Cyfoeth Naturiol Cymru
Natural Resources Wales

Good Practice Guide

Forest Resilience Guide 1
Improving the structural diversity of Welsh woodlands

Date Published: March 2017

GPG 6

Document Owner: Sustainable Land Management Team

Version History:

Document Version	Date Published	Summary of Changes
1.0	March 2017	Document created. (Note: a previous version "*Guidance for the use of silvicultural systems to increase woodland diversity*" was published by Forestry Commission Wales in February 2012).

Notice

All Natural Resources Wales Guidance Notes are covered by copyright. Please be aware that the use of any material within this document must be carried out in line with the NRW Copyright Statement and Disclaimer Standard Notice, a copy of which is available from the Access to Information Team on accesstoinformationteam@naturalresourceswales.gov.uk. Any re-use of this information will be determined by the Re-use of Public Sector Information Regulations 2005, again details available from the Access to Information Team**.**

Published by:

Natural Resources Wales
Cambria House
29 Newport Road
Cardiff
CF24 0TP
0300 065 3000 (Mon-Fri 8am-6pm)
enquiries@naturalresourceswales.gov.uk
www.naturalresourceswales.gov.uk

© Natural Resources Wales
All rights reserved. This document may only be reproduced with the written permission of Natural Resources Wales

Crynodeb gweithredol

Mae'r Canllaw Arferion Da hwn ar gyfer pob rheolwr coedwigoedd a choetiroedd yng Nghymru. Mae'n un o dri chanllaw sy'n rhoi gwybodaeth a chyngor i gefnogi'r broses o wneud penderfyniadau ar gyfer rheoli'r amrywiaeth o goetiroedd Cymru, ac felly eu gwydnwch.

Mae'r canllaw hwn yn ystyried amrywiaeth strwythurol, a dylid edrych arno ochr yn ochr â'r ddau ganllaw arall yn ymwneud ag amrywiaeth rhywogaethol a genetig. Mae'r argymhellion a nodir yn y canllaw hwn yn cefnogi cydymffurfio â Safon Coedwigaeth y Deyrnas Unedig, sef y meincnod ar gyfer rheoli coedwigoedd yn gynaliadwy ar draws y DU.

Oherwydd natur dechnegol y canllaw hwn, darperir crynodeb gweithredol yn Gymraeg ac yn Saesneg, ond dim ond yn Saesneg mae'r brif ddogfen ar gael, yn unol â'n Safonau Cymraeg.

Mae mathau arbennig o goetiroedd yn tueddu i gynnwys strwythurau nodweddiadol. Mae'r rhain yn rhannol naturiol, sydd wedi'u dylanwadu gan oddefiant cysgod y prif rywogaethau coed a'r patrymau amharu nodweddiadol megis gwynt – taflu, hunan-deneuo neu golli yn sgil ymosodiad pla, ac o ganlyniad i arferion rheoli yn y gorffennol yn rhannol. Yng Nghymru, fel yng ngweddill y DU, mae systemau clirio coedamaeth yn dal i ddominyddu'r ffyrdd o reoli coedwigoedd, er yn y blynyddoedd diweddar mae cynnydd wedi bod yn nifer y systemau effaith isel a ddefnyddir, ac erbyn hyn mae nifer o safleoedd enghreifftiol yng Nghymru, yn y sector breifat a chyhoeddus fel ei gilydd. Mewn coetiroedd llydanddail a reolir, mae'r darlun yn wahanol gan fod rhyw fath o system orchudd barhaus yn cael ei defnyddio fel arfer. Fodd bynnag, mae angen gwella amrywiaeth strwythurol cyffredinol coetiroedd Cymru o hyd.

Bydd gwella amrywiaeth strwythurol yn cynyddu gwytnwch coetiroedd Cymru i effeithiau'r newid yn yr hinsawdd, yn ogystal â gwella canlyniadau a chreu cyfleoedd ar gyfer bioamrywiaeth, cynaeafu a marchnata cynnyrch pren a di-bren, a hamdden.

Yn y canllaw hwn, rydym yn crynhoi'r prif fathau o systemau rheoli coedamaeth, gan gynnwys systemau clirio coed a systemau coedamaeth bach eu heffaith megis coedwigaeth gorchudd di-dor, cwympo coed llannerch fach, tocio, coedwigaeth cylchdro byr, ac ymyrraeth leiaf. Mae'r canllaw yn esbonio arwyddocâd pob system coedamaeth o ran y cyfleoedd i wella amrywiaeth strwythurol, a'r effaith y cânt ar wella'r amrywiaeth o fuddion, neu wasanaethau ecosystem, a ddarperir gan goetiroedd. Mae siart lif i helpu'r broses o wneud penderfyniadau ynglŷn â'r system coedamaeth fwyaf priodol wedi'i chynnwys.

Mae pennod olaf y canllaw yn gwneud argymhellion ynghylch sut y gallwn ehangu amrywiaeth strwythurol coetiroedd Cymru, ac mae'n nodi'r camau blaenoriaeth ar gyfer mathau arbennig o goetiroedd. Mae hefyd yn pwysleisio pwysigrwydd teneuo fel rhan o ymyrraeth reoli i gynyddu amrywiaeth strwythurol, a'r angen i gael mynediad priodol ac isadeiledd er mwyn hwyluso hyn.

Er mwyn cynyddu amrywiaeth strwythurol coetiroedd yng Nghymru, mae angen ehangu'r amrediad o systemau coedamaeth yr ydym yn eu defnyddio ar hyn o bryd. Bydd cynyddu'r

amrywiaeth o rywogaethau coed yn gwneud ein coetiroedd yn fwy gwydn i'r newid yn yr hinsawdd, yn ogystal â gwella canlyniadau i bobl a'r amgylchedd.

Executive summary

This Good Practice Guide is intended for all forest and woodland managers in Wales. It is one of three guides that provide information and advice to support decision-making to manage the diversity and hence resilience of Welsh woodlands.

This guide looks at structural diversity and should be considered alongside the other two guides on species and genetic diversity. The recommendations in this guide support compliance with the UK Forestry Standard (UKFS), the benchmark for sustainable forest management across the UK.

Due to the technical nature of this guide, an executive summary is provided in both Welsh and English but the main document is available in English only, in accordance with our Welsh Language Standards.

Particular woodland types tend to have characteristic structures. These are partly natural, influenced by the shade tolerance of the major tree species and typical disturbance patterns such as wind-throw, self-thinning or loss through pest attack, and partly the result of past management practices. In Wales, as in the rest of the UK, clearfell silvicultural systems still dominate conifer forest management although in recent years there has been an increase in the use of low impact systems and there are now a number of exemplar sites in Wales, both in the private and public sector. In managed broadleaved woodlands, the picture is different as some form of continuous cover system is usually used. However, the overall structural diversity of Welsh woodlands still needs to be improved.

Improving structural diversity will increase the resilience of Welsh woodlands to the impacts of climate change and also improve outcomes and create opportunities for biodiversity, the harvesting and marketing of timber and non-timber products, and recreation.

In this guide we summarises the main types of silvicultural management systems including clearfell and Low Impact Silvicultural Systems (LISS) such as Continuous Cover Forestry, Small Coupe Felling, coppicing, Short Rotation Forestry and Minimum Intervention. The guide explains the significance of each silvicultural system in terms of opportunities for improving structural diversity, and the impact they have on the range of benefits, or ecosystem services, that woodlands provide. A flow chart to aid decision making about the most appropriate silvicultural system is provided.

The final chapter of the guide makes recommendations about how we can improve the structural diversity of Welsh woodlands and identifies priority actions for particular types of woodland. It also emphasises the importance of thinning as a management intervention to increase structural diversity, and the need for appropriate access and infrastructure to facilitate this.

To increase the structural diversity of woodlands in Wales, the range of silvicultural systems we currently use needs to broaden. Improved trees species diversity will make our woodlands more resilient to climate change, and also improve outcomes for people and the environment.

1 Overview

This Good Practice Guide is intended for all forest and woodland managers in Wales. It is one of three guides that provide information and advice to support decision-making to manage the diversity and hence resilience of Welsh woodlands.

This guide looks at structural diversity and should be considered alongside the other two guides on species and genetic diversity.

The recommendations in this guide support compliance with the UK Forestry Standard (UKFS), the benchmark for sustainable forest management across the UK and the standard against which compliance is evaluated for felling licences and forestry Environmental Impact Assessments (EIAs).

UKFS Requirements are split into two levels: **Legal** and **Good forestry practice**. Legal requirements are minimum statutory obligations, contravention of which could lead to prosecution. Good forestry practice requirements are non-statutory, but must be adopted to meet the UKFS. The information and advice in this guide will help forest and woodland managers meet the Good forestry practice requirements of the UKFS.

Recent legislation in Wales has recognised the need to embrace sustainability and emphasised the importance of resilience in achieving this. *The Well-being of Future Generations (Wales) Act 2015* aims to embed the principle of sustainable development and introduces seven Well-being Goals for Wales. The Act makes it clear that is about achieving all of the goals as an integrated set, not just a selected one or two in isolation, if multiple benefits are to be realised.

One of the well-being goals is "**a *resilient Wales***":

"*A nation which maintains and enhances a biodiverse natural environment with healthy functioning ecosystems that support social, economic and ecological resilience and the capacity to adapt to change (for example climate change)"*

One of the ways woodlands can be made more resilient is by improving their structural and species diversity and managing their genetic diversity. The need to accelerate woodland diversification is a key recommendation in Welsh Government's *Woodlands for Wales* strategy and supporting Policy Positions.

Positive actions to manage diversity can be taken at different scales: some measures can be taken at a stand level, whereas for others diversity at a whole woodland level can to be tackled. Both approaches, when combined strategically and at a landscape level, can make a significant contribution to healthier and more resilient woodland ecosystems.

2 Introduction

2.1 Characteristics of structural diversity

Good structural diversity is characterised by some, or all, of the following features:

- within-stand age-class diversity, i.e. more than one storey of trees
- a combination of different structures at different scales

- evidence of all stages of tree development and phases of growth (i.e. from establishment to early and late pole stage, opening up thinnings, advance open thinning, final crops and seed crops)
- variation in the size and extent of clearfelling coupes
- a mixture of species suited to the habitat, with different characteristics and levels of shade
- variable crop density (a function of individual tree species and the degree of thinning)
- variation of tree diameters
- presence of standing and fallen deadwood
- areas of open ground within forest environments
- diverse habitats of native and non-native trees, with a diversity of flora and fauna to improve overall ecological value.

Each woodland has its own character and will vary according to the nature of the woodland, its features, and the management objectives being followed. These characteristics may be evident at different scales: within a single forest, between woods locally, or across connected landscapes. Particular woodland types tend to have characteristic structures. These are partly natural, influenced by the shade tolerance of the major tree species and typical disturbance patterns such as windthrow, self-thinning or loss through pest attack, and partly the result of past management practices.

Figure 1: Current status of Welsh woodlands[1]

The vast majority of our managed woodland is…	***Very little of our woodland is…***
planted single species, single aged (over half is coniferous) predominantly manged on clearfell & restock regime	***managed as a forest ecosystem using natural processes as a basis for management with tree species diversity at a variety of scales***
We need a wider spectrum of forest management systems in use and a reduction in the reliance of single species crops at a range of scales – stand, forest and landscape.	

The challenge is to manage the structural (and tree species and genetic) diversity of Welsh woodlands so they are more resilient in the future.

[1] Adapted from "Policy Position in support of *Woodlands for Wales*, the Welsh Assembly Government's strategy for woodland and trees. Welsh Assembly Government (September 2010) - http://gov.wales/docs/drah/publications/130424-welsh-woodland-en.pdf

2.2 The importance of improving structural diversity

Plate 1: Structural diversity at a stand scale – a mix of species of different ages and densities.

Contemporary timber harvesting and processing favours an economy of scale reliant on uniformity and large-scale management. Whilst the introduction of varied regimes will require new ways of working, the reduction in risks can justify the costs and provide a good return on investment. Improving structural diversity can be expected to:

- increase the resilience of Welsh woodlands to the impacts of climate change
- increase the range and continuity of woodland habitats and biodiversity
- increase the range of timber and non-wood products that can be harvested and marketed and help ensure continuity of timber supply due to the presence of a range of different age classes
- improve the visual impacts of forests at the landscape and macro scale, and improve recreational opportunities and potential new income streams
- contribute to a reduction in chemical use in the establishment phase including plant protection against hylobius.

2.2.1 Increasing resilience to climate change

It is predicted that climate change in Wales will result in an increasing risk to trees from pests and disease, as well as from changes to weather patterns. Changes in the seasonal distribution of rainfall may cause more frequent summer droughts and winter flooding and, although the climate will become warmer, exposure will remain a limiting factor. Extreme weather events such as high rainfall, storms, and high winds are expected to become

more frequent. There could be increased growth rates of some species, particularly in west Wales where the climate becomes warmer and soil moisture does not become limiting[2].

Greater structural diversity will create more resilient woodlands which, in the medium to long term, will reduce commercial and operational risks from climate change in three ways:

- A stand and / or woodland with a range of age-classes and species is at less risk of severe damage from a particular incidence of pests or disease. Severe damage typically comes from an agent that affects a particular species and / or stage of tree growth.
- The development of stronger trees is likely throughout the stand, reducing the risk of windblow.
- When windblow does occur, it is less likely to cause severe damage to stands with structural diversity. Even-aged woodlands are more susceptible to catastrophic damage arising from severe storms and windblow damage will often continue to spread through even-aged stands until it reaches a windfirm boundary ("green edge").

2.2.2 Improving woodland habitats and biodiversity

Many species are dependent on or closely associated with woodlands. These include European Protected Species, species identified by Welsh Government under Section 7 of the Environment (Wales) Act 2016, and those listed in the UKBAP and the Wildlife and Countryside Act 1981. Management for these protected and priority woodland species will usually require some intervention to create or maintain conditions for them to thrive.

All silvicultural systems, when appropriately located and managed correctly, have the potential to support specific species. For example, large scale clearfelling and restocking provides vital nesting sites for Nightjars. However, in most cases, increasing structural diversity through the adoption of a range of low impact systems, will provide the greatest benefits for woodland species.

Lower impact silvicultural systems can provide:

- greater habitat stability with fewer and less intense changes arising from harvesting operations
- more opportunities for a well-developed understorey and ground flora achieved through regular thinning interventions
- greater protection for forest soils and watercourses
- less disruption to natural functions (e.g. reduced fluxes of water flow).

2.2.3 Improving timber and wood fibre production

A woodland that is managed to promote structural diversity will often also provide a wider range of timber and non-timber products, allowing greater flexibility with regard to harvesting at desired log sizes, and the ability to take advantage of favourable market conditions. It is important that a desire to improve structural diversity is balanced with short and long term practicalities and market demand. There is a risk that aiming for overcomplicated structural diversity may hamper future timber production but with careful planning, appropriate advice, investment in infrastructure and continuity of management much can be achieved.

[2] Ray D.(2008) Impacts of Climate Change on forests in Wales. Forestry Commission Information Note 301.

2.2.4 Improving woodlands for people

The management of woodlands using lower impact silvicultural systems that promote structural diversity will tend to result in fewer landscape ‘shocks’ like those associated with large clearfells.

Adopting a range of silvicultural systems results in a more varied landscape with less visual monotony; characteristics that are better suited to recreation and public enjoyment of the natural environment. Structurally diverse woodlands are more likely to support the development of new income streams such as mountain biking centres, visitor facilities, and woodland events.

Plate 2: Structural diversity creates woods that are good for people.

2.3 The link to Silvicultural Systems

The choice of silvicultural system dictates how crops are maintained, harvested, and replaced and is the primary factor influencing the structural diversity of a forest. A silvicultural system has three main features[3]:

- the method of regeneration of the individual crops constituting the forest
- the form of the crop produced; and
- the orderly arrangement of the crops over the whole forest, with special reference to silviculture and protective considerations and efficient harvesting of produce.

We use a range of silvicultural systems in Wales, including clearfell and a range of Low Impact Silvicultural System (LISS). Typically, forests managed solely by a clearfell silvicultural system are characterised by poor structural diversity with uniform aged crops, limited or no diversity of structure within a stand and sometimes whole forest blocks using the same system. In contrast, forests managed using one or more of the range of LISS tend to be more structurally diverse, and therefore more resilient.

In Wales, as in the rest of the UK, clearfell and restocking systems still dominate conifer forest management. However, in recent years there has been an increase in use of low impact systems, which in many cases have actively targeted the break-up of even-age forests originally planted over short time frames. There are now a number of exemplar LISS sites in Wales both in the private and public sector such as Bryn Arau Duon, Cwm Berwyn and Clocaenog forest. However, the overall structural diversity of Welsh woodlands still needs to be improved.

In managed broadleaved woodlands the picture is different. Here, where there is active management, some form of continuous cover system is usually used. However it is the prevalence of unmanaged broadleaf woods that presents a challenge in Wales, as a lack

[3] Matthews JD. (1989). *Silvicultural systems.* Oxford University Press.

of proper management can also lead to poor structural diversity, particularly in small fragmented woods which are accessible to livestock.

The table in **Appendix 1** identifies the broad habitat or succession of habitats that are likely to occur within a range of silvicultural systems.

3 Choosing the appropriate silvicultural management system

3.1 Introduction

Clearfelling and restocking is usually considered the simplest and cheapest silvicultural system with the lowest management input. As a result, investment in timber-harvesting machinery, equipment and skills has been largely directed at those suited to this approach. Similarly, the modern timber processing industry, as it exists in Wales, has largely developed to utilise and market products from clearfelling systems.

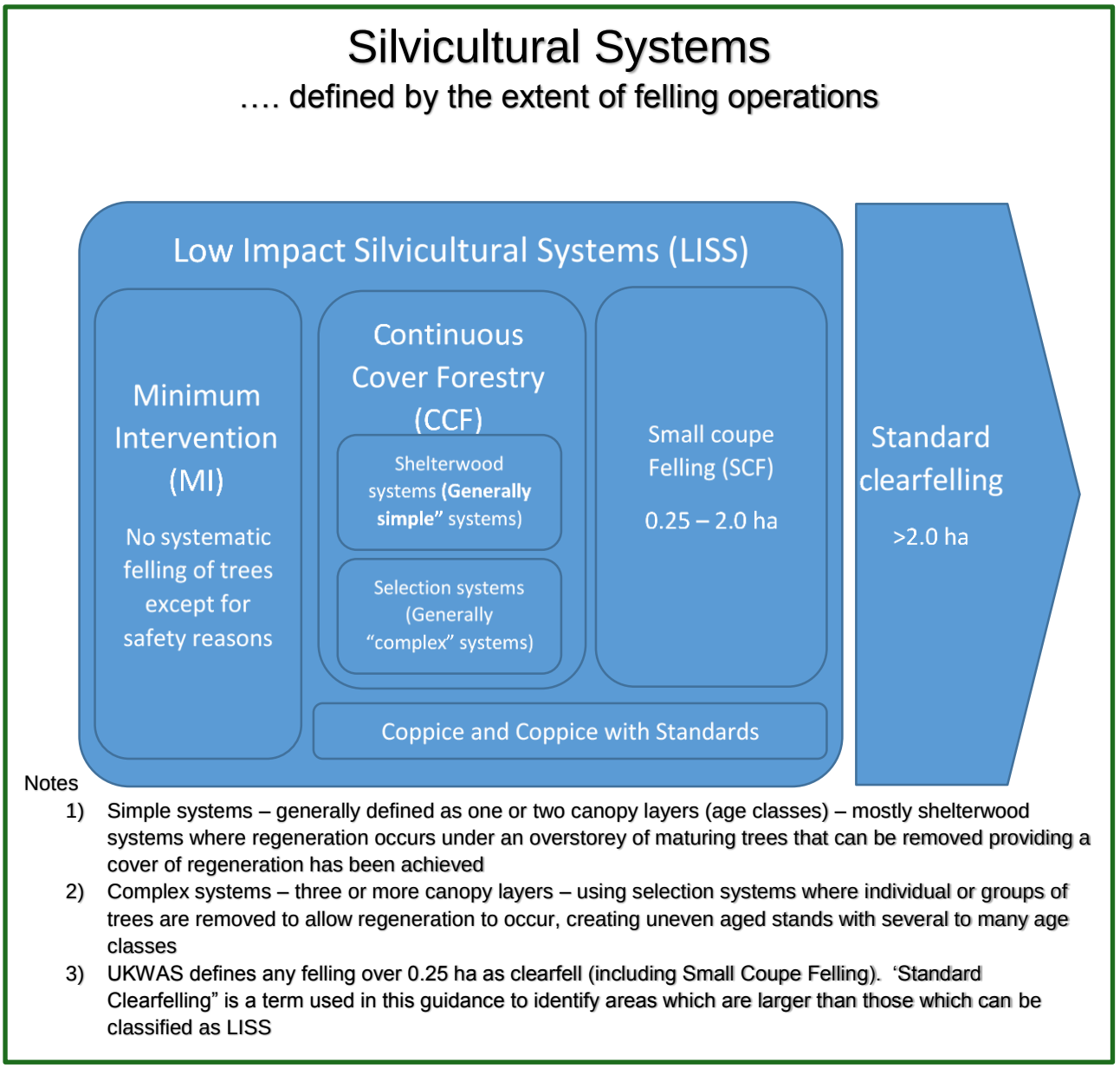
Clearfelling remains the management system of choice for many, but a commitment to improve structural diversity and resilience requires consideration and adoption of lower impact silvicultural systems.

3.2 Silvicultural system management options

This section summarises the main types of silvicultural management systems to choose from and how they may contribute to woodland management objectives and to improving structural diversity. Site specific information will be invaluable: features such as soil type, terrain, existing tree species, exposure and surrounding woodland will always influence the choice of silvicultural system but the predicted effects of a changing climate should not be overlooked. Further sources of information on climatic predictions can be found in **Appendix 2**.

You should not restrict yourself to a single system. A range of silvicultural management systems are likely to be appropriate for different areas of larger forests. You should also be adaptive in your approach and be prepared to change the selected management system if it does not meet expectations.

Figure 2: Silvicultural systems defined by the extent of felling operations



3.3 Standard Clearfelling and Restocking

Clearfelling of larger coupes over 2 hectares may be the best silvicultural option and may be preferred where:

- current tree species are unsuitable for LISS, or not the desired future species, and clearfelling is the only practical option for change
- in mature conifer crops where transformation to another system would be difficult and there is a risk of unacceptable levels of wind-blow
- deforestation is necessary to reinstate priority open habitats such as deep peats
- control of invasive tree species (such as western hemlock) requires early and complete removal rather than long-term and expensive control measures
- maintaining specific habitat conditions for priority species that require clearfell conditions (e.g. Nightjar) and sufficient habitat cannot be secured elsewhere in the forest
- overriding economic limitations prevent transformation to other management systems

- terrain limitations restrict use of LISS and infrastructure cannot be put into place to allow the regular interventions required
- structural diversity is best created at a large scale.

3.4 Low Impact Silvicultural System (LISS)

This term covers a range of silvicultural systems which aim to minimise the environmental impact of forest management operations. The selection of a LISS will depend on the desired outcomes and the nature of the site. Below are overviews of some of the more commonly used systems; further information can easily be found for all of them (see Appendix 2).

3.4.1 Continuous Cover Forestry (CCF)

This is an approach where the forest canopy is maintained, at one or more levels without clearfelling. There are no standard prescriptions and flexibility is key when adopting a CCF system, but all approaches have significant potential to increase structural diversity. Whilst the use of CCF has increased in recent years it is still not widespread. This type of forestry does require a higher degree of skill and flexibility in management but it doesn't have to be complex and can help achieve a wide range of objectives. When considering this approach the following issues need to be considered:

- Is CCF appropriate to achieve the management objectives for your woodland?
- Is the site suitable (soil, climate) or can it be adapted (by improved access, other infrastructure)?
- Are the species suitable for the site and CCF methods?
- Is the site suitable for CCF but the current species are not?
- How easily can the stand be converted?
- Would it make better economic or silvicultural sense to start again? If so, consider replanting the site with suitable species and converting to CCF in the next rotation.
- Does the terrain (slope, roughness, elevation, exposure) limit choice? Can anything be done about it?
- What infrastructure is required to make the site accessible and what is the cost of doing this?
- Which areas should be prioritised for CCF conversion?

CCF can be sub-divided into 'simple' and 'complex' systems[4]. A simple structure will be produced by uniform or group shelterwood systems in which there will be one or two canopy layers. These systems do not have to be complex to manage and a strip felling (or strip shelterwood) may be a relatively simple system to manage and be suitable for steep terrain. A complex structure may result from an irregular shelterwood or a selection system where three or more canopy layers of trees are maintained. A good simple breakdown of the types of systems to potentially use is as set out inForestry Commission Information Note 29[5].

For most existing conifer sites suited to CCF, a simple system is likely to be appropriate at least initially. Simple CCF may, however, be considered as the first phase in the transition

[4] Kerr G, Mason BM. (2004). *Transforming Even-aged Conifer Stands to Continuous Cover Forestry*. Forestry Commission.
[5] Mason B, Kerr G, Simpson J. *What is Continuous Cover Forestry?*, Forestry Commision Informatio Note 29. Forestry Commission.

to more complex systems. Complex CCF has the potential to be developed on a wide range of sites in the future but in the short term could be prioritised on sites where there is:

- the potential to grow high value timber
- broadleaved woodland
- mixed woodland - existing multiple species where the mixture should be maintained
- significant recreational or community value

Using natural regeneration is one of the key components of the management of CCF sites. Natural regeneration will increase structural diversity due to variations in establishment and growth rates. This is likely to be a significant culture change for forest managers who have been reliant on clearfelling and restocking regimes. Adaptation of strategic, tactical and operational business planning will need to take account of this less reliable natural process. It will be important to learn from, and adapt to, factors and events such as grazing pressure or the seeding years of different species. Establishment operations will still be required and may include ground preparation, underplanting, weeding, respacing and forest protection measures. If successful and well-managed, natural regeneration can reduce establishment costs but also ensure the establishment of tree populations that are genetically well-adapted to the site and prevailing climatic conditions.

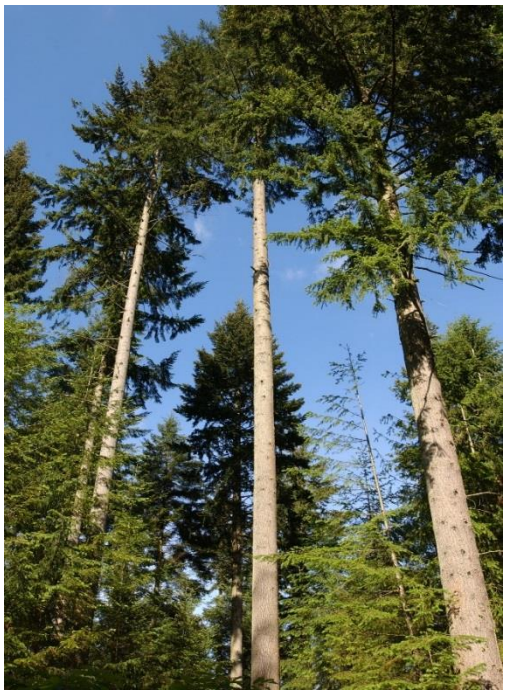


Plate 3: Mature Douglas fir managed under Continuous Cover Forestry

Where there is a need to diversify the range of species beyond those already occurring on the site a combination of natural regeneration and enrichment planting can be considered. Without intervention there is risk that crops designated as CCF could remain, or become less diverse, with the fastest growing species predominating. Underplanting, which can take place without further moderation of the canopy, can also be used; particularly in well-thinned stands where there is side-light. Respacing will help support both structural and species diversity where natural regeneration is adopted. Respacing can favour target species and allow appropriate tree spacing for stem development.

3.4.2 Small Coupe felling (SCF)

This system has potential to help increase structural and tree species diversity in stable crops of single species or those with limited tree species diversity. Its use should be limited, however, to younger crops, and more sheltered or well-thinned mature crops, where the risk of windblow is low.

Where stands have a high density of species at particular risk from climate change, early felling (usually age 20 to 40 years) using SCF can be considered to enable the introduction of new tree species quickly but the economic implications of premature harvesting should be considered.

Small scale working can be more expensive and management-intensive but this should not act as a deterrent. When younger crops are identified for SCF, introducing additional 'green edges' via severance cuts and ride creation should be considered. A good network of rides will be useful when planning coupes in the mature crop.

Increased use of SCF may be the best option:

- in large scale monocultures or other areas with limited species diversity where the risk of windblow is low
- in stands dominated by species most at risk from climate change
- when initiating coppice management in broadleaf woodlands

3.4.3 Coppice and Coppice with Standards

Once widespread in the UK, coppice is a traditional silvicultural management system based on regeneration by re-growth from cut stumps known as 'coppice stools'. The same stool is used through several cycles of cutting and re-growth. Coppice with Standards is a coppice with a scatter of trees or seedlings of coppice origin, grown on a long rotation to produce larger sized timber and to regenerate new seedlings to replace worn out stools.

Coppice practices are experiencing a revival but are often confined to sites where conservation is the major site objective. However, they have great potential to increase structural diversity and can:

- help bring native woodland back into management (many native woodlands would have been managed as coppice or coppice with standards in the past)
- reduce establishment costs in subsequent rotations and simplify woodland management for those less familiar with more complex CCF systems
- provide potential for biomass/fuel production whilst retaining the opportunity for adaptation at a later stage (with some species) to more complex systems (Note that coppice can be considered as a SRF crop - see 3.4.4).
- allow easier administration and yield estimation than more complex CCF systems
- provide a wider range of products on one site (coppice with standards)
- help limit damage from grey squirrels or browsing mammals due to rapid early growth.
- help develp a good succession of woodland habitats within a small area
- be used where larger trees are not desirable, e.g. on boundaries with other land owners, under wayleaves or close to recreational areas.

A disadvantage of coppice systems is that they limit the opportunity for genetic change between generations. If this is a concern, it is possible to combine coppice management with normal natural regeneration or enrichment planting.

Coppicing has particular potential for smaller isolated areas of woodland, but may also form part of a wider range of management regimes for larger forests. It can create a range of unique habitats and, if a variety of species are used, offers a selection of management opportunities. Species that are particularly suited include Oak, Lime, Alder, Sweet Chestnut, Hazel, Hornbeam, and Birch. Other species, including some conifers, do coppice and non-traditional species such as Coast Redwood and Eucalypts may have

potential for development. As with adopting any silvicultural system, it is important to ensure wider management objectives are taken into account, particularly when considering management of ancient woodlands or other sensitive sites.

3.4.4 Short Rotation Forestry (SRF)

SRF is the management of crops through early harvesting; typically between 8 and 20 years of age. SRF is primarily a management regime used for the production of wood-fuel biomass crops; an alternative market that can offer considerable potential for forest managers. Very fast growing species such as Sweet Chestnut, Eucalyptus and Ash have considerable economic potential however, due to transportation costs, proximity to markets such as wood/biomass power stations is critical.

SRF can provide options to improve diversity on the poorest sites where there is a limited range of suitable species. For example, lower quality conifer timber species such as Grand and Noble Fir may be grown effectively for biomass on short rotations on some poor sites.

Research is being carried out to improve understanding of its potential in the UK but as managing crops on shorter rotations gives the opportunity to change species quickly and to create greater diversity it has clear potential to reduce risks in a changing climate. Currently SRF tends to be employed on new planting sites, but it could be considered for use in Wales as an alternative management system when restocking. Modern SRF tends to involve highly-mechanised harvesting, sometimes involving specialist equipment or contractors.

Adopting of SRF may be particularly advantageous when:

- producing for biomass/wood fuel markets
- aiming to create structural diversity in larger broadleaved woodlands
- introducing coppice species to reduce subsequent establishment costs
- increasing options for improving species diversity on poor sites.

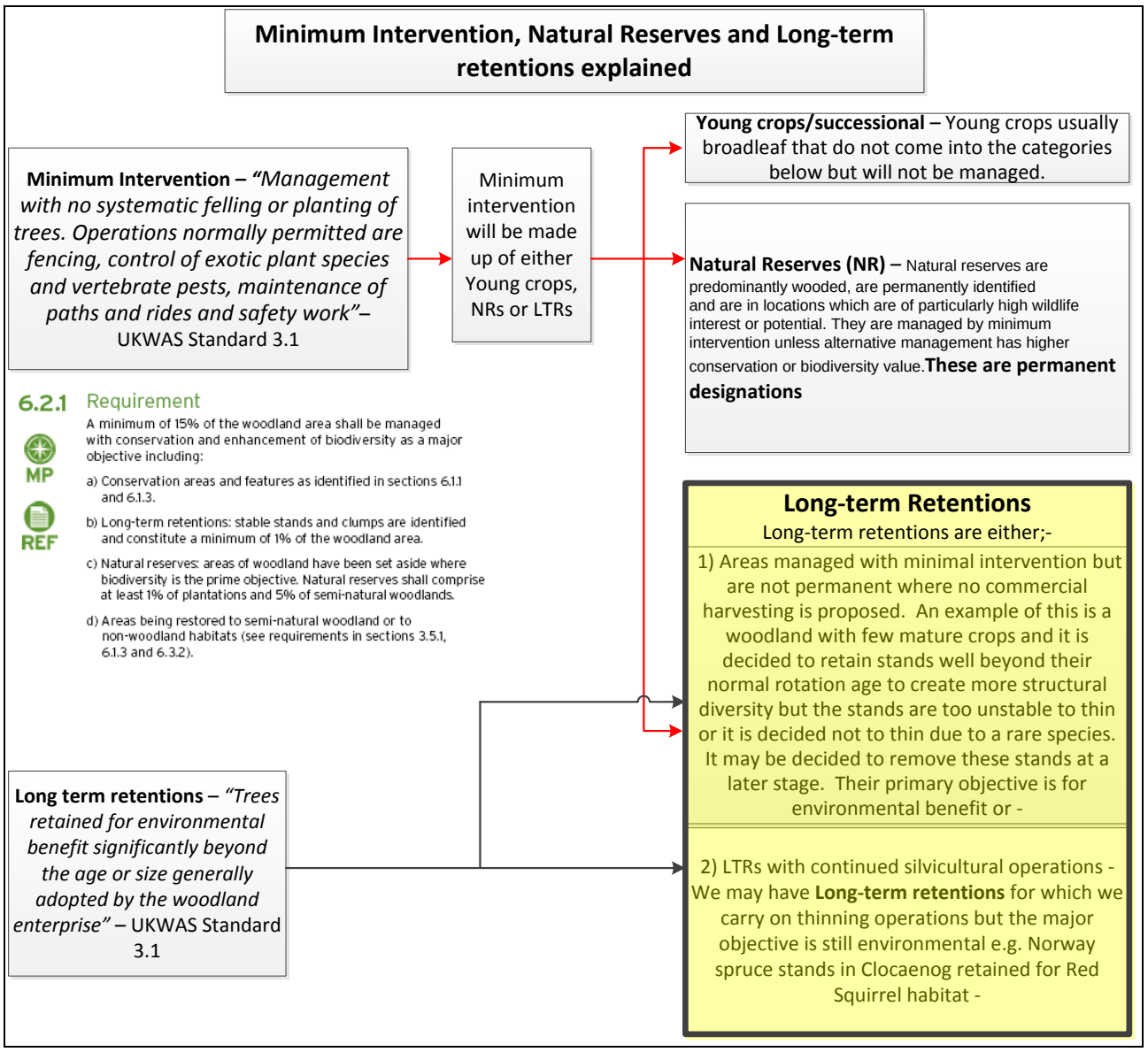
3.4.5 Minimum intervention (MI)

The UKFS defines minimum intervention as *'Management with only the basic inputs required to protect the woodland from external forces or to ensure succession of key habitats and species'.* A more prescriptive definition is provided for meeting UKWAS requirements: "*Management with no systematic felling or planting of trees. Operations normally permitted are fencing, control of exotic plant species and vertebrate pests, maintenance of paths and rides and safety work*".

The decision to use a minimum intervention approach is very site specific and largely determined by the objectives set for the woodland. It can be a valuable method to achieve structural diversity in larger forest blocks where public access or other factors are not significant. It may also be a valuable tool for ancient woodlands or other sensitive sites. A minimum intervention approach may be applied to:

- young or developing crops where a decision is made not to manage them
- more mature stands on a long term but temporary basis (long term retentions)
- woodlands important for their conservation and biodiversity value on a permanent basis (Natural Reserves)

Figure 3: Minimum intervention explained



3.5 Considerations on sensitive sites

When selecting an appropriate silvicultural system for a designated or sensitive site, particular care will be needed to ensure that the special conditions are not compromised, and ideally are enhanced, by any new silvicultural approach.

Ancient Woodland Sites

When managing any ancient woodland including restoring of PAWS to native woodland, managers should avoid the levels of shock to the forest ecosystem associated with clearfelling and replanting operations. LISS will usually be the most appropriate silvicultural systems and gradual restoration of the site can usually be combined with other management objectives (including timber production) although it is often necessary to take additional measures to protect the ecological value the site.

In limited circumstances LISS may not be appropriate for PAWS restoration. Where sites are threatened by disease or invasive non-native species such as western hemlock or

where lack of management of existing conifers has resulted in windblow which is creating a significant risk to the ancient woodland features, carefully planned and controlled clearfelling may be the best option.

3.6 Delivering multiple benefits from woodlands

Woodlands provide a wide range of physical and non-physical benefits. These include the regulation of climate, purification of air and water, flood protection, soil formation and nutrient-cycling. They also provide timber and wood products, opportunities for recreation and an appreciation of nature.

Table1 summarises the impact that different silvicultural management systems may have on the benefits (or ecosystem services) that woodlands provide. It is not a definitive list but highlights some of the key issues. The table assumes that systems are used in appropriate locations and are well managed. Inappropriate choice of site or poor operational standards are likely to have a detrimental effect on the provision of ecosystem services, regardless of the silvicultural system used.

Understanding the role of different management systems in providing ecosystem services is a relatively new science and there is still much to learn. Sources of further information are given in Appendix 2. The potential for delivering ecosystem services is, in many cases, directly linked to the setting of management objectives for that woodland. For example, if the production of timber is the primary objective, and the enhancement of biodiversity is secondary, then this is likely to have an impact on the range of ecosystem services that the woodland provides.

Table 1: Choice of management system and potential impacts on the provision of ecosystem services (Compiled with contributions from Forest Research)

Ecosystem service	Management system			
	Clearfelling	Small coupe felling	CCF – simple structure	CCF – complex structure
Water quality	Forests managed according to UKWAS guidance operate within the *Forests and Water Guidelines* that aim to mitigate the risks of clearfelling to water quality.	As clearfelling – the smaller scale working decreases any risks associated with clearfelling on water quality.	Once the structure is formed there will be generally lower levels of site disturbance and the presence of a mature canopy and/or young trees minimizes risks to water quality.	Once the structure is formed the presence of continuous canopy cover and generally lower level of site disturbance minimises risks to water quality.
Water flux	Clearfelling has the potential to create the greatest fluctuations to water flow and latest *Forests and Water guidelines* identifies “at risk” areas and sets out measures to mitigate the risks associated with clearfelling.	Reducing the scale of clearfelling does help mitigate some of the risks associated with larger scale clearfells.	Once the structure is formed there will be generally lower levels of site disturbance and the presence of a mature canopy and/or young trees minimizes risks but over story removals may still have some effect on water fluxes.	Once the structure is formed the presence of continuous canopy cover and generally lower level of site disturbance minimises the level of water flux.

Ecosystem service	Management system			
	Clearfelling	Small coupe felling	CCF – simple structure	CCF – complex structure
Soil erosion	Forests managed according to UKWAS guidance operate within the *Forests and Water* and *Forests and soil Guidelines* that aim to mitigate the risks of clearfelling to soil erosion. Risks are low on flat ground and higher on steep slopes.	As clearfelling – and the smaller scale working decreases any risks associated with clearfelling for soil erosion.	Reduced risks associated with clearfelling operations and the subsequent bare ground phase. In general stands do not pass through a restocking phase that may involve some form of ground preparation so there are reduced risks for soil erosion. Ground preparation may be used but is likely to be low impact scarification.	Reduced risks associated with clearfelling operations and the subsequent bare ground phase. In general stands do not pass through a restocking phase that may involve some form of ground preparation so there are reduced risks for soil erosion. Ground preparation such as low impact scarification may be used during the transformation but once the structure is formed would not usually be used.
Timber and biomass production **It is likely that the choice of management system will have little effect on the overall production output. However utilising a range of systems or if for example you move all your production to a CCF type system it will have an effect on both the range of products that can be produced and revenue flows. You can target specific markets and higher value products or aim for fuel wood markets or a combination depending on your objectives.**				
Climate change mitigation "Although very difficult to assess in field experiments, evidence suggests that on suitable sites CCF has the potential to increase in situ carbon stocks compared with even-aged management. The structure of the resulting stand will have a large impact on the extent of carbon accumulation, with complex structures offering greatest benefit. As CCF management generally reduces site disturbance it is also likely that carbon losses from the soil will be less than in even-aged management, although careful management of brash will be necessary to avoid soil damage during thinning[6]."				

[6] Kerr, G. & Stokes, V. (2009) *The evidence supporting the use of CCF in adapting Scotland's forests to the risks of climate change.* Forestry Commission.

Ecosystem service	Management system			
	Clearfelling	Small coupe felling	CCF – simple structure	CCF – complex structure
Biodiversity – stand scale	Clearfelling is a significant disturbance to a forest environment similar to the effects of catastrophic windblow. The change will favour some species, such as open ground specialists, and be detrimental to others that are more sensitive to disturbance.	Effects will be similar to clearfelling although the smaller scale of working will reduce the magnitude of the changes.	Stands will fluctuate between the stand initiation, stem exclusion and understory re-initiation phases. This will not favour species that require continuity of habitat.	A complex structure provides continuity of habitat and at any one time there should be elements of all four phases of stand development (The three listed for CCF – simple as well as 'all-sized').
Biodiversity – landscape scale	A diverse landscape should ideally have elements of clearfelling, CCF- simple structure and CCF - complex structure in addition to other stand types such as natural reserves			
Recreation	All the main options for management systems require a sequence of forest operations to intervene in the stand. Good planning, regardless of silvicultural system will reduce conflicts with recreation. Large scale clearfell is the most likely to have a detrimental effect on high profile recreational centres and should be used as a last resort. Investment in less visually intrusive silvicultural systems close to these centres should be considered a priority.			
Landscape – internal views	Even-aged stands can look attractive if well thinned and have the major advantage that vistas and panoramas of the surrounding landscape can be produced when trees are felled.	Similar to clearfelling if the position of coupes is applied in sympathy to the surrounding landscape.	These systems produce attractive forest stands but structural diversity is not as great as complex systems and opportunities for creating views to the surrounding landscape are more constrained than with clearfelling.	These systems produce structurally diverse forests that could be considered internally as the most attractive forest stands but opportunities for creating views to the surrounding landscape are more constrained than with clearfelling.
Landscape – external views	Clearfelling can look unsightly in the landscape and should be strategically placed in the landscape to minimise impacts.	This system is a useful compromise to reduce the negative impacts of larger scale clearfelling.	The appearance of continuous cover helps eliminate any negative landscape effects traditionally associated with clearfelling.	The appearance of continuous cover helps eliminate any negative landscape effects traditionally associated with clearfelling.
Landscape	Creating a diverse and attractive landscape could have elements of all management systems if appropriately used.			
Communities	Any of the four management systems considered in this table can bring significant benefits to local communities but the objectives and benefits need to be clearly set out in discussions and consultations with stakeholders.			

3.7 Economic considerations

Managing more structurally diverse woodlands successfully means working towards a range of objectives and securing a valuable forest resource in the long-term. This requires a recognition of the costs of change which should be considered as part of future management and economic planning. Some evidence suggests that an increased proportion of logs in the short and long term can result from CCF style management. Some of the factors to consider are:

- **Establishment costs** can be cheaper than clearfell systems that require full restocking where natural regeneration is used successfully as part of a management system.
- **Intensity of management**, particularly in managing intimate mixtures or more complex silvicultural systems, will usually be greater with LISS. LISS typically involve more management input and supervision. Forest protection requires investment for successful establishment whatever the system is chosen including NR recruitment
- **Timber flow patterns** in LISS systems will be very different to those with standard clearfelling; although the shelterwood removal phase in simple CCF systems may provide a considerable yield. This should be balanced against the potential for regular higher thinning yields under CCF, the potential for higher average volume per year, the likelihood of growing higher-quality timber, and the potential for development and supply of niche markets.
- **Operational:** There will be increased outputs from CCF thinnings (particularly a high percentage of log and bar material in earlier thinnings) but these need to be balanced against lost efficiency at clearfelling (though over storey removal is still necessary in shelterwood systems). Other systems such as SRF should operationally be very simple with high rates of efficiency possible.
- **Marketing** opportunities can be expected to be affected by the wider range of products likely produced under LISS, and the quantities in which they are produced. Whilst this may present new openings they may require greater investment in marketing such as collaboration between producers.
- **Infrastructure** needs to be developed and maintained for most LISS approaches. Whilst there will clearly be costs involved, investment in infrastructure can be expected to reduce subsequent operational costs, as well as reducing the risk of soil erosion and pollution incidents.

A detailed analysis of the costs and revenues of transformation to CCF in a UK context has been undertaken and published in the journal *Forests*[7].

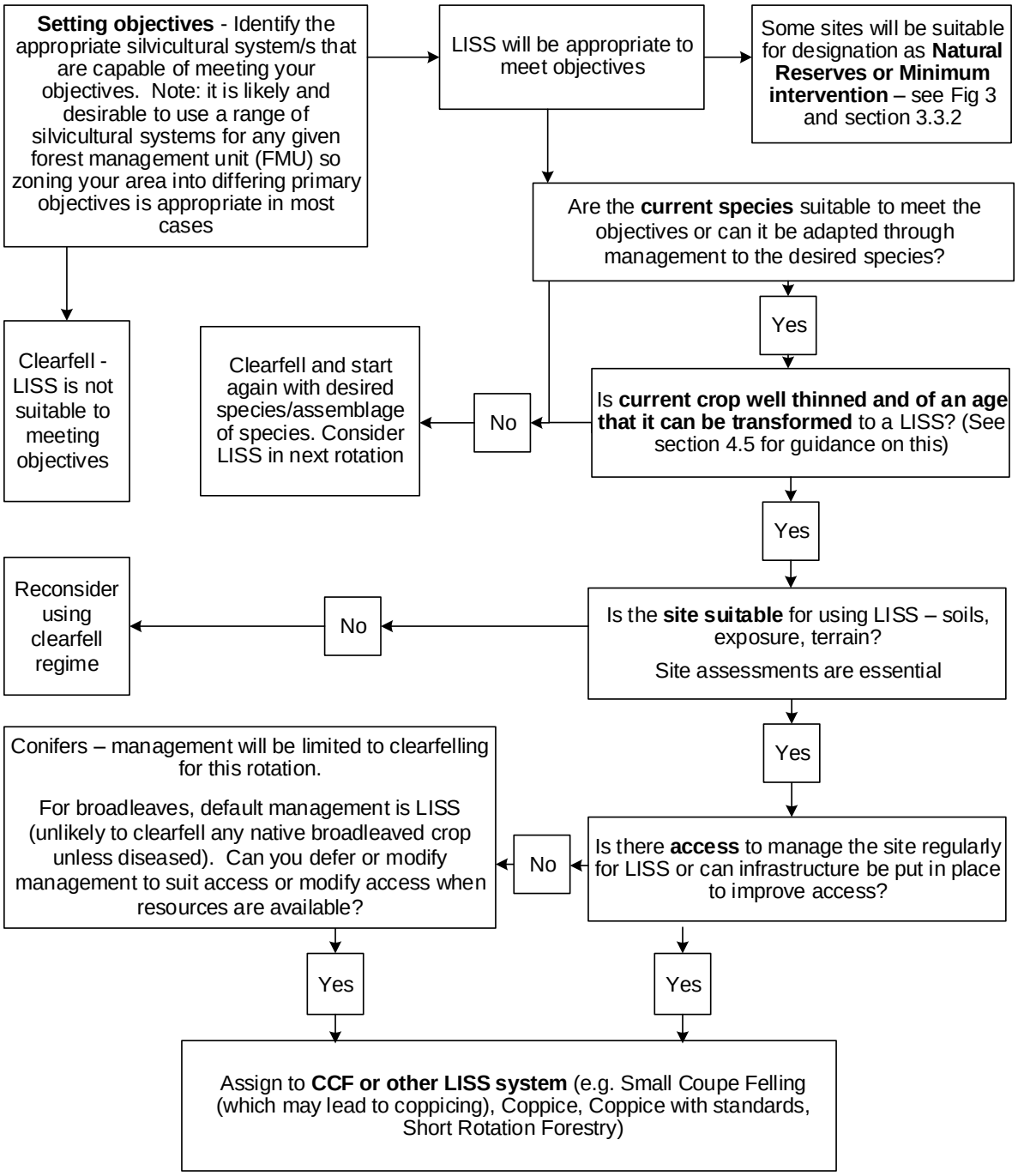
The selection of management systems for native woodlands should, where possible, enable the production of high quality timber. Where the production of quality timber is not appropriate, the production of wood fuel should be encouraged as a strategy to increase economic viability and act as an incentive for positive native woodland management.

3.8 Summary – decision-making flow chart

Drawing together much of the information in this section, Figure 4 can be used to help make a decision about the most appropriate silvicultural system.

[7] Davies O, Kerr G. (2015) *Comparing the Costs and Revenues of Transformation to Continuous Cover Forestry for Sitka Spruce in Great Britain.* Forests 2015, 6, 2424-2449

Figure 4: Flow chart to aid decision making about the choice of silvicultural system



4 How to improve structural diversity

This chapter recommends key actions needed to improve structural diversity in Welsh woodlands and identifies priority actions for particular types of woodland. Desired outcomes may take decades to achieve and appropriate, targeted interventions will enable limited resources to be utilised where they will have the greatest effect.

4.1 Recommendations for all woodland types

Recommendation 1: Low Impact Silvicultural Systems (LISS), or a combination of systems, should be considered as an alternative to large scale clearfelling and restocking where they fit with management objectives.

Recommendation 2: All stands should be considered for thinning at the earliest appropriate opportunity, as this is usually critical for improving structural diversity and moving towards LISS. Adopt thinning regimes appropriate to the silvicultural system, for example crown thinning will be increasingly appropriate to many Continuous Cover Forestry (CCF) sites.

Recommendation 3: Invest in new permanent infrastructure as this is critical to managing many of the low impact silvicultural systems, in particular CCF sites. Managers should identify a prioritised programme for the creation and maintenance of permanent infrastructure.

Recommendation 4: Where CCF is chosen, prioritise conversion according to the age of the stand. Primary areas for transformation to CCF will be young crops (first/second thinning) where the process is most likely to succeed. Other highly suitable sites include those with existing desirable structures and/or presence of regeneration, and high sensitivity sites where a CCF system is seen as critical to secure specific social or environmental benefits.

Recommendation 5: Identify areas for Small Coupe Felling (SCF) as a rapid method of increasing species diversity and improving forest structure in stable uniform crops, or to initiate coppice working in broadleaved crops.

Recommendation 6: For those sites not suitable for CCF or SCF, long-term planning should aim to reduce average clearfell sizes wherever possible, reducing the impacts of large felling operations.

Recommendation 7: Use a variety of regeneration methods - natural regeneration, artificial planting, coppicing, and underplanting. The methods will be related to the objectives for the stand, site conditions and, if natural regeneration is favoured, the likelihood of the preferred species regenerating. Site specific risks and the ability to manage them must also be considered, for example the ability to manage browsing mammals, vegetation competition, etc.

Recommendation 8: Learn from work undertaken by others and create learning networks, e.g. Natural Resources Wales, Forest Research, Prosilva, Continuous Cover Forestry Group.

4.2 Recommendations for native woodlands

Recommendation 9: Clearfelling should be avoided in native woodlands, especially semi-natural woodlands which have particular ecological and social importance.

Recommendation 10: Where possible, native broadleaf stands should be managed using LISS. Particularly sensitive areas may need managing through minimum intervention; however this should be a positive management decision to maintain woodland qualities.

Recommendation 11: Thinning of native woodland should be considered as much a priority as for any other woodland

Recommendation 12: Coppice systems should be encouraged in appropriate situations, such as even-aged native broadleaf stands or areas where grey squirrel damage is particularly severe.

Recommendation 13: Consider the use of SCF to initiate rotational coppice working and increase the use of Coppice or Coppice with Standards.

Recommendation 14: Consider SCF if it can be balanced with achieving other objectives

4.3 Recommendations for Plantations on Ancient Woodland Sites (PAWS)

Recommendation 15: Restoration of PAWS to native woodland should ideally be a gradual process

Recommendation 16: LISS should be the preferred management option on PAWS

Recommendation 17: The sensitive maintenance and restoration of ancient woodland features should be the primary consideration when selecting a silvicultural system on PAWS.

4.4 Recommendations for transforming conifer crops to LISS

When planning the transition of conifer crops that have been managed through clearfelling and restocking to a LISS approach, actions can be prioritised based on the age of the crop.

4.4.1 Establishment and pre thinning (0 – 14 years)

At this stage few operations are likely to be required. Whilst the manager should have a desired system of management in mind, flexibility and adaptability in approach is key. This is a critical period of stand development and it is important to review the health and growth of competing species. In mixed stands (line, intimate or group) monitoring should be undertaken to assess how species are competing against each other. It is possible that some species in this age category could be identified for SRF and benefit from early removal.

4.4.2 First thin/young crops (15 – 29 years)

This age group should be prioritised for conversion to other systems, particularly CCF, assuming the species composition is acceptable or there are realistic opportunities to change or introduce tree species. There is no single “standard” method. The correct approach will depend on species, site, and management objectives.

- Establish any permanent infrastructure at first thinning if it does not already exist including a permanent racking system, main access and egress routes with hard standings where necessary – assessment of infrastructure needs should be made for any change in silvicultural system.
- Thin on time to introduce racking and structure. Failure to thin early enough is likely to reduce the conversion potential of any stand.
- Consider an early first thin followed by a crown thin at the normal age of first thinning as this has the potential to increase crop stability.
- Second and subsequent thinnings should usually be a crown thinning, possibly using ‘frame trees’. Frame trees should be stable, well-formed, and dominant trees, as they may need to be present on the site for a long time. Spacing should be ‘clumpy’ and not regular. Stable trees will have a larger diameter for a given height.

- If sample marking is being used the highest priority stands would usually be second and third thinnings.
- Consider adopting a higher thinning intensity near exposed edges, providing your interventions are early enough. This will encourage the development of larger-crowned, deeper rooted trees which will be better able to withstand windblow and provide some shelter to the rest of the crop. This applies to all thinning.

4.4.3 Semi-mature stands (30 – 44 years)

Depending on previous interventions, the terrain and existing infrastructure, these crops will usually present a greater risk when converting to another silvicultural system; particularly where crops have passed second thinning age. The priorities are to:

- Thin on time and regularly; 'little and often' is the best approach.
- Ensure good infrastructure to ensure successful conversion.
- Select a residual basal area for the stand (see Forestry Commission recommendations for this in Forestry Commission Operational Guidance).
- Look for opportunities to commence the under-planting of new species where you wish to diversify tree species.

4.4.4 Mature crops (45+ years)

These stands will be difficult to convert to another silvicultural system unless sympathetic management has already been carried out and good infrastructure exists.

Consider the practicality and cost of converting these stands and the options available. Identify those stands where investment should be made and most gained in terms of achieving objectives. The same principles apply to these older stands as to the younger ones previously described. Regular interventions must be made. Sometimes it is better to start again and this decision can only be made on a stand-by-stand basis.

4.5 The importance of thinning

Thinning is one of the most important interventions when increasing structural diversity and implementing most silvicultural systems and it is a vital element of sustainable forest management. Effective thinning will:

- encourage the growth of high-quality timber and increasing revenue options (wood/fuel/fibre)
- help to maximise the quantity of good-quality timber that a stand can produce
- improve stand stability resulting in more options for management in older stands
- improve conditions for biodiversity
- increase structural diversity.

Regularly thinned crops will generally deliver a far wider range of benefits and ecosystem services than unthinned crops.

Plate 4: Thinning can encourage structural diversity and is key to almost every silvicultural system

Given the importance of thinning it is recommended that:

- **all** crops should be assessed for their suitability for a regular thinning, with assessments starting prior to the predicted time of first thin.
- timely or early first thinning must be standard practice for all new crops as this is essential for the achievement of future stand objectives; even if the thinning itself appears uneconomic.
- in developing thinning programmes, all potential advantages should be considered including environmental, social and economic benefits.

However, not all crops and sites are suitable for thinning and each site must be assessed separately. The exceptions to the “thinning for all’ rule include situations where:

- thinning is likely to significantly increase the risk of windblow, for example, where rooting is poor and exposure is high
- a single thinning operation is likely to require an unacceptably large initial investment in relation to the potential benefits due to access or markets
- thinning is unlikely to improve poorly stocked or poor quality stands
- environmental constraints outweigh the potential benefits, for example, damage to a sensitive area
- management objectives dictate non-intervention, for example, a natural reserve or in a mature stand of trees that is used for car parking or a picnic area

- regular access cannot be made and improved access cannot be constructed usually on exceptionally steep sites
- management of good quality riparian zones is the priority with minimal harvesting for timber
- in coppicing systems which often do not require specific thinning.

4.6 The importance of infrastructure and access

Woodlands managed through LISS must have appropriate access and infrastructure to allow regular interventions to take place[8]. More frequent extreme weather (especially rainfall) is predicted as a result of climate change and as Wales already has a wet climate, and many sites with fragile soils, well planned access will be increasingly important.

Infrastructure both to and within stands should be planned and prioritised. It is recommended that first and second thinning-age crops should be prioritised for the development of permanent internal infrastructure of tracks and other access features.

Plate 5: Forest road which will help facilitate management by LISS.

[8] Environmental best practice for continuous cover forestry Science Report: SC020051/SR, EA, 2006 contains recommendations for infrastructure for CCF. Operational Experience of Continuous Cover Forestry: UK Case Studies INTERNAL PROJECT INFORMATION NOTE 13/06, Forest Research, Duncan Ireland

5.0 Summary

To increase the structural diversity of woodlands in Wales, the range of silvicultural systems currently used by managers needs to broaden. The aim is to reduce the amount of clearfelling and increase the use of alternatives across the range of management systems that are available. Woodland managers should fully consider which are the most suitable silvicultural systems to use and how best to make their woodlands more resilient to climate change. To succeed, it is important that woodland managers:

- set management objectives
- take action appropriate for different woodland types
- assess site suitability for low impact silvicultural systems and match the silvicultural system wisely
- monitor progress and results and remain flexible if it becomes necessary to adapt the management system that has been chosen
- invest in continuing professional development – there is plenty of support available (see Appendix 2).

Appendix 1: Silvicultural systems and habitat conditions

This table identifies the broad habitat or succession of habitats that are likely to occur within any one silvicultural system (note: these have been grouped into broad categories and that many variations and sub groups do exist). For more information on these, see Figure 2 in this document, Forestry Commission Operational Guidance and sources of further information listed inAppendix 2.		
Silvicultural system	**Structural characteristics**	**Habitat/s conditions created**
Large or small scale clearfelling and restocking	Felling and regeneration, usually with restocking (but can use natural regeneration) on a rotational basis on a large or small scale	A phased succession of woodland conditions will exist from open cleared areas with establishing ground flora, young establishing crop with ground flora, closed canopy with limited ground flora, followed by thinning gradually opening canopy, mature trees and re developing ground flora
Selection systems (Generally complex systems)	Felling and regeneration continuous over the whole forest area	Provides continuity of habitat, continuous canopy cover exists over the whole area, and there is usually more than one strata/layer. Quite often a diverse structure at a macro scale.
Shelterwood systems	This is likely to be the most common in Wales as most crops are being transformed from clearfell systems – more complex systems may or may not develop over time.	
Uniform shelterwood (Simple CCF)	Successive regenerational thinnings that are **even over the whole stand**	A succession of woodland conditions will occur from mature crops with developing understory, over-storey removal (but with opportunity to retain mature trees), development of young crops with ground flora, followed by thinning, opening out canopy, establishing understories and ground flora.
Group/strip shelterwood (Simple CCF)	Successive regeneration felling **in scattered groups or strips**	Different stages of stand development will occur at the same time once the system is developed. No large scale removals occur, interventions limited to the groups or to thinning. Continuity of habitat will exist over the whole stand but will rotate within the stand as different parts of it develop and are removed
Irregular shelterwood (Simple or Complex CCF)	Successive regeneration fellings that are	This will develop in similar ways to uniform and group systems but the distribution of gaps and longer periods of regeneration will produce a more

	irregular and gradual	irregular structure and subsequently may help give more continuity of woodland habitat with a variety of woodland conditions within a single stand
Note that thinning is the most important activity to start the process of improving structural diversity in all woodlands, regardless of silvicultural system.		
Note that you should not look at one stand in isolation. Using a variety of silvicultural systems within a woodland (subject to site location, terrain, tree species selection and management objectives) is most likely to maximise the potential of any woodland for diversity of habitats.		

Appendix 2: Sources of further information

Davies O, Kerr G. (2014). *The Costs and Revenues of Transformation to Continuous Cover Forestry.* Forest Research.

Forestry Commission (2011) *The UK Forestry Standard and associated Standard Guidelines.* Forestry Commission, Edinburgh.

Hart C. (1995). *Alternative Silvicultural Systems to Clear Cutting in Britain - a review.* FC Bulletin 115. HMSO.

Kerr G. (2008). *Managing Continuous Cover Forests.* Forestry Commission Operational Guidance booklet 7.

Kerr G, Mason B, Boswell, R, Pommerening A. (2002). Monitoring *the transformation of even-aged stands to CCF* .Forestry Commission Information Note 45.

McKay H. (2011). *Short Rotation Forestry: Review of growth and environmental impacts.* Forest Research Monograph: 2

Mason B. (2010). *Respacing naturally regenerating SS and other conifers.* Forestry Commission, Practice Note 16.

Mason B, Kerr G, Simpson J. (1999). *What is continuous cover forestry?* Forestry Commission Information Note 29.

Mason B, Kerr G. (2004). *Transforming even aged conifer stands to continuous cover management.* Forestry Commission Information Note 40

Mason B. (2010). *Respacing naturally regenerating Sitka spruce and other conifers* Forestry Commission Practice Note 16.

Matthews JD. (1997). *Silvicultural Systems, Oxford Science Publications*

Natural Resources Wales (2010). *A guide for increasing tree species diversity in Wales.*

Ray D. (2008). *Impacts of Climate Change on forests in Wales.* Forestry Commission Information Note 301.

The UK Woodland Assurance Standard (UKWAS) 2011, Edinburgh.

Troup RS. (1952). Silvicultural Systems, Oxford University Press

Welsh Assembly Government (2009) *Woodlands for Wales – the Welsh Assembly Government's Strategy for Woodlands and Trees.* Welsh Assembly Government.

Welsh Government
http://gov.wales/topics/environmentcountryside/forestry/?lang=en

Forest Research
http://www.forestry.gov.uk/forestresearch

Continuous Cover Forestry Group
http://www.ccfg.org.uk/

Confederation of Forest Industries (Confor)
http://www.confor.org.uk/

Prosilva Europe
https://prosilvaeurope.wordpress.com/

Woodland Trust / Coed Cadw
http://www.woodlandtrust.org.uk/

Forest Research - http://www.forestry.gov.uk/forestresearch