Continuous Cover Management of Woodlands:

A brief introduction

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Introduction

This booklet covers similar ground to that covered by two earlier booklets; Continuous Cover Forestry (Helliwell 2002) and Fundamental Woodland Management (Helliwell 2006), which is currently out of print. My intention is to provide a brief introduction, explaining the basis of Continuous Cover forestry. The primary audience is intended to be owners and managers of woodlands, but it is also hoped that it might be helpful to others who have an interest in how forests and woodlands are, or could be, managed. I have not attempted to cover more general aspects of forest practice, such as how to measure a tree, control deer, market timber, assess the safety of roadside trees, or the current availability of grant aid, etc., for which the reader must look to more general texts (e.g. Lanier 1986, Hart 1991, Wohlleben 2010, Blakesley and Buckley 2010) and local guidance.

There has been a considerable amount of discussion in recent years about alternatives to clear felling, which was the normal method of managing woodlands in Great Britain and Ireland and many other countries throughout the 19th and 20th Centuries. Some of this discussion has been summarised by Helliwell and Wilson (2012), and it is clear that it might be some time before Continuous Cover Forestry (CCF) becomes a generally accepted and understood approach to woodland management in Britain and Ireland.

CCF involves a very different approach to woodland management from that involved in clear felling or coppicing [which is a form of periodic clear felling], and it can be difficult for people who have known only clear felling to change to a different system which lacks some of the apparent certainties of felling and planting trees on a regular rotation. As one Forestry Commission officer said to me a few years ago, he likes to be able to sit in his office and see the plans for the next 10 or 20 years set out on a map. However, the uncertainties and risks involved in CCF are no greater, and in many ways may be less; but they are different. And they do require the manager to spend more time in the forest and less time in the office. CCF is basically reactive rather than prescriptive, and to react appropriately the manager has to observe what is happening; which requires the skills of a forester and not just those of an administrator.

Concepts

Natural woodland

Woodland is the predominant natural vegetation of all regions of the world where there is sufficient rainfall and warmth to support the growth of trees. If an area of land in such a region is left untended for a few decades it will usually become wooded, unless the soil is very poor, or there are large numbers of goats, sheep, cattle, deer, or other herbivores; or frequent fires. Planting is only needed if the owner is in a hurry or if there is a wish to grow trees of different species to those which would grow naturally.

Natural woodlands can regenerate in different ways, depending on the climate and the woodland type. In some circumstances, trees tend to regenerate *en masse* after catastrophic events such as fire or extensive windthrow, particularly in boreal regions; or during a period of reduced grazing. However, in most temperate and tropical regions it is more usual for individual trees or small groups of trees to die or be blown down in storms, providing relatively small gaps of various size which can then become occupied by younger trees, giving an irregular mixture of trees of different age and species, ranging from small seedlings to large veterans.

A theory has been advanced by Vera (2002) that, in some types of woodland, the natural system involves a cycle which operates over periods of several centuries, in which areas of woodland populated by wild herbivores change to grassland when the older trees die, due to the fact that any new tree seedlings will be eaten by the grazing animals. This grassland then gradually becomes colonised by thorns, which allow trees such as oak to grow within their protection, to form woodland again. This system results in a patchwork of woodland, grassland, and scrub, representing different stages of this cycle. The closest example to this in Britain may be the New Forest, although the sequence of events in that instance is affected by the enclosure of some parts of the Forest, to exclude cattle and horses. Vera's theory has been challenged by Mitchell (2005), who claims that forest with large open gaps in Europe and eastern USA has only ever been maintained by human exploitation, and may not be a truly natural system.

Management choices

In the past, many woodlands in Britain and other parts of Europe were managed as **coppice**. Under that system, all or most of the trees in each part of the wood are cut close to ground level, on a regular cycle, every few years, to produce new shoots. The produce can be used for a variety of purposes, including fuelwood, walking sticks, rods for thatching, stakes for hedge laying, wattle for infilling the spaces between the timbers in medieval houses, poles for supporting hops, etc. Before the use of coal and coke became commonplace it also provided wood to make charcoal for the manufacture of glass and iron, and gunpowder. Coppice management is simple to carry out and, in the past, provided valued materials. It also has its own aesthetic attraction, with each periodic cutting being followed by an abundant flowering of primroses, bluebells, anemones or other woodland plants, with associated benefits for some insects and birds. This system is still used in some places, but the demand for peasticks, poles, and charcoal is not very great, and coppicing as a general method of management has not been very widely practised in western Europe since the end of the 19th Century. There may be something of a revival at present, for the production of wood fuel (which is "carbon neutral"). The productivity of coppice is normally rather less than the productivity of high forest of the same tree species, in terms of cubic metres of timber per year, but the small sized material which is produced is easier to handle, if labour is freely available or if machinery can be used to harvest the coppice. It is not a very “natural” system, but it is fairly simple to operate and regulate.

Coppice-with-standards retains some individual trees (“standards”) to a large size and thereby provides some larger timber in addition to the poles and sticks produced by the coppice; but the productivity of the coppice will be reduced, particularly if there are a lot of standards.

There is some current interest in the use of fast-growing clones of willow, poplar, or Eucalyptus grown as **short-rotation coppice**, on a rotation of as little as two or three years, for the production of fuel, but this does not come within the scope of this booklet. The main advantage of such short-rotation coppice is that it can be easily harvested and processed by machinery, in a similar way to other agricultural crops. It requires land of agricultural quality, it does not produce a greater volume of wood per hectare per year than the same species of trees grown as woodland, and it is unlikely to have a very high value for amenity, recreation, or nature conservation.

Following the first World War, the Forestry Commission was created, with a remit to provide a reserve of timber in Britain for use in any future emergency; including the provision of pit props for coal mines. [This is somewhat reminiscent of the planting of oaks by the Crown Estate in the New Forest and the Forest of Dean until the middle of the 19th Century, in order to be ready for building wooden ships for the navy when the trees reached maturity in the latter part of the 20th Century.] The only system of management which the Forestry Commission took seriously for the first 80 years of its existence was based on **even-aged** areas of forest (usually with introduced coniferous species) which were **clear-felled** when the time was judged to be economically right and then re-planted (or very occasionally naturally regenerated) with another crop of trees. The only variation which was normally considered was in the size and shape of felling areas and the species, or mixture of species, of trees to be planted. Such variation became increasingly common in the latter part of the 20th Century, leading to the division of some forest areas into hundreds of small even-aged sub-compartments, which tended to make management more complicated rather than less.

Other approaches to management have been followed in other countries. Switzerland forbad the clear felling of any area of more than 2ha early in the 20th Century, as there was great concern about the risk of landslides and avalanches, the risk from which is increased by clear felling; and Slovenia followed this lead in 1950. Methods of management which involve the periodic removal of single trees or small groups of trees throughout the forest, with regeneration taking place continuously throughout the whole area, were developed. In Germany this approach became known as *Dauerwald* or "continuous forest", and was described by Troup (1927) in the first issue of the journal "Forestry". His classic text on Silvicultural Systems (Troup 1928) describes in some detail the methods which were used to manage forests in this way. This type of approach, which would be described as a selection system when fully developed, has become more widely used in many European countries within the last two or three decades. This has been for a variety of reasons, including the fact that, if it works smoothly, it can be more economic than clear felling, as it avoids all or most of the costs of re-planting. This approach is now being applied more widely in Britain and Ireland, although there remains a lack of widespread experience of its use here.

Continuous cover forestry (CCF)

I would expect Continuous Cover management to be a suitable approach for the majority of owners of multi-purpose woodlands, although there may be circumstances where clear felling or shelterwood systems are appropriate.

Under continuous cover management, felling and regeneration are carried out continually or irregularly throughout the whole of the woodland area, usually making use of natural regeneration rather than planting. There is no defined **age** for harvesting trees, although there may be a maximum **size** of tree which can be easily extracted from the woodland or which is acceptable for local markets; and the concepts of age and area, which govern the management of coppice woodland or clear-felled high forest, are not applicable.

The basic premise which underlies CCF is that each tree which is removed should maximise the potential value of the trees which remain. Trees which have reached their maximum value for timber and trees which are interfering with the growth or survival of other, more valuable or potentially valuable trees should be removed. Normally, between 15 and 20% of the timber volume will be removed at each intervention, which will be at intervals of between 5 and 10 years according to the rate of growth of the trees. In some circumstances, for example where a woodland has not been thinned for many years and there would be a risk of windthrow if it were thinned too heavily, a lesser amount (say 10%) might be removed at more frequent intervals (perhaps 2 or 3 years). In such circumstances, at least some of the sturdiest trees would be retained until the stand as a whole has become more stable, as they would be serving a more valuable function in this way than if they were harvested, even if they are not the best trees to retain in other respects. CCF management is a process of progressive optimisation, and reacts to the circumstances rather than following a pre-determined prescription. The selection of trees for removal requires a consideration of several factors simultaneously, including an understanding of the changes that will occur with the passage of time, and requires experience in addition to knowledge. One might know how to ride a bicycle in theory, but proficiency will only come with practice; and it is the same with CCF.

A basic appreciation of the way in which daylight affects tree growth and the way in which the woodland structure and composition affects the amount and quality of light is important. Also an understanding of soils and the conditions required for natural regeneration of trees; and an appreciation of the manner and routes by which timber will be harvested and the possible conflict that this may present for the maintenance of soil structure and the avoidance of undue damage to the remaining trees.

Objectives

The overall objective of Continuous Cover management is to maximise the benefits from an area of woodland while letting natural processes do most of the work. Under ideal circumstances the only expenditure will relate to the work involved in deciding which individual trees to remove, the costs of removing them, and keeping adequate records. Under such circumstances there should be no need for any planting or tending of small trees, and little if any unremunerative thinning. In practice, there will usually be a need for some tending operations, but the cost of these will be considerably smaller than the cost of re-stocking after clear felling or the fairly intensive thinning of dense natural regeneration which can arise under uniform shelterwood.

Timber production

A properly functioning Continuous Cover woodland or forest can be a very cost-effective producer of timber if there is good access both to and within the woodland, and if the woodland area is large enough to obtain a sufficient amount of timber at each intervention to be economic (which will depend, in part, on the market for the timber).

The average size of log which is produced under such circumstances will be greater than the average log produced from a clear felling system, as there will be fewer small sized trees and more of the timber increment will accrue to the larger trees. Small trees occupy relatively little space in the system, as compared to clear felling, where at least 30% of a normal range of age classes will be occupied by trees of very small size. Under CCF, small trees are likely to occupy about half that figure, although it is not practicable to talk about separate areas, because small trees and larger trees will, to some extent, occupy overlapping areas.

Under CCF it should be possible, once the system is fully developed, to remove poorly formed trees when required, even if these are fairly numerous in some places and their removal would leave a gap, without disrupting the system. In this way, the average timber quality of the remaining trees can be constantly improved, by giving the better trees more space to grow. And no tree has to start life on a windswept open site, which would encourage crooked or curved stems and coarse branching. Trees which are growing in gaps within a woodland will tend to be straighter and less heavily branched, due to shelter from wind and the altered light quality within a woodland environment (Helliwell 2011).

On sites which are prone to windthrow [trees being blown down during gales] a Continuous Cover structure will provide greater security than an even-aged woodland, as the individual trees are likely to be more stable. Additionally, if some trees are blown down there is less likelihood that all the remaining trees will be flattened, so it should be possible to harvest the fallen trees and to carry on managing the remaining trees as if they had merely had an unusually heavy thinning. [This is not a view that was held by the Forestry Commission until recently, but it appears to be now generally accepted as being correct.]

Nature conservation

Clear felling systems can provide a range of conditions which are suitable for some animals, plants, and fungi, particularly species which flourish after major disturbance and species which require relatively large open areas. They are, however, of less benefit to species which require a greater degree of permanence or species which require standing deadwood within a woodland environment.

Continuous Cover provides continuity of woodland conditions, together with small scale heterogeneity, which is likely to benefit the majority of woodland plants and animals.

A mixture of Continuous Cover and clear felling within one forest area may provide the best of both worlds, but where there are permanent gaps in the forest, or there are woodlands surrounded by fields, there is likely to be less need for clear felling.

Landscape

When seen from a distance, Continuous Cover forestry presents a more or less unchanging appearance, as there are unlikely to be any visible areas of felling [and certainly no areas which look like a First World War battlefield].

Similarly, the internal landscape of the forest will be relatively stable, with individual trees being removed from time to time, but with no drastic or sudden changes. There are unlikely to be extensive stands of mature trees all of the same age, forming cathedral-like effects, but there will be some mature trees throughout the woodland, and this can create some quite attractive scenes.

On the other hand, there will be no sudden creation of new long distance views, although there may be some long distance views out of the woodland in hilly terrain. The volume of standing timber in a Continuous Cover woodland is likely to be about 70% of that in a well-thinned semi-mature even-aged woodland of the same species, so Continuous Cover is not normally as dense and impenetrable as most even-aged plantations, but there are not likely to be any long distance views through the woodland on level ground.

If open areas are needed, then these will need to be a part of the overall landscape, as permanent meadows, heathland, or other open spaces, and will need to be managed accordingly.

Conservation of soil and water

Clear felling of woodland or forest causes a sudden and major decrease in the amount of moisture which is taken out of the soil by trees and a decrease in the amount of rainfall which is intercepted by foliage, and the felling operation may also result in widespread disturbance to the soil itself. These factors can result in greater amounts of water flowing off the site during and after heavy rain, and possibly some of the soil being carried with it; which will have unwanted implications for flooding, siltation, and the biological quality of streams and rivers.

Continuous Cover management will not result in such major changes; although care will still be needed to avoid damage to the soil during extraction of timber, which should be *via* a limited number of dedicated trackways and follow the guidance on forests and water issued by the Forestry Commission (Forestry Commission 2011).

Recreation

Continuous Cover woodland provides an attractive and subtly varied landscape in which walking, camping, nature study, orienteering, riding, or cycling can take place. It will always contain some large trees and provide a sense of permanence and apparent naturalness which many people value. The amount of variation in tree species and general character will depend to a large degree on the nature of the terrain and soil, but it may be possible to emphasise this variation to some extent when selecting trees for removal; possibly favouring pines in one area and birch or oak in another, for example.

Site Appraisal

Size and location

The location of the woodland or potential woodland is of importance in several respects, as it will be related to:

- accessibility, for:-
    - maintenance
    - removal of timber
    - enjoyment by the owner and/or the public
- steepness of slope
- exposure to wind
- soil type
- the nature of the woodland boundaries
- presence of grazing animals, such as deer, rabbits, sheep, etc.
- prominence of the woodland in the landscape

The owner should also be aware of any constraints or features such as:

- underground water pipes or other services
- public or private rights of way
- rights to hunting or shooting
- historic or archaeological features
- designations, such as Ancient Semi-Natural Woodland or Site of Special Scientific Interest
- flora or fauna of specific interest
- designated floodplain areas or water courses of significance.

Many of these points will be self-evident, but it is surprising how often people assume, for example, that timber must always have some value, even when the nearest road is a mile away and the woodland is small and on a steep slope. Transporting timber from such a location and delivering it to someone who can use it will often cost more than the price which can be obtained. In such cases, the most economic course may be to leave the timber where it is, as standing or fallen deadwood. However, this does not necessarily mean that the woodland should be left completely unmanaged.

Grazing or browsing animals such as roe or fallow deer may add to the recreational value of the woodland, and may help to control the growth of brambles, but they can be a nuisance by eating or damaging young trees (whether planted or self-sown); and Muntjac deer even eat bluebells. Deer and rabbits can be difficult or impossible to control effectively, particularly in small scattered areas of woodland under different ownership, and there may be a need for permanent or temporary fencing to protect young trees. In some instances plastic tubes or "tree shelters" (which need to be at least 1.5m or 1.8m tall for the larger species of deer) may be used, but if there is only a limited amount of light in the woodland, the additional reduction in light caused by the plastic tube may be enough to result in the death of the tree; and, in more open areas, trees in tubes may be insufficiently stable to stand up to the wind. In some woodlands, sheep and stray cattle can also cause problems and prevent tree seedlings from surviving.

The nature of the woodland boundaries can also be important. Woods which are adjacent to roads may be more accessible for management purposes, but will require a greater degree of care and attention with regard to the safety of trees, particularly where the woodland is on ground which slopes up from the road. On such sites, nearly all the trees are likely to have more branches and therefore more weight on the lower side than on the uphill side, and they will be difficult or costly to fell without them falling onto the road. Trees which are close to boundaries with domestic properties, schools, or other areas which are frequented by people will also require careful management. If there is a very busy road or a railway line adjacent to the woodland it may not be safe to have any trees which have any significant risk of falling or shedding large branches across the boundary. This might include, for example, any hybrid black poplars, even if no branches have yet broken off, as these are, in the words of one Local Authority tree officer, "self pruning" and are likely to lose branches even if they have no specific defect.

The size of a woodland area is also likely to have a major effect on the economics of management, just as size affects the economics of most enterprises. Someone might keep six chickens in their garden, to supply eggs to the household and because the owners like keeping chickens, but a commercial poultry enterprise would need to be on a much larger scale unless it can be combined in some way with tourism, catering, or involve breeds or markets of particular value.

The economics of managing 5 or 10 hectares of woodland will be comparable in many ways with managing a small farm of similar size. It might perhaps fit in with a bed-and-breakfast business or some other part-time occupation, particularly if the owner possesses the necessary knowledge to avoid the need to pay for advice; or has a pension to provide a basic income. However, there may be difficulties in marketing relatively small quantities of timber, particularly if the woodland does not have good road access, and if there is little local demand for firewood or other products.

Soil

The type or types of soil in the woodland will determine the range of tree species that will be suitable, the range of other plant species that might be expected to grow in the woodland, and how quickly the trees are likely to grow. Inspection of other woodlands in the vicinity which are on similar soil will be helpful. The Soil Survey of England and Wales publish maps which may also be helpful in those countries. The most important factors to consider are whether the soil is sandy, loamy, or clayey, whether the drainage is free or impeded, and whether the soil is acidic, neutral, or calcareous. As with all land husbandry, the soil is very important, and in most woodland situations there is little scope to alter the soil by cultivation; particularly under Continuous Cover. Conversion of heath or moorland to woodland might involve some initial cultivation and possibly the addition of some fertiliser, but this will not usually be necessary or appropriate in established woodland.

On some types of soil in particular, the choice of tree species can affect soil fertility in the long term, with species such as pine and beech tending to increase the acidity of sandy soils and species such as birch helping to increase the recycling of nutrients and reduce acidity of soils which have previously been under pines or heath.

On soils with relatively small reserves of mineral nutrients, the periodic removal of trees might also reduce soil fertility, but on most soils the removal of timber alone is not likely to have a significant effect, although the removal of the whole tree, including the branches, twigs, and bark, could have a more noticeable effect, as these parts of the tree contain a fairly large proportion of the nutrients in a tree.

Species and condition of trees

An assessment should be made as to what tree species would be best suited to the site and to the objectives of the owner. Are these species already present; and, if not, is it necessary to change the current species composition of the wood, or the genetic type of these species? If so, will this need to be by planting or can it be achieved by natural regeneration and appropriate selection of individuals from within this regeneration?

And, if such changes are needed, can they take place over a period of several decades or do they need to be made sooner?

The approximate age and condition of the existing trees is also important. If the existing trees are less than about half the age at which they would be expected to go into serious decline, there will be no immediate urgency to obtain young trees. There will, however, almost certainly be a need to commence some management as soon as possible, in order to develop a stable population of trees which can eventually be managed in such a way as to provide space for young trees to grow without the remaining older trees becoming unstable.

Many woodlands which contain trees between 60 and 200 years old might look as if they have always existed, exactly as they are now, since time immemorial. They might not have changed sufficiently, or suddenly enough, for most people to notice any change; and there can be a tendency to think that the woodland will remain like that indefinitely, without any need for management. People are often unaware that an area of woodland was felled during or after one of the two World Wars; and old photographs or paintings often show landscapes which, although now well wooded, were devoid of trees 100 years ago. The fact that woodlands change at a slow pace does not mean that they are static; they simply operate on a slightly longer time-scale than that to which we are accustomed. If an unmanaged woodland contains trees which are all of the same age, and possibly all of the same species, these trees are likely to reach a point where drastic action may become necessary in order to maintain safety; and at this stage the only option would be likely to involve clear felling, as individual trees may not be sturdy enough to remain standing if suddenly isolated. Some types of woodland reach this condition periodically under natural conditions, and then collapse before regenerating again from new seedlings, but this is not something which is likely to be acceptable where there are safety considerations, and it may not look very attractive, although the presence of large amounts of dead wood may be beneficial to some forms of wildlife. Leibundgut (1993) and Packham and Hytteborn (2012) describe this type of process in unmanaged beech forests, although large-scale disturbance in virgin beech forests are reportedly rare (Commarmot 2005) and different parts of a natural forest are likely to be at different stages at any given time.

Constraints

As already mentioned, **deer** in large numbers can be a serious problem, particularly the diminutive Muntjac deer which escaped into the wild in southern England about 100 years ago and which continues to spread at a steady rate.

Squirrels (particularly the now ubiquitous grey squirrel, which was introduced to Britain at about the same time as Muntjac deer) can also be a nuisance, by removing bark from the stems of young trees and from the branches of older ones, although they may not be quite as major a constraint as they are seen to be by some foresters, especially under Continuous Cover management, where they are generally not quite as devastating as in even-aged plantations of single species. However, it may not be advisable to have woodlands which contain nothing but the most vulnerable tree species (which usually include sycamore, beech, and hornbeam). A mixture of oak, pine or other species may be advisable, but perhaps including a few sycamore, field maple, hornbeam, or beech to divert attention from the other tree species. Few tree species appear to be totally immune to damage by grey squirrels, but groups of naturally regenerated trees seem to suffer less damage than trees planted at regular spacing, whatever the species. Such groups should be thinned as little as possible (ideally, not at all), relying on natural thinning processes as much as possible, until the trees are of such a size as to be less vulnerable to catastrophic damage. (This ties in with comments in the section on Natural Regeneration.)

Access by large numbers of **people** can sometimes bring problems, particularly if they are uncontrolled and light fires close to trees, dump stolen cars, or put nails into trees. On the other hand, regular daily access by responsible residents can be helpful in reducing harmful behaviour, and (perhaps) in helping to disturb deer and thereby reducing damage to young trees.

There may also be **additional constraints** if a woodland is within a National Park, Area of Outstanding Natural Beauty, Site of Special Scientific Interest, or other designated area. There will be some control (exercised by the Forestry Commission) over the felling of any significant amount of timber or clearance of woodland in almost any circumstances in Britain, and the Forestry Commission is required to consult Local Authorities and other relevant bodies before issuing a felling licence. Some woodlands may also be affected by a Tree Preservation Order or lie within a Conservation Area, in which case the Local Planning Authority will have a particular interest in their management, which may involve additional delay, but ought not to be a constraint on sensible woodland management (although it sometimes has that effect). And it should be emphasised that the legal liability for the safety of trees always remains with the owner, not with the Local Authority or any other body. This can sometimes place the owner in an awkward position if he or she is prevented from carrying out actions which they or their agent deem to be sensible and necessary, as legal liability does not then pass from the owner to the Local Authority. There is a right of appeal against a refusal of permission, but the whole procedure can be lengthy, troublesome, and not without cost. There can be numerous constraints, and possibly with few or no incentives to prompt an owner to carry out suitable management of existing (as opposed to the creation of new) woodlands.

Commencing Management

Objectives and "vision statement"

The objects of management should be carefully considered and then set out, in approximate order of importance. It might also be helpful to prepare a "vision statement" for the woodland, describing the important features that the owner is seeking to develop. How does the owner envisage the woodland in say 50 or 100 years time? It might be something along the lines of "...there is a mixture of native tree species....a network of gaps and glades....with bluebells in spring....some large old hollow trees...owls and bats...and a steady supply of firewood for the logstove." Or perhaps "....A permanent screen and shelter on the northern side of the house, with a secluded footpath through the middle and a belt of hawthorn scrub along the southern edge to keep out the wind and provide habitat for nesting birds"

To take a slightly dated example, some owners in the past managed woods primarily as fox coverts. These were managed in such a way as to produce thickets of thorn, in which foxes could escape from the hounds, to ensure that there were always some foxes available to hunt. This could involve removing some of the trees from time to time, to give enough light for the thorns to grow well and thereby achieve the owner's main objective, and this required different management from that in woods where timber production or pheasant shooting were the main objectives.

Many woodland owners do not like to see dead trees in their woods, because they regard it as desirable to keep the woods "tidy", even though dead trees and dead branches may provide habitat for many species of fungi, insects, hole nesting birds, and bats. Opinions have changed to some extent in recent years, with a greater acceptance of such trees if they are in places where they are not likely to be a hazard to people passing through or adjacent to the wood, and there has been an increased interest in "veteran" trees; which are old gnarled trees with dead branches and holes, and which frequently support a range of lichens and mosses on the bark.

Some objectives may not be achievable in a particular wood, and some objectives may be mutually exclusive. For example, the greater the amount of public access the less scope there will be for retaining dead trees and branches; unless access can be restricted to marked paths or otherwise steered away from such trees, especially during windy weather.

A typical list of objectives (for one particular wood) might be:

- Maintain trees in an adequately safe condition, in relation to their location
- Maintain adequate tree cover, without clear felling any areas of more than 0.1ha, in order to maintain the visual and ecological functions of the woodland
- Retain a mixture of tree species in the required proportions (e.g. 30-50% sessile oak, 25-40% silver birch, and 20-30% Scots pine)
- Maintain a partial understorey of holly and rowan, covering between 20 and 30% of the woodland
- Retain some dead trees, both standing and fallen, in areas where it is safe to do so
- Eliminate Rhododendron and Japanese knotweed

- Introduce selected native plants, such as red campion, bluebell, and greater stitchwort [in a woodland which lacks native woodland species]
- Maintain footpaths in a usable condition
- Make the best use of any timber which results from management, where this is not required as dead wood, and where it is economic or practical to do so
- Keep the woodland tidy by removing any man-made litter or rubbish
- Maintain permanent open spaces and sites of archaeological interest
- Maintain boundary walls and fences

Each of these items would need to be described in further detail, as part of a management plan; and different woods would have a different list of objectives.

The management plan may not need to be very long or very detailed, but it must be appropriate to the site and to the owner's objectives, and be achievable.

First steps

If there has been little or no management of the woodland for many years, there will be a need to prepare a management plan. This may be no more than a statement that a programme of thinning will be commenced as soon as possible, with the most urgent areas being dealt with first, and possibly dividing the woodland into 5 or 6 areas (compartments) of about equal size or productivity, each of which will in future be thinned in turn, on a cycle of 5 or 6 years.

In the first instance, if the trees are very overcrowded and spindly, due to previous lack of thinning, it may be necessary to thin less heavily, over a larger annual area but on a reduced cycle. Possibly covering two of the 6 areas each year and returning after only 3 years.

Thinning involves the removal of some trees to benefit others. The process of selection of the trees to be removed is ***the*** crucial part of managing woodland on a Continuous Cover basis.

A list of *rules* and *guidelines* for the selection of trees will be helpful, at least to commence with, and it will be helpful to mark the selected trees with clearly visible paint on three sides (so that trees which have already been selected can be seen from any direction). I find a pale yellow oil-based primer or undercoat paint the most useful; and such marking will remain visible for a number of years. However, pale yellow does not show up well on silver birch or aspen, so a different colour might be needed for these. And remember, when marking trees in winter in a wood with bracken or brambles, that these may grow as tall as you in the summer and hide any marks below that height. A suitable list of rules and guidelines should be drawn up.

For example:

Do not remove more than a limited proportion of the tree cover at any one time. This is usually and most conveniently expressed as a proportion of the standing volume of timber (even if timber production is not the main objective). A gentle thinning might remove 10-15% of the standing volume, while a moderate thinning might remove 15-20%, and only rarely would one remove more than 25% of the volume at any one time. For people who are accustomed to thinning even-aged woodlands, the eventual aim under Continuous Cover will be to achieve a stocking level of about 70% of the volume given in the Forestry Commission's *Forest Management Tables* for a mature even-aged crop of comparable species and yield class. If a woodland has not been thinned for a very long time, and has a standing volume well above the Management Table figures, it may take 20 to 30 years or more before the stocking is reduced to something approaching its eventual level.

Retain trees which provide the most stability. It is particularly important on sites where the rooting depth is limited, or on very exposed sites, or in woodland where most of the trees are very spindly (due to lack of thinning in the past), to make sure that any trees which are more robust than the others are retained in sufficient numbers to maintain the stability of the woodland. This may be difficult if there are few such trees or if these trees are themselves unsafe for some reason; and it may be necessary to resort to clear felling if the stability of the trees is deemed to be inadequate. However, if there are no major safety concerns it may be worth giving the above approach a try and risking some windthrow.

Maintain the desired mixture of tree species. If there is too great a preponderance of one or more tree species, then these should be selected for removal preferentially, and individual trees of species which it is desired to increase should be retained, while bearing in mind the other rules. But do not attempt to obtain a very large change in species composition too quickly.

Maintain a balance between different sizes of trees. Appendices 1 and 2 indicate the approximate relative numbers of trees of different sizes that are likely to occur under Continuous Cover. There should be no slavish adherence to any particular "target", but care should be taken to obtain a balance between small, medium, and large trees, in order to keep the system working properly.

Do not remove any tree unless there is a good reason. For example, small trees which are not interfering with the growth of other trees, or dead trees which do not present an unacceptable hazard, can be left.

Do not allow concern over natural regeneration to dominate your management to the exclusion of everything else. Experienced Continental foresters will tell you that “regeneration will come if your management is correct”. Manage the trees, and regeneration should then happen, unless there is a problem due to there being too many deer, etc. The amount of regeneration that is needed to sustain woodland cover is a lot less than many people think, and you should not aim to have more than about 15% of your woodland occupied by tree seedlings or saplings at any one time, under normal circumstances. For the first few years after the commencement of management there may be little or no successful regeneration; but don’t worry too much at that stage. Worry later, if necessary, but don’t reduce the density of large trees to the extent that it results in widespread development of brambles, bracken, or grass if there is no regeneration.

Do not aim for uniformity. A degree of irregularity or “patchiness” is natural and often desirable. Some parts of a woodland may be denser or contain more of one tree species than other parts of the wood. Some areas may be, at least for a while, devoid of trees. In multi-purpose woodlands this is fine, so long as there is a sufficiency of young trees to maintain continuity and no parts of the woodland contain trees which are not sufficiently safe for their location.

Practical targets

Provided that most of the trees in the woodland have several decades of normal life expectancy remaining, it will usually be advisable to progress slowly for the first 10 to 15 years. Nevertheless, unless the trees are very young and are not yet in need of any management, it will be advisable to make a start as soon as possible. The first intervention will probably need to be relatively gentle, as already explained.

Targets which are likely to be relevant include:

- Prepare a statement on the condition of the woodland and any features of importance or relevance
- Prepare a management plan
- Consult the relevant authorities; which are likely to include the Forestry Commission and possibly the Local Planning Authority, before carrying out any tree felling. (You may even be eligible for one or more of the ever-changing grants which are designed to encourage management; although I would caution against the temptation to do something simply because it attracts grant aid.)
- Investigate possible markets for any timber or other woodland produce
- Create and maintain access for vehicles, particularly in large woods, which are likely to require some permanent tracks or roads
- Commence a programme of regular thinning. This should not exclude the edges of the woodland, which are likely to be the most critical in terms of stability and safety, as well as being the most visible part of the wood as seen from elsewhere, and will probably require some careful management.
- Safeguard young trees, as necessary, by fencing out sheep, etc., either permanently or temporarily.
- In the long term, carry out periodic recording of the volume of the trees in the woodland. At its simplest, this may involve nothing more than measuring the basal area of trees in sample areas every five years. These measurements can be compared, if required, with typical figures for continuous cover woodlands of that species or mixture of species, as a general guide to the volume which normally functions most effectively.

Unmanaged beech woodland in Slovakia.

Young even-aged broadleaved trees, in need of thinning.

Uneven-aged woodland on sandy soil, with oak, birch, and Scots pine.

Uneven-aged beech in Slovenia.

A tourist path in Switzerland, in uneven-aged forest of Norway spruce and European larch.

Creating New Woodland

New woodland might be created by simply keeping the cattle or sheep out of a field for a sufficiently long time, or allowing a derelict quarry to become colonised by trees. Rabbits and deer may also need to be controlled or excluded. However, most owners are not sufficiently patient and will want to hasten the process and possibly to obtain tree species which would not arrive naturally.

When planting, species which suit the soil and climate should be selected and, ideally, species which will in the long term provide a basis for a self-regenerating permanent woodland. "Pioneer species" such as birch or pine may be planted or allowed to grow naturally, to provide woodland conditions fairly rapidly, with more long-lived or permanent species being planted in groups, either at the same time or at a later date, if they do not arrive naturally. Decide on long term and short term purposes for choosing particular species. Avoid planting trees which are likely to run amok and cause problems in the future. One such species may be western hemlock (*Tsuga heterophylla*), which can be extremely invasive on some sites, although it can sometimes perform a useful service if it is not allowed to become too extensive, as it is very efficient in shading out brambles and grass and can thereby create suitable conditions for other trees to regenerate when groups of hemlock are removed; but don't allow it to reach an age where it starts seeding too prolifically or it could become a problem.

Guidelines suggested by Pro Silva (the European association of foresters concerned with "natural" forest management) for non-native species are:

- Do not introduce exotic species which are likely to prevent the retention or growth of an adequate representation of native forest types.
- Any introduced species should be suited to the local climate and soils, and should not cause soil impoverishment.
- Any introduced species should not spread disease or create instability.
- Any introduced species should not run an abnormal risk of itself being affected by pests, disease, or climate.
- Any introduced species should be able to merge with the native vegetation without excluding the indigenous flora and fauna.

As described elsewhere (Helliwell 1993), it is advisable to avoid planting too many different main tree species in any one part of a woodland. One, two, or at most three main species, will be enough. Occasional groups or individuals of other tree species or shrubs can also be planted, but in most cases the proportion of these should be no more than 15 – 20%. An exception may be where an understorey of hazel is required beneath a relatively open canopy of ash or oak, to be managed by coppicing; but that would require fairly intensive management, which would only be considered by most owners if there is an assured and profitable market for the produce [and it does not fall within the ambit of Continuous Cover]. Concentrate on the main tree species. At least some shrub and minor tree species will probably arrive of their own accord, in time, although some could also be planted if needed.

On soils of medium to high fertility it may not be possible to manage light-demanding species such as Scots pine or oak on a continuous cover basis very easily, as the shade cast by the trees might not be sufficient to suppress the growth of brambles, bracken, and grass enough to allow the trees to regenerate. Where appropriate, the inclusion of some more shade tolerant species such as beech, western red cedar, or Douglas fir as groups within the planting might enable regeneration of all species to take place, by shading the ground enough to control the vegetation sufficiently. Having more than one main tree species gives more flexibility.

Management of the Growing Stock

Woodland management normally aims to maintain the output of timber at a reasonably constant or predictable level. Removal of too much timber at any one time will result in there being less at some other time. Where woodlands are managed by **clear felling**, control can be achieved fairly simply by clear felling a set percentage of the total area every year or every few years, with some adjustment to allow for differences in productivity between different areas and species. Thinning of woods which are not yet ready for clear felling will also be carried out on a regular cycle, and the timber from this will contribute to the total, and should also be relatively predictable (at least in theory).

Where woods are managed as **Continuous Cover**, there will be a need to ensure that approximately the right numbers and sizes of trees are removed [even in cases where harvesting of timber is uneconomic] in order to maintain the woods in a safe and attractive condition and, where timber is important, to ensure that too many trees are not removed at the expense of future productivity. And it is equally important that enough trees are removed to ensure the future stability and continuity of the woodland.

If an owner only holds a small area of woodland, the output of timber may be of little importance, but the same basic approach to management will still be relevant.

In my earlier booklet on Continuous Cover Forestry (Helliwell 2002) I included some graphs showing the numbers of trees of different diameters in areas of forest managed in this way. These approximate to a "reverse J-curve" (Appendices 1 and 2). As one would expect, there are greater numbers of trees in the smaller sizes and fewer in the larger sizes. However, the steepness of the curve will depend on the tree species, the site, and the intensity of management; and the presence of a few bumps in the curve need not be a matter of great concern. Commarmot *et al.* (2005), for example, recorded fewer trees than expected with diameters of around 30cm diameter in a beech forest in Switzerland. This was attributed to the fact that smaller trees tend to grow slowly until the tree canopy becomes open enough for them to put on a spurt of growth, at which stage they "sprint" and put on girth rapidly, and thereby pass through the intermediate size classes relatively quickly. So that, although there are fewer trees in that size class than one might expect, the numbers are sufficient to maintain the passage of sufficient small trees to the larger sizes.

In their book on "Management of Irregular Forests", L'Association Futaie Irrégulière (Susse *et al.* 2011) provide data from six research stands in France over the period 1993-2008. In this they include a graph showing the number of trees per hectare of different stem diameters for each 5-yearly enumeration. This provides an indication of how the growing stock has changed over this period of time. Their records also include the basal area of timber of different quality, which enables them to assess changes in quality and value of the timber in the stand. Trees of less than 17.5cm diameter are assessed separately, along with saplings and seedlings. For most purposes this gives an adequate record of the state of the trees at a particular time. Comparison over a number of enumerations can help the forester to interpret and understand what is happening at any particular time.

The basal area at a sample location can be calculated by measuring all the trees within a sample plot of given area. A total basal area can be obtained very quickly by viewing the stems of trees through an angled prism (used as a "relascope"), from a fixed point. This takes only a couple of minutes, but does not record the sizes of the stems; so it is much quicker, but not quite as useful.

Natural Regeneration

The following diagram attempts to show the main factors involved in natural regeneration and some of the inter-relationships between them.

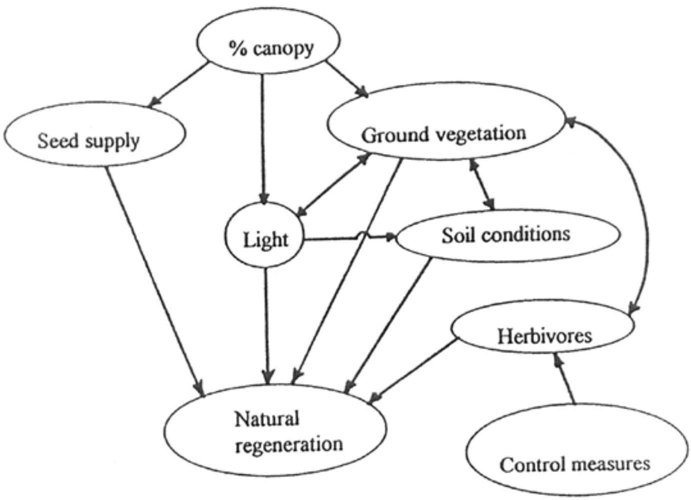

Fig 1. Factors influencing natural regeneration

If there is an adequate supply of seed from appropriate tree species, if there is not too much competing vegetation, if herbivores are not too numerous, and if there is sufficient light reaching the forest floor, then it should be possible to obtain adequate regeneration. There need not be much, or any, seed every year. Many tree species tend to produce large amounts of seed at intervals of several years (known as "mast years” in the case of oak or beech), and it may sometimes be helpful to time thinning operations to coincide with these, so that ideal ground conditions are present at the same time as the seed. However, that would only be necessary if there was particular difficulty in obtaining regeneration, and it is less likely to be necessary under CCF than under shelterwood systems, where it can be crucial. Under CCF, if one “window of opportunity” is missed, any gaps in the tree canopy will gradually become smaller and this will help to prevent the development of a dense growth of brambles or grass, so there should be another opportunity within 5 to 10 years, whereas under a shelterwood system an absence of regeneration at the required time could present a greater problem.

The number of successful seedlings per hectare per year that is required to maintain Continuous Cover is not very large. Extensive carpets of dense regeneration would be likely to require laborious treatment to reduce over-crowding, and are to be avoided as far as possible under CCF. The ideal is to obtain small patches of regeneration scattered irregularly throughout the stand. Seedlings and saplings below a height of 2m should not, as a general rule, occupy more than 15% of the ground at any time. Small patches of regeneration, or even single saplings, can more easily look after themselves than larger areas which contain several saplings per m^2, until they have grown to a size where they are at least worth something as firewood.

This is most likely to be achieved if the density of trees, and hence the amount of light reaching the forest floor, is variable; which is easier to achieve if there is more than one species of tree in the canopy. Regeneration of single-species stands can often be difficult, especially if a carpet of brambles, grass, or bracken has developed. When removing trees, it is desirable to aim for a degree of “patchiness”, with some groups of trees being thinned more heavily than others. Thinning can also be targeted to respond to groups of existing regeneration, if this fits in with other management considerations.

Ideal conditions for natural regeneration are frequently found in places where there is enough light for a small amount of vegetation to grow, or where a tree or group of trees or shrubs have been recently removed, allowing a “window of opportunity” in which tree seedlings can become established before the ground vegetation becomes too dense.

On sites which are suitable, it should be possible to manage light demanding species such as pine, larch, or oak on a Continuous Cover basis. This will typically be on relatively infertile freely -drained sites which do not support more shade-tolerant tree species or a very dense growth of shrubs or herbs.

If the whole of a woodland is thinned too heavily, one of two things might develop:

i. an almost continuous carpet of tree seedlings, or
ii. a dense growth of grass, bracken, or brambles, which prevents tree seedlings from growing.

It is best to avoid this situation, by increasing the amount of light only in small patches, and then taking account of any regeneration during the next periodic intervention. If no regeneration occurs, it will be possible to allow the tree canopy to close again, and then try again.

A similar approach should be used for both shade tolerant and light demanding species, although the basal area of a woodland containing light demanding species will need to be less than that of a woodland containing mainly shade tolerant species.

Daylight in Woodlands

Some understanding of the way in which the amount of daylight varies under woodland conditions will be helpful, together with an understanding of the effect of different amounts and qualities of light on the growth of trees and other plants. There do not appear to be any books which deal with this topic, although a fairly lengthy paper is in preparation (Helliwell *in prep*.) I can recommend the book by Johnsen (2012) as an introduction to light in the natural world. This gives a very clear account of the basic physics of light; which are not by any means simple. Johnsen wrote this book because there was nothing similar for biologists to read; and when it comes to recommending other books on measuring light he notes that "In the end, you are mostly left figuring it out for yourself", as there are few or no texts which are very helpful.

The basic points which are relevant include:

- The human eye adapts very well to changes in light intensity, so it is not possible to assess the amount of light purely by eye.
- The response of plant growth tends to be related to the logarithm of the light intensity; so, although direct sunlight may be about 10 times as strong as diffuse light, direct sunlight for one hour would increase plant growth by a factor of only 2 for that period, not by a factor of 10 (Helliwell 2012).
- Diffuse light from a uniformly overcast sky will be up to 3 times as strong if it comes from directly overhead, as compared to light from close to the horizon.

- The strength of light is proportional to the cosine of the angle at which it strikes a flat surface (such as a leaf, a sward of grass, or a tree canopy). This means that the sun at mid day in June in southern England will be almost as strong as the sun at the equator on that day (or about 87% as strong as the sun in Miami or Dubai on that day); and the day length is longer in England, so the total amount of radiation in June can be greater than in Kampala. The temperature might be greater in Kampala, but the amount of incoming solar radiation will be very similar, if the cloud conditions are the same.
- Chlorophyll absorbs more light in the blue and red spectra than in the green wavebands (which is why plants look green). This can affect the quality of the light in woodlands, by reducing the ratio of red to far-red light and this change can be detected by many types of plant, including trees such as oak, which respond to the reduced proportion of red light as a signal to grow taller and thinner (see Helliwell 2011). The overall increase in biomass of the plant will be related to the total amount of light, and is unlikely to be affected by a change in the proportion of red and far-red light, but the shape of the plant may be altered.
- When there is a uniform cover of cloud, the diffuse light from the sky will be similar from all points of the compass.
- On days with a thin cloud cover there is likely to be more diffuse light from the sky than there would be from a clear blue sky, as water droplets reflect more sunlight than does air, but under a thick cloud cover much of the light is reflected back into space or is lost within the cloud and less light will reach the ground.
- Leaves will normally transmit a small amount of light, although very little light will be transmitted if it has to pass through 2 or 3 leaves. Leaves will also reflect some light. The amount that is reflected is relatively small, compared with the amount reflected by snow or a white painted wall, but on a sunny day it may be significant.

The amount of light that is reflected by a tree will be related to the colour of the foliage and to the density of foliage at the edge of the crown. A neatly trimmed beech hedge, for example, is likely to reflect significantly more light than a freely grown beech tree, where much of the light will disappear into the crown of the tree and be effectively lost.

- The amount of light beneath a woodland canopy can be less than 1% of the amount above the canopy in an unthinned plantation of spruce, about 5% in oak woodland, and perhaps 7% in birch woodland.

These facts are relevant in a number of ways. Under Continuous Cover, the amount of direct sunlight received by a tree seedling will be small. It will be restricted to relatively short periods when the sun is not obscured by clouds and is also in the right place to shine through a gap in the tree canopy. Even on sunny days, the main source of light within woodland will be diffuse light from the sky. In this respect, the aspect of a site is of no relevance, although southerly aspects might (in the northern hemisphere) be warmer than northerly aspects and this may affect growth (possibly adversely if there is a shortage of soil moisture).

Limitation of growth of trees at high latitudes, such as in Northern Finland or Alaska, is not likely to be related to a shortage of daylight in the growing season, but to low temperatures and a short growing season and, often, a shortage of available moisture in the foliage, particularly after mid-day and especially if the soil temperature is low (which limits the ability of roots to take up water from the soil).

It should also be stressed that "side light", which seems to come into any discussion about natural regeneration in woodlands, is not of very much use. Firstly, it comes from the weakest source, and secondly, it strikes the ground at a low angle. When both of these factors are considered (Helliwell 2012) it is evident that light from 1^{o} above the horizon is almost completely useless (even though the human eye tells you differently).

Daylight from an angle of 10° above the horizon will be about 8% as useful as that from the zenith, and light from 20° above the horizon is about 19% as useful. So there would need to be a very large amount of "side light" to provide as much light as a reasonably sized gap in the tree canopy directly above a seedling.

While on the subject of daylight, I would warn against the use of opaque plastic tree shelters in woodlands, as some of these will reduce the amount of light by more than 80% and the enclosed tree will have little chance of survival in locations which are already shaded. Even clear plastic, or wire or plastic mesh will reduce the amount of light to some extent (Helliwell and Rowley 2011) and should not be used in locations where the amount of light is already marginal.

Costs and Returns

Costs can be very variable, and will depend, amongst other things, on the productivity of the site and the tree species, the presence of unwanted species such as *Rhododendron ponticum*, Japanese knotweed, or Himalayan balsam, the need for fencing, amount of public access, and the size, shape, and accessibility of the woodland.

The current condition and state of development of the woodland will also have a large effect on current costs.

In small woodlands, the owner can often do much of the necessary work at little cost other than his or her time.

In round figures it is likely that, if all work has to be paid for, the range of costs is likely to vary between about £100 per hectare per year in relatively extensive woods of low productivity in rural situations with little or no public access, to as much as £2,500 per hectare per year for woodlands in inner city situations on fertile soil and with a very large amount of public usage. A "typical" figure (if there can be such a thing) for the management of woodland in a suburban area might be around £750 per hectare per year, and perhaps £250 in rural areas.

There may or may not be some income from sales of timber which, in suitable circumstances, may yield a net profit, particularly if there are reliable local markets for this timber. There are also likely to be other benefits, in terms of the contribution of the woodland to the landscape, nature conservation, recreation, clean water supply, etc., but it may be difficult to obtain any quantifiable income from these benefits. They may be of some indirect value to the owner, but it should be emphasised that it is extremely difficult to obtain a direct profit from small woodlands. Most will operate at a financial loss, and will need to be subsidised by income from other sources; which may or may not be linked to the woodland.

Concluding Comment

For anyone who has previously managed even-aged woodlands or forests, management without the underlying concepts of age and area can be rather strange and possibly daunting. But equally, it can be a challenge; and for anyone who has not managed woodlands before it is less likely to seem strange.

The main requirement when marking any tree for removal is to keep all the main objectives in mind, and then to select each tree with a clear understanding of why that particular tree is to be removed rather than some other tree. It might be mentally tiring, after a few hours, but is rarely boring; and the development of the woodland and the success of the enterprise will depend on these choices. You might see it as a being rather like conducting an orchestra. You might have the best instrumental players or trees in the world, but if you conduct the orchestra or the woodland without empathy you will not make fantastic music or a successful uneven-aged woodland. This ability will come from a combination of basic knowledge, advice, and experience.

Early stage of transformation from even-aged Sitka spruce to an irregular structure. Northern England.

Self-sown ash and sycamore on abandoned land, in need of active management if the road is to be safe to use in windy weather.

Scots pine of two age groups only. Will probably become even-aged again as the older pines die, are blown down, or removed for timber or some of the older trees might be suitable for retention, to form the beginnings of a fully uneven-aged stand.

Uneven-aged conifers in Southern England, in a rather tight conformation.

Uneven-aged Norway spruce.

Edge of Norway spruce plantation, with young trees where there is more light at the edge of the plantation.

Glossary

Basal area	The basal area of a stand of trees is the sum of the cross sectional area of all the trees of measurable size, usually measured at a height of 1.3m. (This can be used to estimate the volume of standing timber by the use of a conversion factor for that woodland, if such a conversion factor is known from previous records, or if it can be estimated.)
Clear felling	Felling all the trees in a defined area at the same time. (Areas of less than about 0.25ha might be regarded as group felling or perhaps as small scale clear felling.)
Compartment	An area of forest or woodland which is suitable as a unit for long term management and record keeping.
Coppice	Woodland which is managed by cutting trees to ground level and allowing them to produce new shoots. (Many broadleaved trees, but only a few conifers, are capable of doing this.)
Exotic trees	Species of tree which do not occur naturally in a particular region.

Light demanding trees	Trees which will not grow well under heavily shaded conditions.
Management	The overall control of everyday activities and long term planning associated with woodlands.
Natural regeneration	Trees which arise as a result of natural seed-fall and growth.
Regeneration	Either planted or naturally grown young trees.
Relascope	A simple instrument used to estimate the basal area of a stand of trees.
Rotation	The interval between successive crops of trees, in even-aged systems.
Selection system	Silvicultural system involving the periodic removal of selected individual trees or groups of trees on a perpetual basis.
Shelterwood	Silvicultural system involving the retention of a partial tree canopy during a period when new trees are becoming established, with the older trees being removed in one or more subsequent stages, leaving a new crop of younger trees. This may be implemented uniformly over the whole compartment or irregularly, in groups (which may act as a transition between even-aged and uneven-aged management).
Silviculture	The art and science of tending and regenerating forests and woodlands.

Stand	A discrete area of trees, possibly bounded by roads, streams, or woodland of a different age or type. May or may not form a compartment.
Thinning	Removing some trees to benefit others and/or to obtain timber, leaving the majority of the trees to carry on growing.
Top height	The average height of the hundred trees of largest diameter per hectare (in even-aged woodland)
Windthrow	The effect of wind in causing trees to fall.
Yield class	The maximum mean annual volume increment (in m^3 per hectare) of an even-aged stand of a particular tree species on a particular site.

Contacts and Sources of Advice

Arboricultural Association	www.trees.org.uk
Continuous Cover Forestry Group	www.ccfg.org.uk
Forestry Commission	www.forestry.gov.uk
Institute of Chartered Foresters	www.charteredforesters.org
Royal Forestry Society of England, Wales, and Northern Ireland	www.rfs.org.uk
Royal Scottish Forestry Society	www.rsfs.org.uk
Small Woods Association	www.smallwoods.org.uk
Society of Irish Foresters Glenealy, Co.Wicklow, Ireland	sif@eircom.net
Treesource bookshop	www.treesource.co.uk

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Appendix 1

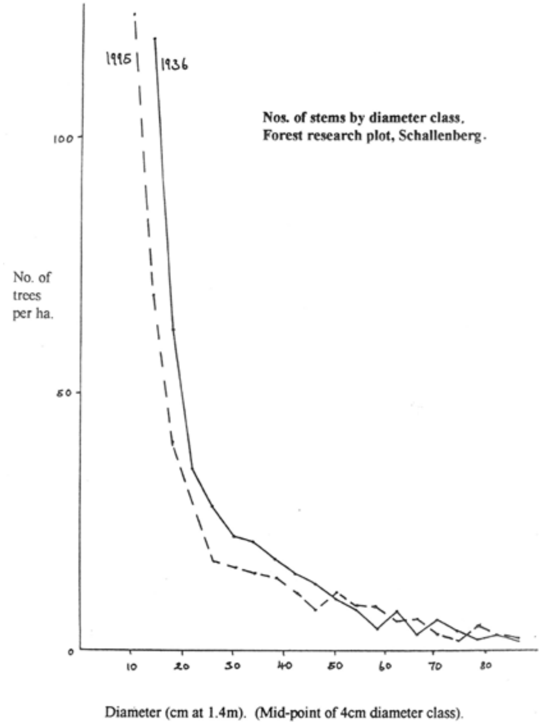
Extract from sample plot data, Schallenberg

Research plot 02-047. Plot size 2.46ha.
(Data supplied by the Swiss Federal Institute for Forest Research, via Mark Yorke, with additional comments by him.)
(All figures are per hectare.)

Year	Species	Main crop after thinning				Thinnings			Total Current annual increment (m³/ha/yr)
		No.	Mean diam. (cm)	Basal area (m²)	Volume (m³)	No.	Mean diam. (cm)	Volume (m³)	
1936	Spruce	44	27.2		31	2	21.6		
	S. Fir	478	26.8		350				
	Beech	83	32.0		87				
	Alder								
	Sorbus	1	8.5						
	Total	606		36.2	468	52		50	14.3
1951	Spruce	48	27.7		35	4	39.8		
	S. Fir	465	26.8		335	55	27.0		
	Beech	90	30.5		86	7	32.3		
	Sorbus	1	9.8						
	Total	604		35.7	457	66		54	11.1
1976	Spruce	65	26.2		43	10	16.1		
	S. Fir	384	30.9		385	53	38.5		
	Beech	84	27.4		64	20	31.5		
	Total	533		37.4	493	83		109	13.6
1995	Spruce	76	25.0		45	13	31.3		
	S. Fir	258	33.7		315	74	39.0		
	Beech	93	24.2		53	15	36.5		
	Oak	1	8.9						
	Total	428		31.0	413	102		160	14.8

Notes:

1. Thinning cycles have varied between 5 and 11 years, hence the variation in thinning yields.
2. Volumes are only measured in excess of 7cm diameter over bark, but each inventory also includes an assessment of the regeneration below 7cm diameter.
3. Additional measurements recorded at each inventory of the sample plot include a) top height, maximum diameter, height/diameter ratio of dominant trees, and height corresponding to mean basal area, of main crop and thinnings; b) total stand volume produced to date; average basal area; basal area increment; c) number of trees (main crop after thinning and thinnings) within 4cm diameter classes, from which a reverse-J curve can be derived (Figure 2).



4. Thinning yield of logs in excess of 18cm top diameter. The mean diameter of the spruce and silver fir combined can be calculated from the above table. Using Forestry Commission Mensuration Handbook (1975) and the stand underbark volume assortment table No.53, the percentage of the the thiining volume falling within the sawlog category can be estimated (very approximately, as this table is based on data from stands of a different type).

Thinnings (per ha)

Year	Species	Mean diam. (cm)	Total vol. (m3)	% in excess of 18cm diam.
1936	Norway spruce & silver fir	30.4	33	75
1951	Ditto	25.0	47	61
1976	Ditto	28.4	88	71
1995	Ditto	37.8	139	84

5. Mean tree size (after thinning) and harvested timber

Mean tree size (m^3)

Year	Species	Whole stand	Harvested timber
1936	Spruce S. Fir Beech	0.70 0.73 1.05	0.50 1.03 0.94
1951	Spruce S. Fir Beech	0.73 0.72 0.95	1.50 0.74 1.14
1976	Spruce S. Fir Beech	0.66 1.00 0.76	0.20 1.62 1.05
1995	Spruce S, Fir Beech	0.59 1.22 0.57	1.00 1.70 1.40

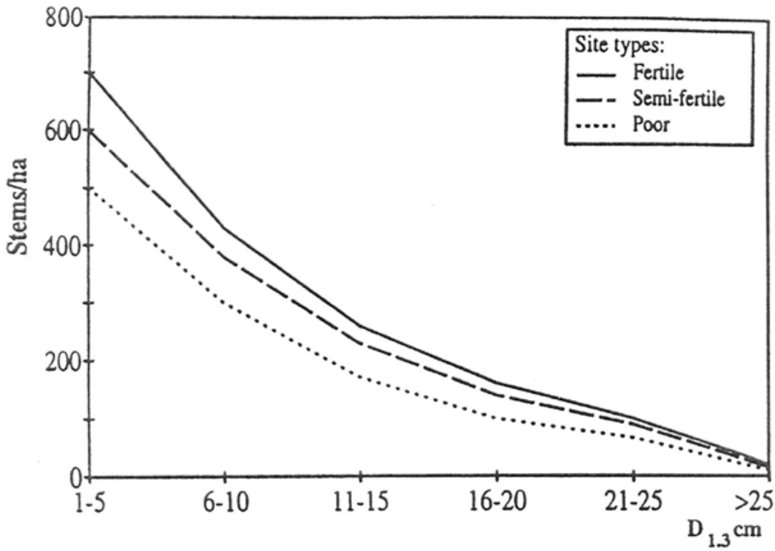
(Note that the mean tree size of the harvested timber frequently exceeds that of the stand as a whole.)

6. The silver fir is *Abies alba*

   The spruce is *Picea abies*.

Appendix 2

Characteristics of Continuous Cover forest in Southern Finland (after Norokorpi, Lähde, Laiho, and Saksa 1997)



Target stem number distribution on different site types, after cutting.

Site type	Dominant height m	Basal area m^2/ha	Volume m^3/ha
Fertile	21	17	135
Semi-fertile	18	15	100
Poor	15	13	70

Dimensions of the target growing stock on different site types.

Appendix 3

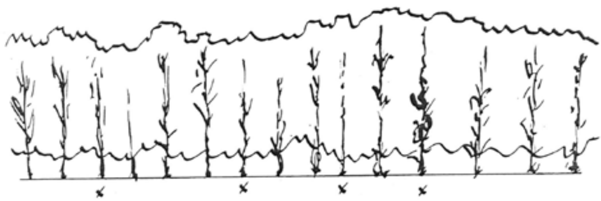
Diagrams showing woodland transformation

The woodland in diagram No.1 is assumed to be of medium age and to have been managed in a normal manner for even-aged woodlands, with some periodic thinning. If there had been no thinning for many years, the initial stages might require less intensive thinning, relatively frequently, before diagram No.2 is achieved.

Trees to be removed at each stage are subscripted **x** on the diagrams.

Diagram No.1 Even-aged woodland at commencement of process

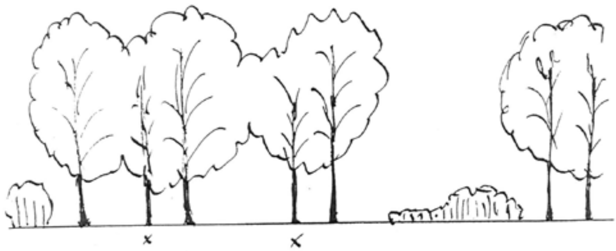
Diagrams No.2 to 9 The same woodland at subsequent interventions, most of which are likely to be at intervals of about 5 years, spanning a period of some 40 years or more.

1. 

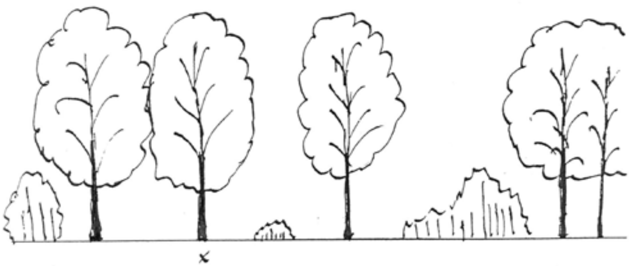
2. 

3. 

4.



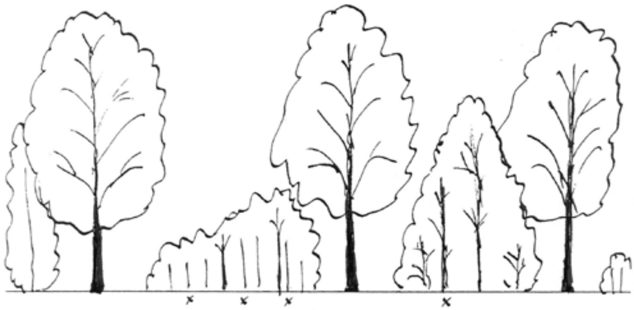
5.



6.

7.

8.



9.