Improving the structural diversity of woodlands in Wales

Guidance note

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What is this document about?

This guidance note provides information and advice on how to improve the structural diversity of woodlands in Wales to improve their resilience to climate change and pests and diseases, and ensure they deliver a range of ecosystem services and wellbeing benefits. The guidance note supports sustainable forest management in accordance with the UK Forestry Standard.

Who is this document for?

This guidance note is for all forest and woodland owners, managers and practitioners, both public and private.

Contact for queries and feedback

Queries should be directed to the Sustainable Land Management team, email: SLMT@cyfoethnaturiolcymru.gov.uk

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Crynodeb gweithredol

Mae amrywiaeth strwythurol yn cyfeirio at gwmpas yr amrywiaeth ffisegol mewn elfennau coedwig neu goetir, yn enwedig dosbarthiad gofodol coed a dosbarthiad fertigol y canopi a haenau eraill o'r llystyfiant. Mae amrywiaeth strwythurol yn berthnasol ar raddfa'r stand ac ar raddfa'r goedwig neu'r dirwedd.

Mae i fathau penodol o goetiroedd strwythurau nodweddiadol. Mae'r rhain yn rhannol naturiol, wedi'u dylanwadu gan allu'r rhywogaethau o goed i oddef cysgod, ynghyd â phatrymau aflonyddu nodweddiadol, er enghraifft dadwreiddiad gan wyntoedd cryfion, hunan-deneuo neu golled yn sgil plâu a chlefydau. Maent hefyd yn rhannol o ganlyniad i arferion rheoli yn y gorffennol a'r presennol. Mae'r math o system rheoli coedwriaethol yn ffactor allweddol sy'n effeithio ar amrywiaeth strwythurol.

Yng Nghymru, mae systemau coedwriaeth llwyrgwympo yn dal i ddominyddu sut caiff ein coedwigoedd conwydd eu rheoli. Mewn coetiroedd llydanddail a gaiff eu rheoli, mae rhyw fath o system gorchudd parhaus yn arferol, er bod coedwigoedd llydanddail heb eu rheoli yn gyffredin o hyd, yn enwedig mewn coedwigoedd bach tameidiog sydd hefyd yn aml yn agored i dda byw. Gall diffyg dull rheoli priodol arwain at amrywiaeth strwythurol wael.

At ei gilydd, mae angen gwella amrywiaeth strwythurol coetiroedd yng Nghymru. Mae ein hinsawdd yn prysur newid, gyda gaeafau mwynach a gwlypach a hafau cynhesach a sychach, ynghyd â digwyddiadau hinsawdd eithafol amlach, er enghraifft stormydd a chyfnodau hir o law trwm neu o dywydd poeth. Bydd coedwigoedd mwy amrywiol o ran eu strwythur yn gallu gwrthsefyll effeithiau newid hinsawdd yn well, yn ogystal â phlâu a chlefydau, a byddant hefyd yn cyflawni canlyniadau gwell i bobl, bioamrywiaeth a'r amgylchedd.

Mae'r nodyn cyfarwyddyd hwn yn cefnogi'r gwaith o reoli coedwigoedd yn gynaliadwy yn unol â Safon Coedwigaeth y DU. Mae'n cynnig crynodeb o'r prif fathau o systemau coedwriaethol ac yn gwneud argymhellion ynghylch sut i wella amrywiaeth strwythurol mewn gwahanol fathau o goetiroedd.

Dylid ystyried y canllaw hwn ochr yn ochr â dau nodyn cyfarwyddyd arall ar amrywiaeth rhywogaethau ac amrywiaeth enetig, er mwyn sicrhau dull cyfannol ar gyfer datblygu amrywiaeth mewn coedwigoedd a'u gwydnwch.

Executive summary

Structural diversity is the degree of physical variation in the elements of a forest or woodland, particularly the spatial distribution of trees, and the vertical distribution of the canopy and other layers of vegetation. Structural diversity is relevant at both the stand scale, and the forest or landscape scale.

Particular woodland types tend to have characteristic structures. These are partly natural, influenced by the shade tolerance of the tree species and typical disturbance patterns such as windthrow, self-thinning or loss due to pests and diseases, and partly the result of past and current management practices. The type of silvicultural management system is a key factor affecting structural diversity.

In Wales, clearfell silvicultural systems still dominate the management of our conifer forests. In managed broadleaved woodlands, some form of continuous cover system is usual although unmanaged broadleaf woods are still common, particularly in small, fragmented woods which are also often accessible to livestock. A lack of appropriate management can lead to poor structural diversity.

Overall, the structural diversity of woodlands in Wales needs to improve. Our climate is changing rapidly, with milder, wetter winters and warmer, drier summers, together with more frequent extreme climate events such as extended periods of heavy rainfall, heatwaves and storms. More structurally diverse forests will be more resilient to the impacts of climate change and pests and diseases, and also deliver better outcomes for people, biodiversity and the environment.

This guidance note supports sustainable forest management in accordance with the UK Forestry Standard. It provides a summary of the main types of silvicultural system and makes recommendations about how to improve structural diversity in different types of woodlands.

This guide should be considered alongside two other guidance notes on species diversity and genetic diversity, to ensure a holistic approach to forest diversification and resilience.

Introduction

Our climate is changing rapidly. Milder, wetter winters, warmer, drier summers and longer growing seasons are expected, together with more frequent extreme climate events such as extended periods of heavy rainfall, heatwave and drought, and storms.

In Wales, a climate and nature emergency has been declared. We need to assess how we manage our forests and woodlands so that they can adapt to the challenges and risks associated with a changing climate, as well as an increased threat from pests and diseases, and a decline in biodiversity. Significant changes to accepted practices are needed to ensure that our woodlands continue to provide multiple ecosystem services and well-being benefits for future generations.

This guide explains the importance of structural diversity as an adaptation measure to improve the overall resilience of forests and woodlands. Woodlands and forests with a more diverse structure are at less risk of severe damage from a particular incidence of pests or disease, and a more diverse structure may also reduce the risk of catastrophic windblow as a result of a severe storm. Improved structural diversity will also support biodiversity.

Adaptation measures more broadly are discussed in the UK Forestry Standard Practice Guide on adapting forest and woodland management to the changing climate, which also summarises the main risks and opportunities associated with climate change and provides an overarching adaptation framework that can be used by practitioners.

This guidance note supports sustainable forest management in accordance with the UK Forestry Standard (UKFS), and Welsh Government's Woodlands for Wales strategy. The UKFS includes good forestry practice requirements relevant to adaptation and protection. It requires forests to be planned and managed to enhance their resilience and mitigate the risks posed to their sustainability by the effects of climate change or attack by pests and disease.

What is structural diversity?

Structural diversity is the degree of physical variation in the elements of a forest or woodland, particularly the spatial distribution of trees, and the vertical distribution of the canopy and other layers of vegetation. Good structural diversity is characterised by some, or all, of the following features:

- age class diversity within a stand so there is 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
- presence of a shrub layer.
- variation in the size and extent of management area / coupe.
- a mixture of suitable species, now and under future climatic conditions, with different characteristics and levels of shade.
- variable stem density (a function of tree species and the degree of thinning).
- variation of tree diameters.

- presence of standing and fallen deadwood. areas of open ground within the woodland environment.

Structural diversity is relevant at both the stand scale, and the forest or landscape scale. The structure of a stand is determined by the age and age range variation of the trees, the presence of any understorey and the mix (if any) of species or types (broadleaf/conifer, evergreen/deciduous).

At the forest and landscape scale, structural diversity is a function of diversification at the stand level but can also be achieved by adjusting rotation lengths and planning harvesting and planting to provide a spread of stand ages, tree sizes and heights. This can help provide continuity of a range of benefits across the landscape, and spreading the risks can reduce overall vulnerability at any point in time. However, there are both benefits and disadvantages of changing rotation lengths as an adaptation measure that need to be considered in restructuring forests or revising management plans. It is important to give careful consideration to tree species, their optimum growth requirements and the risks posed by wind or other threats (including insect pests) before changing rotation lengths.

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 and current management practices.

The type of silvicultural management system is a key factor affecting structural diversity.

Silvicultural systems

A range of silvicultural systems are used in Wales. These can be broadly categorised as:

- Clearfelling (>2ha)
- Low Impact Silvicultural Systems (LISS) covering:
  - Minimum Intervention (MI)
  - Continuous Cover Forestry (CCF)
  - Small Coupe Felling (SCF) with a range of (0.25-2 ha)
  - Coppice and Coppice with Standards

The choice of silvicultural system determines how trees are maintained, harvested and replaced and is the primary factor that influences structural diversity. Alongside management objectives, site specific information will be invaluable in determining the most appropriate silvicultural system or systems for a woodland. Features such as soil type, terrain, existing tree species, exposure and surrounding woodland are relevant and the impacts of climate change should also be considered, for example in relation to future tree species suitability or risk of windblow as a result of more frequent storms.

Typically, forests managed solely by a clearfell silvicultural system are characterised by uniform aged crops with limited diversity of structure within a stand or sometimes whole forest blocks. In Wales, as in the rest of the UK, clearfell silvicultural systems still dominate conifer forest management. At a landscape scale, clearfell systems are less resilient than LISS, even if there is structural diversity within a stand or at the forest scale.

Although there are now some exemplar LISS sites in Wales both in the private and public sector such as Cwm Berwyn and Clocaenog forest, the overall structural diversity of conifer woodlands in Wales remains poor and needs to improve for example to reduce the risks associated with catastrophic windblow events like those in 2024-5. There is no definition of good structural diversity but based on the National Forestry Inventory Woodland Ecological Condition (NFI WEC) survey, four storeys or more are considered to be favourable.

In contrast, forests managed using one or more of the range of LISS tend to be more structurally diverse. In Wales, LISS systems dominate the management of broadleaved woodlands. However, there are still many unmanaged broadleaf woods that present a challenge in Wales, as a lack of proper management can also lead to poor structural diversity, particularly in small, fragmented woods which are accessible to livestock. Occasionally, poor structural diversity in native broadleaved woodlands may support rapidly declining species such as specialist woodland birds and also lichens and liverworts, but generally more structurally diverse broadleaved woodlands will be beneficial.

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

Clearfelling

Clearfelling and restocking is usually considered the simplest and most cost effective silvicultural system with the lowest management input. It is typically, therefore, associated with commercial forestry. It tends to be preferred where:

- current tree species are unsuitable for LISS, or clearfelling is the most practical option to allow a change to different species in the future.
- mature conifer crops exist and transformation to another system would be difficult and there is a risk of unacceptable levels of windblow.
- control of invasive tree species (such as western hemlock) requires early and complete removal rather than long-term and expensive control measures.
- it is necessary to manage some tree pests and diseases.
- 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.

Low Impact Silvicultural Systems (LISS)

This term covers a range of silvicultural systems which aim to minimise the environmental impact of forest management operations. The choice of system will depend on the desired outcomes and the nature of the site. The following is an overview of some of the more commonly used systems.

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 does not have to be complex and can help achieve a wide range of objectives.

When considering this approach, the following issues need to be considered:

- whether CCF is appropriate to achieve the management objectives for the woodland.
- whether current species are suitable for the site and CCF methods.
- whether the terrain (soil, slope, roughness, elevation, exposure) limits the use of CCF, and if yes, whether anything be done about it.
- whether infrastructure is required to make the site more accessible to support CCF and the cost of doing this.
- whether the site is suitable for CCF, but the current species are not.
- how easily the stand can be converted, and whether it might make sense to clearfell and replant with suitable species for conversion to CCF in the next rotation.
- whether there are areas which should be prioritised for CCF conversion.
- if structural diversity is best created at a large scale.

CCF can be sub-divided into ‘simple’ and ‘complex’ systems. 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 breakdown of the types of systems is set out in Forestry Commission Information Note 29.

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 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 elements of CCF management. Natural regeneration will increase structural diversity due to variations in establishment and growth rates. Being flexible around adapting plans is important to allow for this less reliable, and often slower, natural process, as well as 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. Respacing will often be essential when relying on natural regeneration in productive crops, to favour target species and allow appropriate tree spacing for stem development.

In all forests, it will be important to pay particular attention to light levels in the understorey to ensure that they are adequate for natural regeneration or the growth of underplanted seedlings to succeed. Some species are more shade tolerant than others, and particular care needs to be taken when planting a mix of conifer and broadleaves to ensure that faster growing conifers do not shade-out slower growing broadleaves.

If successful and well-managed, natural regeneration can reduce but not eliminate establishment costs and also ensure the establishment of tree populations that are genetically well-adapted to the site and prevailing climatic conditions. 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 some intervention there can be a risk that crops designated as CCF could remain, or become, less diverse if faster growing species begin to dominate.

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, where the coupe size is 0.25-2 ha in size. 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.

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 below).
- 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, although coppice stools may still need protection from deer browsing after felling.
- help develop a good succession of woodland habitats within a small area.
- be used where larger trees are not desirable, e.g. on boundaries with other landowners, 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 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 options in larger forests as part of a forest or woodland management plan. 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.

Short rotation forestry (SRF)

SRF is the management of fast-growing 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 and Eucalyptus have considerable economic potential however, due to transportation costs, proximity to markets such as wood/biomass power stations is critical. Other species such as Alder and Willow can also be managed via SRF, although the market for these products is more limited. 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. Managing crops on shorter rotations also provides an opportunity to change species quickly which has potential to reduce risks in a changing climate.

Research is being carried out to improve understanding of SRF potential in the UK. In Wales, three short rotation forestry (SRF) trial sites were established between 2014-15 and an update on progress in terms of tree growth and survival is available (Forest Research, 2025). Results show that the fastest growing trees were the two eucalypts, Tingiringi gum and cider gum and two exotic alders, red and grey alder. Of the native species, common alder exhibited the fastest height growth; the growth of other native or naturalised broadleaves was relatively slow. The trials are now well established and have the potential to demonstrate the relative height growth and survival of a good range of potential SRF species across three very different sites in Wales.

Currently SRF tends to be employed on new planting sites, but it could be considered for wider 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.

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’. UKWAS requirements state “Management with no systematic felling or planting of trees. Operations normally permitted are fencing, control of non-native 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 by allowing stands to mature 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, as it can support the development of old-age characteristics of trees that are currently lacking in many native broadleaved woodlands in Wales, particularly those that may have been coppiced in the last 100 years. A minimum intervention approach may be applied to:

- young or developing crops where a decision is made not to manage them.
- more mature stands (retained beyond their normal rotation age) on a long term but temporary basis (long term retentions) for predominantly environmental reasons.
- woodlands important for their conservation and biodiversity value on a permanent basis (natural reserves).

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.

On designated sites and woodlands with sensitive habitats or species, the silvicultural system employed should aim to maintain and enhance the features of the site and improve ecological condition. CCF, coppice or minimum intervention are most likely to be suited to native woodland management on these sites.

When managing any ancient woodland including restoring Plantations on Ancient Woodlands Sites (PAWS) to native woodland, care should be taken to avoid the levels of shock to the forest ecosystem associated with clearfelling and restocking operations. LISS will usually be the most appropriate option 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, followed by restocking and management via LISS thereafter.

Implications for ecosystem services and wellbeing

All woodlands provide a range of ecosystem services and well-being benefits, including climate regulation, air and water purification, flood protection, soil formation and nutrient-cycling. They also provide timber and wood products, opportunities for recreation and an appreciation of nature.

The choice of silvicultural management system will, to some degree, affect the range of ecosystem services and well-being benefits provided by the forest or woodland.

Carbon

The situation is complex covering: soil carbon; overall greenhouse gas balance (whether the forest is acting as a source or a sink); sequestration rates (which will be affected by tree species choice, tree age and age structure, growth rates); and long term benefits (linked to the nature and use of harvested wood products). There will be significant temporal and spatial variations in all of the above. It is often suggested that CCF is more favourable than clearfell from a carbon perspective, but there is no consensus in current literature and more longer-term studies are needed to research the complex interaction of variables.

In summary, under a clearfell system:

- carbon stocks show high variability, with large losses as harvested timber is removed followed by gradual accumulation during regrowth.
- soil carbon can decline due to exposure and disturbance during clearfelling and site preparation, especially on peaty soils.
- long-term climate benefit depends more on biomass yield and substitution effects (use of harvested wood to replace fossil-based materials) than on silvicultural system choice.

In summary, a CCF system:

- maintains higher standing biomass and soil carbon stability because canopy cover and root systems remain intact.
- reduces risk of carbon emissions from soil disturbance and avoids large carbon fluxes associated with clearfell cycles, although careful management of brash will be necessary to avoid soil damage during thinning.
- may only result in minor differences in long-term climate benefit compared to CF when growth and wood utilisation are similar, because substitution effects dominate overall carbon balance.

Water

Forest practices can have positive and negative impacts on water quality and quantity. Clearfelling has the greatest potential to negatively impact water quality and water flow but the risks should be mitigated through careful adherence to the requirements of the UKFS. In contrast, once a CCF structure is established, the presence of a mature canopy and different structural layers will tend to reduce the risk of water quality and water flow impacts. Similarly in relation to soil erosion, LISS reduce the risks associated with the bare ground phase of clearfelling and disturbance associated with ground preparation for restocking, particularly as natural regeneration is often favoured.

Timber

The overall production output may not change, but the choice of silvicultural system may affect the range of products harvested and marketed, as well revenue flows due to more the phased and flexible approach to harvesting. A woodland that is managed to promote structural diversity will often provide a wider range of timber and non-timber products, allowing greater flexibility for harvesting at desired log sizes, and the ability to take advantage of favourable market conditions. Currently timber harvesting and processing favours an economy of scale reliant on uniformity and large-scale management, typically based on a clearfell and restock system. LISS require different ways of working but with careful planning, appropriate advice and investment in infrastructure, the time and costs involved in transitioning can provide a good return on investment.

Biodiversity

In relation to biodiversity, the situation is quite complex. Many species are dependent on or closely associated with woodlands. These include European Protected Species (EPS) species such as bats, dormouse and otters, as well as UK protected species including red squirrel and pine marten. 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 LISS will provide the greatest benefits for woodland species. LISS can provide greater habitat stability with less intense changes

arising from harvesting operations, and more opportunities for a well-developed understorey and ground flora achieved through regular thinning interventions.

People

Good planning regardless of silvicultural system will reduce potential conflicts and negative implications for people and well-being. 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. At a landscape scale, the management of woodlands using LISS will tend to result in fewer landscape 'shocks' like those associated with large clearfells, which can negatively affect peoples' association with and enjoyment of woodlands.

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

Landscape

Landscape considerations apply at various scales, within the forest and outside the forest, and there are both positive and negative impacts associated with clearfell systems and LISS. Attractiveness is subjective so much depends on good forest design and consideration of key viewpoints, in accordance with the UKFS. More even-aged stands can look attractive if well thinned, and after clearfelling may offer the advantage of new vistas and panoramas opening up. However, clearfelling can look unsightly and is sometimes viewed as a 'landscape shock'. LISS typically offer more attractive views within the forest given their more complex structures, although wider views to the surrounding landscape may be more constrained because of the continuous cover approach. A continuous cover approach, however, offers more stability in the landscape.

Soil

Soil considerations are strongly linked to carbon as soil disturbance and compaction during forest operations can lead to carbon losses, but the management of drainage and run-off is also important to maintain soil reserves and prevent erosion. Potential impacts will depend on the intensity of operations and the type of machinery and equipment used. Again, negative impacts should be minimised through adherence to the UKFS.

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. Key considerations include:

- establishment costs in LISS 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.
- timber flow patterns in LISS 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.
- 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 should reduce subsequent operational costs, as well as reducing the risk of soil erosion and pollution incidents.

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 the main management objective, 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.

How to improve structural diversity

This chapter recommends actions to improve the structural diversity of woodlands and forests in Wales. Desired outcomes may take decades to achieve so interventions need to be planned and carefully targeted to achieve the best results.

Thinning

Thinning is one of the most important interventions to increase structural diversity and is relevant to most silvicultural systems. Effective thinning will:

- encourage the growth of high-quality timber and increase 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.
- allow development of multiple canopy layers within the stand.

- improve conditions for biodiversity, such as increasing light levels reaching the forest floor allowing the development of an understorey and the spread of important lower plant communities, or halo thinning to support the condition of veteran native broadleaved trees.

Regularly thinned stands will generally deliver a far wider range of benefits and ecosystem services than un-thinned ones. Given the importance of thinning it is recommended that:

- all stands are assessed for their suitability for 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, whether this is via restocking, new planting or natural regeneration, 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 stands 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.
- coppicing systems are being used which often do not require specific thinning.

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) will occur 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 interventions should be prioritised for the development of permanent internal infrastructure of tracks and other access features.

Recommendations for all woodland types

- LISS should be considered as an alternative to large scale clearfelling and restocking where they fit with management objectives, site conditions and exposure.

- All stands should be considered for thinning at the earliest appropriate opportunity, as this is usually critical for improving structural diversity and longer-term stability. Thinning regimes appropriate to the silvicultural system should be adopted, for example crown thinning will be increasingly appropriate to many CCF sites.
- Investment in new permanent infrastructure is critical to managing LISS, particularly CCF sites. Managers should identify a prioritised programme for the creation and maintenance of permanent infrastructure.
- Where CCF is chosen, conversion should be prioritised 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.
- 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.
- For those sites not suitable for CCF or SCF, long-term planning should aim to reduce average clearfell sizes wherever possible, as long as this doesn't destabilise surrounding trees and increase the risk of windblow, to reduce the impacts of large felling operations.
- Take opportunities to buffer riparian zones with broadleaved trees and shrubs.
- Use a variety of regeneration methods, including natural regeneration, active restocking, coppicing, and underplanting, taking in account management objectives, 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.

Recommendations for native woodlands

- Clearfelling should be avoided in native woodlands, especially semi-natural woodlands which have particular ecological and social importance.
- Where possible, native broadleaf stands should be managed using LISS. Particularly sensitive areas may need managing through minimum intervention but this should be a positive management decision to maintain woodland qualities.
- Thinning of native woodland, including halo thinning to support veteran and mature trees, should be considered as much a priority as for any other woodland.
- Coppice systems should be encouraged in appropriate situations, such as even-aged native broadleaf stands or areas where grey squirrel damage is particularly severe.
- Consider using SCF to initiate rotational coppice working and increase the use of Coppice or Coppice with Standards.
- Ensure localised protection of areas of natural regeneration of native canopy forming saplings if there is a risk of damage by squirrels or browsing mammals / livestock.

Recommendations for Plantations on Ancient Woodland Sites (PAWS)

- Restoration of PAWS to native woodland should ideally be a gradual process.
- LISS should be the preferred management option on PAWS.
- The sensitive maintenance and restoration of ancient woodland features should be the primary consideration when selecting a silvicultural system on PAWS.
- Consider halo thinning to support veteran and mature tree that exist within PAWS.

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, species and exposure of the crop.

Establishment and pre-thinning age (0 to 14 years)

At this stage, few operations are likely to be required. 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.

Young crops (15 to 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 “standard” approach: 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. An 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.

Semi-mature stands (30 to 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, soils are thin or the stand is exposed. There are still some priorities though.

- 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 to ensure it's not over-thinned.
- Look for opportunities to commence the under-planting of new species where you wish to diversify tree species.

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 via a planned clearfell, but this decision can only be made on a stand-by-stand basis.

Summary

To increase the structural diversity of woodlands in Wales, the range of silvicultural systems currently adopted needs to broaden. The aim is to reduce the amount of clearfelling and increase the use of LISS, to improve resilience and support adaptation. Woodland managers should be forward-looking in selecting the most suitable silvicultural systems, recognising the challenges now being faced, and the length of time needed for woodlands to grow and reach maturity. Success will be based on:

- a clear understanding of the risks posed by climate change and pests and diseases, together with a need to support biodiversity.
- having clear management objectives.
- taking action that is appropriate for different woodland types.
- correctly assessing site suitability for LISS.
- monitoring progress and results and remaining flexible if it becomes necessary to adapt the management system that has been chosen.

Annex 1: Silvicultural systems and habitat conditions

Below is a summary of the broad habitat or succession of habitats that are likely to occur within a range of silvicultural systems. Thinning is the most important activity to start the process of improving structural diversity in all woodlands, regardless of silvicultural system. 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.

Large or small scale clearfelling and restocking

Structural characteristics: Felling and regeneration, usually with restocking (but can use natural regeneration) on a rotational basis on a large or small scale.

Habitats / conditions created: 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)

Structural characteristics: Felling and regeneration continuous over the whole forest area.

Habitats/conditions created: 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.

Uniform shelterwood (simple CCF)

Structural characteristics: Successive regenerational thinnings that are even over the whole stand.

Habitats/conditions created: 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)

Structural characteristics: Successive regeneration felling in scattered groups or strips.

Habitats/conditions created: 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)

Structural characteristics: Successive regeneration fellings that are irregular and gradual.

Habitats/conditions created: This will develop in similar ways to uniform and group systems, but the distribution of gaps and longer periods of regeneration will produce irregular structure and subsequently may help give more continuity of woodland habitat with a variety of woodland conditions within a single stand.

Annex 2: Sources of information

UK Forestry Standard. https://www.gov.uk/government/publications/the-uk-forestry-standard

UKFS Practice Guide Adapting forest and woodland management to the changing climate. https://cdn.forestresearch.gov.uk/2022/05/UKFSPG026.pdf

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TranSSFor Transformation of Sitka spruce to CCF. https://teagasc.ie/crops/forestry/research/transformation-of-sitka-spruce-to-ccf/

Forest Research:

- Short rotation forestry. https://www.forestresearch.gov.uk/tools-and-resources/fthr/biomass-energy-resources/fuel/energy-crops-3/short-rotation-forestry/
- Continuous cover forestry. https://www.forestresearch.gov.uk/research/continuous-cover-silviculture/

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

Silviculture Research International. https://silviculture.org.uk/