees in Great Britain.*

In preparation: *Forest insects – a guide to those feeding on trees in Britain.*

FOREST RECORDS
57 *The relationship between resin pressure and Scolytid beetle activity.**
83 *The Pine shoot moth and related species.*
84 *Winter temperatures and survival of the Green spruce aphid.*
96 *Beech bark disease.** (Revision in preparation.)
104 *Towards integrated control of tree aphids.*
105 *Experiments with insecticides for the control of Dutch elm disease.*
115 *Dutch elm disease.** (Revision in preparation.)
116 *The EEC Plant Health Directive and British forestry.*
117 *Gilpinia hercyniae – a pest of spruce.*
119 *Pine looper moth.*
120 *Pine beauty moth.*

LEAFLETS
2 *Adelges cooleyi, an insect pest of Douglas fir and Sitka spruce.**
3 *Pine shoot beetles.*
7 *Adelgids attacking spruce and other conifers.**
8 *Megastigmus flies attacking conifer seeds.**
10 *Oak leaf roller moth.**
15 *Felted beech coccus.**
29 *Pissodes weevils.**
35 *Pine sawflies.**
58 *The Large pine weevil and Black pine beetles.*

RESEARCH AND DEVELOPMENT PAPERS
116 *Impact of Green spruce aphid on growth.*
118 *Population aggregation of Scolytus scolytus.*
129 *Chemically mediated behaviour in the Large elm beetle – field trials 1979.*
135 *Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests.*

OCCASIONAL PAPERS
4 *Control of Pine beauty moth by fenitrothion in Scotland, 1978.*
11 *Aerial application of insecticide against Pine beauty moth.*

RESEARCH INFORMATION NOTE
74/82/ENTO *The Great spruce bark beetle.*

INSECT PESTS

ARBORICULTURE RESEARCH NOTES

11/82/ENT	*Insect pests – what kind of control?*
55/84/ENT	*The Knopper gall.*
57/85/EXT	*The Brown-tail moth.*
60/85/ENT	*Oak defoliation.*

Other publications

BRITISH CROP PROTECTION COUNCIL (1983). *Pest and disease control handbook*, (2nd edition). Eds. N. Scopes and M. Lebieu.

BUCZACKI, S. T. AND HARRIS, K. M. (1981). *Collins guide to pests, diseases and disorders of garden plants.* Collins, London.

CHRYSTALL, R. N. (1948). *Insects of the British woodlands*. F. Warne, London.

DARLINGTON, A. (1968). *Plant galls*. Blandford Press, London.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (ANNUAL). *Approved products for farmers and growers*. HMSO.

CHAPTER 6

Wildlife management

Woodland wildlife encompasses the whole range of living organisms, including the trees which make up a woodland ecosystem. In British commercial forestry the term 'wildlife' is usually restricted to the mammals and birds which require management to prevent damage. The term 'game' covers some of the same wildlife species when these are being utilised for sport hunting. A broader spectrum of species is involved where conservation is the main concern. In the context of forest management, the definition of wildlife may embrace the non-timber elements of the ecosystem or may narrow to focus on particular species or communities.

OBJECTIVES

While the definition of the species that constitutes woodland wildlife may depend upon the reason for considering the wildlife, nonetheless the objectives of managing wildlife in forests fall into three groups: first, preventing damage to forest or farm crops by animals resident in woodlands; secondly, utilising forest wildlife for sport, meat, recreation or amenity; and thirdly, conserving species and communities which are becoming rarer locally, regionally or nationally.

The methods by which any or all of these objectives can be achieved also fall into three groups: first, by keeping damaging wildlife away; secondly by killing the animals doing, or expected to do, the damage; and thirdly by altering components of the ecosystem to reduce risks of damage or enhance survival of crops or other species.

Doing nothing may also be a powerful method of achieving an objective as long as it is done with full knowledge of the consequences. Too often nothing is done due to inertia or lack of interest or failure to recognise a changing situation until a problem arises. The solution then requires a rapid input of resources although less money and effort could have been spent had time been given to early analysis of the situation.

The forester and wildlife manager need to be able to predict possible problems arising from the normal sequence of forest practices. To do this they need to: recognise the local wildlife of importance for damage, utilisation or conservation; predict for a 5-year span or thereabouts what changes there will be in the areas of woodland at risk; consider to what extent achieving damage prevention must be integrated with local farm or estate interests and priorities; and consider how changing forest succession and practices may affect species and habitats with conservation or amenity values.

It must be realised that wildlife management can only work effectively when priorities among the management objectives have been clearly stated. They are not necessarily mutually compatible. In many cases there may be a simple economic forest yard-stick. Inevitably there are times when, for example, the complexities of estate management objectives dictate a higher priority for pheasant production than for squirrel control or access for deer utilisation. Then such sources of conflict should be recognised in advance and the loss in timber value from squirrel damage, loss in venison and increased risks of damage by deer recognised as a cost attributable to pheasant production.

CROP PROTECTION

The wildlife management objective given the highest priority in commercial timber production should usually be damage prevention. This can be achieved most efficiently if damage types and seasons are known; their possible causes identified; the impact on the crop estimated; and tactics for prevention put into practice if the expected level of damage would otherwise reduce crop values significantly. Such tactics should also be prepared if, over a foreseeable period, damage might be expected to increase to such a level.

On occasion, prevention is not possible or is not achieved and reduction in the damage level must be the aim. The first step should be to measure the amount of damage that has occurred to provide information against which the cost of action can be assessed.

Types of damage

BROWSING is the removal by biting of apical buds and all or part of the current year's growth of foliage or shoots. On occasion, part of the previous year's growth may also be removed. Browsing is usually for food and can occur at any time of year but is most common in winter and during the period of shoot elongation in spring. This is the most widespread form of damage affecting young trees before the leading shoot is out of reach (0.6–1.8 m high, depending on browsing species). It is rarely significant on mature trees and shrubs unless the form and shape are of amenity value. Browsing may result in reduced height and diameter and in deformation such as bushing or multiple leadering, but rarely death. Different tree species have different growth responses to browsing pressure and also vary in susceptibility in different parts of the country. It is usually sufficient to measure browsing damage by assessing the proportion of trees with missing leaders to obtain an estimate of crop damage.

STRIPPING is the removal by biting of bark from the main stem. Different animals attack different species and age classes of tree at various times of year. Stripping may result in tree death if the tree is girdled. Wind-snap may occur, particularly in conifers, even when less than the whole bark circumference has been removed. Timber degrade is inevitable as the tree calluses over and some species are susceptible to rotting and staining organisms entering through the exposed wound surface.

Measurement is best done by scoring all stripped trees in a stand. While various subjective grading systems (light, medium, severe or 0–25%, 25–75%, >75% bark circumference removed) have been tried, these have not been sufficiently well correlated with actual loss of timber value, wind-snap, degrade or death to justify generalisations.

FRAYING is specifically attributed to deer using their antlers to abrade and partially remove the bark from stems and branches. The bark often hangs in strips and tatters. This kills or deforms the tree but usually only relatively few trees in small areas are affected. It may be done at various times of year – predictable for different deer species – to help remove velvet from antlers annually; to mark territory; or as part of aggressive behaviour during the mating season.

GIRDLING (RING-BARKING) is bark removal at any height on stem from fraying or stripping around the complete circumference of main stem or branch and results in death of the tree or branch beyond that point.

BUD REMOVAL is eating or pecking out apical or lateral buds. This is rarely sufficiently widespread to reduce increment except when associated with shoot or foliage removal.

DISPLAY SITES: rutting stands, roosts and the 'leks' of blackgame may have trees battered, rubbed, frayed or pulled up as part of behavioural displays. These are often long-term traditionally used sites and it is often cheaper to accept them as forest features and manage their surroundings as such than to attempt to eradicate them. Starling roosts can be dispersed if necessary.

Damaging animal species

The animals most likely to cause damage in British forests are listed in Table 6. The relative importance of expected damage types has been indicated crudely but the extent to which they have an important impact varies with local site factors. These include tree species and provenances, area and shape of coupe and presence of alternative food plants. The latter may be modified by forest practices such as weeding and fertilising the tree crop. It is particularly important to consider whether changing forest practices or successional changes are likely to affect the local animals over the period that a crop is at risk.

Methods of prevention

Once the degree of risk has been estimated then the least costly action can be taken. In low risk situations regular monitoring, backed by 'fire brigade' action if necessary, is appropriate. That is, no action should be taken until damage begins or until the monitoring system suggests that damage is imminent. Monitoring is particularly important in such low risk situations and it is equally important that the necessary equipment and facilities are available in working order at short notice. Such actions occur where there are climatic problems – heavy snow or rain allowing break-ins by sheep or deer – or with animals such as field voles whose numbers fluctuate over a 3–5 year cycle.

In high risk situations it is important to consider the relative costs and efficiencies of animal control measures (which usually have a high labour content) and of tree protection techniques (with a high capital content). Habitat modifications rarely prevent damage altogether although they may improve the efficiency of the other techniques.

Protection techniques

These include fencing, individual tree protection and chemical repellants. Individual tree protection is often cheaper than fencing on small areas of less than 2–5 ha. Chemical repellants are neither as cheap nor as effective as individual tree guards for commercial forest use but may provide a tool for 'fire brigade' action while other tactics are being considered.

The use of fencing to prevent forest damage should not be confused with its more common agricultural roles of enclosing stock or marking boundaries. In general, fencing is at its cheapest in cost per hectare protected when used for areas over about 25 ha. Fencing too large an area with perimeter fencing alone

Table 6 Mammal species damaging forest trees

Animal	*Time and type of damage*				*National distribution of animal*	*Protection measures*
	Browsing	*Stripping*	*Fraying*	*Other*		
Roe deer *Capreolus capreolus*	Mid–Nov. to early spring		March to May and July		Southern England; northern Britain; invading mid-Wales	Fencing, tree guards, shooting. Close seasons for all except Muntjac. Deer doing damage during the close season may only be shot in specific circumstances. Production of revenues from stalking, venison or trophy heads need special consideration.
Red deer *Cervus elaphus*	,,	August to September	March to May		Scotland; some English populations	
Sika deer *Cervus nippon*	,,	,,	,,	Bole scoring	Spreading in west and north Scotland; some English populations	
Fallow deer *Dama dama*	,,	Occasional	,,	Feeding on farm crops	Midlands and southern England; few Welsh and Scottish populations	
Muntjac deer *Muntiacus reevesi*	,,	,,	,,		Spreading through southern Britain	
Feral goats *Capra* (domestic)	,,	,,			Scattered populations in uplands of England, Scotland and Wales	Populations may be of conservation importance.
Sheep *Ovis* (domestic)		At any time			Main alternative land use in upland Britain	Fox control may be required as good neighbour policy. Must be kept out by fencing. Should be herded out not shot, when woodlands are invaded.
Cattle *Bos* (domestic)		At any time		Rubbing and ground compaction	Widespread	Must be kept out by fencing or trees individually protected.
Ponies/horses *Equus* (domestic)	At any time	Mainly in winter		Rubbing and soil trampling	Feral ponies in upland areas and New Forest. Domestic stock widespread	Must be kept out by fencing or trees individually protected.
Rabbit *Oryctolagus cuniculus*	Mid–Nov. to early spring, occasionally summer			Grazing farm crops	Widespread	November to March – trapping and poisoning (phosphine or cyanide). Fencing, tree guards. Legal obligation to control rabbits (Pests Act 1954; Agricultural Act 1947; Agriculture (Scotland) Act 1948).

Animal	*Time and type of damage*				*National distribution of animal*	*Protection measures*
	Browsing	*Stripping*	*Fraying*	*Other*		
Brown hare *Lepus capensis*	Winter and spring clipping shoots	Uncommon			Widespread in lowlands	Shooting.
Blue hare *Lepus timidus*	,,	,,			Widespread in uplands	Shooting.
Field vole *Microtus agrestis*		At any time			Widespread	Tree guards, poisoning (0.25% warfarin on cut wheat). Use monitoring methods to predict potentially damaging peaks in numbers.
Bank vole *Clethrionomys glareolus*		Occasional			Widespread	
Wood mice *Apodemus sylvaticus* *A. flavicollis*				Autumn and early spring seed removal from nursery seedbeds, and seed trees	Widespread	
Mole *Talpa europaea*				Seedbeds, transplants and new plantings disturbed by tunnelling	Widespread	Poisoning (phosphine gas or strychnine under licence).
Grey squirrel *Sciurus carolinensis*		May–July		Seed cones; walnut and chestnut current shoots	Southern Britain and lowland Scotland	Poisoning April–July (0.2% warfarin on whole wheat). Illegal in specified counties with red squirrels (Grey squirrels (Warfarin) Order 1973).
Red squirrel *Sciurus vulgaris*		May–July		Seed cones	Scotland and northern England. Scattered populations in Wales and east England	Shooting and trapping may only be done under licence (Wildlife and Countryside Act 1981).
Edible dormouse *Glis glis*		Summer			Chilterns	Trapping.

Bird species damaging forest trees

Animal	*Type of damage*	*National distribution*	*Protection measures*
Starling *Sturnus vulgaris*	Roosts: defoliation	Widespread	(November–April) Scaring using amplified distress call.
Gulls *Larus* spp.	Breeding roosts: defoliation	Widespread	Birds are protected by legislation. Scaring or seed protection methods are usually appropriate.
Finches	Bud removal. Nursery seedbeds	Widespread	
Woodpeckers	Pecking holes may allow stain or rot penetration	Widespread	
Black grouse *Lyrurus tetrix*	Bud removal	Northern Britain	Shooting. Game-birds subject to close seasons.
Red grouse *Lagopus scoticus*	Bud removal	Northern Britain	
Capercaillie *Tetrao tetrao*	Buds, needles and shoots taken	Eastern Scotland	

may make it difficult to deal with break-ins and consideration should be given to internal fencing for areas of 400 ha and over.

Control techniques

These include shooting, trapping and poisoning. All of them are constrained by legislation for use on particular species in particular circumstances and at certain times of year. The 1981 Wildlife and Countryside Act provides the most comprehensive guidance and refers to other relevant Acts. Table 6 indicates the methods appropriate for the main damaging forest animals.

As far as possible, the aim is to kill the individual animals responsible for or expected to do the damage. General killing without reference to damage prevented is a waste of resources. While nothing can supersede practical experience with a competent trainer in learning how and when to use such techniques, the forester and practical wildlife manager will also find knowledge of the biology of the species essential for predicting whether population levels are changing and what local factors significantly influence animal numbers and behaviour.

Habitat modification

The most important habitat modifications are concerned with making damaging animals more accessible for control. Such techniques vary from the provision of glades where deer can be safely shot to the clearance of trap-sites to improve squirrel control. While a certain amount of success has been attributed, for example, to provision of willows to reduce fraying in upland sites, there is no good evidence on the value of planting alternative browse without also increasing control of deer. There is a little evidence that increasing the number of predators by, for example, putting in nest boxes and retaining raptor nest sites may reduce the likelihood of field voles reaching damaging peaks. This becomes of more importance when there is also a conservation objective since such action ensures increased diversity.

Other considerations

The requirements of woodland wildlife management cannot be considered in isolation from neighbouring land use. It may be necessary to agree mutual policies over animals such as fallow deer and rabbits. Where the same animals may be damaging in one land-use system and of value to the neighbour then exclusion and tactics following break-ins must be agreed, e.g. for sheep and red deer. The control of predators, such as foxes, in the interest of sheep farming may locally be justified. Similarly, action may be required to protect pheasant release pens although foxes are generally an acceptable and valuable part of woodland wildlife. Traditional country sporting activities may well be pursued if they do not interfere with normal forest practice. It should be noted however that there is little evidence that fox or deer hunting are more efficient in preventing damage by specific animals than is control by shooting. There may be legal requirements such as for rabbit management in neighbours' interests.

CONSERVATION

A fundamental starting point to planning for wildlife conservation is the formation or the existence and location of species or communities of conservation importance. One then needs some idea of their importance on a local, regional or national scale to judge how far damage prevention or utilisation practices should be modified in and around a particular site, when these practices have been given a higher priority elsewhere in the forest as a whole. (The techniques and rationale for conservation are discussed in Chapter 14).

UTILISATION

Wildlife in a broad sense may be utilised for amenity or for sport. Meat production is usually a sideline from sport or damage prevention. Wildlife management for amenity usually favours habitat manipulation as the most generally effective method. Planting shrubs and non-timber trees around car parks, campsites and picnic places or for landscape reasons has a value for increasing wildlife diversity, when the scale is large enough, and thus provides a spin-off for conservation.

A range of woodland animals can be utilised for sport. They include pheasant, woodcock, black grouse, capercaillie, wood-pigeon, rabbit, grey squirrel, hares and deer. Wetlands, lakes and rivers may attract a range of wildfowl as well as providing fishing. Wildlife management for game and fish production involves the same range of methods as damage prevention except that the harvesting is done by shooting or fishing.

The main conflict with a damage prevention objective is usually over the levels of population which may be higher than desirable for damage prevention if the species concerned is to be easily harvested. Additional problems arise where, for example, predatory animals such as stoat are destroyed in the interests of maintaining harvestable game bird surpluses. This may affect rabbit damage prevention on one hand and conservation interests on the other. Access for other forest or wildlife management practices may also be restricted during, for example, the open seasons and at other times of significance to game utilisation. Provided it is clearly understood that the utilisation objective has the higher priority the additional costs of risks incurred can be measured. Similarly, the loss to sport where damage prevention is the overriding consideration can be evaluated.

FURTHER READING: WILDLIFE MANAGEMENT

Forestry Commission publications

FOREST RECORDS

64 *Pine martens.*
65 *Butterflies in woodlands.*
66 *Blackgame.*
76 *Polecats.*
77 *Hedgehogs.*
85 *The coal tit.*
86 *Crossbills.*
89 *Titmice in woodland.**
90 *Voles and field mice.**
91 *Birds and woodlands.**
92 *Woodpeckers in woodlands.*
98 *The crested tit.*
99 *The roe deer.**
101 *Red squirrel.*
103 *Badgers in woodlands.*
109 *The capercaillie.*
118 *Woodland mice.*
123 *Reptiles and amphibians in woodlands.*
124 *The fallow deer.*
125 *Rabbits.*
131 *The fox.*

LEAFLETS

56 *Grey squirrel control.*
67 *Rabbit management in woodlands.*
68 *Badger gates.*
69 *Starling roost dispersal from woodlands.*
73 *Chemical repellants.*
74 *High seats for deer management.*
82 *Assessment of wildlife damage in forests.*
86 *Glades for deer control in upland forests.*
87 *Forest fencing.*

ARBORICULTURAL LEAFLET

10 *Individual tree protection.*

RESEARCH AND DEVELOPMENT PAPERS

104 *Public demands on forests in relation to forest wildlife.**
130 *Notes on the behaviour of roe deer at Chedington, Dorset, 1970–80.**
137 *Mammal/bird/damage questionnaire 1983.*

RESEARCH INFORMATION NOTES

87/84/WILD *Animal incident investigation – abnormalities or deaths.*
88/84/WILD *Birds of pre-thicket restocked plantations in North Wales. Report of joint RSPB/FC study 1983.*

ARBORICULTURE RESEARCH NOTES

5/83/WILD *Plastic tree guards.*
43/82/WILD *Rabbit control – phostoxin.*

MISCELLANEOUS

Wildlife rangers handbook.
Improving upland forests for birds.
Grey squirrel control groups.

Other publications

BURDEKIN, D. A. (1982). Protection problems in broadleaved woodlands. In, *Broadleaves in Britain – future management and research*, 47–52. Institute of Chartered Foresters, Edinburgh.

GAME CONSERVANCY (1980). *Feeding and management of game in winter*. Advisory Leaflet 14.

GAME CONSERVANCY (1981). *Woodlands for pheasants*. Advisory Leaflet 15.

SMART, N. and ANDREWS, J. (1985). *Birds and broadleaves handbook*. RSPB.

CHAPTER 7

Fire protection

The size, location and nature of a woodland estate dictate the level of fire precautions and fire fighting capacity which can be justified. The various options available are described in this chapter, but it is the owner's responsibility to assess his own situation and to select the most appropriate scheme. It is possible to insure against fire losses but insurance companies usually require reasonable precautions to reduce fire danger.

FIRE DANGER is a combination of *fire risk* and *fire hazard*. Fire risk is defined as the likelihood of a fire starting. It increases with the presence of people, especially children, day trippers and other holiday-makers; with the presence of neighbouring moorland during the heather and grass burning seasons, or a harvested corn field if stubble burning is practised; and with the presence of railways, even when the locomotives are diesel. Fire hazard is the susceptibility of vegetation to burn if a fire occurs. It depends on the kind of vegetation present, its flammability, and the wind force and relative humidity. There is obviously no fire danger even if fire hazard is high, if there is no risk of a fire being started, nor if the risk is high but the hazard is nil. There is extreme fire danger however if high risk of a fire being started occurs when an area is in a highly hazardous condition.

FIRE PROTECTION METHODS

Fire protection methods try to prevent fires by reducing the risk, and to limit the size of a fire when one starts.

Rather than warn of fire danger by formal letter, an owner should personally maintain good relations with his neighbours. People generally take more care when they appreciate the danger, and good neighbours can be an important source of help in reporting fires or helping to fight them.

Woodmen and contractors

It should be impressed on every individual who works in the woods that he is responsible for taking the utmost care with all types of fire. Estate and woodland staff should be reminded of fire danger, especially when fire hazard increases after a spell of little or no danger. Contracts for the sale of timber, or for carrying out forest operations, should always include clauses defining responsibility for fire precautions and for compensation for any damage incurred. In practice it is useless to try to prohibit all smoking by workmen in the woods. A more practical line is to lay down times and places where workmen may smoke, explain the precautions to be observed, and insist upon compliance.

Reducing the risk of a fire spreading from nearby ground

Fire breaks

These are semi-permanent strips kept clear of inflammable vegetation and having a width of at least 10 metres. If possible their surface should be firm and level enough to allow access and movement of vehicles and equipment for fire fighting. A fire spreading from adjoining land has time to build up in size and fire fighting teams may have to be deployed along a considerable length of boundary in order to stop it. Fire breaks are an expensive form of protection and therefore an attempt should be made to assess the likelihood of fire and the value of the crop at risk, reconciling these with the cost of preparing the break. There are various means of preparing and maintaining breaks, and these are described and compared in Table 7.

Methods aimed at prevention

Publicity

Statistics indicate that the public, by accident or intent, are responsible for about 80 per cent of fires on or immediately adjacent to Forestry Commission land. Almost all other fires spread from adjoining land, often the result of careless moor burning by farmers or from railways and the like. The Commission makes use of opportunities offered by the press, radio and television, both nationally and locally, to make the public more aware of forest fire danger, concentrating its effort in the periods of highest danger. Details of fire losses and the damage done to fauna and flora by fire are

Table 7 Fire breaks – comparison of alternative methods

Method	*Appropriate situation*	*Advantages*	*Disadvantages*
Cultivation: by plough, hand tool, bulldozer or discs, usually smoothed later by tine harrow or discs.	Particularly dangerous situations, and infertile ground unsuitable for improved grazing.	No risk. Can be done in any season, subject to ground conditions. Cheap by machine.	Unless cambered and on suitable soil type may hinder access. Expensive by hand. Maintenance may be difficult on wet sites. Unsightly.
Chemicals (paraquat and glyphosate): by knapsack or machine mounted sprayer.	Coarse grass, especially *Molinia*.	May give protection for two seasons. With hand application can be used on steep rocky ground. Suitable for wet sites.	Expensive. Not effective on calcareous soils or on some types of vegetation. Unsightly.
*Burning	Plantation boundaries where cultivation is difficult.	Suitable for a wide range of ground conditions. Will last several years on heather.	High risk. Dependent on season. Needs annual repetition on *Molinia*.
Mowing: by large gang mower or swipe.	Sites suitable for machine operation.	Good appearance. Low maintenance cost.	Mowing debris left *in situ* may become a hazard. Desiccation may reduce effectiveness during extreme drought.
Grazing: usually necessary to cultivate, fertilise and reseed.	On soils which will carry pasture grasses.	Good appearance. May be integrated with estate management.	Stock management problems e.g. fencing. Initial cost can be high. Desiccation may reduce effectiveness during extreme drought.

***Burning**

The following publications will be useful:

ENGLAND AND WALES

The heather and grass burning code: advice on the burning of heather and grass.
Heather and grass burning: summary of good burning practice.

Both are obtainable from any Regional or Divisional Office of MAFF or the Welsh Office Agriculture Department.

SCOTLAND

A guide to good muirburn practice: produced jointly by DAFS and NCC and available from HMSO.
Muirburn – A code of practice. Publication No. 25; available from the Scottish Agricultural Colleges.

Ideally, protective boundary burning should shortly precede controlled burning on the adjacent land, and therefore good liaison with the neighbour is required.

Burning must comply with the statutory provisions – i.e. The Heather and Grass Burning (England and Wales) Regulations 1983 (Statutory Instrument 1983 No. 425 as amended by Statutory Instrument 1983 No. 1439) and in Scotland, Sections 22–27 of the Hill Farming Acts 1946. The principal provisions are as follows:

a. In England and Wales, unless a licence has been issued by the Minister, burning is lawful only:
    i. from 1 November to 31 March inclusive, and
    ii. from 1 October to 15 April inclusive in upland areas shown on maps which can be seen at any Regional or Divisional Office of MAFF or the Welsh Office.

    In Scotland, for a tenant without the written authority of the proprietor muirburn is lawful only from 1 October to 15 April inclusive. For a proprietor, or a tenant with the written authority of the proprietor, this period is extended to 30 April, and on land over 450 m (1500 ft) a.s.l. to 15 May.
b. In England and Wales, but not in Scotland, a licence may be applied for and granted exceptionally to burn outside the statutory period.
c. Burning must not commence at night.
d. Neighbours must be given not less than 24 hours notice in writing, and in England and Wales this must not be more than 72 hours.

publicised in order to increase public awareness. Staff involved with the public always stress the risk of fire whether at a school or college talk on forestry or simply meeting people at a picnic site or walking in the forest.

If a private owner considers that the conditions call for publicity in the news media, he should, in order to ensure proper co-ordination, make representations to the local Forestry Commission Conservator. A more direct approach to the visiting public by such means as fire warning signs and beater stands should also be considered. Good quality signs are not cheap and should be used where their message will achieve maximum effect, such as hazardous areas where the public are invited or have a right to enter. Greater impact will be achieved by putting up warning signs only during fire danger periods, and removing them when the danger ends. Most fire signs simply warn, but some tell the public what action to take in case of fire, locating the nearest telephone and giving the appropriate number to ring. Well-maintained beater racks or stands may also be used as a visual reminder of fire danger to the public, as well as being immediately available in the event of fire.

Normally the plantation or land ownership boundary dictates the position of fire breaks but topographical features can be used to reinforce their effectiveness. Ridges, brows of hills and physical barriers like streams have advantages. On occasion a break can be set up some way inside a plantation if cost or protection benefits can be gained, justifying the higher risk of losing the plantation left between the break and the boundary. The effect of the proposed barrier on the landscape must also be borne in mind.

Fire belts and barriers

Belts of trees which do not themselves readily catch fire can provide a useful barrier in many cases. Providing site conditions are adequate, larch is the first choice because of its good growth rate. Broadleaved species on the other hand usually grow too slowly, but where they already exist they may be retained in a continuous strip and enriched if necessary by further planting. Closer planting and complete beating up are usually required to ensure the early suppression of ground vegetation necessary for an effective barrier. The width of the belts is a matter of judgement, 10–20 m normally being adequate. Care should be taken to integrate these belts with the landscape; and it may be possible to vary the width so that the broadleaved or larch bands run up into any natural gullies, or to use some other means to break up an unnatural banded appearance while maintaining a continuous barrier. Other forms of barrier worth preserving include hedges, walls, ditches and water courses. These, and indeed all fire breaks, should never be regarded as fire proof but only as obstacles to the rapid spread of a fire.

Brashing

Where neighbouring ground vegetation grows up to the forest edge, the complete brashing of all the trees to a height of 2 m in a 10–20 m wide strip may stop a fire getting into the tree canopy. As the aim is to create a gap between ground vegetation and branches, cut material should be removed.

METHODS AIMED AT REDUCING LOSS WHEN A FIRE OCCURS

Breaking up a plantation into smaller blocks

Roads

As well as allowing access by vehicles with pumps and water or foam, roads are valuable as internal fire breaks and fires can be fought from them.

Rides

Ordinary untreated grass rides are not a fire barrier in themselves, but once crops reach the thicket stage, rides can provide access and breaks at which to fight fire.

Changes in crop

It is a common experience when fighting a forest fire to find that its progress is checked when it reaches a crop of another species or age. Where the layout and scheme of management of the woods permit, it is therefore a good plan to break up large blocks by changes in species or age class.

Provision of early warning of a fire

Small fires are more easily extinguished and therefore it is important to make provision for early notification.

Fire lookouts and patrols

Employing men specifically to watch for fire outbreaks is so expensive that it can be considered only at times of extreme fire danger. The men must be equipped with some ready means of reporting an outbreak. Fixed structures, such as towers, allow the installation of telephones, but they are usually only appropriate for very large properties. Mobile patrols are more versatile and, as well as reporting fires, can warn people and tackle outbreaks. They must however be equipped with either a radio pocket set or a vehicle so that they can reach a telephone quickly.

Neighbours

Often neighbours are in a good position to see and warn of any fires, and they can be helpful if the position of a smoke report needs verification or its cause confirmed. A list of neighbours' telephone numbers should be maintained.

Public

Notices should encourage members of the public to report outbreaks of fire, and even to help fight them initially. It is helpful if notices give the location name.

Access and water supplies

Good access is an important factor in containing any fire. It can, however, be prohibitively expensive to invest capital in roads years before they are justified for timber extraction. Access provision must therefore be carefully assessed, and it may be possible to carry out relatively inexpensive work to improve access while not providing roads to the load bearing standards necessary for timber extraction. Fire Services, however, depend on good access to carry their fire fighting tenders to a fire, and it is important not only to consult them about the suitability of roads but to ensure that they are acquainted with entrances from public roads, which may not always be obvious. Use of the correct access route by the Fire Service and other assistance can be ensured by using *route markers*. The officially recognised marker is a 3 m length of coloured polythene streamer, red to the fire and green for the way out. Full details of use and source of supply may be obtained from the Fire Service or the Forestry Commission.

Where roads suitable for Fire Service tenders cannot be provided, plans should be made for landrovers and tractors to move Fire Service hoses and transportable pumps, estate water bowsers, other equipment and personnel to the fire. Where the use of helicopters is anticipated, landing sites need to be provided if the roads themselves are inadequate for the purpose.

Water is invaluable in fire fighting and in damping down after a fire. The minimum useful static supply is considered to be 2000 litres (440 gal), and the smallest reliable flowing supply about 5000 litres (1100 gal) per hour with 0.6 m depth at the pumping point. Wherever possible the damming of streams is to be preferred to the erection of water tanks, which are often unsightly and difficult to maintain. FC Forest Record 75 *Design, construction and maintenance of earth dams and excavated ponds* may help an owner considering the provision of dams. Their size and number will depend on the extent of the woodland and the availability of other water supplies, but bearing in mind that the standard Fire Service tender carries about 1800 litres (400 gal) a reasonable size is about 20 000 (4400 gal). The local Water Authority or Regional Water Board should be consulted before impounding water as a licence may be necessary; and it should be remembered that children and other visitors may find reservoirs attractive and therefore possibly dangerous.

All principal water supplies should be provided with vehicular access for water collection; and where there is the possibility of helicopters being used to collect water in underslung buckets there should be a minimum water depth of 2 m at the collecting point, and trees must be kept well back to provide the necessary flight path clearance. Where they exist, Water Authority hydrants should be identified for use in fire fighting.

The desirability of seeking the advice of the local Fire Service on all aspects of provision of access and water supplies cannot be overstressed.

Foam

Instead of plain water, foam is now used increasingly in forest fire fighting by the Forestry Commission and some Fire Services. When used properly it enables fires to be controlled more easily with smaller manpower and pump resources, and as it facilitates water economy by reducing evaporation and run-off it enables water to be used more effectively. In addition to an ordinary pump, hose and water supply, suitable foam concentrate is required together with a special branchpipe (nozzle) for foam production. A 5 hp pump and a medium expansion branchpipe are suitable for application of foam to the ground and to tree canopies up to 3 m high, whereas a 12 hp pump and low expansion branchpipe will project it to heights of 20 m. Foam solution may be formed by pre-mixing, but to produce foam from a natural or a continuous artificial water supply an inductor is required to introduce the concentrate at the pump or into the hose line. Foam concentrate is non-toxic, but because of amenity considerations neither the concentrate nor the solution should be flushed directly into water courses. The same foam concentrate, in very much weaker solution, will produce 'wet' water, which is of particular value for damping down or dealing with ground fires because of its increased power of penetration. See FC Leaflet 80 *Forest fire fighting with foam*. Application of foam by helicopter is of great value where quick action is required, particularly in difficult or remote terrain.

Beaters and other fire fighting equipment

A small readily available supply of fire fighting equipment is essential so that a fire can be tackled quickly before it grows too large to be easily extinguished. What equipment is needed depends on the scale and nature of the woodlands. For the commonest type of fire, involving ground vegetation and small trees, beaters are used; but some means of applying water is always useful.

Fire beaters

A number of different types are used. *Birch brooms*, made by wiring together freshly cut birch twigs in lengths of 0.6–0.9 m (2–3 feet) on to a springy birch pole some 1.8 m (6 feet) long are the most common. They are of greatest value in rough heather or tussocky ground. Their drawback is that if left in the open they remain serviceable for only one year. It is therefore best to leave a few out in the forest for propaganda and immediate fire fighting purposes, and to maintain a larger stock in a covered store where they will remain serviceable for 2 or more years and are less likely to be borrowed by visitors. *Conveyor belting*, in pieces about 0.4 × 0.5 m (15 × 18 inches) can be attached to poles with small bolts. To match the life of the belting the poles should be of longer lasting wood. These beaters will last for a number of years especially if stored under cover. Any stored in the open should have the belting pads supported horizontally or hung vertically to avoid deterioration. Alternatively, a doubled or tripled piece of *rabbit netting* can be attached to the pole, usually by threading spring steel wire through the outer edge of the netting and binding the ends to the pole. Both belting and netting types are best used on grass fires or where there are not too many tussocks or rocks, as they cannot be used to poke out embers in awkward corners. *Long handled shovels* are another option, and can be used for digging embers and scattering soil as well as for beating. *Hessian sacks*, especially if they can be wetted, are very useful for smothering grass fires and have the advantage that a small supply can be carried in a car boot.

Other equipment

Even on a small estate some items of equipment in addition to beaters are considered essential. Wire cutters are often required for speeding up access, and there should be effective torches for night work. Knapsack sprayers are needed, not only for backing up beaters but for damping down after a fire. A supply of wetting agent (ordinary household detergent or foam concentrate) is a useful addition to the knapsack pump to provide better water penetration; and small canvas or plastic buckets are often invaluable for filling knapsack sprayers from forest drains and shallow streams.

In a larger estate or where the number of helpers would permit the cutting of fire lines, chain saws, axes and bushcutters should be available. Small portable pumps (about 5 hp) are useful if there is good enough vehicular access to allow the pump to be brought within carrying distance of a fire and if there are adequate water supplies to serve the pump's rate of delivery (up to 50 gal/min). Portable canvas or plastic dams holding not less than 450 litres (100 gal) are also useful. They are filled on site either by portable pumps or by the Fire Service tender, and used in turn to supply knapsack sprayers or portable pumps. Heather burning torches are recommended where counter-firing may be necessary.

Whatever equipment is chosen it should be kept close to the vehicle garage, it should not be used for any other purpose, it should always be checked prior to the start of a fire season and if possible it should not be locked away.

Training fire fighters in advance

A trained gang is far more effective than men called in only when there is an emergency. The possible saving in fire losses makes training well worthwhile and it can often be tied in with controlled burning of dangerous boundaries or the testing of fire equipment. Training should be made as realistic as possible and should include reporting the fire and transporting the men and equipment to the scene. Wherever practicable, exercises should involve the Fire Service and other sources of assistance.

All estate staff should know what to do if they come across a fire. The most useful general rules are:

If you see a fire starting, tackle it.
If, after a few minutes, it is clearly beyond your control (i.e. if it is extending), leave it and report immediately to:
  a. the Fire Service (dial 999)
  b. the estate fire control centre.
If there are two or more of you, one should run to report the fire while the rest tackle the blaze.

Calling out fire fighting teams

Whenever a report of a fire is received the Fire Service and the Police should be informed immediately, giving whatever details are known of its location, type and size. As speed of response is vital the Fire Service should be informed even if the report is only of suspicious smoke which needs further investigation. If the report proves to be a false alarm any Fire Service tender en route can usually be recalled to base by radio.

The man in charge on the estate should gather as many men as he can find quickly, and hasten to the fire with the fire fighting equipment. He should not wait to muster a large gang, as fires can grow rapidly and a few determined hands soon at the scene can be far more effective than a score or more half an hour later. The rest of the staff should be under instructions to go at once to the scene of any suspected fire by the best available means. As a rule staff soon see smoke rising, but some kind of audible warning such as a siren, huntsman's horn or a loud whistle may be of help, depending on the size of the estate and the scatter of the workforce.

FIRE PLANS

Plan layout

Once an owner has assessed the fire danger on his estate as a whole and in each component block of woodland and has decided on the fire precautions he will take and on the arrangements for fire fighting, he should set out the details in a fire plan. This will be useful for keeping the matter under review and for advising all who will be involved with fire protection measures. On a small estate the whole plan, including maps, may be no more than a few sheets which can be used in the field under emergency conditions. Larger estates, however, may consider having two plans, an *organisation plan* and an *emergency plan*. The former would be a planning document setting out prescriptions, organisation, responsibilities and non-emergency procedures, whereas the latter would be restricted to information needed in a fire emergency and would be made accessible at all times.

Consultation with Fire Service

The Local Authority Fire Services have the statutory responsibility for dealing with all uncontrolled fires, and therefore an important part of planning should be consultation with the local Fire Service. They are willing, within the limits of staff availability, to help owners by discussing the best means of preventing and tackling fires on their properties. Annual contact is recommended.

FURTHER READING: FIRE PROTECTION

Forestry Commission publications

BOOKLET

40 *Chemical control of weeds in the forest.*

FOREST RECORD

75 *Design, construction and maintenance of earth dams and excavated ponds.**

LEAFLET

80 *Forest fire fighting with foam.*

MISCELLANEOUS

HOLMES, G. D. and FOURT, D. F. (1961). The use of herbicides for controlling vegetation in forest fire breaks and uncropped land. In, *Report on Forest Research 1960*, 119–137.

Other publications

See note to Table 7.

CHAPTER 8

Wind

Wind affects forests in two main ways. Firstly, under prolonged exposure to persistent high winds tree growth rates are reduced and stem form changes, and in very extreme conditions of wind exposure young trees may die as a result of severe tissue desiccation and mechanical abrasion. Secondly, semi-mature plantations, particularly on exposed upland sites where wet or compacted soils restrict root development, are susceptible to premature windthrow during the frequent winter gales which occur in such areas.

A high proportion of Britain's plantation forests have been established on high elevation sites, mainly in the north and west of the country, where wind exposure levels and cold wet soils are serious site limitations which can frequently reduce tree growth rates and lead to shortened crop rotations as a result of the progressive spread of windthrow. Such progressive windthrow on sites with restricted root development is termed *endemic windthrow*, and results from normal winter gales. Up to a point, the occurrence of endemic windthrow can be predicted, and its effects minimised by appropriate silvicultural action and planning. In contrast, *catastrophic windthrow* damage is much less predictable, and results from the more infrequent severe storms which can devastate localised forest areas affecting stands with both good and restricted root development.

MANAGEMENT RESPONSES TO WIND

In order to make sensible forecasts of production it is necessary to predict rates of tree growth and risks of windthrow at various heights on exposed sites and several techniques have been developed for this purpose. It is often necessary to adopt particular silvicultural practices on sites where wind exposure levels are critical, so as to minimise growth restrictions and increase plantation stability. Improved prediction of windthrow susceptibility enables more accurate production forecasting and resource planning. The adoption of effective preventive measures against windthrow is highly desirable to ensure maximum rotation length and increased yields of the more valuable sawlog material at the time of clear felling.

Surveys

As a first step in dealing with the problem of protection against wind damage, it is desirable to carry out assessments to determine the severity of exposure of the site and two main methods are commonly employed:

1. *Topex assessment* is a method which indicates the degree of site exposure, based on the amount of shelter given to the area by surrounding high ground. Skyline angles for the eight major compass points are measured by clinometer or Abney lever and totalled to produce a Topex score, which allows the site to be classified into one of five exposure classes, ranging from sheltered to severely exposed. Topex surveys are useful in assessing the afforestation potential of bare land, and are also necessary in predicting the windthrow susceptibility of forest areas.
2. *Exposure flag* surveys involve the use of special cotton flags distributed over the assessment site, covering a representative range of site elevation and aspect. The cotton material slowly erodes away from the free edge of the flag at a rate which is dependent on the wind exposure level present at a flag site, and differences in site exposure over an extensive area are reflected in the different rates of flag attrition. Increased elevation leads to increased rates of flag attrition, and forest managers can determine the approximate elevation limits for economic tree planting from an exposure flag survey. When wind exposure on any site gives flag attrition rates in excess of 12 to 13 cm^2/day, tree growth rates are likely to be depressed below yield class 6, and such sites would normally be considered unsuitable for commercial afforestation. A typical exposure flag survey on a 500 ha area will require deployment of between 10 and 20 flags within the survey area. Worn flags are replaced and assessed every 2 months, and the whole survey should run for 2–3 years to cover the effect of annual variation in exposure levels.

Although flag attrition generally increases with elevation, the rate of increase changes in different geographical locations. In particular, the more exposed

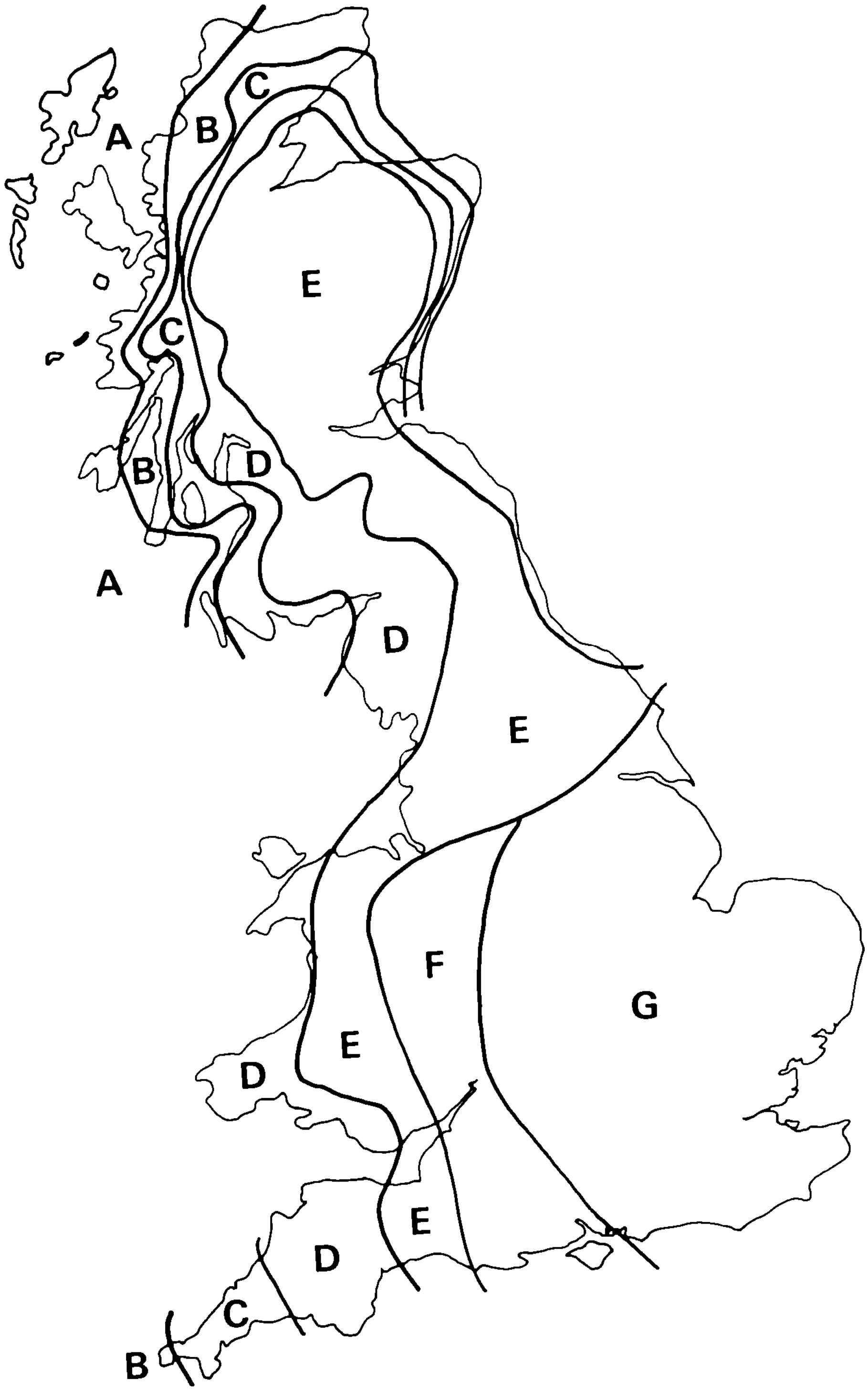

Figure 3. Wind zonation map of Great Britain, based on a combination of wind speed data and exposure flag surveys. (Equal gradation of wind exposure from high – A to low – G.)

north and west of Britain exhibit rapid increases in flag attrition with small rises in elevation, compared to the less windy southern and eastern parts of the country. It has been possible to divide Britain into seven wind zones based on the rate of flag attrition with elevation. This wind zonation is shown in Figure 3 and is an important factor in assessing the windthrow susceptibility of forest areas.

The serious economic losses associated with endemic windthrow make it important for forest managers to be able to predict where and when windthrow is likely to occur, and to select the most appropriate silvicultural and management treatments to delay or restrict the incidence of windthrow in plantations.

WINDTHROW HAZARD CLASSIFICATION

To assist windthrow prediction in British forestry a Windthrow Hazard Classification has been developed, as described in FC Leaflet 85. The classification involves assessing four separate site factors, allocating a score to each, and using the total score to allocate one of six windthrow hazard classes to the forest area:

WIND ZONE ELEVATION TOPEX SOIL

=

COMBINED SCORE

=

WINDTHROW HAZARD CLASS

Each windthrow hazard class is associated with a *critical height*, which is the stand top height at which windthrow is likely to start; and a *terminal height* which is the stand top height when windthrow has spread progressively to reach the 40 per cent damage level and clear felling would become necessary. Critical and terminal heights are influenced by thinning practice, and the interaction is summarised in Table 8 below.

As can be seen from Table 8, thinning generally leads to windthrow, starting at lower top heights (and earlier age) than in unthinned stands, and systematic thinning (line or chevron patterns) is worse than selective thinning. In addition, the timing and intensity of thinning also influence windthrow.

It is important to appreciate that the actual critical and terminal heights which are observed in any forest may deviate widely from the figures shown in Table 8. The critical heights shown are quite well supported by field validation surveys, but the terminal heights given are only to an approximation, based on casual observation, and the rate of spread of windthrow is highly variable. As a general rule, stands in the highly susceptible windthrow hazard classes 5 and 6 should be left unthinned. For those in the most stable hazard classes 1 and 2 the manager is free to choose any normal thinning technique, and stands can usually be grown to full economic rotation without difficulty. In the intermediate hazard classes 3 and 4, thinning options are more limited, and care must be taken over the timing, pattern and intensity of thinning to avoid precipitating the onset of serious windthrow.

The windthrow hazard classification and derived critical and terminal heights are very broad approximations, and cannot be applied safely to individual stands in a forest. The main purpose of the classification is the zonation of extensive forest areas according to windthrow susceptibility, as an aid to general decisions on thinning policy and to production forecasting. Decisions on felling or thinning of individual compartments and stands are subject to a wide range of additional constraints and objectives.

The clearance of windthrow pockets and normal clear felling operations can also carry an increased risk of windthrow spreading in surrounding forest, by exposing unstable edges of plantations to the full force of the wind. It is recommended that in the clearance of windthrown pockets, leaning edges should be left intact, and clear felling operations should be planned to avoid leaving susceptible forest margins, by cutting to existing rides, roadlines and species or age class boundaries.

Table 8

Windthrow hazard class	*Critical heights (m) (onset of windthrow)*			*Estimated terminal heights (m) (40% stand area blown)*		
	Non-thin	*Selective thin*	*Systematic thin*	*Non-thin*	*Selective thin*	*Systematic thin*
1	Unconstrained by windthrow					
2	25.0	22.0	21.0	31.0	28.0	28.0
3	22.0	19.0	17.0	27.0	25.0	23.5
4	19.0	16.0	14.0	24.0	21.5	18.5
5	16.0	13.0	12.0	19.5	17.5	15.5
6	13.0	10.0	9.0	15.5	13.5	11.5

REDUCING THE RISK OF WINDTHROW

Site preparation and soil type are important influences on the incidence and extent of windthrow. In particular, spaced furrow ploughing can result in restrictions to root spread, with the main structural roots tending to align along the plough ridge, and being unable to cross the open furrow. Double mouldboard ploughing is likely to produce less serious root restriction than single mouldboard ploughing, since there are fewer open furrows per hectare, and the more gently sloping sides of the ridges and furrows may encourage increased development of structural rooting at these points. On the drier podsols and ironpan soils complete ploughing may promote improved root architecture, and on the wet gley soils subsurface drainage by mole ploughing with shallow surface cultivation, or mounding, are attractive alternatives to spaced furrow ploughing for improved rooting and stability.

Silvicultural treatments

Spacing or respacing of plantations can be expected to influence windthrow susceptibility to some extent, mainly through their effect on tree shape. The use of wide spacing at planting or subsequent respacing treatment will encourage development of heavily tapered individual tree stems which may resist wind loading more effectively than close grown stems with lower taper. However, any benefits of improved individual resistance to windloading from more tapered stems may well be counteracted by the increased canopy roughness which will generate higher turbulence levels above the forest. The deeper tree crowns in widely spaced stands will also permit deeper wind penetration and, in combination with increased turbulence, the wind loading on individual stems will increase. In addition, widely planted stands will suffer from a reduction in timber quality (due to increased branch size, branch retention and large juvenile core) which reduces the attractiveness of this option even further. Other silvicultural options such as precommercial thinning, or chemical thinning of plantations have potential application on high windthrow hazard class sites where conventional thinning is undesirable. Provided the operations are carried out well before critical height, stability should not be impaired and timber quality is unlikely to be prejudiced.

FURTHER READING: WIND

Forestry Commission publications

BULLETIN
40 *Rooting and stability in Sitka spruce.**

FOREST RECORDS
51 *The use of flags to estimate the relative exposure of trial plantations.**
69 *Guide to site types in forests of north and mid Wales.*

LEAFLET
85 *Windthrow hazard classification.*

RESEARCH INFORMATION NOTES

72/82/SILN	*Scaled topographic models.*
96/84/SILN	*The use of 'tatter' flags for exposure assessment in upland forestry.*

Other publications

BOOTH, T. C. (1974). Silviculture and management of high risk forests in Great Britain. *Irish Forestry* **31**(2), 145–153.

MALCOLM, D. C. and STUDHOLME, W. P. (1972). Yield and form in high elevation stands of Sitka spruce and European larch in Scotland. *Scottish Forestry* **26**(4), 296–308.

MILLER, K. F. and HUNT, J. (1986). Wind exposure assessment for forestry in upland Britain. *Forestry* **58** (in press).

CHAPTER 9

Management for timber production

This chapter is divided into four parts: the first deals with the management of a forest enterprise; the second describes some of the needs and methods of data collection for forest management; the third deals with the planning, organisation and control of production; the final part deals with forest mensuration.

Management

Successful management is the result of careful planning, organisation and control of all forest operations to fulfil the policy objectives of the owner. Management involves choosing between two or more possible courses of action and comprises three main functions:

1. Setting the objectives of the enterprise.
2. Planning and organising operations.
3. Controlling operations.

Policy

The major objectives of the forest enterprise should be established in a statement of policy. The objectives are the criteria used by managers when choosing between alternative courses of action and by which the success of management is judged. An organisation can expect objectives to change and forest management should be sufficiently flexible to meet this. Only when the objectives have been clearly stated with an order of priorities can the best method of achieving them be worked out.

Planning

Planning is the task of organising the forest operations to achieve the policy objectives. It comprises three main phases:

1. Collection of data.
2. Analysis of the various possible courses of action.
3. The formulation of plans.

Long-term plans should reflect the long-term policy objectives of the forest enterprise. They should only be altered when a fundamental change in the environment affecting the enterprise has been recognised. *Medium-term* plans will usually be in the form of 5-year forecasts of work. They will deal with quantities of work but not locations and they should be prepared at the forest rather than the individual stand level. *Short-term* plans will usually be prepared to cover a single year's operation. They will deal with quantities and locations of work by compartments or sub-compartments for all forest operations. As such they become the annual programmes of work and thus form the basis of the annual budget. They should take account of the immediate circumstances and will be subject to constant modification.

Control

Control of all operations ensures that short-term plans are implemented. Control is exercised by checking the progress of work weekly or monthly throughout the budget period and adjusting the allocation of resources as necessary. Automatic data processing using computers allows managers to review budget decisions quickly and effectively. Consideration needs to be given at the time of plan preparation to the type and quantity of data that will be received by managers at all levels of the enterprise and also how the data is to be collected, processed and distributed.

Data collection

The first step in planning is to describe the forest resource qualitatively and quantitatively. This involves the collection and analysis of data. Without this it is impossible to evaluate the results of future actions and hence impossible to judge which course of action is most likely to fulfil the objectives of the enterprise. Forest surveys may be undertaken for many purposes but it is usually necessary to know the legal boundaries of the forest estate, the area distribution of stands by species, age class, stocking and yield class, and the roading layout.

Although all activities on a single estate interact with one another to some extent, the critical element concerns the management of the growing stock of trees. From this flows the requirement to find markets, to programme replanting following felling, to design a system of access routes for general management purposes and for harvesting, etc. In view of this central concern with the growing stock, it is natural that surveys and the records derived from them should concentrate on composition of the growing stock and the following sections therefore deal with this aspect.

There are other kinds of survey which may be found necessary. The assessment of windthrow risk is one, the method for which is described in Chapter 8. At the time of replanting after felling and before new planting is undertaken, a soil survey will often be of assistance in deciding on species, cultivation and drainage. Surveys designed to serve other objectives than timber production are often required, for example to provide the best layout for pheasant shoots, to record interesting wildlife habitats including species lists and to evaluate the demand for informal recreation provided by a picnic place.

Planning of growing stock surveys

The essential data required and standards of collection must be decided before planning the survey. Data from earlier surveys, planting and felling records, compartment schedules and forest histories will provide a useful guide to the survey intensity required. A preliminary reconnaissance enables the manager to make an assessment of the broad nature of crop classification required and will give an indication of the value of existing records available. There are two main ways of recording forest survey information, firstly on a map and secondly on a manual or automatic data retrieval system.

Administrative divisions

The basic management unit of a forest is the stand or sub-compartment. This is described as being an area comprising a more or less homogeneous crop in terms of age, species composition and condition. Sub-compartments are not necessarily permanent units of management since they will probably change as the forest develops through felling, restocking, etc. Sub-compartments are sub-divisions of compartments delineated on a basic forest map. Compartments are permanent management units and their boundaries should be permanent and clearly defined on the ground. They should as far as possible be based upon the forest road systems and other well defined features such as streams, paths or other natural features. The size of the compartments will depend upon a number of factors including the terrain, the intensity of working and the size of the forest.

Forest maps

The first step in the preparation of any management plan for a forest enterprise is to define the extent of the area under management. The external boundaries of the area should be marked on basic planning and record maps. The map is required for day to day planning of operations and to find the way around the forest.

In the Forestry Commission, Ordnance Survey 1:10 000 scale sheets are used as the basic maps but 1:25 000 scale O.S. maps may be a convenient and complementary base for broad brush planning in large forests. Internal crop boundaries should be identified and mapped whenever possible direct from air photos, when a minimum of ground check will be necessary to confirm their validity.

Maps should generally be sufficiently accurate to measure the area of individual stands to at least the nearest 0.5 ha. It is often convenient to prepare a basic map of the forest based on O.S. sheets, showing permanent features such as streams and rivers, rides, roads and boundaries, from which transparencies may be prepared to provide the basis for stock, road and other management maps. It should be noted however that O.S. hold the copyright to all their maps and their permission must be obtained before copies are taken from them. Over-complicated maps should be avoided. Stock maps will show road lines which form compartment or sub-compartment boundaries, but it will usually be more convenient and less confusing to show road classification, bridges, culverts, and proposed road lines on a separate roads map. Figure 4 shows an example of a Forestry Commission stock map.

Data recording

There are no generally accepted standard forms for data recording. The design of forms or schedules depends upon the information to be collected and on the way it is to be stored and presented. Automatic data processing on computers allows management data to be sorted and summarised in a wide variety of ways, but it may still be desirable to retain some form of manual data retrieval system, unless access to the computer is fast enough for local operational use.

Aerial photography

The availability of up-to-date good quality photo cover* has radically altered the approach to forest survey and crop inventory. Survey and inventory design should combine air photo interpretation with ground checks requiring only the use of fairly simple equipment. Where up-to-date photography is available, features can often be transferred directly on to the base map within a framework of known ground control points. When scale differences between plots and basic map are small, this task can be done by means of a scale rule or proportional dividers.

Vertical photographs are essential for basic mapping and for crop interpretation. Panchromatic black and white film is normally adequate for general inventory

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* Central registers of aerial cover are held at Ordnance Survey, Southampton and at Scottish Development Department, Edinburgh for Scottish cover.

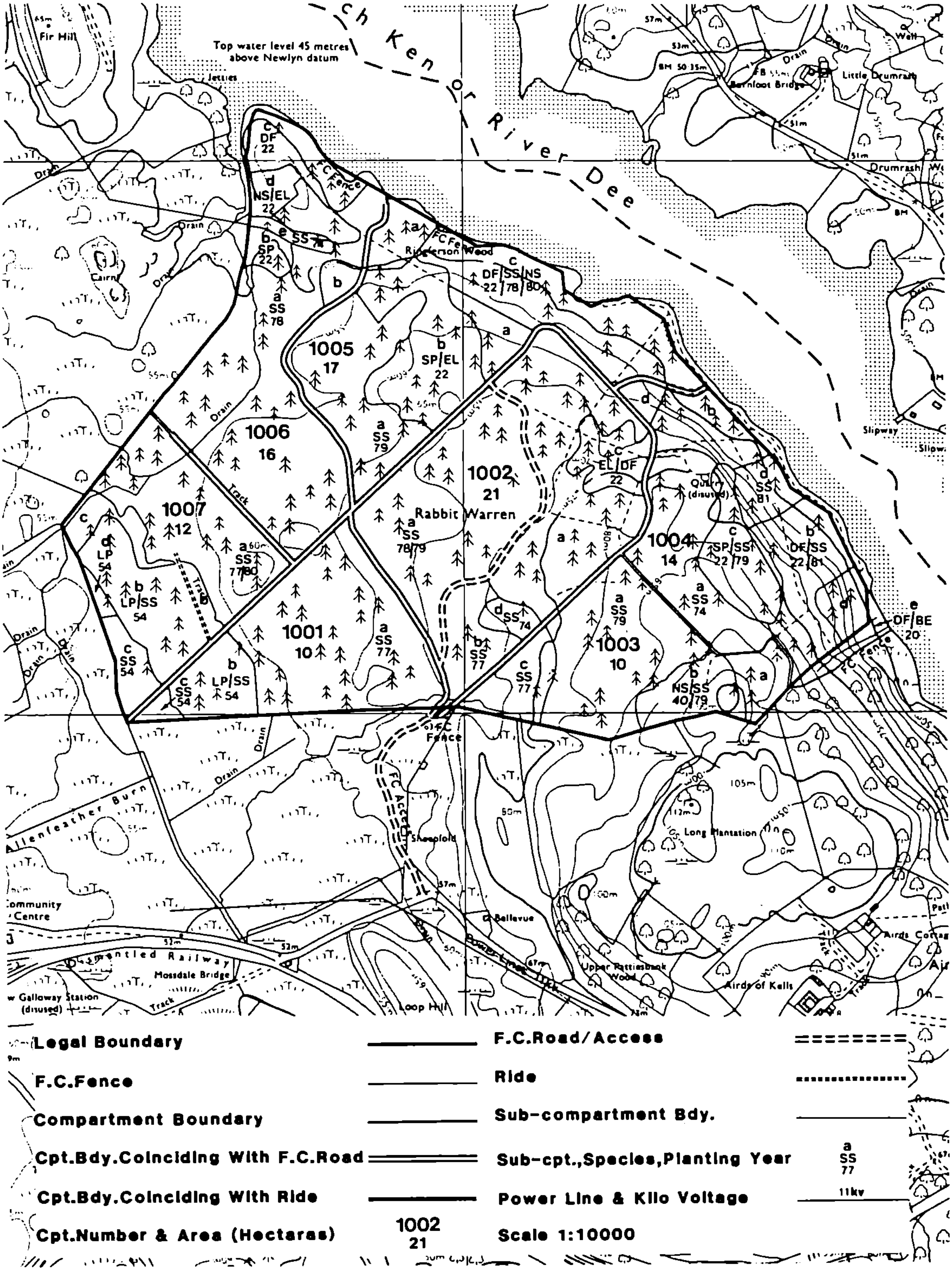


Figure 4. Part of a Forestry Commission stock map.

work, preferably used as stereo pairs. Ideal photo scales are 1:10 000 for ground work and 1:20 000 for machine plotting but scales of 1:7500 to 1:25 000 are acceptable where photo cover already exists.

With practice and some elementary training, relatively inexperienced surveyors can readily learn to use stereoscopes to identify tree crops in air photos. The major tree genera, if not the species, can be seen on good quality air photographs at 1:10 000 or larger scales. These instruments enable the surveyor to construct a three dimensional image from a pair of adjacent overlapping photographs. Cheap pocket stereoscopes can be used in the forest with a pair of photographs mounted on a clipboard. The more expensive table or mirror stereoscopes give a fuller view of the stereoscopic model, thus speeding up interpretation work, but they cannot be used in the field.

At 1:10 000 or larger scale, the proportions of species in mixtures, stocking densities, blank areas and canopy cover in two-storeyed crops are more readily and accurately measured from aerial photos than from ground survey. The ages of crops are generally obtained from records, but may be estimated by whorl or ring counts where they are not otherwise available, or where extensive and late beating up has taken place.

Where suitable photographs are not available, 35 mm photography, taken from a light aircraft by hand-held or fixed mounted camera, can be quite cheap provided the pilot and photographer have had some experience. The photography will probably be unsuitable for basic mapping, but can be invaluable for sketching in sub-compartments within reliably mapped compartmentation.

Where air photos are not available it is seldom worth conducting detailed surveys on the ground. Adequate sub-compartmentation can be achieved by pacing, combined where possible with sketch mapping from adjacent hillsides. Where there are considerable height variations and/or stocking densities between adjacent groups which are too small to map individually, arbitrary grouping may be necessary by applying average crop features to the whole sub-compartment.

Additional data

Additional surveys to provide management information may be required, for example on the assessment of disease occurrence or damage, the estimation of growth rates, the assessment of risk of windblow, planning road alignments or estimating the need for cultural operations such as draining and fertilising.

Planning, organising and controlling the production of wood

The principal objectives of any forest enterprise are likely to depend upon the composition, growth and yield of the growing stock. Control of the growing stock is achieved by applying specified cutting regimes to the forest. Certain basic information is required when making decisions about the cutting regimes to adopt. Knowledge of the area, age and species composition of the crops is essential, together with some information about the standing volume and rate of growth of each stand. Rates of growth are conventionally defined through yield classes as described below. With this information available a manager is able to plan, organise and control the cutting regimes and to forecast the supply of timber and thus to adopt an appropriate marketing strategy.

The following paragraphs explain how to forecast production, describe the yield class system, give guidance on the choice of cutting regimes, describe the various factors which constitute a thinning regime and consider how to control the thinning and felling yields.

Forecasting production

Forecasts of future volume production are essential for market planning, for the planning of labour and machinery resources and to provide the basis for the valuation of growing stock. To forecast production it is necessary to know:

- the present condition of the forest (inventory);
- the pattern of present and future growth (yield class);
- the thinning and felling proposals (cutting regimes).

Forecasts of production from the forest are calculated by totalling the forecasts of production from each stand within a forest. For each stand the following information is needed: species, age, yield class, area, past treatment including plant spacing, and proposed future treatment. The species and age are relatively easy to discover. The assessment of yield class is discussed in FC Booklet 48 *Yield models for forest management*. Accurate maps are required to determine the area and it is most important that this is the area of fully stocked forest, excluding roads, rides and any other unproductive areas such as ponds. Finally, details of past treatments and the proposed future treatments are needed to select the most appropriate yield model. The expected volume and other stand characteristics at each thinning can be read directly from the yield model and the figures for the felling can be calculated by combining the figures for the thinning at that age with the main crop after thinning at the same age. The volume estimates are for one hectare so they must be multiplied by the area to give the figure for the whole stand. Mixtures or two-storeyed stands are most conveniently dealt with by separating the component species or storeys and deriving an effective net area of each based on the proportion of the canopy it occupies.

The forecast thinning and felling volumes can be separated into volumes of large timber to stated top diameters and volumes of smaller timber, using Stand Assortment Tables. Their use is discussed in detail in FC Booklet 39 *Forest mensuration handbook.* Further tables based on wide spacing and for no thin stands are available in FC Booklet 48.

The Yield Class system

In an even-aged stand the cumulative volume production, including dead trees and thinnings, divided by the age of the stand, is referred to as the Mean Annual Increment (MAI). After planting, MAI increases during the early years of vigorous growth, reaches a maximum, and then declines with increasing age. The point at which the MAI curve reaches the maximum is the maximum average rate of volume increment which a particular stand can achieve, and this indicates the yield class. For example, a stand capable of a maximum MAI of 14 m^3/ha has a yield class of 14. The range of yield classes commonly encountered in British conditions varies with individual species and may be as low as 4 for many broadleaves, and as high as 30 in the case of some conifers. When assessing the yield class it is possible to avoid the measurement or prediction of cumulative volume production because there is a good relationship between top height and cumulative volume production of a stand. The relationship allows yield class to be read directly from top height/age curves. An example of the top height/age curve for Sitka spruce is shown in Figure 5.

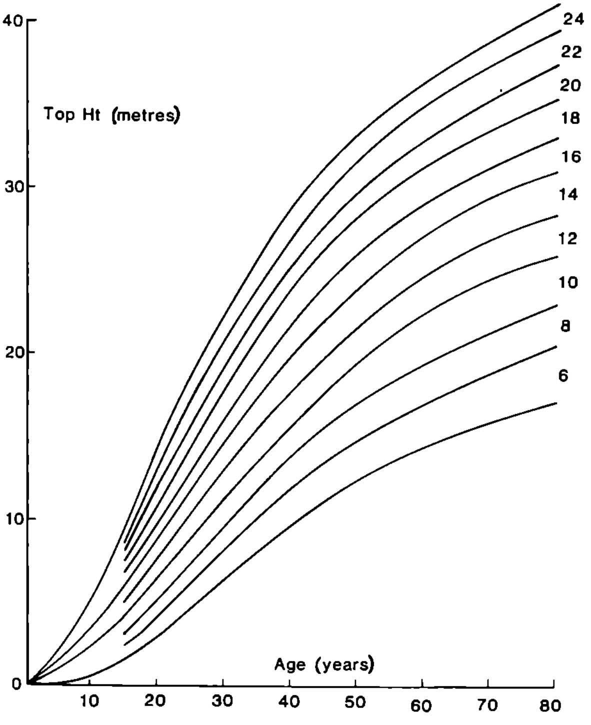


Figure 5. Top height/age curve giving general yield classes for Sitka spruce.

Yield class obtained through top height and age of the stand alone is termed General Yield Class (GYC). Yield class obtained from some measure or prediction of the actual mean annual volume increment of the stand is termed Local Yield Class (LYC). Where LYC is known it should be used in preference to GYC. The assessment of General and Local Yield Class is described in FC Booklet 48.

Cutting regimes

Yield models have been prepared for all the major forest species in Britain and for a wide variety of treatments including a range of initial spacings and thinning treatments, including no thinning. They are available with FC Booklet 48. These models are tabular presentations of stand growth and yield. Table 9 is an example of the yield model for Sitka spruce, Yield Class 12, unthinned, planted at 2.0 m spacing. The models can be used to compare the results of alternative treatments before deciding how to manage a particular stand or group of stands, and to forecast future thinning and felling yields.

Thinning

Thinning is the removal of a proportion of the trees in a crop. It is usually practised in order to provide more growing space for the remaining trees, to increase the total yield of usable timber over the life of the stand, and to provide an intermediate yield of timber. It affects the growth and yield of stands, their size class distribution, quality and stability. These factors need to be translated into economic terms. A policy of no thinning may be desirable on windy sites or where early thinnings are difficult to work and sell profitably. The various factors which constitute a thinning regime are considered separately below and in more detail in FC Booklet 54 *Thinning control.*

Thinning type

Thinnings may be selective or systematic. A *selective* thinning is one in which trees are removed or retained on their individual merits. In *low* thinning, trees are removed predominantly from the lower canopy, that is the suppressed and sub-dominant trees. In *crown* thinning trees are removed predominantly from the upper canopy, that is some dominants and co-dominants, with the aim of giving selected dominants freedom to grow rapidly. The commonest type of selective thinning is known as *intermediate* thinning. It involves removal of most of the suppressed and sub-dominant trees and also opening up the canopy by breaking up groups of competing dominant and co-dominant trees so as to encourage the development of the better trees and to leave an open and fairly uniform stand.

Table 9 Yield model for unthinned Sitka spruce, YC 12, 2.0 m spacing

Age (years)	*Top height (m)*	*No. of trees /ha*	*Mean dbh (cm)*	*Basal area /ha* (m^2)	*Mean volume* (m^3)	*Volume /ha* (m^3)	*Per cent mortality*	*Mean Annual Increment volume/ha* (m^3)
20	7.3	2309	11	24	0.03	66	0	3.3
25	10.0	2249	14	34	0.06	133	0	5.3
30	12.5	2123	16	43	0.10	214	1	7.1
35	14.9	1911	18	49	0.16	301	2	8.6
40	17.2	1714	20	54	0.23	386	3	9.7
45	19.2	1547	22	58	0.30	465	5	10.3
50	21.0	1405	23	61	0.38	534	6	10.7
55	22.5	1293	25	63	0.46	593	8	10.8
60	23.7	1209	26	65	0.53	642	9	10.7
65	24.8	1145	27	67	0.60	683	10	10.5
70	25.7	1092	28	68	0.66	718	11	10.3
75	26.5	1046	29	70	0.72	751	12	10.0

Systematic thinning is a thinning in which trees are removed according to a predetermined system, such as line thinning, which does not permit selection according to the merits of individual trees. Systematic thinning is usually cheaper and easier to manage than selective thinning but the operation may leave parts of the crop unthinned and may result in losses of volume production and reduced stand stability. Systematic thinning should only be considered where the saving in cost is greater than the likely loss of future revenue.

Thinning intensity

The thinning intensity is the rate at which volume is removed, for example 10 m^3/ha/yr. The maximum thinning intensity which can be maintained without causing a loss of cumulative volume production over the rotation is known as the marginal thinning intensity. For most species this critical intensity assessed from the time of first thinning is about 70 per cent of the yield class per year. The marginal thinning intensity is often chosen but there are circumstances when it will not be the best choice. If thinnings are difficult to sell, thinnings may not be undertaken or a lower thinning intensity adopted. If large sized trees are required as soon as possible, a higher thinning intensity may be adopted even though total volume production will be reduced.

Thinning cycle

The thinning cycle is the interval in years between successive thinnings. Long cycles involve heavier single thinnings which are usually more profitable but may increase the risk of windblow and in extreme cases they may result in some loss of volume production. The usual length of thinning cycle is from 4–6 years in young or fast growing crops, and about 10 years for older or slower growing crops.

Thinning yield

The thinning yield is the actual volume removed in any one thinning. If a fully stocked stand is thinned at the marginal thinning intensity, the thinning yield will be 70 per cent of the yield class, multiplied by the cycle. For example, the annual thinning yield for a stand of Yield Class 14 being thinned at the marginal thinning intensity on a 5-year cycle is: 70% × 14 × 5 = 49 m^3/ha.

The thinning yield should not be so heavy that it opens up a stand to the risk of windblow or to invasion by other woody species, and thinning should not take all the dominant and good quality trees so that none is left to form a reasonable crop after thinning.

Other considerations

The treatment of understocked and overstocked stands, mixtures, uneven aged stands, diseased stands with patchy growth or partial check, and treatment of line thinning are dealt with in FC Booklet 54 *Thinning control.*

Field procedure for thinning

Inspection racks should be cut at intervals throughout the plantation to assess the need for thinning. With selective thinning it will usually be necessary to undertake a measure of brashing, that is the removal of the lower branches to head height, to gain access to view the trees and to mark those to be cut. It is an expensive operation however and even in selective thinning it is rarely justifiable to brash every tree. Brashing is usually unnecessary with row thinning as only the end trees in each row to be removed need to be marked. Marking may be done with paint, a timber scribe or more conventionally by cutting a blaze on the side of a tree with a slasher. If it is decided to mark trees that are to be retained, paint should be used. With selective thinning every tree selected should be marked on at least two sides so that it is possible to see from every angle which trees have been chosen for removal. Having decided on the thinning treatment which will yield the maximum benefit, it is essential to exercise some measure of control in order that these aims and long-term plans may be realised.

Yield control

The felling yield is determined by the area of felling and the standing volume per unit area. The detailed application of a yield control system is relatively straightforward if the annual programme of production is drawn up stand by stand and if the progress of work in terms of both area and volume is recorded alongside the planned cut. Control of felling is achieved by keeping a cumulative record of the volume cut and comparing this at intervals with the planned yield for the same period. With thinning yields it may be necessary to supplement the retrospective form of control using records of production with another form of control which can be exercised at the marking stage before the trees are cut. Failure to control the volume removed as thinnings can result in overcutting which leads to a loss in volume production, or undercutting which depresses profitability. It may also produce an erratic flow of timber to the consumer. The subject of thinning control is dealt with comprehensively in FC Booklet 54 *Thinning control.*

It may be an advantage to divide the forest area into thinning blocks related to the thinning cycle and designed to avoid marked variation in thinning and felling yields from one year to another. The use of thinning blocks is usually necessary unless the area in production is small or there is a relatively limited period of rapidly expanding production.

Crop assessment summaries should give a realistic picture of the growth potential of the forest. Areas which are markedly under or over-stocked or which, owing to delayed early growth, are unlikely to be ready for thinning at the standard age, should be identified individually and their predicted yield modified accordingly. The reliability of forecasts of future yield depends upon:

- the accuracy of the growing stock data;
- the accuracy of the growth predictions;
- the thinning and felling policy being carried out as planned.

Mensuration

This section deals with the measurement of standing and felled timber.

Measurement methods

Measurement of timber is required for several purposes. The most obvious of these is the need to quantify forest produce for sale. Measurement is also required for management, notably for planning purposes and for the control of resources. The measurement of yield class for production forecasting has been described earlier.

There are many different ways of measuring any piece of timber, with inevitable differences in the estimates arrived at. It is thus a fundamental necessity to describe fully the method of measurement and the conventions used in order to convey the full meaning of such estimates. Timber quantity can be expressed in terms of solid volume, stacked volume, green weight, dry weight, length, number of pieces, etc. Traditionally timber quantity has been expressed in terms of solid volume.

Choice of method

Measurement methods are fully described in FC Booklet 39 *Forest mensuration handbook* and in FC Booklet 49 *Timber measurement – A field guide*. These booklets describe in detail the most commonly used methods for measuring standing and felled timber. The choice of whether the timber should be measured standing or felled depends on who is responsible for the felling and extraction. Where this is done by the buyer the tendency is to measure standing, but if the grower is responsible, felled measure is more usual. However, with small lots of timber, very diverse crops or high value produce such as veneer timber, it may be better to provide a very rough and cheap estimate of standing volume in order to attract the interest of the prospective buyer, but to agree to sell on the basis of an appropriate felled measure.

Simple methods for estimating the volume of a single standing tree, a stand of trees and felled timber are described below. Each of these methods is described in more detail in the publications mentioned above which should be consulted for further information.

Estimating the volume of a standing tree

A rough estimate of the volume of a standing tree can be derived using the following method, based on form factors:

a. Measure the diameter at breast height (dbh) of the tree. The breast height point is the point on the tree at 1.3 m above ground level.

Table 10 Radius or side length for various plot sizes

	Length in metres for plot size (ha)						
Shape	*0.005*	*0.01*	*0.02*	*0.05*	*0.10*	*0.20*	*0.50*
Circular (radius)	4.0	5.6	8.0	12.6	17.8	25.2	39.9
Square (sides)	7.1	10.0	14.1	22.4	31.6	44.7	70.7

b. Calculate its basal area using the following formula:

$$BA = \frac{\pi d^2}{40\ 000}$$

Where BA = total area in sq m
d = diameter at breast height in cm.

c. Measure the total height of the tree in m.
d. Estimate the form factor of the tree. Use 0.5 for mature conifers in plantations, 0.4 for open grown conifers and 0.35 for younger trees.
e. Multiply the total height by the basal area and by the form factor to give the estimated total volume in cubic metres.

Estimating the volume of a stand

The following method applies to even aged, single species stands. In stands containing a mixture of species or ages, each component of the mixture should be considered separately.

a. Inspect the stand and decide if separate samples are required for different species, ages or crop types. The following steps relate to a single species, age and crop type.
b. From Table 10 above choose a convenient sample plot size which will contain between 7 and 20 trees.
c. Decide on the number of plots to be measured from Table 11 below.

Table 11 Number of sample plots

Area of stand (ha)	*Uniform crop*	*Variable crop*
0.5–2	6	8
2–10	8	12
over 10	10	16

d. Select the plots at random. In each plot:
   - measure and record the diameter at breast height of all trees greater than 7 cm dbh.
   - measure and record the total height of the tree of largest dbh within a 5.6 m radius of the plot centre.
e. Calculate the average height of the samples taken in each plot. This gives an estimate of the top height of the stand.
f. Estimate the tariff number of the stand using Table 12 for top height/tariff numbers.
g. Calculate the mean dbh using the measurements taken in all plots together. This can be done using a calculator with a square root key as follows:
   - square each dbh.
   - add all the squared values together.
   - divide by the number of trees.
   - calculate the square root, which is the mean dbh.
h. Estimate the mean volume from the mean dbh and tariff numbers which have already been calculated, by using the chart (Figure 6).
i. Work out the average number of trees in the plots and divide by the individual plot area to give the estimated number of trees per hectare.
j. Multiply the mean volume by the number of trees per hectare to give the total volume per hectare.
k. Multiply the volume per hectare by the stocked area of the stand to obtain the total volume of the stand.

Measuring felled timber

The traditional method for estimating the volume of sawlogs is the mid diameter method.

a. Measure the length of the log. If the log is longer than 15 m it should be measured in two or more sections.
b. Measure the diameter at the mid point of the log.
c. Calculate the volume of the log using the following formula:

$$V = \frac{\pi d^2 L}{40\ 000}$$

where V = volume in cu m
d = mid diameter in cm
L = length in m.

Table 12 Tariff numbers

Top height (m)	*Species*														
	SP	*CP*	*LP*	*SS*	*NS*	*EL*	*JL/HL*	*DF*	*WH*	*RC*	*GF*	*NF*	*OAK*	*BIRCH*	
8.0	17	16	15	16	16	14	16	15	17	14	14	14	16	14	Subtract 1
8.5	17	16	16	16	17	15	16	16	17	14	15	15	17	14	from the
9.0	18	17	16	17	18	15	17	16	18	15	16	16	17	15	tariff
9.5	18	18	17	18	18	16	18	17	19	15	16	16	18	15	number
10.0	19	18	18	18	19	17	18	17	19	16	17	17	18	16	for inter-
10.5	19	19	19	19	19	18	19	18	20	16	18	18	19	16	mediate
11.0	20	20	19	19	20	18	20	18	20	17	18	18	19	17	and low
11.5	20	20	20	20	20	19	20	19	21	17	19	19	20	17	selective
12.0	21	21	21	21	21	20	21	20	22	18	20	20	20	17	thinning
12.5	21	22	21	21	22	20	22	20	22	18	20	21	21	18	
13.0	22	23	22	22	22	21	22	21	23	19	21	21	21	18	OAK
13.5	22	23	23	23	23	22	23	21	24	19	22	22	22	19	Use also for
14.0	23	24	24	23	23	22	24	22	24	20	23	23	22	19	beech,
14.5	24	25	24	24	24	23	24	22	25	21	23	23	23	20	ash, elm,
15.0	24	25	25	24	24	24	25	23	25	21	24	24	23	20	alder and
15.5	25	26	26	25	25	25	26	24	26	22	25	25	24	21	Sweet
16.0	25	27	26	26	26	25	26	24	27	22	25	25	24	21	chestnut
16.5	26	27	27	26	26	26	27	25	27	23	26	26	25	22	
17.0	26	28	28	27	27	27	28	25	28	23	27	27	25	22	BIRCH
17.5	27	29	28	27	27	27	29	26	28	24	27	27	25	22	Use also for
18.0	27	30	29	28	28	28	29	26	29	24	28	28	26	23	sycamore
18.5	28	30	30	29	29	29	30	27	30	25	29	29	26	23	and poplar
19.0	28	31	31	29	29	29	31	28	30	25	29	29	27	24	
19.5	29	32	31	30	30	30	31	28	31	26	30	30	27	24	
20.0	29	32	32	30	30	31	32	29	31	26	31	31	28	25	
20.5	30	33	33	31	31	31	33	29	32	27	31	31	28	25	
21.0	30	34	33	32	31	32	33	30	33	27	32	32	28	25	
21.5	31	34	34	32	32	33	34	30	33	28	33	33	29	26	
22.0	31	35	35	33	33	34	35	31	34	29	34	33	29	26	
22.5	32	36	36	33	33	34	35	31	35	29	34	34	30	27	
23.0	32	37	36	34	34	35	36	32	35	30	35	35	30	27	
23.5	33	37	37	35	34	36	37	33	36	30	36	35	30	27	
24.0	33	38	38	35	35	36	37	33	36	31	36	36	31	28	
24.5	34	39	38	36	35	37	38	34	37	31	37	37	31	28	
25.0	34	39	39	36	36	38	39	34	38	32	38	37	31	28	
25.5	35	40	40	37	37	38	39	35	38	32	38	38	32	29	
26.0	35	41	40	38	37	39	40	35	39	33	39	39	32	29	
26.5	36	41	41	38	38	40	41	36	39	33	40	39	32	29	
27.0	36	42	42	39	38	40	42	37	40	34	40	40	33	30	
27.5	37	43	43	39	39	41	42	37	41	34	41	41	33	30	
28.0	37	43	43	40	40	42	43	38	41	35	42	41	34	30	
28.5	38	44	44	41	40	43	44	38	42	36	42	42	34	31	
29.0	38	45	45	41	41	43	44	39	43	36	43	43	34	31	
29.5	39	46	45	42	41	44	45	39	43	37	44	43	35	31	
30.0	39	46	46	42	42	45	46	40	44	37	44	44	35	32	

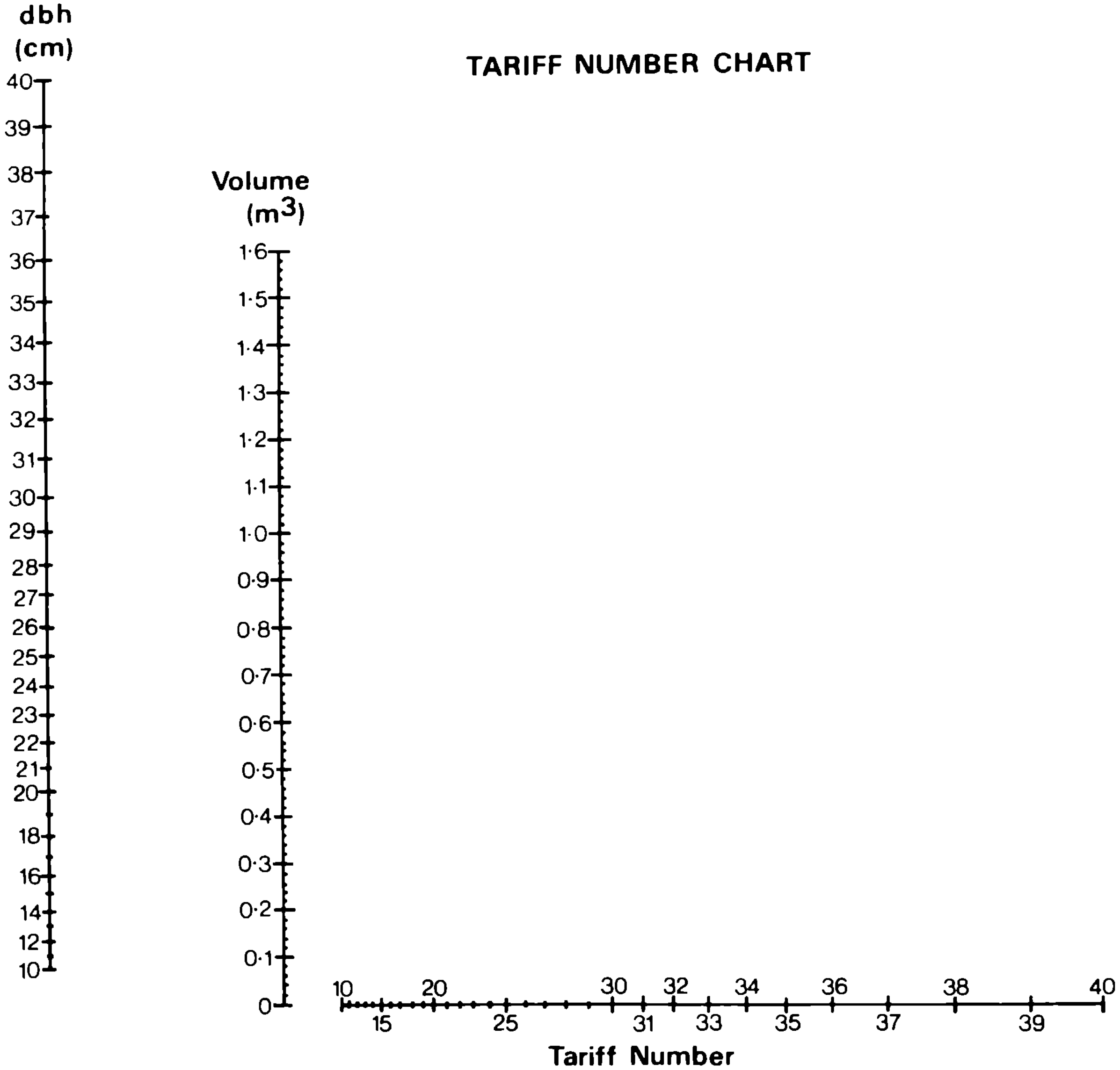


Figure 6. Tariff number chart.

MANAGEMENT FOR TIMBER PRODUCTION

FURTHER READING: MANAGEMENT FOR PRODUCTION

Forestry Commission publications

BULLETINS

44 *Operational research and the managerial economics of forestry.**

52 *Influence of spacing on crop characteristics and yield.**

55 *Aspects of thinning.*

BOOKLETS

26 *Mid diameter sawlog tables.*

31 *Top diameter sawlog tables.*

37 *Volume tables for smallwood and round pitwood.*

39 *Forest mensuration handbook.*

47 *Investment appraisal in forestry.*

48 *Yield models for forest management.*

49 *Timber measurement – a field guide.*

54 *Thinning control.*

FOREST RECORD

114 *Terrain classification.*

LEAFLET

77 *Line thinning.*

RESEARCH AND DEVELOPMENT PAPERS

96 *Construction and application of stand yield models.*

102 *Production planning in the Forestry Commission.**

110 *Initial spacing in relation to establishment and early growth of conifer plantations.*

RESEARCH INFORMATION NOTES

77/83/MENS *Assortment forecasting service.*

94/84/FS *The Forestry Commission subcompartment database. I. Description of the data held.*

95/84/FS *The Forestry Commission subcompartment database. II. Background and current applications.*

OCCASIONAL PAPER

12 *Spatial analysis of forest growth.*

Other publication

JOHNSTON D. R., GRAYSON, A. J. and BRADLEY, R. T. (1967). *Forest planning.* Faber and Faber, London.

CHAPTER 10

Harvesting

Timber harvesting can be carried out by timber merchants to whom the standing trees have been sold, by specialist firms who do some or all harvesting operations on contract, or by workers employed directly by the forest owner. Modern timber harvesting requires competent planning and a high degree of operator skill, it is not a job for amateurs. Machines such as power saws are highly dangerous in untrained hands. Inadequately planned and poorly executed logging is a certain way to waste money.

Harvesting by direct labour must be on a large enough scale to make it worthwhile training operators, providing adequate equipment and keeping production teams employed all the year round. Few owners of small woodland properties can do this, and they are strongly recommended to use merchants or contractors instead.

On some small estates, woodmen are employed on small-scale harvesting operations at times when no other work is possible. This may be worth doing as a means of keeping men usefully employed, but adequate training in safe working techniques is absolutely essential. Part-time harvesting work seldom allows operators to develop a satisfactory degree of skill, and the financial results are usually disappointing.

PLANNING

Careful planning is necessary to select the methods best suited to the circumstances of the operation. The most important factors are:

- Terrain.
- The forest crop: in particular, tree size, and type of cutting (i.e. thinning, clear felling).
- Markets: these determine specification of produce.
- Machinery available.

Other factors, such as availability of labour, may also be important.

Terrain

The term 'terrain' is used here to mean land as a working surface. Good knowledge of the forest terrain is the starting point for operational planning. The Forestry Commission uses a classification system based on the three factors of ground conditions, ground roughness and slope. These factors influence the use of machinery in the forest, and the classification system provides a convenient 'shorthand' method of describing working sites. The main features of the system are given in Table 13.

The forest crop

In general, harvesting operations are easier and cheaper when trees are large and there is plenty of space to move (clear felling of mature crops is a good example). First thinnings, in contrast, combine small trees and confined working space. They can present considerable difficulty, and the cost of the operations may be greater than the value of the timber produced.

Markets

These govern the specification of products, which in turn influence the harvesting operations. If two or three simple products are required it is possible to prepare them at stump. Where more products are made, preparation at stump can result in sorting difficulties. Products which demand accurate measurement are best prepared at roadside or, in the case of pitwood, in a depot where working conditions are better.

Machinery available

Developments in specialised forest machinery have been rapid in the past decade. Many of the more advanced extraction and processing machines are highly efficient, but their purchase prices are so high that economical operation requires large programmes and intensive use. This precludes many forest owners but some of the larger merchants and contractors are now operating in this field.

Harvesting machinery in general use includes the following:

Chain saws

Now used for practically all felling and delimbing as well as most cross-cutting carried out in the forest.

Table 13 Classification of terrain

Class				
1	*2*	*3*	*4*	*5*
Ground conditions				
Very good	Good	Average	Poor	Very poor
e.g. dry sands and gravels	Firm mineral soils	Soft mineral or ironpan soils in drier areas	Peaty gleys in drier areas; soft mineral soils in wetter areas	Peaty gleys in wetter areas; deep peats
Ground roughness				
Very even	Slightly uneven	Uneven	Rough	Very rough
e.g. obstacles (boulders, plough furrows, etc.) small or widely spaced	Intermediate	Obstacles of 40 cm at 1.5–5 m spacing	Intermediate	Obstacles of 60 cm or more at 1.5–5 m
Slope				
Level	Gentle	Moderate	Steep	Very steep
0–10%	10–20%	20–33%	33–50%	50%+
0–6°	6–11°	11–18°	18–27°	27°+

Sites are described by the class numbers. A 4.3.2 site means:

4. Poor ground conditions.
3. Uneven ground.
2. Gentle slope.

The standard order of 'Ground conditions, Roughness, Slope,' must always be observed. The examples of ground conditions and ground roughness given above are to illustrate typical instances, and are not intended as precise definitions of the classes.

Lightweight models are most commonly used for conifers and smaller hardwoods.

The chain saw is potentially a very dangerous piece of machinery and it is important that:

a. It is suitable for the use to which it is to be put. Forestry Safety Council guides should be carefully followed.
b. Operators be properly trained. Untrained personnel must *never* be asked or allowed to use chain saws.
c. Correct working methods must be used. Forestry Safety Council guides should be observed.
d. Operators must be properly equipped with protective clothing, as detailed in FSC guides.
e. Saws are regularly serviced and maintained to maker's specifications.
f. Chains are kept sharp and to design specification.

Most of the large manufacturers market a range of saws sufficient to meet the needs of British forestry. Within the overall range of suitable saws the decision as to which to buy will often be influenced by local availability of spare parts and service.

Forwarders

These are tractors which extract timber lifted entirely clear of the ground. The timber is carried on a linked trailer or integral rear bunk. All use a fitted loading crane. The most usual types are:

1. Forwarders consisting of an agricultural tractor of about 60–80 bhp, equipped with safety cab and extra guarding. Drive can be 2-wheel, often with additional band tracks, or 4-wheel, and fitted with a hydraulically operated loading crane. The trailers are usually detachable, 2 or twin-bogie wheeled, with load capacities of 6 to 10 tonnes. Some Scandinavian firms produce a trailer with the crane pillar mounted on the drawbar, so that a suitable farm tractor, or a skidder, can be converted to a forwarder by simply coupling on the trailer unit and the hydraulic connections. The distinguishing feature of this type of forwarder is the absence of any drive to the trailer wheels.
2. Forwarders essentially the same as type 1, but with power drive to the trailer wheels. This can be a

mechanical drive from the tractor PTO shaft, or hydraulic drive. A variation of the latter is hydraulic drive to a ribbed wheel mounted centrally above each pair of rear bogie wheels, and which can be brought to drive directly on to the bogie wheel tyres when traction is required.

3. Purpose built, frame-steered forwarders, with engine, cab and crane mounted over the front axle or bogie and the load carried over the rear axle or bogie. Engine size generally 80 bhp and above, though some successful smaller models have been produced. Most forwarders have a rear 4-wheel bogie and a single front axle but some, especially later machines, have a front bogie. All wheels are driven mechanically or hydraulically.

The engine-power requirements for forwarders per tonne of load are less than for other forms of extraction, because the fully-supported load makes for more efficient traction. Ten to 12 bhp per tonne of load is usual. The cross-country ability of modern purpose built forwarders is equal to other forestry machines on rough and steep ground.

Forwarders use twin bogies to reduce the ground pressure which can be further reduced by fitting band tracks. Wheel chains provide safe grip on difficult ground. Correct tyre choice is important and can reduce the need for band tracks and chains.

Purpose built forwarders have good ground clearance but some type 1 forwarders are limited by the low position of the trailer drawbar connection which creates difficulties on undulating ground. Forwarders are much more manoeuvrable than is generally realised and have a turning radius as good as other tractors. Purpose built forwarders have a rotating seat which allows the driver to operate the loader easily, and there are usually dual controls which enable the machine to be moved with the driver facing rearwards.

Choice of loader for a forwarder is important because crane work usually takes up the bulk of working time. Most hydraulic cranes are of the 'knuckleboom' type, consisting of an inner and an outer boom, with a rotatable grapple at the end of the latter. Reach should be at least 4.7 m, and a telescopic extension to the outer boom is an advantage. The size of log to be loaded will determine the lifting torque required: 2.5 tonne-metres is an absolute minimum. Lifting and slewing should be quick and smooth. Good operator training is essential and, in addition, it is worth equipping forwarder cranes with the more efficient 2-lever controls in place of normal 6-lever controls. The grapple should be of the horizontal-cylinder type, preferably full rotating. For general work, a grapple of 0.35 m^2 jaw area is required, but if loading is nearly all in pulpwood, a special 1.0 m^2 grapple allows faster work.

The loader can be pillar-mounted behind the cab or on the trailer drawbar but this blocks vision, and a better mounting position is on top of a specially strengthened safety cab. Loaders should not be mounted in front of the cab. Practically all the hydraulic loaders used on forwarders in Britain are of Swedish or Finnish manufacture.

Because of their larger load carrying capacity, the cost of the actual movement of timber is less per cubic metre for forwarders than for other tractors. This affects requirements for forest roads, as forwarders can extract economically over long distances and so roads can be spaced further apart. This aspect is discussed in Chapter 11.

The ability to carry timber economically over fairly long distances, entirely on wheels, makes forwarders particularly attractive for work on estate woodlands. They can travel over intervening fields with minimum damage to grass and the amount of stacking space required at roadside is little because the crane can make high stacks. Timber extracted by forwarder is generally clean.

Effective use of forwarders requires careful planning and control of preparatory work. Extraction routes should be carefully laid out and crops thinned or felled to concentrate produce for quick and easy loading. Unless there are minor products with the very high values which will cover the high costs of extracting a relatively small volume of each product it is generally desirable to cut timber for forwarder extraction to only two, or occasionally three, specifications. Furthermore timber is cut to specification before it is extracted and a buffer stock of material ready for extraction is usually necessary to ensure good machine utilisation. This requires close liaison with customers to ensure balance of supply and demand by end product specifications.

As a general rule forwarder output should be machine capacity per hour in use, e.g. a 10 tonne forwarder should average 10 m^3/hour or better.

Skidders

These are tractors which extract by lifting one end of the load clear of the ground and pulling it out with the other end dragging on the ground. Timber pieces, poles or whole trees can be extracted in this way. Skidders can be of several types:

1. Two-wheel drive farm tractors with engines of around 50 bhp, fitted with safety cab and extra guarding on sump, radiator and wheel valves, and with some form of butt plate at the rear. Load attachment can be by a small rear-mounted winch, single or double-drum, or by a simple hydraulic grapple.
2. Larger farm/industrial tractors with engines in the range of 60 to 80 bhp; nearly always with 4-wheel drive, and safety cab, extra guarding and butt plate. Usually equipped with a double-drum 3 or 4-tonne winch, and often with a front-mounted stacking blade as well.

3. Specifically designed forest tractors with frame steering, and engine sizes generally from 80 bhp to 150 bhp and above. They have all the features of type 2, and can have winches of up to 10 tonne pull. They are also available with rear-mounted hydraulic grapples as an alternative to the winch.

Because a skidder suspends its load behind the rear wheels, weight distribution is important. Most farm tractors carry a greater proportion of weight on their rear wheels in the unladen state, and when used as skidders are grossly unbalanced. All type 1 skidders require front weight to correct this. Type 2 skidders also require front ballast, though the front stacking blade may assist. The frame-steered skidders, in contrast, start with a front–rear wheel ratio of 60:40, which becomes a near–ideal 50:50 when the load is attached.

Rough forest terrain requires good ground clearance. Farm tractors, particularly the smaller ones, may have only 300 mm clearance, which limits their use on rough ground. The best of the type 2 skidders have about 450 mm, which is generally adequate; frame-steered skidders normally have 470–500 mm or more.

The size of the skidder required is largely determined by the average load size. A rough guide is that 30 flywheel bhp are required for each cubic metre of load. This rule holds good up to 120 bhp or so; above this size, horsepower requirements are somewhat less, perhaps 20–25 bhp per cubic metre.

Small agricultural tractors can be highly manoeuvrable with a turning radius of about 3.0 m. Many of the type 2 skidders can achieve 6.0 m turning radius, but in both cases brakes have to be used to 'skid steer'. Frame-steered skidders generally have smaller turning radii than conventional tractors of equivalent size, and do not require to use brakes for tight turns. In rough, boulder-strewn conditions the frame-steered skidders are far superior, because of more precise steering and better axle oscillation. In soft ground, the performance of types 1 and 2 can be improved by the use of demountable band tracks ('half tracks'), but conventional front-wheel steering becomes progressively less effective as conditions deteriorate.

Specially-designed wheel chains will greatly improve tractor performance in rough and moderately soft conditions. On the poorest bearing surfaces, large flotation tyres are a help, together with the use of branches and tops to form a 'mat' over which the machines can run.

The skidder is used with detachable sliding choker hooks, to which poles are fastened by detachable slings, called chokers. Chain chokers are common, but polypropylene rope chokers are better, being cheaper and lighter. A single winch rope (9 mm diameter is typical for work in smaller conifers) can carry six choker hooks comfortably, which allows perhaps 10 or 12 small poles to be attached. At, say, 0.07 m^3 per pole, this is not a full load. So double-drum winches should always be chosen for small timber work, thus allowing twice the number of chokers to be used. Only in this way can economic load sizes be obtained. Double-drum winches are better than single-drum for average tree sizes of up to 0.5 m^3. Above this size, single-drum winches can be used efficiently.

Three or 4 tonne winches are adequate for the general run of conifer and small hardwood logging. Larger winches may be necessary for large hardwoods, or where it is particularly desirable to have drums with the capacity to carry a long rope. Modern tractor extraction uses the winch as a means of load assembly only; it relies on getting the tractor as near the timber as possible, then pulling it out by tractor power, not by winching, but the load can be dropped in more difficult terrain and then winched in to the skidder once the obstruction has been cleared. This technique cannot be used with grapple skidders because there is no facility to retrieve the load. Earlier techniques using a tractor as a means of transporting and powering a massive single-drum winch, which then moved the timber from stump to roadside by winching only, are now rarely employed, having been supplanted by more efficient skidders.

Crawler tractors were formerly used as skidders but their use in this country is now confined to a few larger timber operations. High cost of track maintenance and inability to run on public roads are major disadvantages.

Cablecranes

These are ropeway systems where timber is extracted by means of moving cables, powered by a stationary winch. The timber load is usually carried wholly or partially clear of the ground. Two types of cablecrane are in general use:

1. *High lead cablecranes:* these are double-drum winches, generally mounted on a tractor. One drum hauls in the 'main-line' with load attached, the other pulls in the 'haul-back' line, which passes round a pulley block on a spar tree at the far end of the cableway and so to the main line, drawing it out again. A 6 or 7 m tower mounted on the tractor, and the height of the 'tail block' on the spar tree, help to raise the cables and load off the ground. The lifting effect is increased by suspending the load from a block, running on the haul-back line: each winch drum has a clutch and brake, and by applying the haul-back drum brake when the haul-in drum pulls in the load, the line system tightens and lifts the load. Loads can be picked up 10–12 m or more from the line of the cablecrane.
2. *Skyline cablecranes:* these also have two main rope drums but the load is supported by a block running on a tensioned fixed cable, the 'skyline'. This burden

cable may be held by fixed supports at intervals along its length.

Cablecranes used in this country are those based on the Norwegian Igland double-drum winches, or the 'Timbermaster' models manufactured by G & R Smith, Aberfeldy. The former can be tractor or trailer-mounted, while the Timbermaster is now only trailer-mounted. Skylines require additional drums to carry the skyline cable and a light cable, the 'straw-line', which the riggers lay out first of all and which is then used to pull out the heavier ropes.

High lead cablecranes are the more efficient over short distances, up to 120 m maximum extraction distance, depending on site. Distances beyond this become difficult to extract by high lead, and 180 m represents the limit for this type of machine. Skyline cablecranes can operate at ranges of up to 600 m with equipment on the lines described above. Ranges greater than this are possible with special cablecranes of Norwegian or Austrian manufacture, but there are few instances where extraction distance is so great as to require their use.

In almost every case it is preferable to use skidders or forwarders for extraction if at all possible owing to the high cost of extraction using cablecranes. Cablecranes need a crew of at least two men and their outputs are generally well below efficient tractor operations. Cablecranes can, though, extract timber on the most difficult sites where all other methods fail.

Loaders

Timber handling, stacking and loading by hand, is extremely hard work and should be replaced by mechanical handling wherever possible. The maximum size of billet for manual handling should not exceed 30 kg. The main types of loader are:

1. *Hydraulic 'knuckleboom' loaders.* These can be lorry-mounted or tractor-mounted and their use on forwarders is described above. Lorry-mounted loaders are usually mounted behind the cab, though mid-body or tail mounting are sometimes used. A demountable lorry crane is also obtainable, so that the crane is left behind in the forest and the lorry can carry its full payload, undiminished by weight of the crane. Knuckleboom loaders are available in a wide range of sizes, with maximum reaches of 4 m to 14 m, and lifting torque of from 2 to 10 tonne-metres or more. Loaders with a reach of 5–6 m lifting torque of 3 tonne-metres are commonest in this country at present.
2. *Front-mounted loaders.* These are purpose-built, high-capacity loaders, which are very efficient if there is a sufficiently high volume to keep them fully employed. Maximum lift height is about 3.8 m, and lifting capacity is in the range of 4 to 7 tonnes as a rule.
3. *Tractor foreloaders.* Basically farm tractors with foreloader attachments. These are machines which make timber handling possible at low cost. Maximum lifting capacity is about one tonne.

The tractor foreloaders are the cheapest but are limited to relatively simple operations, front-mounted loaders are the most efficient but require high-volume operation. Both these types need a certain amount of space to move around. The knuckleboom loaders are the most versatile and most used. The choice of loader depends on type of produce handled and frequency of use. The range of choice is described in two publications: FC Forest Record 78 *Loading and unloading timber lorries*, and FC Forest Record 87 *Hydraulic grapple cranes for forest use*. Both publications contain useful charts to assist in the selection of a loader.

Harvesting systems

Tree-length system

In the past, most of the timber cut in Britain was harvested by this system. The tree is felled and delimbed at stump; extracted by tractor or cablecrane to roadside; crosscut into sawlogs and other products (pulpwood, stakes, etc.), and these products are then sorted and stacked for collection by lorries.

The principal variation of this system is when the sawlog part of the stem is cut off at stump and extracted separately from the rest of the stem. This is usually done to make sorting at roadside easier, so that sawlogs can be stacked separately from other products. However, the shorter pieces may reduce the load size, and so the efficiency, of the extraction. This variation is common in hardwood logging where the main stem may be extracted entire and branches made into short cordwood pieces at stump.

Tree-length harvesting needs careful supervision to ensure that the three phases of felling, extraction and crosscutting are kept in step with each other. It allows a number of different products to be cut from the stems and sorted at roadside. The concentration of crosscutting means that this can be done by a skilled operator, trained to select the cutting points that will give maximum value of products cut. This is particularly important with valuable timber.

Although forwarders can extract in this system if the poles are not too long, skidders are normally used. Cablecranes can also carry out tree-length extraction, though roadside space for crosscutting is necessary.

Shortwood system

Here the feller combines delimbing with crosscutting at stump, so that all subsequent extraction handles only saleable products and all waste is left in the forest. This system can be highly efficient if a small number of products are cut. More than four products presents difficulties of sorting, both at stump and roadside.

Shortwood is relatively easy to organise and control, with only two phases of felling/delimbing/crosscutting and extraction to keep in balance, but poor organisation can be very costly – either by underutilised extraction equipment or weight loss from excessive stocks at stump.

Winch skidders are unsuitable for shortwood work; either the chokering of many short pieces is too time-consuming, or the preparation of large enough piles of billets (perhaps with pre-set wire slings) requires too much work by fellers. Grapple skidders can extract billets but the short pieces mean inefficiently small loads. Forwarders are the ideal extraction method for shortwood, exactly suited to the bulk-handling concept of this system. Cablecranes can also operate shortwood efficiently, and the elimination of roadside crosscutting makes the system particularly suitable for mountain forests where roadside space is limited or non-existent.

Other systems

There is currently a rapid switch to mechanised harvesting and this trend is likely to continue in the future. Recent technical developments have produced efficient and reliable processors (machines which delimb and crosscut trees to the required products) and harvesters (machines with processor functions plus the ability to fell standing trees). These machines can be used for clear felling and for thinning, presenting shortwood products in the stand similar to manual shortwood working.

There are a number of possible harvesting systems incorporating the process of chipping. The whole tree can be chipped, or only part of the stem and branches, and the chipping can be done at stump, rack, roadside or depot. Chip systems have not yet been developed as harvesting systems to any extent in this country.

Table 14

Shortwood system	*Tree-length system*
Efficient with small and large trees.	Less efficient on trees smaller than 0.1 m^3 average.
Two-phase system, easier to supervise.	Three-phase system needs good co-ordination.
Preferably not more than two products.	Several products can be cut.
Stacking space only required at roadside.	Working space necessary at roadside.
(Can be loaded direct on to transport.)	Sorting and stacking required at roadside. (This can be mechanised.)
Fellers pile smaller billets in wood.	Timber dirty in wet conditions.
Lower density of roads required for forwarder extraction.	Higher density of roads required to organise skidder extraction.

Choice of system

Shortwood has an important advantage in small-size crops, i.e. where average tree cut is 0.1 m^3 or less. The small trees are cut into logs or billets at an early stage and thereafter the timber is handled not as small trees but large bundles. Tree-length work retains the tree as the unit of load until a late stage. This is less efficient with small stems but can be advantageous with large trees. The main advantages and disadvantages of the two systems are summarised below in Table 14.

It is not possible to give a single set of rules for selecting a harvesting system because different factors affect particular situations. For example, a forest where the principal product is pitwood is almost bound to use a tree-length system, even if other factors favour shortwood. Similarly, an owner of a large forest might decide that the savings on road investment associated with a shortwood-forwarder system outweigh all other factors.

HARVESTING TECHNIQUES

Felling

Organisation

The underlying principle is that felling should facilitate later operations, particularly extraction. If no rack system exists the racks should be marked out to suit the particular extraction system. An existing rack system should be checked and improved if necessary. Racks required for particular extraction methods are described later.

The felling area should be divided into sections. Each section is felled by one, or at most two, fellers. It is essential to keep a safe working distance between fellers. This should be not less than twice the height of the tallest tree to be cut. If possible the felling sections should be sufficiently uniform to allow a single piecework price to be set for the whole section.

Felling should be carried out in an orderly manner, following organised felling methods to give the best possible presentation for extraction, as the extraction rate is the key factor in harvesting organisation. Felling should follow established techniques, making maximum use of aid tools and with the fellers carrying out minimum movement of the timber.

Modern working methods reduce effort and increase output. In bench felling, trees are first felled at right angles to the general felling direction to provide supports across which trees are subsequently felled. The resultant increased working height greatly facilitates snedding, and movement of poles or large end products is eased by their pivoting at points of balance on the bench. With contour felling, benches are aligned up and downhill and gravity assists with produce movement to timber zones. This concentration of produce speeds up forwarder or cablecrane extraction. Contour felling has the added advantage of increased safety on steep ground where conventional strip felling may give very unstable snedding, crosscutting and stacking conditions.

Extraction with forwarders

Organisation

Racks must be planned and marked beforehand. They should be straight, up and downhill if possible, avoiding side slopes. Minimum width is 1.25 m plus forwarder width, and wider on bends, soft or rough terrain. Rack spacing should be 20–30 m in thinnings, 15 m or less on clear felling. Spacing should be such that all produce can be reached by the knuckleboom loader of the forwarder.

Extraction with skidders

Organisation

The extraction routes, or 'racks', must be planned and clearly marked on the ground before felling starts. The selection of routes should not be left to fellers or tractor drivers. The best direction is generally straight up and downhill, with as few bends as possible. In thinnings racks should be at least 1.0–1.25 m wider than the maximum width of the tractors, and preferably wider on soft or rocky ground. Spacing should be close enough for the felled trees to be easily accessible from the rack; 25 m centre-to-centre spacing is common in thinning, and on clear felling this can be reduced to 15 m. Racks should be curved at junctions and main road exits to avoid damage by the load to standing trees. Stretches of firm, even ground should be utilised for main racks, which are cut wider than normal, and on which fast driving is possible.

Tip-first extraction gives higher outputs than butt-first when winch skidders are used, particularly with small trees. Fellers should leave 2 cm branch projections on the last whorl, to give a good grip for the choker slings. Butt-first extraction is easier for grapple-skidders and is often desirable with larger stems because the butt log suffers less damage, particularly in rocky terrain. On steeper, firm ground, butt-first extraction may give better traction than tip-first.

Extraction with cablecranes

Organisation

The choice of high lead or skyline cablecrane depends on the road system at the forest. If the existing road system is dense, at 270–300 m spacing or less, high-lead cablecranes will be the more economic. If road spacing is wider, up to 900 m, skylines should be chosen. If the forest area is unroaded, the road network should be laid out for cablecranes with a maximum range of 500 m.

Good planning of the extraction racks is more important for cablecranes than for any other means of extraction. In mountain forests when this method is used, stacking space on roadsides is usually limited and this often determines the position of racks in thinning operations. Clear fellings usually allow more effective use of available stacking space. Stacking on sloping ground requires care in building up a secure base for the stack. 'Offset' working allows stacking on the road carriageway but this blocks the road.

As well as starting at an acceptable stacking space, racks should:

- be straight – this is essential;
- be 3.0–3.5 m wide;
- be spaced at 20–27 m;
- have adequate spar and anchor trees; and
- if possible, be parallel, all the same length, at right angles to the road.

If possible, avoid convex slopes for high lead rack alignment. Racks for skylines can be laid out on convex slopes, particularly where knolls, etc., provide higher points on which intermediate supports can be erected. In both cases racks on side slopes should be avoided.

The best solution to the problem of restricted stacking space is regular clearance of produce by lorries. Other solutions rely on moving the produce from the rack mouth to an adjacent or distant stacking site by trailers, forwarders, hydratong-grapple skidders, etc., or by special rigging techniques which allow the cablecrane to move timber laterally along the road.

Roadside and depot conversion

Shortwood harvesting requires only stacking space at roadside, which makes it well suited to cablecrane extraction on narrow mountain roads. All tree-length extraction requires greater stacking space. Occasionally the timber can be delivered to the customer in long lengths but in most cases conversion must be done in the forest.

Roadside crosscutting and processing (i.e. peeling, splitting, ripping, pointing stakes, etc.) is a form of depot working where the work is spread out in a linear fashion. With adequate road width it is possible to accommodate the full range of conversion operations, but it is normal to find considerable interference between operations causing delays. This can often be accepted and there are no hard and fast rules as to when roadside conversion (giving shorter extraction distances but greater conversion difficulties) should be replaced by conversion depots (with longer extraction distances but more efficient conversion). Whichever is chosen, the principles of efficient working are the same.

FURTHER READING: HARVESTING

Forestry Commission publications

BOOKLETS
43 *Forest road planning.*
45 *Standard time tables and output guides.*

FOREST RECORDS
78 *Loading and unloading timber lorries.**
87 *Hydraulic grapple cranes for forest use.*
114 *Terrain classification.*

LEAFLETS
55 *Hydratongs.*
59 *Hydrostatic skidder.*
75 *Harvesting of windthrown trees.*
81 *Aid tools for timber harvesting.*

RESEARCH INFORMATION NOTE
82/84/WS *Harvesting machines – nomenclature.*

FOREST INDUSTRY SAFETY GUIDES
10, 11, 12, 13, 14, 15, 17, 21, 22, 23, 25, 30, 31 (see full list of titles in Appendix II).

CHAPTER 11

Forest roads

The function of forest roads is to provide access for the transport of timber to the market and also for general management purposes. Roads are essential in all but the smallest woods, but they are costly to construct. It is important that they should be planned and designed with care.

FOREST ROAD PLANNING

Forest road construction involves significant capital expenditure and continuing charges for road maintenance; but a good road system will reduce the amount of cross-country movement of timber in extraction operations, and may allow greater use of larger, more economical road transport vehicles for delivery to the customer. The purpose of planning roads for timber exploitation is to try to achieve the combination of road cost and extraction cost (and sometimes road haulage cost as well) which gives the lowest overall cost of moving timber. There may, of course, be other purposes for roads through woodlands, such as general management, access for sporting and to property beyond the forest edge. Such needs may generally be accommodated within the road system designed for timber extraction.

An investigation of road planning calculations, taking into account a substantial number of cases involving different terrain conditions, with variable factors of road construction and timber movement costs, has resulted in a general assumption that the optimum spacing for well-constructed roads in large forests is about 1000 metres. This wide spacing arises from the major developments in efficient high capacity extraction machines, such as skidders and, especially, forwarders. A detailed calculation of the best road spacing can be made for any given wood. In smaller woods, densities of 20 or more metres per hectare may well be appropriate. FC Booklet 43 *Forest road planning* is recommended for further reading. Apart from dealing in detail with the economics of forest road planning it also covers the upgrading of existing sub-standard roads, the timing of the investment and the extension of existing road systems.

Public highways

The internal forest road system should be planned with the public highway layout in mind: the public roads to which connection is to be made must be of a standard sufficient to carry the traffic generated by the forest. All new accesses, and major alterations to existing accesses, on to the public highway system require approval by the Local Highway Authority. An approach should be made to the Highway Department in the first instance to ensure that the proposals being made are in accordance with their regulations. When the plans have been approved by the Local Highway Authority it will be necessary to ensure that they are constructed in accordance with their specification.

The effect of terrain, soils and other factors on road location

Road location is greatly affected by topography and ground conditions, both of which vary over a wide range in Britain. The normal procedure on cross-sloping ground is to locate the road alignment in such a way that excavation is minimised, but the terrain may well introduce the problems of both horizontal and vertical curvature. It is essential to avoid substantial outcrops of rock, but excavation is less of a difficulty where the rock can be ripped using a large angle dozer fitted with a hydraulically operated ripper. Forming roads on deep peat, in embankment form, is commonly practised especially when morainic, or other suitable deposits occur nearby as sources of good construction material. In high rainfall areas the existence of streams and rivers poses a special problem of road location, and it is not uncommon for a bridge or culvert crossing to dictate the position of the future road.

Harvesting systems, whether involving forwarder, skidder or cablecrane methods of timber extraction, as well as engineering design considerations, influence road location and alignment. Consideration of the incidence, size and positions of timber handling, stacking and conversion facilities, is also important.

Table 15 Summary of forest road standards

Item	*Feature*	*Dimension*		*Remarks*
Tree felling for forest road	Clearance width	Variable		Depends on site conditions but must accommodate all roadworks and associated drainage, with adequate clearance to avoid excessive shading of road.
Road formation	Formation width	min 4.7 m		Batters – upper as steep as possible. Lower batters normally 1 in 1¼.
Road formation	Formation width on peat	min 5.6 m		Road formation is constructed on top of deep peat but with shallow peat up to 500 mm the peat can be excavated.
Road formation	Formation camber	min 75 mm		On slack gradients road camber is increased to 90 mm.
Road formation	Crossfall	min 150 mm but not exceeding 190 mm		On roads located on steep cross slopes crossfall replaces camber.
Gradient	Longitudinal	max 10%		Except on horizontal curves where road pavement width has to be increased.
Gradient	Longitudinal	min 1%		On flat country for efficient drainage.
Road pavement	Width	3.2 m		Standard width but increased for sharp horizontal curves as necessary.
Forest road	Horizontal curves	Radius m	Road pavement width m	Road pavement is widened on sharp horizontal curves for vehicles up to 32 ton (articulated) and up to 28 ton (fixed platform). Road pavement widening is achieved on the inside of the curve with a straight transition, 15 m length, to the inner radius.
		60.0	3.2	
		45.0	3.5	
		30.0	4.0	
		25.0	4.2	
		20.0	4.5	
		15.0	5.0	
Forest road pavement	Thickness of (i) base course + surfacing course (ii) combined base and surfacing course	Varies from 150 mm to more than 450 mm		Dry bound macadam construction.
Turning places	Width	4 m		Set out in the form of a T.
	Length	21 m		
Passing places	Width	4 m		
	Length	33 m		

Forest road standards

In the United Kingdom the Motor Vehicles (Construction and Use) (Amendment No. 7) Regulations 1982 took effect on 1 May 1983. These regulations permit the use of vehicles of up to 30.49 tonnes gross vehicle weight of the 4-axled rigid type and up to 38 tonnes gross vehicle weight of the 5-axled articulated type. Both of these types of vehicles can have maximum overall width of 2.5 m, maximum length of 11 m and 15.5 m respectively and maximum axle loads of 10.17 tonnes and 10.5 tonnes respectively. The vehicle trailer combination is permitted to have a maximum normal gross vehicle weight of 24.39 tonnes (if certain conditions are fulfilled this can go up to 35.52

tonnes), a maximum axle load of 10.17 tonnes and a maximum overall length of 18 m.

Because of the distance from the forest to the market, it is normally good economic practice to use the largest vehicle available and the summary of forest road standards set out in Table 15 is designed for this purpose. However, there may be a case for lower standard roads suitable for use by vehicles less than maximum size in small plantations, especially if existing forest roads and/or the existing approach public highway are sub-standard and material has to be hauled to a local mill.

Survey methods

Once the location of the road in terms of a broad corridor has been planned, the road survey can take place. If the ground conditions are difficult, and especially if bridges or large culverts are concerned, then a detailed survey will no doubt be warranted. This will involve the preparation of a longitudinal section, with cross-sections, and a plan. These provide the basis for detailed design of the road, taking into account such aspects as the specification data, water crossings, soil conditions, road construction methods, the type of plant to be used on construction, the availability of suitable material and other items.

CONSTRUCTION OF ROADS

In private woodlands it is more than probable that most road construction work will be put out to contract. This involves the preparation of contract documents even if only in a simple form. The main items of the road specification recorded elsewhere in this chapter should be observed, in relation to the particular site, to achieve a forest road of efficient and sound design. It is not feasible to describe all the types of ground conditions here, but one of the most common is that of a cross-slope in firm sub-soils.

Road construction in these conditions takes the form of a shelf, excavated by a large angle dozer (normally fitted with hydraulically operated ripper), or medium sized excavator with face shovel equipment. The latter is used mainly where the ground tends to be wet and sleeper mats may have to be considered. Where hard conditions prevail, a rock ripper can often be applied to facilitate rock excavation, and this is of great benefit compared to the operations of drilling and blasting of rock, which tend to be fairly slow, much more costly and less safe.

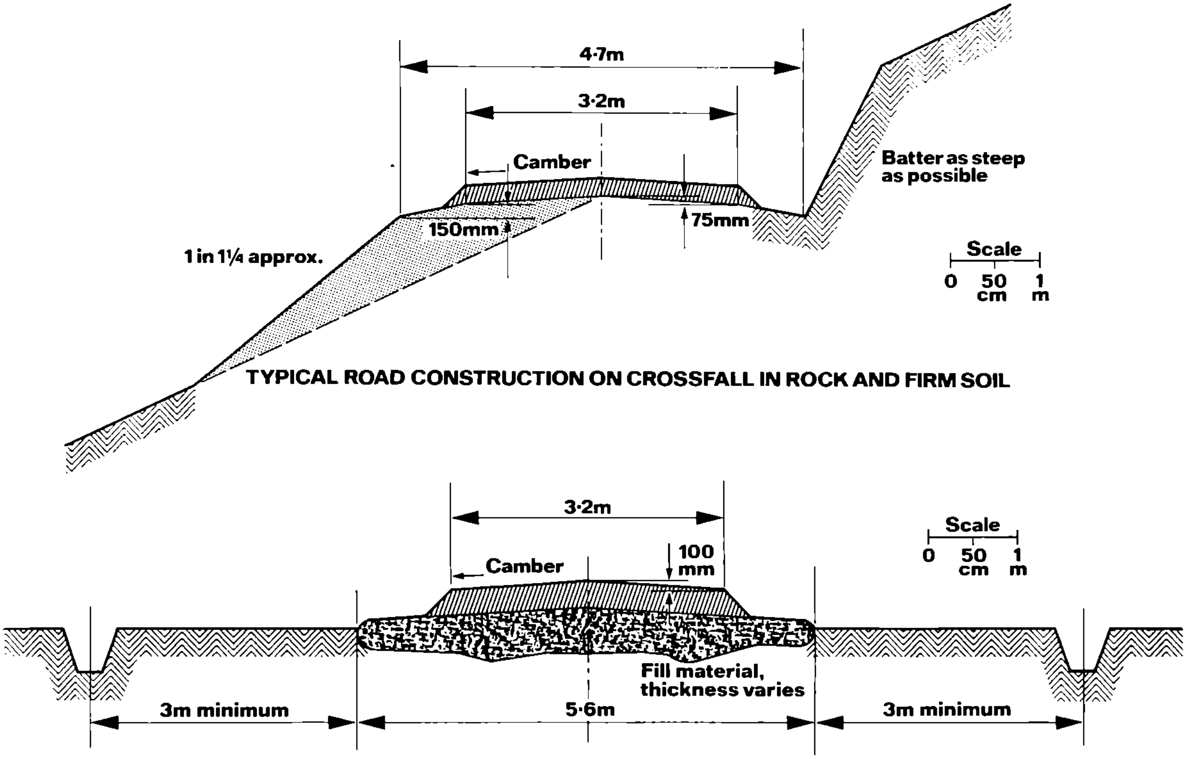
Another type of ground condition which is quite common in the uplands occurs where peaty soils prevail, on fairly flat ground, and this includes both shallow and deep peat. Where the peat is shallow it is usually excavated, and the sub-grade thus exposed is shaped accordingly. Where deep peat is concerned the established method is to construct a road embankment on top of the peat using suitable, locally won, materials.

The importance of an efficient drainage system for the road, in the form of side drains, lateral water crossings and road camber or cross-fall, cannot be over-emphasised. It is imperative for bridges and culverts to have waterway areas of adequate size and to be constructed of sound materials.

The road formations resulting from the various types of construction are compacted, so far as possible, using a vibratory roller. In wet and soft conditions the

Table 16

Type of machine/equipment	*Recommended application*
Crawler tractor/angle dozer	Light angle dozing work and spreading stone on road formation.
Large crawler tractor/angle dozer (over 100 dbhp)	Excavate and side casting, road formations in cross, sloping ground. In addition, cutting and filling longitudinally on an undulating road alignment.
Large crawler tractor/angle dozer (over 100 dbhp) fitted with ripper	Ripping of rock in quarries and on road alignments.
Tracked excavator fitted with face shovel (½–¾ cu m bucket capacity)	Excavation of road formation in soft ground – using sleeper mats if necessary.
Front loading shovel (approx. 1 cu m bucket capacity)	Loading of stone at quarry.
Digger/loader	Excavation of drains, culverting. Loading stone on minor works.
Compressors, tractor-mounted or towed (with rock drilling equipment)	Drilling in rock.
Tractor and trailer	Transporting stones from source to roadhead on minor work.
Dumper/dump waggon	Transporting stone from source to roadhead over short distances.
Medium to large tipping lorry	Transporting stone from source to roadhead on major work.
Motor grader	Maintenance of roads.
Vibrating roller	Compaction of road stone.



TYPICAL ROAD CONSTRUCTION ON CROSSFALL IN ROCK AND FIRM SOIL

ROAD CONSTRUCTION ON DEEP PEAT:'ON TOP' CONSTRUCTION

Figure 7. Typical cross-sections of road construction.

compaction of road formation is often difficult to achieve.

The next consideration is that of pavement construction. Materials from proved sources, such as existing quarries, can be used but on many sites considerations of cost make it necessary to search for and identify materials such as gravels, morainic deposits, burnt shale, tunnel spoil, etc., for use in road works. The plant required for the construction of the road pavement consists basically of the front loading shovel working at the rock or gravel face or stockpile. Tipper lorries then transport the material to roadhead, where it is spread on the road formation by a small angle dozer or similar equipment. However, where this is not available, spreading by hand is feasible. The pavement should be capable of being maintained by motor grader and compacted by roller. If the latter equipment is not available, compaction by traffic may have to suffice.

The major influence on road performance is the drainage of the surface layers. It is important, even for low grade roads, and for any form of construction, to have a camber on the road sufficient to dissipate rainfall quickly and to ensure that the surface is compacted and as dense as possible to prevent rain water entering the road and causing potholes. The road surface should be well clear of standing water and the side drains should be made in a manner that will ensure quick runoff. Typical cross-sections of the road are shown in Figure 7.

Road construction and maintenance plant

In view of the references to the type of construction plant used on roadworks it is useful to set this down in tabulated form. The schedule shown opposite in Table 16 provides an indication of the types of machine and their recommended application.

BRIDGE DESIGN, CONSTRUCTION AND MAINTENANCE

The incidence of water-crossings which are encountered in forest road alignments is a feature of many forests. Normally the need is for permanent bridges, designed with adequate waterway area, and capable of taking Department of Transport's Standard Highway loadings, which covers the largest vehicle permitted under the Construction and Use Regulations. Both reinforced concrete and mass concrete abutments are suitable, although shortage of skilled labour would suggest that the latter design is more appropriate in small forest blocks.

As far as the deck superstructure is concerned the design, for spans up to 6.0 m, is that of a simply supported reinforced concrete slab. Precast, pre-stressed concrete inverted tee beams, with *in situ* concrete infill and topping, acting compositely, and with mild steel distribution, are used for superstructure spans over 6.0 m and below 15 m. This type of design is both economical and calls for little skilled labour in erection. A different type of superstructure for spans in excess of 15 m is advocated, in the form of steel Universal Beams acting compositely with an *in situ* reinforced concrete slab.

If there is a need for a temporary bridge a Bailey Bridge of required span would satisfy the need. This type of bridge was designed for military use, is expensive to maintain, and should be used only as a temporary expedient. It is possible to design short span bridges in timber.

It is usual in private forestry work for bridge design to be carried out by a consultant and the bridge constructed under contract, following the usual civil engineering procedure.

A number of forest blocks on private estates have old, existing road bridges. Experience has taught that some of these are unsafe for timber vehicles. It is essential that the existing bridges should be examined in detail, by a qualified engineer, and their load capacities assessed. Restriction notices should be erected, and reconstruction or replacement of the sub-standard bridge may be required. Load carrying assessment of existing bridges should initially be calculated in accordance with the Department of Transport's *The assessment of highway bridges and structures*. If any limits thus calculated are too restrictive then the effects of specific vehicles only should be considered.

MAINTENANCE OF ROADS

Generally, roads in small forest blocks tend to be only intermittently used, and consequently do not suffer the deterioration that is experienced by the main traffic route through a large block of woodland. Forest roads should be designed with mechanised maintenance in mind, and where there are a lot of small blocks, it is feasible for a motor grader team to move from block to block on a pre-arranged system, reinstating the road as required. This work may be necessary only at intervals of a few years. Where plant cannot be justified, the repair of the road surface can be done by hand on the road, using a tractor with tipping trailer or tipping lorry to supply the material from the source used for maintenance purposes. If compaction equipment is unavailable, compaction by traffic may be the answer, although not the ideal one. The reinstatement of the road surface is important but another essential item is that of regular maintenance of roadside drains and culverts, including the clearance of debris and silt. Among the other features is the need to maintain roadside bank batters at a safe angle and generally to clear brash and timber waste from the vicinity of the road. A forest road, especially in a small block, may be used not only for vehicle passage but also as a platform for the working of timber. This throws an added burden on road maintenance.

FURTHER READING: FOREST ROADS

Forestry Commission publications

BOOKLET

43 *Forest road planning.*

FOREST RECORDS

81 *Protection of small steel structures from corrosion.*

114 *Terrain classification.*

RESEARCH AND DEVELOPMENT PAPER

127 *Developments in forest road planning.**

Other publications

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ROYAL SOCIETY FOR THE PREVENTION OF ACCIDENTS (1970). *Construction regulations handbook.*

TRANSPORT AND ROAD RESEARCH LABORATORY – OVERSEAS UNIT (1981). *Maintenance management for district engineers.* Overseas Road Note 1.

TRANSPORT AND ROAD RESEARCH LABORATORY – OVERSEAS UNIT (1981). *Maintenance techniques for road engineers.* Overseas Road Note 2.

CHAPTER 12

Marketing and utilisation

Good marketing requires a sound knowledge of what is to be sold and what the timber is worth. The first requirement means that a grower should have:

i. A long-term estimate of production from the woodland covering the next 10 to 20 years. Such an estimate, even in broad terms, indicates the size of the marketing task in the years ahead, and allows the prospects for co-operative marketing to be assessed.
ii. A short-term estimate for production, for each of the next 5 years. The estimates for the next 2 years should be in greater detail and should give information on the planned cut by species, size class, and whether from thinning, clear felling, or selective cutting in mature stands. However, market conditions may change and plans should be sufficiently flexible to allow for this.

Knowledge of timber value requires a study of local, regional and national markets, both of price levels and current demand. Such knowledge is important, even where trees are sold standing, as the price the buyer can afford to pay is determined by the markets he can supply. The Timber Growers' organisation (TGUK) can provide their members with extensive market information, and can advise on merchants and contractors for harvesting and haulage, etc. Forestry consultants in practically every part of the country can prepare production estimates, measure and value timber and provide marketing and general management advice.

LICENSING OF FELLING

The felling of growing trees is controlled by a licensing system under the Forestry Act 1967. There are exceptions to the need for a licence, the main examples being:

- the felling is in accordance with an approved plan of operations under the Forestry Commission's Dedication or Forestry Grant Scheme;
- trees are in a garden, orchard, churchyard or public open space;
- the trees are all below 8 cm in diameter, measured 1.3 m from the ground; or in the case of thinnings, below 10 cm in diameter; or in the case of coppice or underwood, below 15 cm in diameter;
- the trees are interfering with permitted development or statutory works by public bodies;
- the trees are dead, dangerous, causing a nuisance or are badly affected by Dutch elm disease;
- the felling is in compliance with an Act of Parliament;

As the licensing system applies only to the felling of growing trees, no licence is necessary to cut up trees that have blown over, even if a whole wood has blown down.

Most other fellings must first be licensed by the Forestry Commission, and the appropriate regional Conservator (see addresses in the Appendix) will supply the necessary application form on request. Any owner who foresees problems in completing it is invited to seek the Conservator's advice when requesting the form.

Licences often bear conditions requiring the land to be replanted after felling, but the owner is always consulted before such conditions are imposed, and should he object to the proposed conditions he would be advised as to the course of appeal open to him. A free leaflet *Control of tree felling* is available from the Forestry Commission.

Except where trees are covered by a Tree Preservation Order, forestry work is not subject to control under the Town and Country Planning Acts. Nevertheless, as the felling of trees can conspicuously change the appearance of the countryside, the Forestry Commission consults local planning and other interested authorities about most applications for licences, particularly where the trees are in an area of high amenity value.

METHODS OF SALE

This section discusses the marketing arrangements that may be used to sell trees or their products to best advantage.

Negotiation

Here the prices and other conditions of sale are agreed between buyer and seller, and a suitable contract drawn up between them. Some growers negotiate mutually advantageous sales with the same merchant for several years in succession, and this has the benefit of stabilising the merchant's labour force, including sub-contractors, who are often extensively employed by merchants. It also allows the merchant to invest in harvesting equipment, with greater assurance. Negotiated sales depend on the grower having a particularly good knowledge of timber value, including the merchant's probable markets and revenue, his costs and the amount he can be expected to be able to pay for the timber in consequence. If the grower does not possess this knowledge, the services of a consultant or one of the growers' organisations are necessary.

Tender

Sales by tender are competitive and can generally be expected to give a true reflection of market prices. They can be invited from selected merchants or by advertising in the trade press. The precise terms of sale must be determined before advertising, and copies sent to interested potential buyers so that they know exactly what these conditions are before tendering. This is necessary because acceptance of a tender automatically concludes a contract on the advertised or published conditions.

Auction

Auction sales avoid the drawback of the tendering system, whereby a merchant can lose a parcel of timber because his tender is only marginally lower than the highest offer received and he has no chance to revise his price. Such an outcome could disrupt the merchant's working, resulting in possible inefficiency and lower prices being offered. Auctions also attract more interest and this can bring better prices.

It is possible that major buyers will outbid smaller competitors at auctions, and this may not be to the grower's long-term benefit. One can only sell specific goods ('ascertained goods') at auction, and some types of produce may be difficult to describe with the accuracy an auction sale legally demands. Sawlogs arising from future felling, where the range of sizes may be difficult to estimate, are an example. On a falling market, merchants tend not to bid at auctions and this can accelerate the fall in prices.

Auction sale expenses make it uneconomic to sell isolated timber parcels in this way. The Forestry Commission holds regular auction sales in various parts of the country, and private growers can make arrangements to sell lots immediately after the auction of Forestry Commission lots, so reducing sale costs.

No one method of sale is best for all circumstances, and even the most experienced growers will find it advantageous to consult the growers' organisation. This is particularly true of competitive sales, where careful timing and grouping of advertisements and advance warning of future sales is necessary to achieve maximum effect. There are also advantages to be gained by co-ordinating marketing efforts with neighbouring growers, so as to be able to offer larger and more concentrated volumes of timber in a locality. This enables growers, or merchants buying standing timber, to make the best use of harvesting resources, to negotiate better road haulage contracts, and be in a stronger selling position with regard to customers.

POINT OF SALE

Timber can be sold standing, as felled trees in the length or as converted produce: the relative merits are discussed below.

Standing sales

The sale of trees 'standing' to a timber merchant is simple, involving the grower in the least outlay, work and commercial risk. It also tells him, before a tree is cut, what his financial return will be. The trees to be sold are either individually marked or the boundaries of the area to be worked are marked and the individual trees to be felled within that area are indicated in some way.

It may be preferable to divide a large parcel of timber into two or more smaller lots, especially if the timber comprises widely different types, such as small conifer thinnings and mature hardwoods. Each parcel should be described separately, giving estimated number of trees, estimated total volume, and estimated average volume per tree for each species. Recording the number of trees by breast height diameter classes, and calculating the total volume estimated for each class, is often helpful to both sides in arriving at the price to be paid. Owners whose local supervisors are not skilled in estimating volumes of standing trees, should seek the services of a forestry consultant or their growers' organisation.

The conditions under which the timber is to be sold should be clearly defined,.so that the growers' interests are safeguarded and contingencies catered for. Unnecessary restrictions will reduce the price a buyer is prepared to offer, and should be avoided. Conditions of sale should be notified to interested merchants before they inspect the timber.

Standing sale contracts

When a sale bargain has been made, the conditions of sale should be incorporated in a legally binding contract signed by both parties. It is not possible to list every detail which might be covered by an individual contract, but the following items are normally included:

a. A general description of the timber included in the sale. A precise description of the boundaries of stands, of the methods used to identify trees to be cut, and details of estimated numbers of trees and volumes should all be given. Method and time of measurement (e.g. before or after felling) should be specified. Many growers find it preferable to sell a stated or estimated number of trees, rather than a volume of timber since the number of trees is easier to assess than the number of cubic metres they contain. In addition, in the event of any dispute over the quantities involved in a sale, it is comparatively simple to verify the number of trees cut, by counting stumps: verifying the volume of trees after removal is much more uncertain. It is, of course, up to the buyer to satisfy himself that the estimate of volume stated, but not guaranteed, in the sale particulars, is sufficiently accurate.

b. The purchase price, method of payment (either by lump sum or per cubic metre or per tonne), terms of payment, the method of invoicing, and the point at which ownership passes from grower to the purchaser.

   Growers should note that sales by volume can either be by measured volume or by weight converted to volume using an agreed volume–weight conversion factor. This latter method, like sale by weight on a price-per-tonne basis, is easy to operate using the weight tickets of the delivery lorries as a control and is sensible provided the grower is satisfied that all timber has been weighed. Sales by weight operate in favour of the grower if the material is despatched promptly and weighed in a green state, but against the grower and the road haulier if the produce loses weight by drying-out.

c. The period of the contract, date of entry by the purchaser, completion date for the whole contract, and the dates for removal of produce and purchaser's equipment.

   Provided the starting dates are sufficiently far ahead to allow the buyer enough time to organise his harvesting operations, markets, etc., it is as well for the grower to insist that the completion dates agreed with the buyer be adhered to. Extensions to completion dates should be exceptional. If the completion date is uncertain at the time the sale is agreed, the contract might specify the circumstances under which extension would be granted, the maximum length of extension and the extra sums payable by the buyer in consideration of such extension. Time limits for removal of produce even if already paid for, should also be adhered to firmly. Merchants should not be allowed to use the forest as free storage space.

d. Method of working. The standard of workmanship required, e.g. height of stumps, disposal of lop and top, avoidance of damage to remaining trees, drains, ditches and streams, fences and walls, and extraction routes. Special requirements regarding spar, support and anchor trees necessary for cablecrane work, and the removal of processing waste such as sawdust, peelings, etc., from processing sites. Any logging methods not acceptable to the purchaser should be specified, e.g. use of crawler tractors or skidders on forest roads.

e. Access routes to be used including their ownership and condition of their use preferably supported by a map.

f. Working sites. An indication of sites owned by the seller which may be used by the purchaser, and under what conditions, e.g. sites for processing, stacking, seasoning, loading, erection of sawmills and other buildings. Any provisos regarding entry on seller's land let to tenants.

g. Liability. The settlement of third party claims for damages caused by the purchaser or his employees, and claims for damages to the seller's property, including standing trees not in the sale. Claims by the purchaser for improvements carried out by him. Descriptions of the condition of seller's properties, e.g. fences, gates, roads, buildings, etc., will be required to facilitate subsequent settlement of claims, and such descriptions must be agreed by the purchaser.

h. Responsibility for safety under the Health and Safety at Work Act 1974.

i. Fire precautions. The precautions to be observed by the purchaser or his employees, including liability of the latter to assist in extinguishing fires.

j. The treatment of stumps after felling.

k. The restrictions on use of, or keeping of animals on the forest or estate by the purchaser or his employees.

l. The limitations on employment of sub-contractors by the purchaser and the obligations by sub-contractors to observe general conditions of sale.

m. Force majeure.

n. Action in the event of serious fire or windblow.

o. Breaches of contract giving the right to terminate.

p. Action on termination of the contract.

Felled trees in the length

Some growers may not wish to sell their timber standing, for various reasons. For instance some of the timber may be required for conversion in the grower's own sawmill, it may be desirable to do the felling at a particular season or the owner may want to provide work for woodsmen in the worst months of winter. Sometimes trees for sale may be too scattered to attract a timber merchant, or may have to be felled with extreme care to avoid damage to remaining young or specially valuable trees.

Whole trees can be sold felled at stump or at rideside or roadside. A purchaser should be found before the trees are felled, and the sale should be subject to a contract covering the same points as for a standing sale.

Sale of converted produce

Where the felled trees are to be converted and sold as separate products, e.g. sawlogs, pulpwood, mining timber, etc., it is essential to find a purchaser for the produce before a tree is felled. It is also essential to have trained men and the right equipment available. Above all, the supervisor in charge of the operations must be competent and experienced.

Sales of produce can be made through or to a timber merchant, who will often be willing to arrange collection and transport by road haulage vehicles. Other customers may require produce to be delivered, either on the grower's transport or through a road haulage firm. The latter is generally preferable, as road haulage is a specialised business. In negotiating or quoting prices, it should be made clear whether prices are 'at roadside', where the customer does his own haulage and loading; 'free on transport' (FOT), where the grower is responsible for loading the customer's vehicles; or 'delivered', where the grower is responsible for loading and delivery.

Contracts for the sale of converted produce are simpler than those for standing sales but the essential points on duration of the agreement, description of the produce, quantity, property and risk, measurement, price and method of payment should be covered.

PRICES

Because home produced timber accounts for only a small part of the country's total needs, the prices of imported timber and wood-based products have a strong influence on the general level of home timber prices. Large timber users, such as the major pulpwood and chipboard makers, negotiate contract prices with their suppliers, which reflect the price of the imported finished product, haulage distance to mill, species supplied, etc. Sawlogs and standing trees are usually sold to timber merchants whose prices may be affected by their particular requirements. If a merchant has a full order book and his round timber stocks are low, he may be prepared to pay higher than normal prices: conversely, if trade is slack and a merchant's stocks are high, he is likely to consider only low prices for further purchases.

Timber quality affects price to a varying degree. according to the locality and markets. For example, high quality Douglas fir may command a good price if local millers can themselves obtain premium prices from their customers, but may fetch no more than average prices if the local users are interested only in general purpose timber. The factors which also affect price are tree size, species, size of parcel, ease of harvesting and access by road haulage vehicles. These, together with local or regional demand, will have to be taken into account when deciding the market value of a parcel of timber. Each factor will carry varying weight in different circumstances.

It must be emphasised that the grower who sells only occasional lots is in a weak selling position. It is not uncommon to find parcels worth thousands of pounds being sold with no independent valuation. Professional advice is available, and its use is strongly recommended.

The Forestry Commission regularly publishes average prices paid for standing sales of conifers from its forests and indices showing changes in log and standing sale prices. These schedules appear in forestry journals and the trade press as do the prices realised at Forestry Commission auctions.

PRODUCTS

The market for particular products may vary considerably in different parts of the country, and from time to time, and the grower is strongly recommended to find out what markets are currently available before preparing specific products. The following paragraphs are a guide to the main categories of round timber produce in Great Britain.

Conifer sawlogs

British sawn softwoods compete with imported timber in the major sawn timber markets although very little British grown softwood is suitable for high grade joinery work. There is a trend in the imported trade to reduce the range of specifications readily available and this results in there generally being a good market for British sawn softwood in the less common size categories. British sawmillers have the advantage of being able to respond rapidly to a requirement for special sizes although this may result in the sawlog specification being changed at short notice. All logs over 14 cm top diameter overbark can be regarded as potential sawlog material. Certain sawmills which use chipper headrigs can prepare squared timber from the round log, converting the outside rounded portions to saleable chips and these sawmills can take logs of top diameters less than 14 cm. The sawlog specifications normally used by the Forestry Commission are given in the free publication *Softwood sawlogs -presentation for sale.*

Hardwood sawlogs

Prices for hardwood sawlogs vary according to species, quality and diameter to a much greater degree than those for conifer sawlogs. The highest prices are paid for veneer logs, a considerable proportion of which are exported for slicing or peeling in Europe. Logs which are not quite good enough for veneer may make joinery grade timber, while logs of poorer grade are normally converted to fencing material or mining timber. Because of the degree of price variation and specialisation in certain sectors of the market, it is particularly important that owners of good quality hardwood parcels seek professional advice on the optimum timing and method of sale.

Pitwood

Round pitwood is almost entirely conifer and is generally supplied to the collieries peeled and seasoned. Some unpeeled pitwood is supplied to South Wales collieries. Requirements do change and current sizes should be checked with the NCB's purchasing department, although the NCB now buy from only a limited number of suppliers.

Industrial roundwood

There are currently four pulpmills and six particleboard mills in Great Britain all of which require small diameter material normally termed small roundwood. Small roundwood billets for these markets are usually supplied in lengths between 1 m and 3 m with a diameter range between 5 cm and 40 cm. It is important to obtain details of specifications and prices direct from the firms concerned. Method of payment e.g. by weight or volume and delivery arrangements must also be agreed with the firm in advance.

The two purely softwood pulpmills at Workington and on Deeside in North Wales require mainly spruce but will accept a proportion of other conifer species. The two other pulpmills at Sudbrook in Gwent and Sittingbourne in Kent accept almost any hardwood species and the former also accepts larch while the latter accepts a variety of conifers. The six particleboard mills are located near Inverness, and at Cowie and Irvine in Scotland, at Hexham and South Molton (Devon) in England, and at Chirk in Wales. They will accept most coniferous species and certain manufacturers may also accept hardwoods. All the particleboard mills except the one at Inverness produce chipboard and a large proportion of their wood requirement is provided in the form of sawmill residues. The Inverness plant produces a board made from wafers of wood and residues are not acceptable.

Fencing materials

Sizes and specifications of fencing materials vary considerably (Table 17). Oak, Sweet chestnut and larch are commonly used without preservation treatment, where they contain a high proportion of durable heartwood. Other species are generally preserved, with

Table 17 Fencing timber specifications

Type	*Material specification*
Posts and rail fences for roadsides, morticed, cattle-proof	Posts, sawn: 150 × 75 mm, 2.1 m long Rails, sawn: 90 × 40 mm, 2.7 m long Intermediate posts: 90 × 40 mm, 1.8 m long
Motorway fences	Posts, sawn: 150 × 75 mm or 130 × 100 mm minimum, 2.3 m long Rails: 90 × 40 mm (hardwood) or 100 × 40 mm (softwood) All species to be pressure treated with preservative
Posts and rail fences nailed	Posts, sawn: 140 × 65 mm, 2.0 m long Rails: 90 × 40 mm
Post and wire fences	Posts, sawn: 75 × 75 mm, 1.7 m long or 90 × 90 mm, 1.7 m long or quartered from 180–200 mm top diameter or round, 75–90 mm top diameter or half-round, 100 mm face at top Straining posts, sawn: 150 × 150 mm or 180 × 180 mm or round, 180–200 mm top diameter, all 2.1–2.3 m length
Deer fences	Posts: 75 × 75 mm, 2.6 m long, or equivalent in quartered material Straining posts: 230 mm top diameter, 3.2 m length

pressure treatment the most effective process. Fencing materials are made to a very wide range of specifications and producers are advised to check BS 1722 for specific requirements.

The following are some typical specifications of fencing materials but producers are advised to check BS 1722 for specific requirements.

Telegraph poles

British Telecom purchase a proportion of their annual pole requirements from British growers. Pines, larch and Douglas fir are currently accepted but the poles must be of a high quality and have to be inspected and passed in the forest by British Telecom pole inspectors. The full specifications are given in BS 1990.

Turnery poles

Some turneries take hardwood, notably birch, ash, sycamore, beech, and Common alder normally in poles of 7.5 cm minimum and 18 cm maximum top diameter, in lengths of 2.0 m and upwards. Turnery squares, sawn from round logs, are also used in a variety of hardwoods.

Rustic poles

This can be a useful market near towns, for conifers (especially larch) and sometimes hardwoods. Sizes range from 2.5 to 6.0 m length, with top diameter of 2 cm and butts of 4–10 cm.

Other forest produce

Over three million Christmas trees are sold in Britain each year and they can be a profitable market although quality is becoming increasingly important. The British Christmas Tree Growers Association was formed in 1980 to advise on the management of Christmas tree plantations and provide marketing information.

Foliage of Western red cedar, Silver firs, Lawson cypress and holly are sold to the florist trade for wreaths and decoration, but the market is largely fragmented and unco-ordinated.

FURTHER READING: MARKETING AND UTILISATION

Forestry Commission publications

BULLETIN
51 *Forest products in the United Kingdom economy.*

FOREST RECORDS
29 *Use of forest produce in sea and river defence in England and Wales.**
68 *Pulpwood supply and the paper industry.*
70 *Imports and consumption of wood products in the United Kingdom, 1950–67.*
72 *Experiments on drying and scaling close-piled pine billets at Thetford.**
95 *Wood resources and demands.*
108 *Tests on round timber fence posts.*
110 *Conifer bark – its properties and uses.*
121 *Production of wood charcoal in Great Britain.*
128 *The production of poles for electricity supply and telecommunications.*

RESEARCH AND DEVELOPMENT PAPERS
77 *Treatment of Christmas trees to inhibit needle fall.**
102 *Production planning in the Forestry Commission.*
128 *Developments towards whole tree utilization of softwoods.**

RESEARCH INFORMATION NOTE
97/85/WU *Timber research on the output of structural grade timber in unthinned Sitka spruce grown at different spacings.*

ARBORICULTURE RESEARCH NOTE
23/80/SILS *How much wood for the stove?*

OCCASIONAL PAPER
1 *Wood production outlook in Britain.**

MISCELLANEOUS
Softwood sawlogs – presentation for sale.
Horticultural and equestrian uses for bark.
Uses for wood residues.
Control of tree felling.
Consultation procedures for forestry grants and felling permissions.
Wood as fuel – a guide to burning wood efficiently.

CHAPTER 13

Landscape design

Forestry has had the greatest impact on rural landscapes in Britain this century and it is therefore important to find a balance between the economic demands of forestry and the requirements of the landscape. More resources will often need to be allocated in sensitive areas such as National Parks, National Scenic Areas in Scotland, Areas of Outstanding Natural Beauty and Areas of Great Landscape Value where landscapes are of higher quality. In most cases careful landscape design will be needed to achieve a satisfactory appearance for the forest, with cost as the balancing factor.

DESIGN PRINCIPLES

Of the numerous aesthetic factors which affect forest design, shapes related to landform, scale and diversity are fundamental and objective principles for the achievement of a satisfactory appearance.

SHAPE is of paramount importance, especially that of external boundaries and felling coupes. These edges have the most visual impact due to the combined effect of tree heights and their shadows and colour contrast. In both cases they should be irregular, diagonal to the contour and reflect the shape of the ground by rising uphill in hollows and falling downhill on convex slopes. The extent of these inflexions should increase with the size and prominence of the hollow or convexity. Visually intrusive geometric effects should be avoided and in particular:

- long straight edges
- right angles
- parallel edges
- symmetrical shapes
- vertical boundaries (perpendicular to contours)
- horizontal boundaries (following contour).

Appropriate shapes for external margins, species and coupe boundaries should be developed as follows:

- imitating shapes from the surrounding landscape, e.g. the angular geology of the Lake District or the smooth flowing shapes of Northumberland and the Borders.
- following visual forces in landform (see 'Shape' above).
- following natural vegetation shapes (although fussy scale and conflict with landform forces should be avoided).

SCALE depends on the amount of landscape that is seen. It increases with the vertical height, breadth of view and distance to the observer. With a number of viewpoints scale often needs to be gradually changed from one part of the landscape to another; usually larger at hill top and decreasing towards the valley floor.

DIVERSITY depends on the number of different features within the landscape. The apparent uniformity of the forest should be reduced by revealing open space, views, crags, rocks, water and scrub, and creating felling coupes and a varied age structure. A diversity of tree species including broadleaved should be developed sufficiently to reflect patterns and colours of existing vegetation.

DESIGN METHOD AND TECHNIQUES

While contour, soil and stock maps, aerial photographs and crop information are needed for planning, accurate sketches are essential for design. These should be based on a photograph or tracing from a projected transparency. Besides information on crop details the following factors should be recorded on a contour map and/or sketch as a basis for design:

- hollow and convex slopes (represented by upward and downward arrows)
- existing intrusive design
- features to provide diversity
- areas suitable for larch and broadleaves
- existing and potential recreation facilities
- potential deer control areas.

All the information should then be analysed to identify problems, opportunities and priorities. Design should be carried out on the main sketched view, in the following order, then checked and adjusted from subsidiary views:

1. Complete set of felling coupes (at restocking).
2. Timing of felling coupes (at restocking).
3. Design and improvements of external boundaries.
4. Species layout.

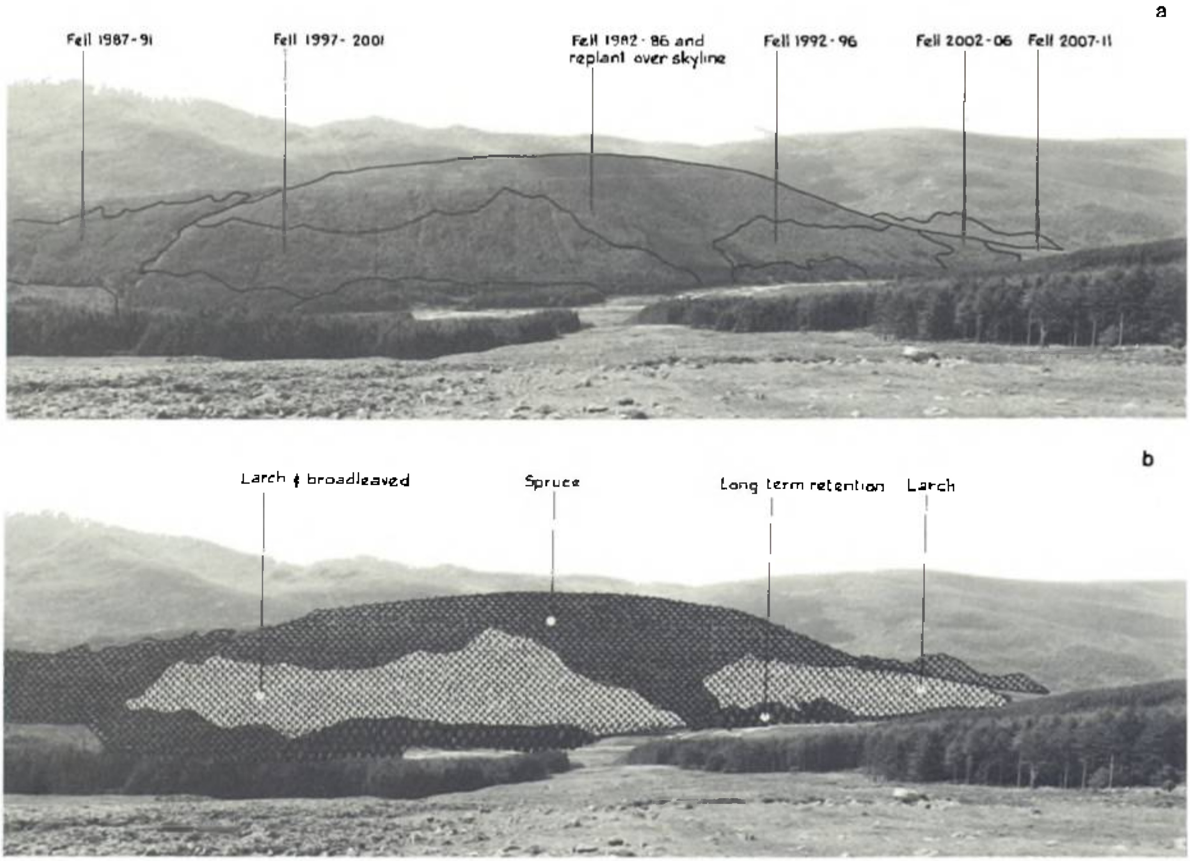

Figure 8. Felling and replanting design for part of Ennerdale Forest (Cumbria): (a) pattern of coupes and approximate felling dates, (b) proposed species pattern and improvements to external boundaries and landscape.

If extensive improvement to the external boundary is needed at restocking it may need to be carried out before the felling design.

Planting design

The following points should be considered when implementing design principles for planting:

- A satisfactory external forest margin should be achieved before species layout begins.
- Side margins should be tapered diagonally towards the lower edge and can be successfully terminated at major watercourses.
- Leave unplanted those areas that would screen main landscape features.
- Vary the width of unplanted verges beside public roads.
- A geometric lower edge is acceptable where there is a strong pattern of field enclosures, with irregular groups of broadleaved trees along the lower edge and extended up major watercourses.
- Avoid thin slivers of open ground or forest in long views or near skylines.
- Include areas of larch where possible to provide diversity; preferably located on convexities to highlight landform.
- Avoid belts by shaping their general alignment, varying their width, and leaving irregular gaps where possible. (Irregular groups and areas of broadleaved trees extending up watercourses are preferred.)

Felling design

Clear felling and restocking provide important opportunities for improving the appearance of the forest by the correction of previous bad design and introducing greater variety of open space (felling coupes) and tree size (Figure 8). The development of a well-designed pattern of successive felling coupes and a varied age structure is essential to such an increase in visual diversity. The appearance of restocking is so dependent on the shape and timing of felling coupes that they must be designed together.

The following points are important when implementing design principles:

- Where short views are important the apparent scale of large coupes can be reduced by adopting a very irregular shape or by retaining areas in the foreground to be felled when restocking behind is established.
- The apparent scale of coupes can be increased in the long view by extending felling to include the forest edge.
- A calculated risk of windthrow may need to be taken to achieve a satisfactory design. Wherever possible coupe boundaries should follow windfirm edges that are sympathetically shaped to landform. Intrusive windfirm shapes should be avoided.
- Skylines should either appear completely open or as solid forest; diffuse belts and scattered trees appear out of scale and should be avoided.
- With cable crane systems currently working to 650 m from roadside there is little need to leave intrusive belts of trees at the upper margin. Where this is unavoidable the belt should be broken into groups by felling.
- The practice of screening coupes with belts of trees is intrusive and to be avoided. Well placed groups of trees will reduce the impact of lop and top and give a more sympathetic landscape composition.
- Where there is a need to retain single trees in felling areas only well formed individuals in coherent groups should be kept.

Replanting design

Replanting layout should include any improvements to external margins. The screening of open spaces, views, crags, water, broadleaved trees and other features should be avoided by leaving land unplanted.

Species layout should follow the same design principles and coincide with coupe boundaries as closely as possible.

Advice

Limited general advice on forest landscape design is available from local Forestry Commission staff. More detailed and comprehensive advice can be obtained, e.g. for sensitive areas, from a landscape architect or suitably qualified members of the Institute of Chartered Foresters. Names of landscape and forestry consultants can be obtained respectively from the Landscape Institute, 12 Carlton House Terrace, London SW1Y 5AH or from the Institute of Chartered Foresters, 22 Walker Street, Edinburgh EH3 7HR.

Landscape design training

There are several further education establishments that provide both graduate and post-graduate training in landscape design at degree equivalent status (refer to Landscape Institute for details).

The Forestry Training Council, in association with the Forestry Commission, offers a short course, specifically dealing with Forest Design, for private woodland owners and managers.

FURTHER READING: LANDSCAPE DESIGN

Forestry Commission publications

BOOKLET
44 *The landscape of forests and woods.*

MISCELLANEOUS
The Forestry Commission and landscape design. Forestry Commission Policy and Procedure Paper 3.

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CHAPTER 14

Conservation

There are three distinct objectives for conservation in forestry practice. The first is to maintain a monument, a site, a species or an assemblage of species of national, regional or local value. The second is to ensure that normal forest operations do not damage or destroy a site of conservation importance. The third is to increase the variety of wildlife present in a commercial forest or woodland.

In order to achieve any of these objectives, the presence of conservation features must be identified and their location adequately mapped. The significance, and therefore the priority to be attached to their management, must be understood and the extent of legal obligations and constraints on forest practices must be recognised and incorporated into management plans.

PROTECTION OF SITES AND SPECIES

Geological features and ancient monuments of national significance are usually notified by the appropriate authorities. They are more likely to be at risk during the processes of afforestation than in the course of subsequent forest operations. As they are fixed points, their accurate location on maps and on the ground is relatively straightforward and there is no reason why subsequent forest operations should affect them.

The plants and animals which are of importance in wildlife conservation may be more difficult to manage. However, under the Wildlife and Countryside Act 1981, the Nature Conservancy Council has a duty to notify land-owners of the boundaries of Sites of Special Scientific Interest (SSSIs) and of the operations which may affect the site and for which prior notification of forest operations is required. Since a number of normal lawful operations (fertilising, herbicide use, draining, etc.) can have indirect adverse consequences it is essential that these are discussed. These discussions should take place well in advance since the programme for forest operations is usually planned months or even years in advance.

It is particularly important to check the status of land prior to afforestation or of woodland prior to reforestation. Over the last two decades or so the proportions of unafforested moorland in the uplands and of ancient broadleaved woodland in the lowlands have decreased. This means that further inroads into either may have greater consequences in relation to the total available now than in the past. If surveys of the wildlife present on land suitable for afforestation or in old woodland are not available, they should be made a matter of priority if expensive public enquiries and litigation are to be avoided. Quite often information is available from the Regional Officer of the Nature Conservancy Council, or from bodies such as the local Naturalists Trust or the Royal Society for the Protection of Birds.

The Wildlife and Countryside Act 1981 also controls the disturbance, removal or killing of a variety of plants (Schedule 8), birds (Schedule 1), and other animals (Schedule 5). It is the duty of the forester in charge to be aware of the presence of such wildlife and to ensure that forest operations are not destructive. It is a defence in law that disturbance which was the incidental result of a lawful operation and could not reasonably have been avoided, does not constitute an offence, but clear legal guidelines have yet to be established for what could or could not reasonably have been avoided. This underlines the need for the existence and location of conservation features to be accurately identified and the legal and practical constraints to be recognised as part of operational forest planning. The most useful method found so far is to record on maps the site or sub-compartment in which such limits operate. It is for the forester in charge to ensure that sub-contractors are aware of damage that they may inadvertently do. The reasons for conservation interest and limits on operations can be detailed in a written conservation plan, parts of which may need to be confidential if the safety of particular habitats or species is to be assured.

BACKGROUND TO POSITIVE CONSERVATION

While the first and second objectives are essentially concerned with protection of existing assets, the third, that of increasing the variety of wildlife, offers great scope for positive action by foresters. The distribution and abundance of wildlife in Britain is rarely entirely natural: it has mostly been established and maintained by previous forms of woodland or land management. In the lowlands the association of woodland wildlife with coppice is the prime example; and in the uplands moorland fauna and flora were established by deforestation and maintained by traditional forms of sheep management. Accordingly, where traditional forms of land management are to be changed, active conservation management is required to maintain traditional wildlife features. Wildlife associated with new forms of land management should not necessarily, however, be regarded as inferior. The development of a flora or fauna in new forest plantations can constitute an enrichment for the area as a whole. Encouragement of new communities in a changed landscape can therefore be as important as maintaining continuity elsewhere.

Forest and woodland wildlife can be manipulated by adopting particular forms of forestry practice, some of which will be more expensive than others. Ideally, an owner should calculate the cost to his forest management and decide what he is prepared to pay. Consequently foresters must be aware of the means of developing or maintaining wildlife to best advantage. This chapter indicates the type of forest management most appropriate for wildlife over a range of site conditions and through the forest rotation. Many measures designed to benefit wildlife will also benefit sporting, recreation and the landscape; this should be taken into account when plans are being formulated and costed.

It should be recognised at the outset that wildlife management for conservation is rarely a clearly defined matter. What is best for one animal or plant may not be appropriate for another and may conflict strongly with timber growing. Similarly, the relationship between management input and conservation benefit has not been precisely quantified, and therefore foresters cannot easily know if a particular level of economic loss will produce a worthwhile conservation benefit.

The two most important concepts in wildlife conservation are *continuity* and *variety*. Continuity is the more important in long-established, especially ancient, woodland where wildlife features of value already exist and need to be conserved, and where sudden and extreme change can drastically alter ecosystems which have taken centuries to develop. Variety is the more important in new afforestation schemes which, by definition, do not have an established forest fauna and flora. Here the need is to create variety of habitats to produce variety of wildlife. Variety is also desirable in long-established woods, but not in forms which damage existing valuable wildlife features. It is important that the right form of variety, that is of age-class or crop species, is employed on the right area and scale.

LOWLAND WOODS AND FORESTS

Value of existing woodlands

Most lowland woods are on old broadleaved woodland sites, which are often now of only limited extent. They are usually fertile and therefore are capable of supporting vigorous growth of many plant species. Where the woodland site is ancient, that is, it has been wooded since medieval times, the flora is particularly rich in rarer plants which may have difficulty colonising new plantations. This applies both to ancient high forest sites and to coppice, although the quantity of ground vegetation is often much greater under the latter. Plantation woodlands on agricultural and heathland are markedly less rich, particularly in rare herbs, although those on calcareous soils may be an exception. The total number of wildlife species generally increases with the size of forest blocks.

Choice of crop system and species

Wildlife is most surely maintained by coppicing (Chapter 3) or by broadleaved high forest. Long rotations, small scale group felling, overwood or other two-storey systems and an even distribution of age-classes will also contribute to continuity and variety. Where natural regeneration is inadequate but there is ample woody weed growth to afford the necessary side shelter, planting broadleaves at wide spacing is to be preferred so that ground and shrub layers can develop freely. Tree shelters, providing protection and faster early growth at modest cost, combine well with such a technique.

Hand and mechanical weeding, although more costly, are preferable to chemical weeding for maintaining the ground flora. A useful compromise is spot or strip chemical weeding, except for rhododendron which should, wherever possible, be eradicated. Non-essential cleaning to remove broadleaved species should be avoided and the operation generally confined to releasing potential crop trees.

Native species of trees and shrubs are generally superior for wildlife conservation because native plants and animals have evolved in conjunction with them. For instance, the timing of their leaf break and leaf fall closely matches the flowering behaviour of native woodland plants. Native trees and shrubs often support a wealth of insects which in turn supports a diverse bird population; and together with the associated ground flora they are the food plants of a number of butterflies.

Although species native to the locality are to be preferred the recently introduced Southern beech has been found to support a wide variety of insects and ground plants as do some long naturalised exotics such as larch and sycamore.

Rides and gaps

Ridesides and unplanted gaps should be regarded as the most critical areas for enriching and retaining wildlife. Wide rides, of the order of 10 m or more, are a particularly important site of variety in the lowlands, where with sensitive management a rich flora and fauna can be sustained. Ride widening should be considered when marking for thinning. To develop a vegetation and habitat gradient towards the wood, the edges should be cut less frequently and later (mid-September/October) leaving established shrubs. This favours biennial and perennial plants and is best achieved by cutting opposite sides alternately. Central strips should be mown annually between August/October to favour summer flowering low herbs. Such rides should be permanent, to allow establishment of slow colonising species and provide continuity.

Drainage ditches at the sides of rides provide further habitat variety. Gaps, sufficient for sunshine to reach the woodland floor, provide habitats not only for woodland plants and birds but also reptiles and amphibians.

Thinning

Where old woodland sites have been restocked with conifers, early and heavy thinning will help to minimise losses of plant species during the period of maximum canopy shading. In new plantations, heavy thinning on a short cycle will maintain plants and help to build up a reserve of seed, rhizomes and bulbs in the soil.

Final felling

Mature, overmature and dead trees support rich epiphyte and invertebrate populations, and provide numerous birds with essential foraging and breeding sites. They are also necessary for cavity dwelling bats. Retention of five or more poorly formed overmature trees per hectare is desirable and wherever possible unmerchantable branchwood of broadleaves should be left on the ground to rot. Burning should be avoided because although it enriches the soil locally, the improvement is only temporary and it causes long-established ground plants to be replaced by ephemeral and invasive species such as fireweed and nettle. Clear fellings should be dispersed if possible to avoid creating large, more or less even-aged, stands.

Restocking

The choice of species is constrained by the requirements of the Broadleaves Policy (1985) but will generally favour conservation. This phase provides considerable opportunity for positive conservation initiatives.

UPLAND FORESTS

Afforestation

Much upland afforestation represents a sudden and fundamental change of vegetation from moorland and bog to woodland. There is a risk of losing or radically altering some plant and animal communities of local or even national importance. New acquisitions should be checked for areas of such special value before planning afforestation. Furthermore, due consideration must be given to the possibility that there may be small quantities of an individual, rare or sensitive species in the area and that provisions should be made to retain representative areas housing it.

Potential of plantation forests

Most upland forests are extensive areas of conifer afforestation established on land of low fertility which was previously maintained as open moorland for sheep, grouse or red deer. Although the potential of the new forest for habitat variety will largely depend upon the nature of the original site, diversity can be increased by planting a range of species, by arranging felling and restocking to produce structural variety, and by leaving areas unplanted to provide non-forest habitats. The native Caledonian pinewoods of Scotland are a special case, limited in extent but of high conservation value because of their ancient origin and associated specialised fauna and flora. Similarly, valley oak and birchwoods may have an existing woodland wildlife which requires that they be considered in the same way as lowland woods.

Choice of crop system and species

Sitka spruce provides a habitat for a variety of song birds but the usual dense canopy provides little opportunity for the establishment of a ground flora other than a few ferns, bryophytes and fungi and occasionally a few vascular plants such as bilberry and heath bedstraw, unless it has been heavily thinned or allowed to grow beyond normal rotation age. Therefore larch and pine, with their lighter canopies and heavier ground cover, provide better opportunities. Also, it is well established that Grand fir and Douglas fir can support rich and varied flora on well-drained fertile soils. In mature stands the ground flora under these trees and indeed under heavily thinned spruce may contain a similar species list to that of neighbouring oak and so offer some prospect for limited expansion of a woodland flora in upland forests. They are also likely to support more small mammals together with their predators.

Native broadleaves are the first choice to provide habitat variety. Where resources are limited, modest block planting on the more sheltered sites is likely to give greater overall wildlife benefit than a low percentage admixture to a large area of conifers. Oak, birch, willow, rowan and alder are valuable for birds either for their seeds or their associated insects and provide browse for deer. Existing broadleaves will rarely be of any commercial value in the uplands but as their extent will usually be very limited they should be retained. They may be reinforced by planting the same species while retaining some of the existing woodland glades.

Structural diversity may be achieved vertically where conifers, especially light demanders, on sheltered fertile sites can be heavily thinned from an early age and grown beyond economic maturity on sites that are not susceptible to windblow, but this structural diversity can only be provided horizontally by ensuring that there is good juxtaposition of different age-classes, including establishment, pre-thicket, thicket and, if present, thinned crops.

All age-classes provide good habitats for song birds. Middle-aged stands are favoured by the sparrow hawk, and older stands by such species as goshawk and tawny owl. The provision of suitable nest boxes can encourage birds and bats which would not otherwise find suitable nesting sites in conifer stands. The grallochs and feet of culled deer may be left unburied as carrion for birds of prey and other predators, provided they are not too close to neighbouring farmers who may fear that this practice will encourage foxes.

Rides and gaps

Leaving certain areas unplanted to provide non-forest habitats can be done in many ways. Areas which are clearly unplantable due to exposure, rock, water, etc. will automatically be left, but in marginal cases or where future extraction will be difficult the question of whether forestry investment is worthwhile should be carefully considered.

Areas well above the upper planting limit may be too exposed for vigorous growth of heather, but on extensive areas in intermediate zones controlled rotational burning can maintain habitat variety for moorland birds. Rare mosses and liverworts will survive in areas of scree and in rock gullies; but some of the rarer dwarf plants of the uplands will only survive if their more vigorous competitors are grazed.

Roads and rides are other normal forestry provisions which have wildlife value. They have a particularly large edge to area ratio and therefore a high 'edge effect' value. This can be maximised by ensuring that roads and rides are wide enough from the outset so that the deep crowns which develop on the plantation edges do not have to be cut back. The edge effect is improved by retaining bramble and natural regeneration of broadleaves or conifers along the edges, and by controlling them by cutting rather than by application of herbicide. When natural regeneration does not occur, the planting of scattered broadleaved trees and shrubs should be considered. Roads and rides can provide a permanent network of field and dwarf shrub layer habitat, enriched along roadsides by the associated soil disturbance and sometimes by the addition of imported limestone road material, and by roadside drains. Widths should be sufficient (preferably at least 10 m) to avoid substantial shading as the crop develops.

Open areas, termed deer glades, are necessary for culling deer; and as they will often be located at the more fertile sites in order to attract deer, they are also likely to have a considerable flora and associated insect fauna. Browsing by deer can help to conserve the low growing plant species which depend upon a grazing regime for survival; and therefore fertile areas left specifically as deer glades and areas left open primarily for conservation of flora can both perform a dual role. Such conservation areas should not be fertilised or reseeded although deer glades may need such treatments. Sites identified as having uncommon plant or animal species or communities should remain unplanted, and adjacent planting kept well back from them. No fertilising or reseeding should be carried out.

Unregulated grazing by farm stock, or access for shelter, can be damaging, particularly to rides and old broadleaved woodland sites. Downfalls for red deer in the Highlands to reach their wintering grounds should be provided at the afforestation stage.

Probably the most important category of gap is that provided by stream and lake margins. By combining water, shelter and usually better soils in a network throughout the forest these margins have a high wildlife potential. In order to achieve this, conifers should not normally be planted closer than about 10 m from the water's edge, and some broadleaved trees and shrubs should be introduced where they do not already exist. These measures also help to provide the best environment for fish and other freshwater life. In addition the rate of surface water run-off into streams, and the amount of silt deposition, should be reduced by ending ploughing furrows 5 m or more from them and by carefully aligning main drains for gentle gradients.

Thinning and felling

Frequent thinning is desirable in high yield-class crops.

The more frequent the thinning operations, the shorter will be the dark periods through which plants must survive dormant as seeds, rhizomes, etc. Although only a limited ground flora is normally established under upland Sitka spruce, the seeds of many common plants survive for more than 40 years and therefore even when Sitka spruce is the main species short rotation forestry is likely to have good ground cover in the establishment and pre-thicket stages at each restocking. This is significant because with shorter rotations these stages represent a greater proportion of both the rotation length and the forest area. The ground cover will support small mammals which, although possibly not in such large numbers as occur after afforestation, will in turn support predators; and deer, which feed in the pre-thicket and establishment stages, will also be encouraged.

The pattern of felling also has an important influence. Although smaller felling coupes have a greater edge to area ratio which in some circumstances will support a greater density of birds, reasonably large coupes may better accommodate birds with larger territories, such as short-eared owl and kestrel, and therefore support a greater variety of bird species. Isolated mature trees provide valuable raptor perches, and the retention of some wind-snapped or dead trees of more than 30 cm diameter will encourage cavity nesting birds.

Conduct of harvesting operations

During timber extraction and stacking in both uplands and lowlands efforts should be made to avoid damage to watercourses and small sensitive sites, such as badger setts. Timing of these operations should also seek to avoid the flowering period where there is a rich spring flora; and felling should avoid the breeding season where clumps of trees in which raptors' nests occur cannot be retained. Felling debris, harvesting machines and all chemicals should be kept out of streams; and fire ponds should be constructed alongside, not by damming them. In the uplands in particular, the large-scale burning of lop and top after clear felling may encourage soil erosion and adversely affect water quality.

FURTHER READING: CONSERVATION

Forestry Commission publications

FOREST RECORD

130 *Thetford forest management plan – a conservation review.*

LEAFLETS

78 *The management of forest streams.*

84 *Guide to upland restocking practice.*

RESEARCH AND DEVELOPMENT PAPERS

81 *Forest management for conservation, landscaping, access and sport.**

123 *Research aspects in forestry for quality of life.*

MISCELLANEOUS

The Forestry Commission and conservation. Forestry Commission Policy and Procedure Paper 4.

The policy for broadleaved woodlands. Forestry Commission Policy and Procedure Paper 5.

Broadleaved woodland grant scheme.

Other publications

COUNTRYSIDE COMMISSION. *The countryside conservation handbook.* A series of free leaflets available from the Countryside Commission, Publications Despatch Department, 19 Albert Road, Manchester M19 2EQ. Leaflet binder price £1.75.

In preparation: *Practical work in farm woods.* A series of leaflets prepared by the Ministry of Agriculture in collaboration with the Forestry Commission.

CHAPTER 15

Recreation in the forest

The structure of society is changing and leisure opportunities are increasing. Whilst many people are spending more of their leisure time in the countryside other, reliant upon public transport, are unable to do so. All this plays a significant part in influencing the needs of different people for appropriate recreation opportunities and facilities, which recreation providers need to identify. The ability of the forest to absorb large numbers of people engaged in a wide range of recreational activities, without detriment to the landscape, is now widely appreciated by both public and planners alike especially in respect of woodlands close to towns and holiday centres.

Since the opening of the first National Forest Park in 1935, the Forestry Commission has allowed public access for the quiet enjoyment of its forests, wherever it is able to do so. Its policy now is to satisfy the needs of as wide a range of the community as possible by providing appropriate recreation facilities of a high standard of design. The provision of recreation opportunities for the public is an important consideration for private forestry as well. Under the Basis III Dedication Scheme, the Forestry Grant Scheme, and the Broadleaved Woodland Grant Scheme, the management of woodlands is also required to secure, where appropriate, opportunities for public access and recreation.

RECREATIONAL VALUES AND USES

The main recreational value of forests and woodlands is that they offer a unique setting of trees in great variety, wildlife, sheltered spaces, quietness and fine scenery for the pursuit of a wide range of activities. This can provide different and stimulating experiences and knowledge for our largely urban population, thereby making a significant contribution to the quality of life.

Walking, relaxing and picnicking are by far the most popular activities. Nearer towns they are supplemented by jogging, walking the dog, and informal play by children. These are all satisfied by simple types of recreation provisions, such as car parks and picnic places, which do not require large areas and from whence waymarked walks can encourage visitors to see places and things of interest within the forest.

Leaflets from convenient dispensers as well as discreet signs can interpret the forest, its wildlife and management for the public and thus widen the understanding of forestry. In popular areas, the interpretation of the forest and its environment can be augmented usefully by the provision of exhibitions and classroom facilities within a visitor centre building.

The demand for educational visits and horse riding facilities is often high near towns. Forest bridle tracks may have to be created to separate riding from other uses and permits issued at modest charges for its control. Carefully selected forest roads and tracks can also provide attractive opportunities for 'off highway' pedal cycling, which is increasing in popularity. Other well established uses are orienteering, the competitive sport, whence wayfaring, which is the exploration on foot of part of a forest using a map, is derived.

Maintaining the quiet of the forest is important; but careful planning can allow limited motor vehicle access along selected forest roads or 'forest drives', for the benefit of the disabled, elderly and families with young children. Provided the forest is large enough and possesses an adequate system of forest roads, the occasional motor sport event can also take place without significant conflict with other uses. It is desirable to organise such events under the auspices of the appropriate national motor sport organisation (see list of useful addresses).

The forest also offers many opportunities for specialist recreational uses, including archery and the traditional field sports of shooting, deer stalking and fishing. These activities can be controlled by let and/or day permit, which can allow their wider availability to the public. The detailed requirements of a wide range of recreation activities can be obtained by reference to appropriate publications in the bibliography. Advice on the encouragement of game birds, wildfowl and small game for sporting in woodlands can be obtained from the Game Conservancy, Fordingbridge, Hampshire.

All of the activities mentioned can be enjoyed by the public over a longer period by the provision of overnight accommodation in the forest. Caravan and tent sites and self-catering forest cabins can be successful enterprises in achieving this aim as well as providing significant returns for their owners.

The impact on the forest

In the planning of recreation schemes, it is essential to identify all the requirements and interactions between different recreation activities, the forest environment and its management. This enables activities to be zoned in the forest, in terms of location, time and level of use so as to minimise possible conflicts. In this way a reasonable balance can be achieved between the provision of recreation and the main production of wood which, usually, is not constrained significantly.

In general, the main influences upon wood production occur in the creation and maintenance of good forest landscapes for recreation. This can include small clearances of trees for vehicle access and for the development of car parks, picnic places, walks, glades and views. The interest of the forest in the vicinity of the facilities may need to be improved by the introduction of a variety of tree species. Broadleaves and larches are especially useful as they provide diversity as well as reducing the fire hazard. Likewise brashing, thinning and sometimes pruning will also be beneficial and will encourage access into the forest. The size and timing of clear felling in certain areas may require adjustment to maintain an interesting landscape or to create variety.

In most situations, the visitor is well behaved and does no harm. However, heavy use and poor behaviour can cause problems and this is most prevalent in woodlands near towns. In these areas the main problems tend to be vandalism, frequent fires, persistent rubbish dumping, theft of trees and produce, unauthorised access by motor cyclists, disregard for the Country Code, and impediments to some forest operations such as harvesting and pest control at certain times.

All these problems can be solved or mitigated by creative and positive management at reasonable costs. These are detailed in a new guide on woodland recreation close to towns *The public in your woods* produced by the Land Decade Educational Council. The increased social benefits obtained from town edge woodlands make the additional management effort worthwhile.

PLANNING FOR FOREST RECREATION

It is essential to plan recreation projects from the outset in order to achieve a good balance between the needs of the visitor, the objectives of the owner and the potential of the site.

A plan will enable the owner to properly appraise these issues, including costs as well as benefits to himself and the visitor. It should prevent errors arising from development on an *ad hoc* basis, which might require costly remedial treatment at a later stage.

An early consideration is how the owner intends to carry out the planning required to implement a project. He will be influenced by its complexity (e.g. a simple day visitor facility such as car park and walks, as opposed to a campsite or chalet development) and the staff of relevant skills that he has available. In general, it should be possible for an owner to undertake day visitor projects with his own staff, obtaining information/assistance as required from the Forestry Commission and other appropriate bodies such as the local planning authority, Countryside Commission(s), Regional Tourist boards, Sports Council, Nature Conservancy, The Landscape Institute, etc. (see list of useful addresses). This approach will be facilitated if a project team, with a designated leader, is appointed to carry out the work throughout all its stages.

If, however, the project is likely to be complex, large and/or located in a sensitive landscape, then it could be worthwhile having the work undertaken by a firm of landscape architects or specialist recreation consultants. The planning authority must, of course, be consulted at an early stage, in order to obtain development approval.

The planning of a recreation project can be divided broadly into survey, analysis, and design, including financial appraisal. Through these three main processes, information about the visitors background and needs (including those of the disabled), the owners short and long term objectives (or his 'brief'), and the opportunities and limitations of the site, is collected, organised and used creatively to produce an attractive and functional facility at acceptable cost.

Survey

A map at 1:25 000 (2½ inches to the mile) scale or smaller as required, can be helpful in considering the location of possible sites in relation to centres of population, principal traffic routes, main approach roads, other tourist attractions, possible visitor demand, planning considerations, etc.

The local planning authority and regional tourist board should be able to provide guidance on these points as well as for likely demand and marketing. Most trips to the countryside for recreation are made by car within a 50 km (*c*.30 mile) radius of home, although there is evidence to suggest that this may be decreasing due to increases in oil prices and may now be as small as 15 km (*c*.10 miles). Only a few travel by public transport, while visits to woodland on foot are generally confined to those within 5 km (*c*.3 miles) of towns.

Sites should be carefully chosen so that they offer the visitor a good quality of environment and enjoyment. It is important that they should accommodate facilities without damage to the visual or natural environment and artefacts of interest. Having selected a particular site a contoured plan, usually at 1:500 scale, is essential at this stage of the survey. All factors affecting the site(s), e.g. main access, public rights of way, existing use, topography, vegetation, and aesthetic quality, should be recorded on one copy of the plan. At the same time the requirements of the owner's brief and any relevant additional information should be noted.

Analysis

All the information collected should then be analysed and organised to provide a basis for design. The assets, defects, problems, opportunities and constraints of the site need to be identified and those most likely to influence the design of the facility recorded on a copy of the plan; this will facilitate the assessment of the interaction of factors. The range of issues to be shown on the analysis plan include: main landscape features, slope in relation to proposed uses, aspect and shelter, important trees/vegetation to be conserved and their stability, estimated areas required for cars, coaches and picnicking, requirements for toilet or other facilities, provision for disabled people, possible user conflicts (horse riding, shooting), information signs and proposed walks, viewpoints, etc.

This analysis should indicate the most compatible match between site factors and brief and will enable a zoning plan to be prepared showing the approximate location of various facilities (car park, picnic place, toilets, etc.) and the required vehicle and pedestrian circulation (Figure 9). This plan forms the basis for site design.

Principles and practice of recreation design

The importance of providing an enjoyable experience for the visitor has already been stressed. To achieve this it is essential that all recreation sites and associated buildings, structures, and artefacts are designed on sound aesthetic principles.

Principles

In general, a good and well tried approach to woodland recreation is to aim not only for peace and quiet, but for an experience that contrasts significantly with that of the town. Thus in recreation design it is important that the impact of artefacts is reduced to a level where the natural qualities of the site can dominate. Urban materials, light and bright colours should therefore be avoided. The cumulative visual impact of the numerous functional small structures such as traffic barriers, signs, fences, toilets, etc., is often overlooked to the detriment of the facility. While a certain level of diversity is required to prevent boring regimentation, it should be provided by the natural features of the site such as rocks, water, trees, ground vegetation and open space. Careful attention to the detailed and co-ordinated design of these elements is important in maintaining a sense of continuity on the site.

Site design

Site design is developed by applying these principles to the zoning plan produced in the site planning process. The extent and location of all proposed artefacts and retained features (such as roads, car parks, paths, trees, etc.) should be shown on a contoured plan (1:500 scale) with reasonable accuracy. Some details, e.g. a planting design around a car park or building may require to be designed at a larger scale of 1:200.

Options, costs and benefits

Efficient function and good appearance occasionally coincide in imaginative design but it is often necessary to find a compromise between the two, which may involve additional cost. It is therefore advisable to design a number of options, either on separate plans or by overlays on a single plan, in order to identify that option which is likely to produce the best results at the least or most acceptable cost. Both capital costs and annual running costs need to be considered; to facilitate this it is often convenient to express capital cost as an annual equivalent value. This must be done when comparing options of differing time lengths.

Benefits can accrue to the owner from the direct income obtained by charging for the facility, from the management of visitors to avoid conflicts and from good public relations.

Maintenance

The constructed facility should be regularly inspected by management to ensure that a good standard is maintained. Monitoring, by survey, of usage and visitor reaction can often reveal unforeseen problems and/or suggest improvements.

Provision for the disabled and infirm

Site planning and design should integrate the requirements of the disabled whenever possible and provide reasonable opportunities for recreation. This will be mainly for paraplegic, ambulant disabled and where appropriate, the blind.

Disabled people recognise their limitations but need to feel that they can use the same facilities as others whenever possible. Attention to detail is important. Access to picnic tables, information, the most attractive parts of the site, etc., all need to be considered, as well as parking, toilets and paths. Unnecessary barriers such as steps should be eliminated from any design.

Existing facilities may often be radically improved for the disabled through very minor modifications, e.g. a ramp into a building, widening of a toilet cubicle, easing a gradient on a walk (1:40 is ideal), replacement of a stile by a gate, etc.

Those concerned with planning and design for the disabled should, at an early stage, consult the relevant references listed at the end of this chapter, and national or local organisations for the disabled.

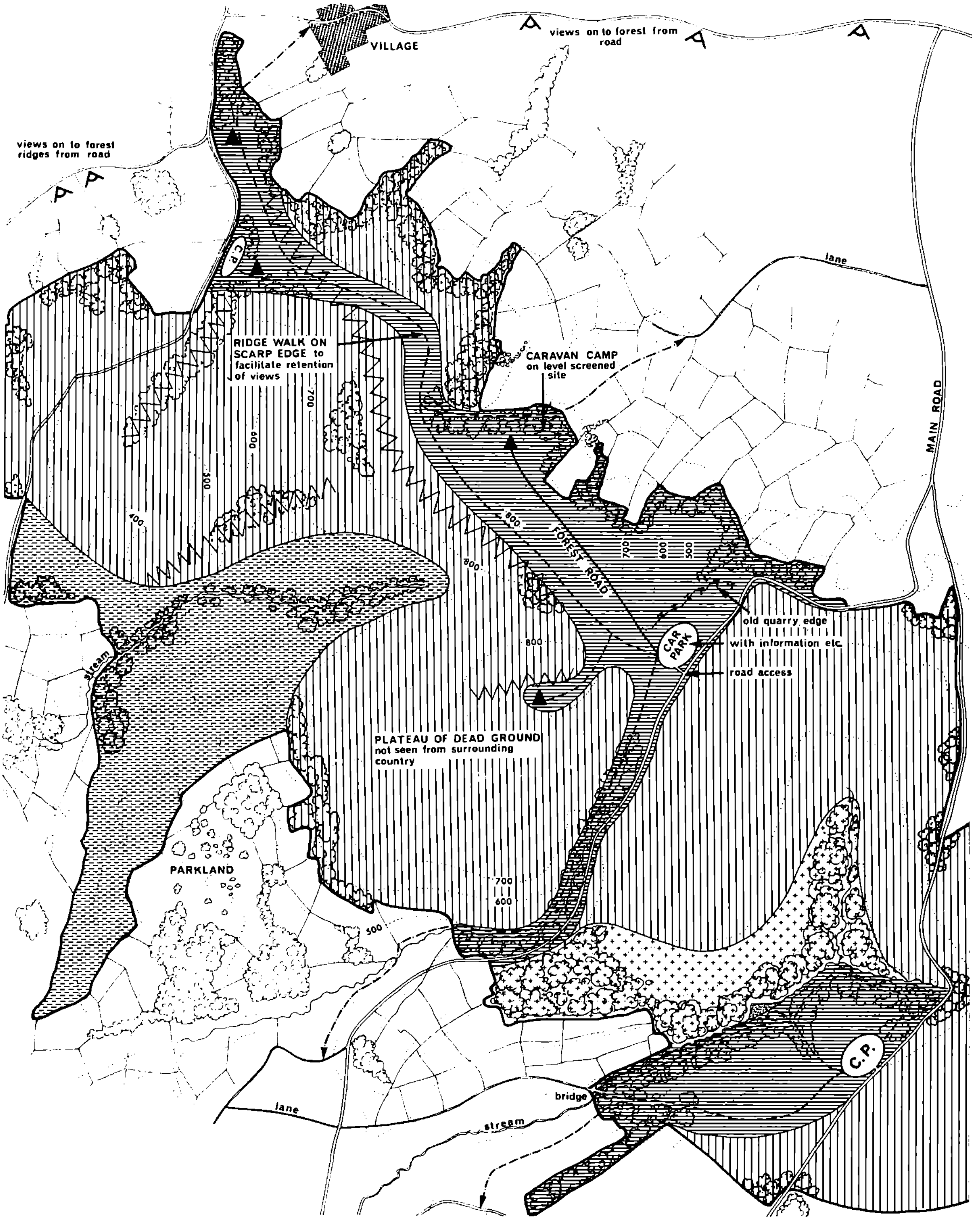

Figure 9. Recreational zoning plan.

KEY

▲	viewing points
⋀⋀⋀	prominent skylines
— — —	footpath in forest
–·–·–	public footpath outside forest
☁	broadleaves within forest
⁘	broadleaves on adjoining land
(C.P.)	car park with picnic area
〜	stream
▤	area of fragile ecosystem containing S.S.I. No access
⁘	area of naturalist interest with deer lawns, pools – separated from picnic area by stream
☰	area of maximum public access
—	forest boundary

Table 18 Summary of planning and design considerations

Scheme	*Objective*
1. Prepare a plan 1:25 000 scale	Survey the estate and note features of recreational interest.
2. Assess the demand	Consider: population characteristics within day-trip range both for residents and tourists; traffic flow patterns; public transport routes; existing provision of participation levels within a radius of 30 miles; prediction of future trends.
3. Review recreational potential	Compare demand data and the attractiveness of the woodland for recreation. Decide also whether, due to its situation and size, the estate offers a particularly good site for overnight facilities.
4. Prepare a survey plan @ 1:500 scale	Record all factors affecting the site; access, rights of way, topography, vegetation, aesthetic quality, owners brief, etc.
5. Prepare an analysis plan @ 1:500 scale	Analyse assets, defects, problems, opportunities, constraints, etc., likely to influence the design of the facility.
6. Prepare a zoning plan @ 1:500 scale	Show approximate location of car park, picnic place, toilet, walks, etc., as a basis for site design.
7. Prepare a design plan @ 1:500 scale with detail @ 1:200	Show the extent and precise location of all proposed access points, roads, car parks, paths, vehicle and pedestrian circulation, trees, structure, artefacts, etc., to create a facility, with provision for disabled people, which is pleasant and efficient and which does not intrude on the general landscape. Consider options using overlays or on separate plans.
8. Carry out a financial appraisal	To determine the financial viability and the acceptable level of investment. Assess possibility for grant aid.
9. Submit plans to the planning authority	To obtain development permission. Revise plan if necessary (consultation with the planning authority will have started at an early date in the planning process).
10. Progress development	Carefully brief and supervise the construction work. Use the minimum structures consistent with efficiency. The form, materials and location of structures should be chosen with care in harmony with good principles of design. Ensure site is properly restored after reconstruction.
11. Achieve a high standard of maintenance	To ensure visitor satisfaction.
12. Monitor usage and compare with predictions	Adjust management plans if necessary.

Main design considerations for car parks, picnic places, woodland/forest walks and small structures

Car parks, picnic places, walks and structures usually form the main components of the type of simple day visitor facility which is in greatest demand and could be provided by a private owner with least intrusion upon his privacy or conflict with the management of his property. For this reason a brief indication of the main design considerations is given here although details will have to be obtained from the relevant further reading references.

Access

The sequence of visitor experience from approaching the site, through use of the facilities until departure has a major effect on the enjoyment of the visit. First and last impressions are particularly important. Thus, well before the entrance to the site, landscape improvements may include reshaping the forest edge by felling, thinning, pruning, planting and removal of eyesores, e.g. unnecessary signs, fences or their replacement with improved ones.

Car parks

Typically, a small forest car park should be an informal arrangement of parking spaces in a woodland setting fairly close to a forest edge and serving picnic places and walks. Normally a single access point should be adequate for the car park which should be sufficiently far from the public or forest road to give visual separation; the access road should be curved. The car park should have minimum visual impact on the site and surroundings and yet provide an enjoyable environment for those who wish to stay in their cars. Thus the edges of car parks, roads and paths should be curved on plan and related to underlying land form – rising in concavities and hollows and fall on convexities.

The location of toilets and information points should be clear from the point where the access road enters the car park. Vehicle circulation should be two-way as far as possible to avoid numerous directional signs and allow proper separation of vehicles and pedestrians.

Usually, surfacing will be required and stone aggregates, natural in colour and texture to the locality, should be used. Generally surfaces should not be sealed with tarmac or bitumen except at main accesses and exceptionally heavily trafficked zones. Where sealed surfaces are used they should be top dressed with aggregates of similar local natural colour to that used on other parts of the site.

Natural features should be used wherever possible to limit vehicles to the parking areas. Rock outcrops, sharp changes in ground level, drainage ditches and the tree crop itself are the most appropriate devices. These can be supplemented by artificial barriers appropriate to the site, e.g. short posts amongst trees and low wooden rails or low banks on open areas.

Picnic places

Picnic places should be located and oriented for their shelter, aspect (generally SSE–WSW) and view. They are usually close to the car park but with sufficient ground or tree separation to give visual detachment and minimise traffic noise intrusion. A range of picnic furniture from simple benches to picnic tables may well be necessary with more sophisticated structures close to the car park and decreasing provision for visitors penetrating further into the forest. In some situations, no furniture will be needed. At the larger facilities, especially campsites and chalet sites, it may be appropriate to develop children's play areas specifically designed for the countryside.

Small buildings and structures

The cumulative visual impact of all the structures required in a recreation facility has a profound effect on its overall appearance. Colour and texture affect the visual impact of all elements. Darker more neutral colours with coarse matt finishes are generally more suited to the rural environment.

Small buildings such as toilets need to be kept as simple as possible. A monopitch roof running with any natural slope and/or with the high wall against a backdrop of trees or rocks is a basic way of providing a building well related to its site.

Generally signs should be of simple design and well constructed and their impact, number and size should be kept to the minimum necessary for satisfactory function. Where a recognised symbol exists it should be used in preference to text.

Forest/woodland walks

The walks should provide for as full a range of physical ability as topography permits. This should range from short gently sloping walks for the disabled to a full day's walking in strenuous conditions. The maximum amount of landscape diversity should be included with as much variety, e.g. open spaces of varying width, strong enclosure, long views and short views out of as well as into the wood, different tree sizes and species, moving and still water, and varied vegetation as can be reached by the walk. All should be combined in a well co-ordinated sequence with as much contrast and surprise as possible. The route should be planned to minimise scour and erosion problems and avoid the need for steps. Walkers and horses should not use the same path or track.

Site restoration

Although disturbance to vegetation should be kept to a minimum during construction some bare ground is inevitable at the edges of roads, car parks, etc. It is important to reinstate such areas as soon as possible to maintain a satisfactory appearance on the site. Any harsh geometric edges should be rounded off to develop a smooth, continuous ground plane. Additional tree and shrub planting may also be necessary to improve the setting of buildings, as a screen for cars, to provide separation between picnic benches, etc.

Recreation training

At present there are few further education establishments offering recreation management training at degree equivalent, although the Institute of Leisure and Amenity Management (ILAM) is developing a training syllabus aimed at degree equivalent to enable people to obtain the ILAM qualification.

Both Countryside Commissions and the Centre for Environmental Interpretation offer short courses on a wide range of recreational issues, often via special study centres in National Parks, which are of value to owners and their staff involved in recreation.

Financial assistance

Grant aid for recreation schemes is available to the private owner from both Countryside Commissions. Financial assistance may also be available for joint schemes from local authorities and regional Tourist Boards. It may also be possible to obtain sponsorship from the commercial sector for all or part of a recreation scheme.

CONCLUSION

Though multiple land use is no stranger to the private estate, in which good integration of different land use objectives is often achieved, there are still very few public recreation facilities in private woodlands. There is no doubt that the increasing pressure for recreation in the countryside has brought a real public awareness of the social benefits of the forest. The owner of private woodland is encouraged to welcome the public on his land, and so make a worthwhile contribution towards satisfying the recreational needs of society.

FURTHER READING: RECREATION IN THE FOREST

Forestry Commission publications

BULLETIN

42 *Forest of Dean day visitor survey.**

BOOKLET

21 *Public recreation in national forests.**

FOREST RECORD

112 *Monitoring day visitor use of recreational areas.*

RESEARCH AND DEVELOPMENT PAPERS

81 *Forest management for conservation, landscaping, access and sport.**
93 *Valuation of non-wood benefits.**
107 *Organisation of outdoor recreation research in the Netherlands.**
123 *Research aspects in forestry for quality of life.*
124 *The impact of forestry on recreation.*

GUIDE

Explore the New Forest.

MISCELLANEOUS

The Forestry Commission and recreation. Forestry Commission Policy and Procedure Paper 2.

Broadleaved woodland grant scheme.

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Useful addresses for recreational activities

Auto-Cycle Union
Millbank House, Corporation Street, Rugby, Warwickshire CB21 2DN

British Horse Society
National Equestrian Centre, Stoneleigh, Kenilworth, Warwickshire CV8 2LR

British Orienteering Federation
Riverdale, Dale Road North, Darley Dale, Matlock, Derbyshire DE4 2JB

Camping and Caravan Club of Great Britain and Ireland
11 Lower Grosvenor Place, London SW1W OEY

Caravan Club
East Grinstead House, East Grinstead, W. Sussex RH19 1UA

Centre for Environmental Interpretation
Manchester Polytechnic, John Dalton Building, Chester Street, Manchester M1 5GD

Council for British Archaeology
112 Kennington Road, London SE11 6RE

Cyclists Touring Club
Cotterell House, 69 Meadrow, Godalming, Surrey GU7 3HS

English Tourist Board
4 Grosvenor Gardens, London SW1W 0DU

Game Conservancy
Fordingbridge, Hampshire SP6 1EG

Institute of Leisure and Amenity Management
Lower Basildon, Reading, Berks RG8 9SE

National Federation of Anglers
2 Wilson Street, Derby DE1 1PG

Nature Conservancy Council Scotland
12 Hope Terrace, Edinburgh EH9 2AS

Ramblers' Association
1/5 Wandsworth Road, London SW8 2LJ

Royal Association for Disability and Rehabilitation
25 Mortimer Street, London W1N 8AB

Royal Automobile Club
31 Belgrave Square, London SW1X 8QM

Scottish Auto-Cycle Union
'Kippilaw', Longridge Road, Whitburn, West Lothian EH47 0LG

Scottish Rights of Way Society
52 Plewlands Gardens, Edinburgh EH10 5JR

Scottish Sports Council
1 St Colme Street, Edinburgh EH3 6AA

Scottish Tourist Board
23 Ravelston Terrace, Edinburgh EH4 3EU

Sports Council
16 Upper Woburn Place, London WC1H 0QP

Appendix I: List of addresses

FORESTRY COMMISSION

Headquarters

The Forestry Commission, 231 Corstorphine Road, Edinburgh EH12 7AT (031-334 0303)

Research Stations

Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH (0420 22255)
Northern Research Station, Roslin, Midlothian EH25 9SY (031-445 2176)

Conservancy Offices

NORTH ENGLAND
1A Grosvenor Terrace, York YO3 7BD (0904 20221)

EAST ENGLAND
Great Eastern House, Tenison Road, Cambridge CB1 2DU (0223 314546)

WEST ENGLAND
Flowers Hill, Brislington, Bristol BS4 5JY (0272 713471)

NORTH SCOTLAND
21 Church Street, Inverness IV1 1EL (0463 232811)

SOUTH SCOTLAND
Greystone Park, 55/57 Moffat Road, Dumfries DG1 1NP (0387 69171)

MID SCOTLAND
Portcullis House, 21 India Street, Glasgow G2 4PL (041-248 3931)

WALES
Victoria House, Victoria Terrace, Aberystwyth, Dyfed SY23 2DQ (0970 612367)

PRIVATE FORESTRY ORGANISATIONS

Economic Forestry Group, Head Office, Forestry House, Great Haseley, Oxford OX9 7PG
English Woodlands Ltd., 125 High Street, Uckfield, East Sussex TN22 1EG
Flintshire Woodlands Ltd., Winston House, Bailey Hill, Mold, Clwyd CH7 1BR
Fountain Forestry Ltd., Lower North Street, Cheddar, Somerset BS27 3HF
Home Timber Merchants Association of England and Wales, Blackburn House, 1 Warwick Street, Leamington Spa, Warwickshire CV32 5LW
Home Timber Merchants Association of Scotland, 16 Gordon Street, Glasgow G1 3QE
Scottish Woodland Owners Association (Commercial) Ltd., NCR House, 2 Roseburn Gardens, Edinburgh EH12 5NJ
Tilhill Forestry Group, Greenhills, Tilford, Farnham Surrey GU10 2DY
Timber Growers United Kingdom Ltd.,
  London Office: Agriculture House, Knightsbridge, London SW1X 7NJ
  Edinburgh Office: 5 Dublin Street Lane South, Edinburgh EH1 3PX

FORESTRY ASSOCIATIONS AND OTHER USEFUL ADDRESSES

Royal Forestry Society of England, Wales and Northern Ireland, 102 High Street, Tring, Hertfordshire HP23 4AH
Royal Scottish Forestry Society, 11 Atholl Crescent, Edinburgh EH3 8HE
Association of Professional Foresters of Great Britain, Brokerswood House, Brokerswood, Westbury, Wiltshire BA13 4EH
Institute of Chartered Foresters, 22 Walker Street, Edinburgh EH3 7HR
Arboricultural Association, Ampfield House, Ampfield, Romsey, Hampshire SO5 9PA
Royal Institution of Chartered Surveyors, 12 Great George Street, London SW1P 3AD
Landscape Institute, 12 Carlton House Terrace, London SW1Y 5AH
Countryside Commission, John Dower House, Crescent Place, Cheltenham, Gloucestershire GL50 3RA
Countryside Commission for Scotland, Battleby, Redgorton, Perth PH1 3EW
Nature Conservancy Council, Northminster House, Northminster, Peterborough PE1 1UA
Tree Council, 35 Belgrave Square, London SW1X 8QN
Oxford Forestry Institute, South Parks Road, Oxford OX1 3RB
Building Research Establishment (timber research), Princes Risborough Laboratory, Princes Risborough, Aylesbury, Buckinghamshire HP17 9PX
Timber Research and Development Association Ltd., Hughenden Valley, High Wycombe, Buckinghamshire HP14 4ND

Appendix II: Forest Industry Safety Guides

FORESTRY SAFETY COUNCIL, 231 Corstorphine Road, Edinburgh EH12 7AT
Telephone 031-334 0303

FSC No.	*Published/ revised*	*Title*	*Checklist available*
N	4/84	Noise and hearing conservation	Yes
1	4/81	Clearing saw	Yes
2	4/81	ULV herbicide spraying	Yes
3	4/81	Application of herbicide by knapsack spraying	Yes
4	4/81	Application of granular herbicide	Yes
6	4/81	Tractor mounted weeding machines	Yes
7	6/84	Planting	Yes
8	5/83	Hand weeding	Yes
9	5/83	Brashing and pruning with handsaw	Yes
10	6/80	The chain saw	Yes
11	9/83	Felling by chain saw	Yes
12	9/84	Chain saw snedding	Yes
13	5/83	Chain saw – crosscutting and stacking	Yes
14	2/84	Chain saw – take down of hung-up trees	Yes
15	6/84	Chain saw – clearance of windblow	Yes
17	6/84	Chain saw – felling large hardwoods	Yes
18	10/81	Tree climbing and pruning	Yes
21	10/84	Forest tractors	Yes
22	10/82	Extraction by skidder	Yes
23	1/84	Extraction by forwarder	Yes
24	1984	Processor (limber bucker)	Yes
25	1980	Extraction by cable crane	Yes
26	1984	Use of tractors with winches in directional felling and takedown	Yes
30	6/80	Mobile saw bench	Yes
31	4/81	Mobile peeling machine	Yes
32	3/80	Fencing	Yes
33	1983	Hand-held power post hole borer	Yes
34	12/82	First aid	None to be issued
35	1984	All-terrain cycles	No

In addition to the above the booklet 'The Avoidance of Danger from Overhead Electric Lines and Underground Electric Cables in Forests and Plantations' published by the Forestry Commission and carrying Forestry Safety Council Approval is available from this address.

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