Comisiwn Coedwigaeth Cymru
Forestry Commission Wales

Guidance

A guide for increasing tree species diversity in Wales

Contents

1. Introduction

This document provides advice on increasing species diversity in Welsh woodlands and forests. It is aimed at professional foresters and woodland owners.

FCW is committed to encouraging species diversification in Wales' forests. This commitment is stated in our policy document, Woodlands for Wales (Section 2.2), and is particularly relevant in the context of recent research on climate change. An overview of this background is given in Section 2 below; see also the further reading section.

In this guide we:

- Explain the need to increase tree species diversity in the context of predicted climate change, and associated ecological change
- Encourage woodland management in pursuit of defined objectives
- Explain how increased diversity – while not itself an objective for many woodland owners – may help them to achieve their objectives
- Suggest a way to accommodate diversification into existing procedures for woodland planning
- Explain the role of scale in delivering species diversity
- Explore the site and climatic factors which need to be understood to make appropriate species choices
- Outline a decision support system for increasing diversity in Welsh forests, including:
    - Species tables which can be used to identify potentially useful species for particular sites types and growing conditions
    - Species notes, which describe the suitability (or otherwise) of trees in the context of the best available predictions for climate change in Wales.

To help people who are actively managing woodlands in Wales, this guidance includes discussion of planning changes at "whole-forest" level, and at the level of individual sites (e.g. clearfell / restock sites).

This document assumes prior knowledge and experience of silviculture, and is not intended to be a comprehensive handbook. Please see Section 6 for a list of supplementary material.

It is essential that in delivering species diversity that we maintain the principles of **sustainable forest management** as set out within the UK Forest Standard and that we all follow the most recent published Forestry Commission guidelines.

FCW intends to publish further detailed guidance on structural diversity and choice of tree provenance, as well as a range of diversification case studies – please check the website for updates.

2. The changing climate

A lot of research has been published recently on the effects of climate change on forests: of particular relevance are 'Combating climate change – a role for UK forests' (known as 'The Read Report') and 'Impacts of climate change on forestry in Wales'. Research in this area is continuing, and it is strongly recommended that readers visit the Forest Research and FCW web pages on the subject for updates.

The key points arising from the research are that:

- There will be an increased risk from **pests and diseases**:
    - It is not possible to predict with certainty the extent to which individual species will be affected.
    - To increase the resilience of woodlands, we need to use a broader variety of trees, and reduce the scale at which we plant them.
- **Soil moisture** and increased occurrence of **droughts** will increasingly become a limiting factor:
    - This will affect a number of species, including Sitka spruce in some areas.
    - If a site is (currently) at the "dry end" of the species tolerance range, that species should no longer be planted.
- **Exposure** will remain a limiting factor and continue to restrict the range of species that prefer more sheltered sites.
- There could be **increased growth rates** of some species, particularly in west Wales where the climate becomes warmer and soil moisture does not become restricting.
- **Extreme weather events** such as **storms** and **high winds** could become more frequent, and more extreme:
    - Managers should work towards cultivating forests with increased structural diversity, to improve resistance to extreme weather.
    - FCW is working on further guidance regarding diversity of age-class distribution within woodlands.

A general conclusion from the above points is that we must use species that are **well-suited to the site now**, and are **likely to remain suited to the site** given climate change predictions.

3. The need for diversification

The section above indicates that the growing conditions for trees and forests in Wales are likely to change; however the precise extent of that change is unknown. We anticipate a greater future threat from pests and diseases, but we cannot accurately anticipate specific infestations or outbreaks.

In the face of these uncertainties, it is essential to take action now to increase the resilience of our woodlands and forests.

Risk mitigation means responding to uncertainties in a rational way, by designing forests and woodlands which are as resilient as possible to anticipated changes to climate and forest ecology. This is of particular interest to private woodland owners, who wish to safeguard the value of their investment - both with regard to the market value of the entire woodland, and future timber production.

In practice mitigating for these risks will mean greater species, structural and genetic diversity; this document concentrates on *species* diversity.

3.1 What is diversification?

Diversifying woodlands **does not** mean creating unmanageable or inappropriate mixtures of species; **nor does it necessarily involve "intimate" mixtures of species.** It is important to understand and use the appropriate scale for diversification.

- Diversification will mean **making better use of the tree species commonly planted** in Wales, while ensuring that they are well suited to the site in the context of predicted climate change.
- Take opportunities to use tree species **not historically widespread** in Wales, but which will become more suitable under current climate change predictions.
- Be sure that you have given appropriate consideration to a choice of **silvicultural system** when making decisions on species and mixtures.
- Make sure that any intimate, line or group mixtures are of **compatible species** and they will meet the long-term management objectives (this will be the subject of later guidance).
- **Use existing or expected natural regeneration** to diversify stands where the species you expect will be able to meet the set objectives and will remain well suited to the site, even where you are not practising CCF.
- **When thinning or re-spacing, take the opportunity to retain minor species** where they will contribute to the long-term objectives of the stand.

3.2 Targeting diversification

Diversification of Wales' woodlands and forests cannot be achieved everywhere, at once. In this section we indicate situations where work towards diversification should be given a high priority.

Geographic criteria and site types

- We believe that east and south Wales are most at risk from future drought, and have the best opportunities for change. Planting proposals in these areas should be reviewed as a priority, particularly **on south-facing** and / or **dry** sites, or sites with **shallow soils**.
- In west Wales, planting sites at **lower elevations** on **better soils** present a high-priority opportunity to diversify tree species.

Opportunities for diversification are more limited in upland Wales. The presumption is that **all** opportunities will be taken to utilise site variations to increase diversity. This means looking particularly **at peaty gley** sites, to see if diversity can be favoured by site variations.

Species

- Recent outbreaks of **forest pests** may influence priorities for diversification. For example mature stands of Corsican pine (susceptible to red band needle blight) and larch (phytophthora) may be considered for felling and restocking with a more diverse range of species.

Figure 1 – Trees affected by red band needle blight (left) and phytopthora (right)

- Identify opportunities to create **stands of mixed conifer and broadleaf** where it will suit management objectives.
- Identify opportunities to diversify tree species by **under-planting** of other species to supplement natural regeneration.

- Where conifers are chosen, the presumption is that **Douglas fir and other redwoods** will be the preferred conifer species where site and exposure allow.
- **Habitat networks** (e.g. ancient & native woodland; riparian zones) should be the focus for expansion of woodlands of predominantly native species.

Constraints

The speed with which woodland diversification can take place in Wales is likely to be affected by:

- The extent of **engagement** and **participation** in diversification within private-sector forestry
- The speed with which **existing planning** regimes can be adapted
- Existing **contractual commitments**
- The time taken for seed suppliers and **forest nurseries** to adapt to different levels of demand for various tree species. (FC is currently reviewing its arrangements with nursery stock suppliers at a GB-level, with a view to increasing the range of species available.)
- The length of time needed for the appropriate **knowledge and skills** to become widespread in the industry

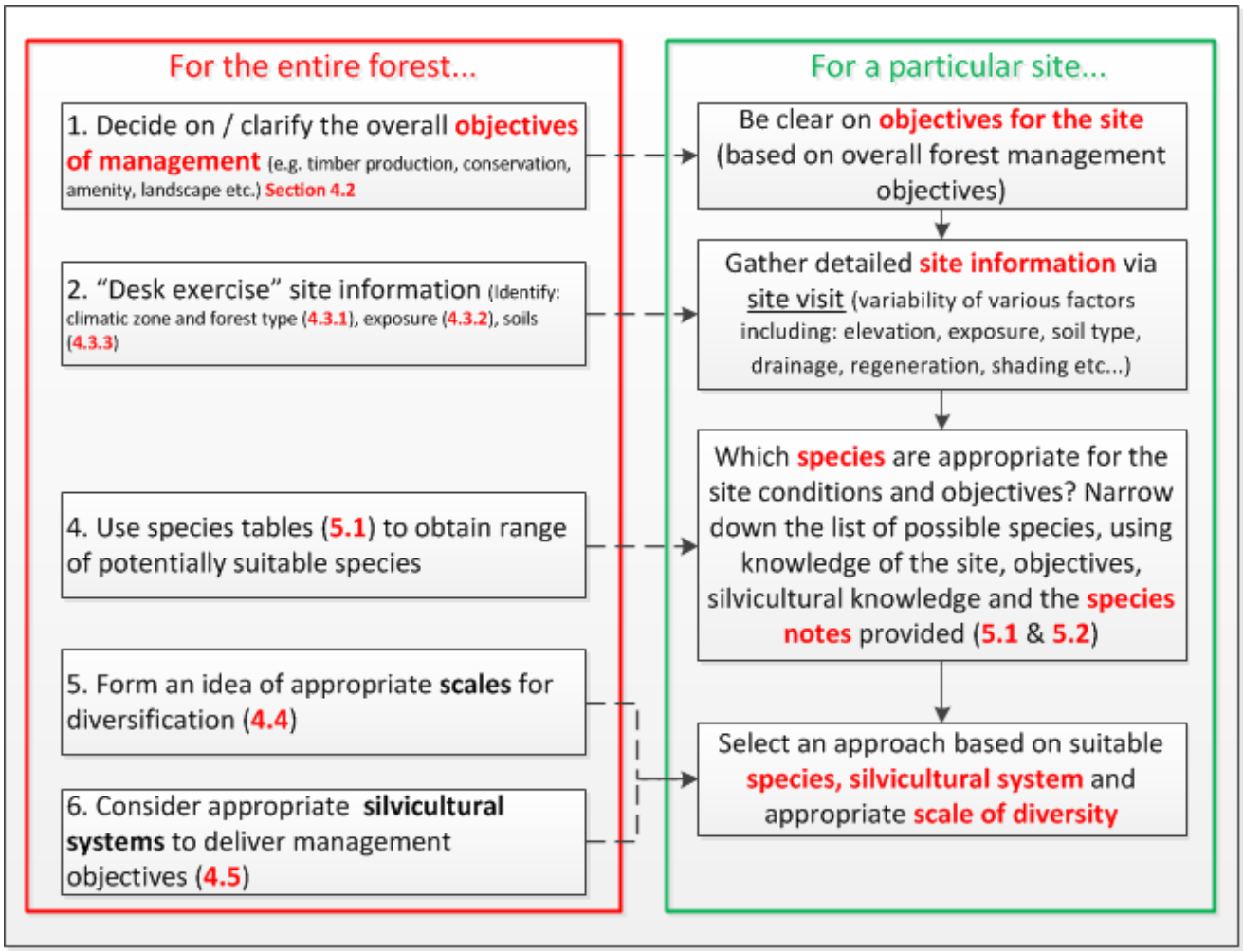
4. Implementing diversification

We recommend an approach based on objective-based management planning, using the best available information to choose species (and species-mixtures). This section introduces a decision support system, and explains the key concepts.

4.1 Planning for forest diversity

The recommended planning process for species diversification is set out in the following diagram. Each of the steps is explained in further detail in the numbered sections. (Please note that this does not represent the entire planning process, which is likely to require detailed consideration of a range of issues relevant to the situation and management objectives.)

Figure 2 – Decision support flowchart



In recommending the approach set out above, we acknowledge that Wales' woodlands are in a wide variety of ownerships and situations, with different management structures in place. It should be possible to accommodate diversification without abandoning existing forest management plans; however it may be appropriate to reconsider some aspects in the context of climate change.

There are likely to be particular opportunities at a "site-level" – for instance where an existing clearfell site, or proposed clearfell, gives opportunities to broaden species diversity when restocking. It may be possible to make meaningful changes in the short-term, without entirely re-writing the existing management plan, or substantially altering the harvesting programme.

If you decide to revise an existing woodland management plan, consider how the changes would relate to Felling Licences and grant contracts. It may be appropriate to discuss your proposals with the local FCW Woodland Officer before implementing them.

4.2 Setting objectives

Forestry Commission Wales works towards achieving objectives set at an EU and UK level, as well as implementing the policy of the Welsh Assembly Government. These are clearly set out within Woodlands for Wales – the Wales Woodland Strategy and the associated Policy Positions.

At Welsh Assembly Government level: implementing a range of policies in relation to biodiversity, timber / wood fibre, climate change and carbon sequestration, and woodlands in a social context.

At UK-level: implementing the UK Forest Standard. FCW also has statutory and regulatory responsibilities under UK law.

At EU-level: including a range of environmental regulations, European Protected Sites and Species, Water / Soils Framework Directives etc.

Many of these considerations have an impact – directly or indirectly – on private woodlands. For example, the European Water Framework Directive and Soils Framework Directive will put increasing pressure on all land managers to protect water and soils; European Protected Species regulations directly affect the planning of forest operations in many circumstances.

Private woodland owners have their own management objectives – often multiple objectives within one property – which frequently include:

- Generating revenue through timber sales
- Improving the capital value of the property
- Improving the condition of habitats and species
- Restoring or preserving ancient woodlands
- Public or private recreation
- Providing a location for sports (ranging from pheasant shoots to mountain biking) which in turn provide a source of revenue.

We strongly recommend that woodland owners consider "risk mitigation" as an objective in its own right. It is clearly in a landowner's interest to take account of the threats posed by climatic changes (and the risk of pest damage) to the other objectives of management.

If there is not already an objective-based management plan, it is a good idea to clearly **establish the objectives of management** – setting down the objectives in writing – before considering diversification in any detail. This will be helpful further along when making decisions, as making species choices and selecting approaches to diversification will be informed by the management objectives for the woodland.

Defining objectives is the basis of Better Woodlands for Wales: woodlands in the scheme will already have their objectives set out in the form of "management features".

4.3 Gathering information

The decision support system presented here relies on forest managers correctly interpreting the guidance in relation to accurate information about the site. Information gathering can be broadly split into two categories:

- **Desk-exercise** information which can be readily obtained from existing records or published guidance, and
- **Site visit information**: more accurate information gathered by a suitably skilled person on while visiting the site for the purpose. This is particularly important as there can be a lot of variation, even on small sites, which affects the viability of different tree species and mixtures.

4.3.1 Climatic zones

Identifying the climatic zone of a property can be done as a desk exercise using this guidance. It is essential for both forest-level and site-level planning. These zones form part of the basis of the Forestry Commission Ecological Site Classification1 tool (ESC).

[1] Pyatt *et al,* 2001.

The Forestry Commission introduced the Ecological Site Classification tool as a site based approach to tree selection. It uses a combination of four climatic factors to form climatic zones relevant to choosing tree species:

- warmth
- wetness
- continentality (seasonal variability)
- windiness

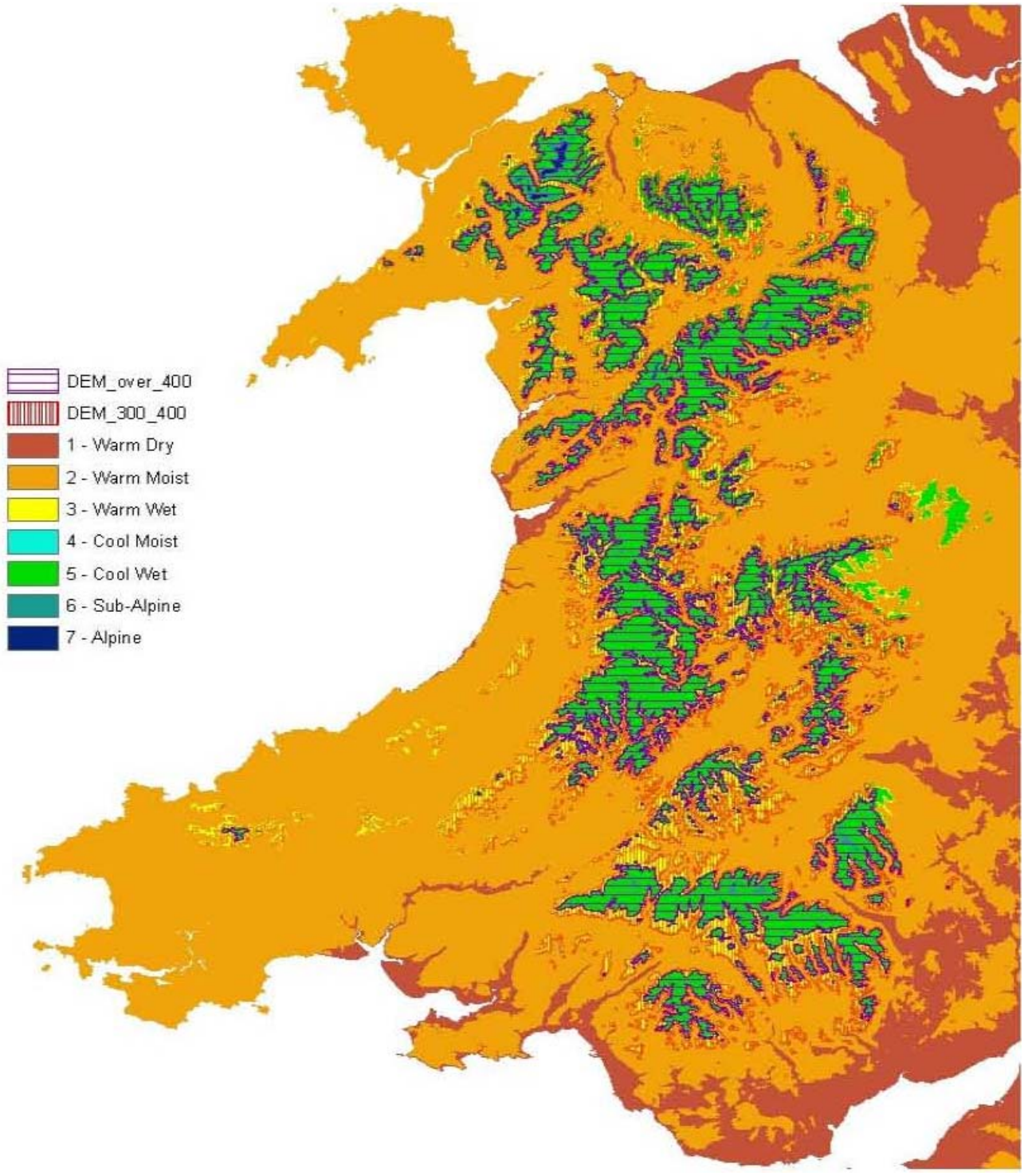
Potentially there are seven climatic zones recognised in Great Britain, but there are only three occurring in Wales: Two are widespread and one is limited to the south and east of the country. The major zones are those of **Warm Moist** (generally below 400m) and **Cool Wet** (over 400m) – see Figure 3 below. At lower elevations, especially in the east and south there are areas of **Warm Dry,** and it is this climate that is predicted to expand most in Wales under most climate change predictions.

These zones relate to elevation and geographical location. In Wales the hills are steep and climatic zones can change over short distances. Analysis has shown a strong correlation between appropriate species choice and elevation, with potential for diversification decreasing considerably above 400 metres elevation.

The three main climatic zones are used as the basis of species selection guidance. They can be seen to correspond with the "Forest Types" used the species tables (Section 5.1), as follows:

Figure 3 – Current climatic zones in Wales

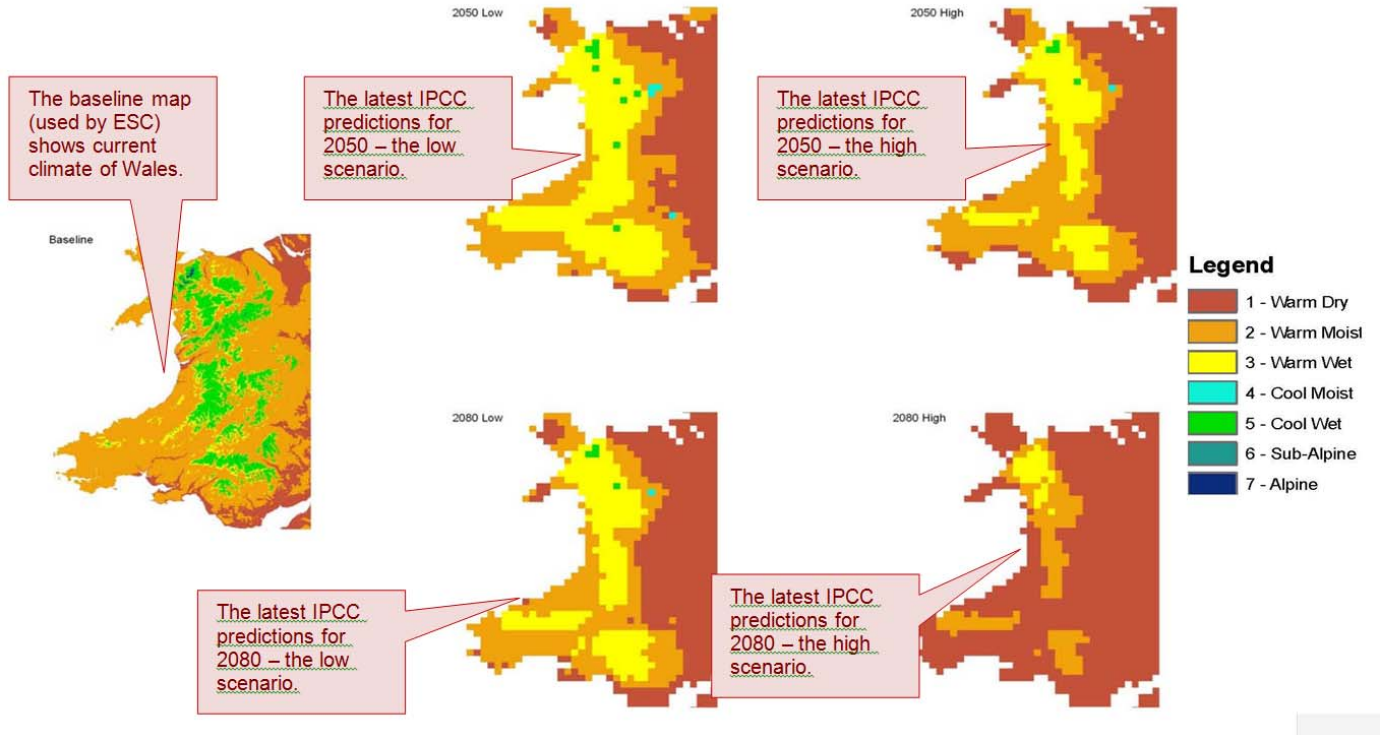
Dominant climatic zone	Forest type
Cool wet	Upland Wales
Warm moist	Mixed woodland
Warm dry	Mixed forest / pine



As well as picking species suited to current conditions, it is important to consider the changing climate in the context of the life of the crop. The **Species Notes** in Section 5.2 describe predicted changes in suitability of the main species used in Wales, and an overview of the changes is given in the following table. The main factors influencing future suitability relate to **accumulated temperature** and **moisture deficit**.

Figure 4 – Predicted climate changes for Wales

Current climatic zone	Current extent	Predicted changes
Cool wet	Close correlation with elevation > 400 metres.	Largely disappears under all scenarios; becomes "warm wet" in low-change scenarios and "warm moist" in higher-change scenarios.
Warm moist	Most of the lower land in Wales (below 400 metres)	Will largely become restricted to higher elevations in the east
Warm dry	Mainly below 50 metres in SE corner of Wales	Will increase in extent from the east and could dominate Wales under high-change scenarios.



The species notes in Section 5.2 identify the predicted changes in suitability for the main forest tree species of Wales. Information on predictions and on specific species is improving all the time so it is important that you seek the latest published information on climate change for individual tree species: go to the Forest Research website .

An **online version ESC** is available to use (free) via the Forest Research website[2]. This tool enables users to access basic data about a site – identified by a six-figure grid reference – including DAMS scores, accumulated temperature, moisture deficit, rainfall figures and projected suitability of various species. The tool includes projected suitability of species in future, for particular climate change scenarios. Please note that the information provided in this way is (necessarily) somewhat crude, and should be used in combination with detailed site information and professional judgement.

The online tools also include access to a wide range of maps indicating envisaged species suitability in different future climate scenarios, and a range of decision support tools.

Figure 5 – Part of the online ESC analysis showing species suitability

[Example Wood SH694085] ESC Analysis - Key Species | NVC Analysis | Future Climate Analysis | Amend Soil Settings

Species (Provenance)	Analysis Summary			ESC Factors					
	Suitability	Lim. Factor	Yield Index	AT5	CT	DAMS	MD	SMR	SNR
Scots Pine		CT	12 (10-14)						
Corsican Pine		MD	14 (10-14)						
Lodgepole Pine		DAMS	14 (12-16)						
Sitka Spruce (WSS)		MD	18 (14-20)						
Norway Spruce		CT	16 (12-16)						
European Larch		SNR	8 (6-8)						
Japanese Larch		MD	10 (10-14)						
Douglas Fir (WACO)		DAMS	18 (12-18)						

Site Location [Latitude: 52.46076867916547 Longitude: -3.675098419189453]

Climate Variables				Soil Variables			
AT5	CT	DAMS	MD	SMRS	SMRW	SMR	SNR
1009.6	7.4	19.3	48.5	Fresh	Wet	Moist	Poor

[2] Registration is required.

4.3.2 Exposure

Understanding the level of exposure on a site is critical when choosing suitable tree species. For purposes of forest-level or strategic planning, it may be appropriate to use tools such as FC's DAMS & ForestGales; however a detailed assessment of site – based on a site visit for the purpose - is essential for selecting appropriate species. To assess exposure, it will be necessary to consider a combination of factors including:

- Elevation
- Aspect
- Shelter (e.g. from nearby hills or adjacent forest)
- Topography and variations within the site (e.g. variable levels of exposure, frost hollows etc.)

The decision support approach taken in this document suggests categorising a site as follows:

- Exposed (DAMS score >18)
- Moderately exposed (DAMS 16-17)
- Moderate or sheltered (DAMS <15)

Climate change predictions are unclear about changes to the 'windiness' of Wales. We **recommend using current exposure conditions** when deciding species choice: add to this good silvicultural management and use of a wider range of silvicultural systems, and you will provide resilience to the risk of wind damage, including the predicted increase in frequency of storms.

FCW will produce further guidance on structural diversity in forests, which will explore ways to promote greater stability and resilience to wind damage.

4.3.3 Soils

Identifying the soils that we have, and making best use of variations in soils on site is critical to achieving increased species diversity and developing woodlands that will be resilient to climate change.

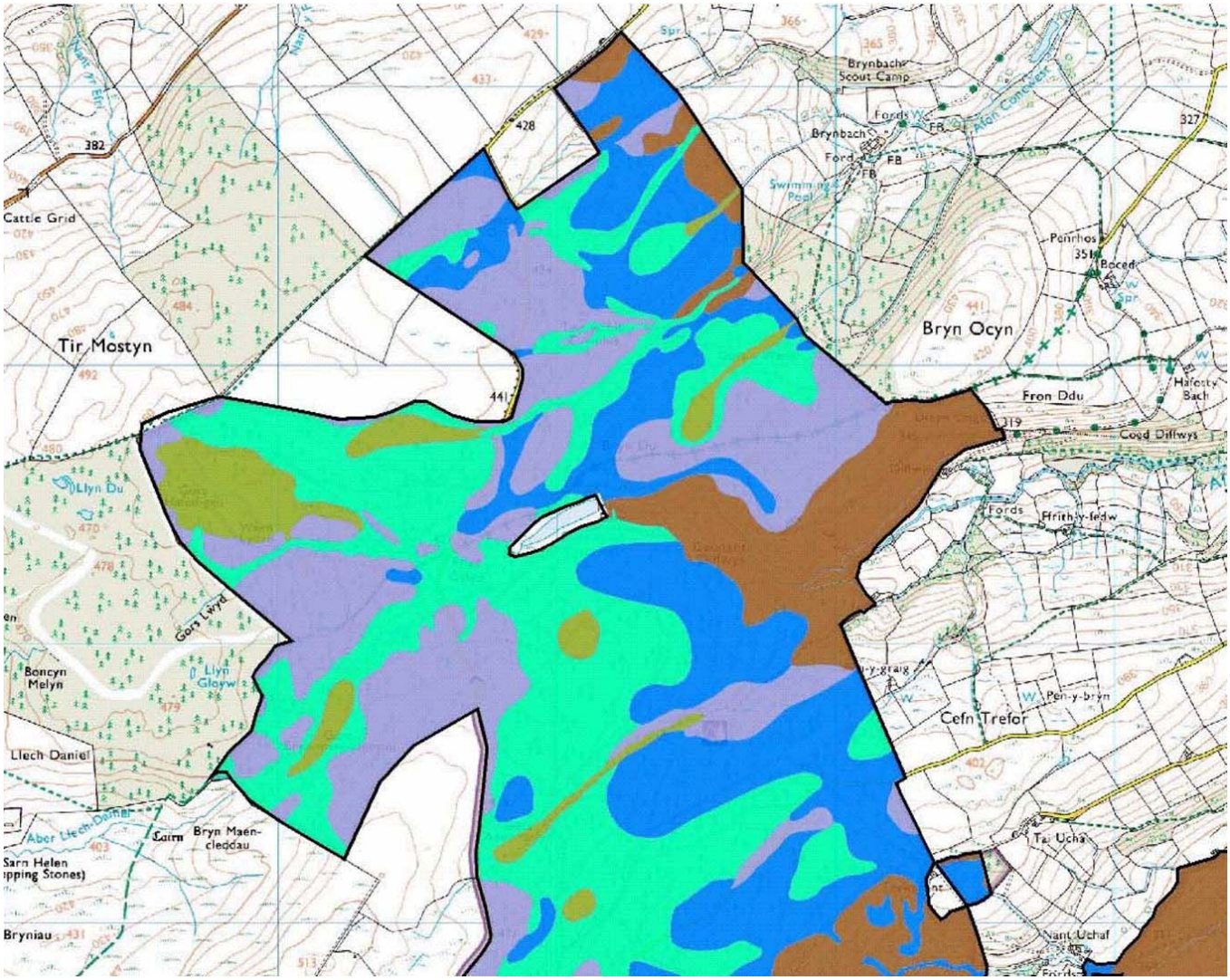
For this guide, we have grouped soils into categories (see species tables, Section 5.1). We have used these to define a range of species that will be suitable for those soils. It is important to note that soils vary considerably and that it can be difficult to define them. For example, a brown earth can range from a very deep, fertile, completely free draining soil on the best lower elevations, to either very shallow upland brown earth or verging on a peaty-gley or intergrade at higher elevations. You must take these variations into account when selecting species.

The numbers used for soil groups in this document are based on the Forestry Commission classification system. An FC field guide to the system is available[3], which includes a photographic guide and flowcharts to aid soil identification. The system used in the field guide corresponds to the table in Section 5.1.

Existing survey data vs. site visits

It is important to understand that only **site inspections** will give the detailed soil or vegetation information you need, to achieve tree species diversity. Soil data, even if collated from general soil surveys, (see Figure 3) does not give enough information to maximise the potential of sites. Digitised soil maps do have value in selecting the main species for forest-level planning.

Figure 6 – Digitised soil map for part of the Assembly Estate



[3] Kennedy, 2002

4.4 Gathering information

Increasing the range of species we use in Wales is critical to resilient forests. However, the scale we use for diversification is also important. In this section we discuss the range of scales and how they can be used to achieve management objectives for the woodland.

It is important that we share an understanding of the terminology.

- **Stand (or subcompartment)** – areas of forest comprising a more-or-less homogeneous crop in terms of age-class distribution, species composition and condition". ("Homogenous" in this context should be understood as "of consistent composition". Thus, a stand is not restricted to a **single** species or age class, and may mean an area of reasonably consistent diversity.)
- **Coupe** – a felling area or individual management unit within a forest plan or forest design plan, not necessarily consistent with earlier stand boundaries. May vary considerably in size.
- **Forest Block** – individual block of forest or woodland used as a management unit. Can be any size.
- **Catchment** – river catchment areas, as defined by Environment Agency Wales. Catchment-level management is expected to increase in importance.

No single scale will achieve the full range of benefits, and **it is essential in larger forests that you use a range of options to help create greater diversity**. You should make sure that the scale you use is appropriate to the site conditions, the proposed management system and the objectives.

Figure 7 – Intimate and group mixtures in a landscape

The tables below will help to identify the scale at which forest diversity can be delivered.

Table 1 defines what we mean by the various 'scales'. This is your range of options.

Table 2 identifies the range of objectives we seek and how using the different options will help meet these objectives. Some of the evidence for this is still unclear or speculative, but the table attempts to link what we currently understand as the likely benefits of various scales of forest diversity in delivering a series of objectives. Please bear in mind that the "star" ratings are a rough guide, and should be interpreted as such. Any 'scale' may be rendered more or less suitable by particular site conditions & management objectives.

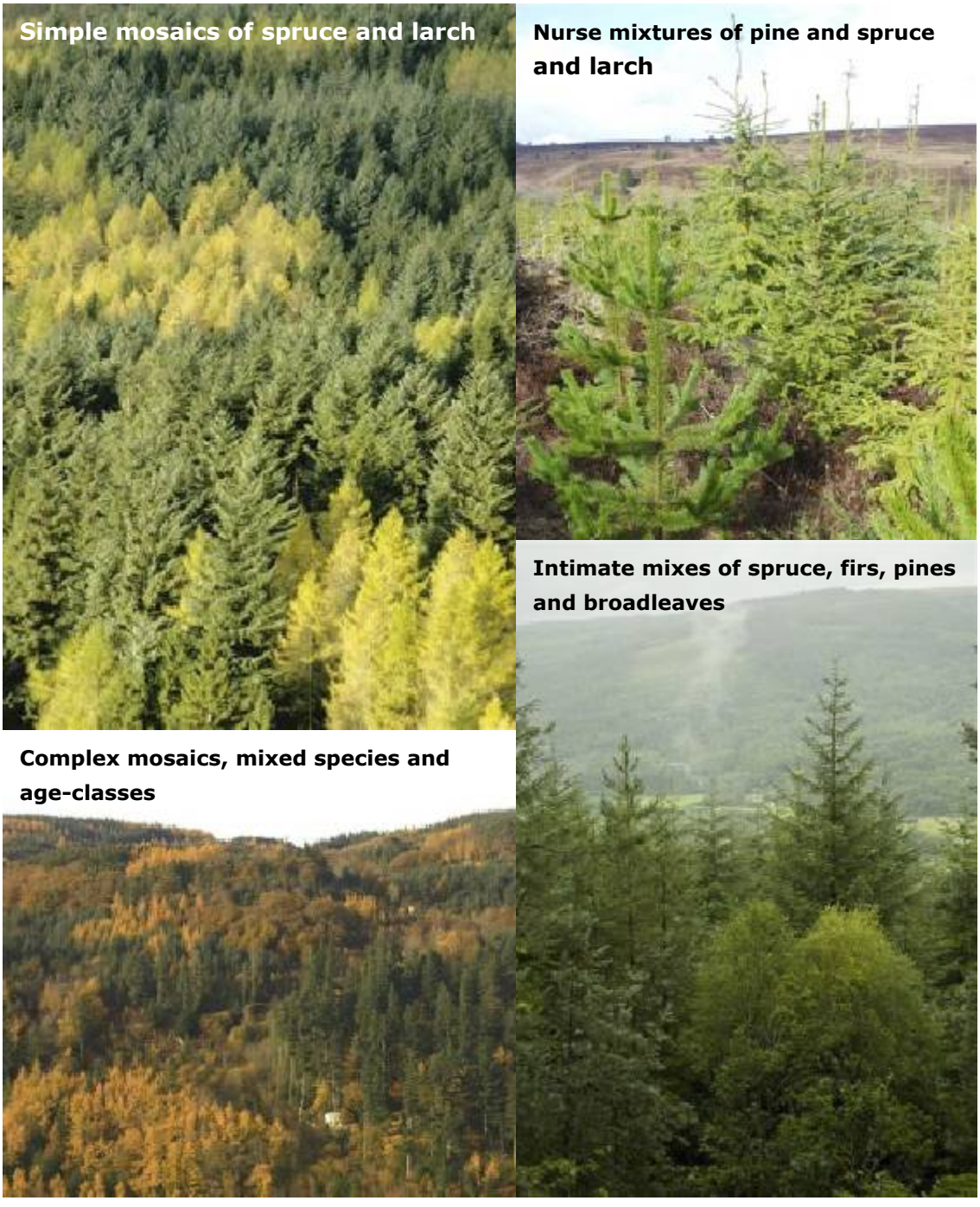


Table 1 – Scales of forest diversity

Scale of mixture	Definition	Limitations/issues with use	Comments
Intimate or random mixtures within a stand	Randomly planted trees with groups of individual species ***no larger than nine trees***. Species should be well-suited to growing together and / or shade tolerant. **Minimum standard -** Two or more species in an intimate or random mixture throughout a stand with each component permanently composing at least 25% of the canopy	Operational limitations of working with multiple species. Long-term intimate mixtures need compatible species and skilled management to maintain diversity. It is more expensive to establish and harvest intimately mixed crops. Management costs will be higher in more complex mixtures. These types of crop are currently most commonly associated with LISS or CCF management.	**Diversity within stands** Potential of a site is dictated by a range of site factors including, soils, elevation, exposure, water and nutrient availability. Using individual site variability is core to this achieving diversity. Monitoring diversity at a stand scale will be necessary to make sure it is done correctly.
Line/group mixtures within a stand	Line mixtures can be easy to plant and establish but can develop in different ways. They can be managed to develop into intimate mixes or can be used as nurse crops where one of the species will eventually remain. **Groups**: between ***10 trees together, up to groups 0.25ha*** in area. For some species it may be necessary to plant in groups of over 25 trees. **Lines**: Any combination of line mixtures designed to meet set objectives.	Requires compatible species and/or interventions on time to ensure species diversity is maintained. Line mixtures should be avoided where landscape (especially historic landscape) is an important factor. Lines / groups may enable slower growing or more light-demanding species to remain viable in a mixed stand.	
Mosaic of stands - Diversity at a Sub-compartment/stand scale	Two or more species at a coupe or stand scale. Maximising diversity using discrete groups of a species a ***> 0.25 ha*** within a compartment or coupe.	Planting a variety of species in mosaics which best fit species to site conditions will optimise the growth potential of species.	Traditionally defined as sub-compartments. Range of species used and size of sub-compartments may vary considerably.
Forest block	The forest block comprises large, more-or-less homogenous blocks of (frequently) single-species stands.	Operationally efficient, and relatively simple to plan; however at forest-level, likely to be more susceptible to changes in climate, storms and pest infestations.	Typical of large plantations established in the 1950s-1970s, some of which are now being restructured.
Catchment	FCW will bring out guidance on catchment-level management in due course. Monitoring of diversity and extent of woodland cover at catchment level is likely to become increasingly important.		

Table 2 – Suiting diversity to management objectives

Forest management objective	Diversity type (see Table 1)				Comments
	Intimate / random	Line / group	Mosaic of stands	Forest block	
Increasing biodiversity – stand scale	★★★★★	★★★★	★★★		Diversity is achieved by creating as wide a variety of habitats as possible within a given area ensuring that the diversity is at the right scale to be beneficial. Although intimate mixes are considered beneficial, in maximising diversity, you should consider the full range of structural and scale options available. The right approach will depend on the type of habitat you are dealing with.
Increasing biodiversity – forest or catchment scale.			★★★★	★★★★★	
Increased protection – for example against pathogens. Linked to improving diversity, wider range of species should one or two get attacked by disease, but also by generally improving the wider forest health and increasing the range of predators against disease.	★★★★★	★★★★★	★★★★	★★	Improving the ecological health is better achieved at a more intimate level of diversity in combination with structural diversity increasing the range of diversity. Increasing the range of species at a strategic scale will improve our overall resilience to attacks from individual pests or diseases.
Better defence against climate change – as climate patterns shift, the suitability of species to an area will change, but the predictions vary and are unclear, so we need to utilise a range of species that are well suited to the site now and in most future climate change scenarios.	★★★★★	★★★★★	★★★★	★★★	It is important to consider diversity at all levels to increase resilience against the impacts of climate change.
Ecological or site improvement – increase the range of site conditions, for example light, improvement to soil condition and water quality. Focus on improving the condition of the site by using a greater range of species including those that are known to improve site conditions.	★★★★★	★★★★★	★		The European Water Framework Directive (EWFD) and European Soil Framework Directive (ESFD) will put increasing pressure on all land managers to protect water and soils.

Forest management objective	Diversity type (see Table 1)				Comments
	Intimate / random	Line / group	Mosaic of stands	Forest block	
Maximising output or tree suitability – more efficient use of site. Site management making best use of changes to the site will give you a wider range species and species better suited to the specific micro site.	★★★★	★★★★★	★★★★★		Often for simplicity of management compromises are made to planting regimes. Planting more species suited to specific site conditions could increase yield and compensate for lost potential yield from establishing greater areas of native species.
Reducing risk – increasing management options – wider range of tree species. Can convert to CCF systems at a later stage. Wider range of tree species reduces risk.	★★★★★	★★★★★	★★★		Series of benefits of species diversity combined with increasing structural diversity will achieve a wider range of objectives, which need to be balanced with economic costs of achieving these outcomes.
Social – woodlands providing a safe and welcoming environment for the local community and all visitors. **Recreation** – improving the recreational experience by providing increased species and structural diversity of our woodlands. **Community** – increasing the value of woodlands to communities by providing increased species and structural diversity.	★★★★	★★★	★★★★★	★★	We need to provide a variety of species and habitats and creating these at a variety of scales will provide greatest improvements to the experience of all people using the forest rather than at one specific scale.
Landscape – to make sure that the landscape value of trees and woodlands is considered in the planning and management of woodlands.	★★★	★★	★★★	★★★	Intimate mixtures or varied canopy structure may look better close-up, but have minimal benefit at a larger landscape scale. Varieties of species and structures at a mosaic or stand level may well create most benefit at this scale or combinations of scale.
Maximising economic output – the current objectives of the private grower and private woodland manager needs to be balanced with the increased threats to woodlands as identified above. The economic output is not always timber.	★	★★★	★★★★	★★★★	There is a need to consider the economic drawbacks of implementing more complex species mixtures, in the context of overall risk mitigation.

4.5 Silvicultural systems

Choice of species is integral to your choice of **silvicultural system.** In selecting species for sites, it is essential that you consider the silvicultural system as part of the same decision process. **Species or combinations of species must be suited to the silvicultural system**. Many of the species we currently use are light demanders (such as pine) and choices need to be realistic and achievable. This guidance can only be very limited in the information it provides and you may need to seek more information on managing intimate mixtures under CCF, depending on your objectives.

To achieve tree species diversity without recourse to clearfelling the current crop, **underplanting** will be a valuable option (sometimes the only option) for increasing the diversity of the stand. Not all species are suitable for underplanting, although some species may be considered *only* suitable for underplanting, e.g. silver firs. Select only the appropriate species and make sure underplanting regimes are compatible with harvesting plans.

Where you are going to use intimate or line mixtures. it is essential to take account of **tree compatibility** i.e. where permanent mixtures are proposed, that the species you choose are compatible in growth rates, demand for light and regeneration. This document does not include suggestions of appropriate mixtures: subsequent guidance will identify some of the best mixtures to meet a range of objectives within Wales.

4.6 Operations

As well as restocking and new planting, we have opportunities to use natural regeneration, thinning and respacing to manipulate stands with the aim of maintaining or increasing tree species diversity.

4.6.1 Natural regeneration and enrichment planting

Consider using existing or expected natural regeneration as a method of diversifying stands where the species you expect, will be able to meet the set objectives and will remain well suited to the site, even where you are not practising CCF. Identify the opportunities on sites and whether they will meet your objectives. In many cases it will be appropriate to consider broadening species diversity by supplementing regeneration with some enrichment planting.

See Section 6 for publications relating to natural regeneration and silvicultural systems.

4.6.2 Thinning and respacing

Many of our established stands contain minor components of different species. These may have been natural regeneration of previous or surrounding crops. These can (if a suitable species) be an opportunity to ensure diversity is maintained or increased within existing crops. Depending on the species it may well be that these minor components would disappear over time or could be lost in thinning operations if you do not take positive steps to keep them.

When thinning or respacing, take positive action to retain minor species where they will contribute to the long-term objectives of the stand.

4.7 Economic impacts of change

It is essential to understand the economic impacts of tree species diversification.

Consider the following factors:

1. **Establishment costs**
2. **Intensity of management, particularly in managing intimate mixtures**
3. **Operational (especially harvesting) costs**
4. **Marketing – a wider range of products can have positive and negative impacts**

These factors should not stop the process of diversification, but you should consider them in future management and economic planning. Forest Research are currently investigating the economic implications of diversification.

4.8 Native and ancient woodlands

Within the Welsh Assembly Government's Strategy for Woodlands and Trees we have identified key commitments to native woodlands that will be taken into account in the diversification of Welsh woodlands.

> *"The published BAP targets for native woodland to 2010 and beyond are met, including those for maintaining the net extent of native woodland; achieving favourable or recovering condition; and restoring and expanding a proportion of the native woodland resource"*
>
> *"The woodland network is strengthened in key areas of Wales, by improved management of existing woodland, creation of new woodland, or by making the intervening spaces more friendly to woodland species (without harming priority species that rely on open habitats)[4]"*

[4] Welsh Assembly Government, 2009.

This guidance does not deal directly with the restoration or management of our Ancient and Native Woodlands, which will be dealt with in **separate guidance**. However, here we identify some of the key impacts of climate change on our native and ancient woodlands.

Wales has a range of different types of native woodland, reflecting variations in soil type, climate and wetness; and five priority woodland habitat types are recognised in Wales. One of our objectives is to improve habitat networks of native species. Networks have been identified throughout Wales. Habitat networks can be seen using the FCW Land Information Search tool.

Although climate is predicted to change in Wales, most of the native tree species are not thought to be at risk. However, groups of species might need to be adapted and our approach to local provenance will need to be reconsidered. Many of the species that make up our native woodland, such as Oak, Birch and Ash have a wide geographic distribution though out Europe, which would suggest that it will be possible to develop more robust ecosystems if we use a wider genetic resource.

Bringing native and ancient woodland into sustainable forest management and planting to improve habitat networks is essential to improving the resilience of our native woodlands. You can find more details on the appropriate groups of species in FC Bulletin 112 *Creating New Native Woodlands*[5].

4.8.1 Priority woodland habitats

There are five priority woodland habitats identified within Wales:

- upland oakwood
- upland mixed ashwoods
- lowland beech and yew woodland
- wet woodland
- lowland mixed deciduous woodland

Details on predicted impacts of climate change on these habitats can be found in the document *Impacts of climate change on Forestry in Wales*[6]. You can find more information on changes to individual species distribution can be found on the Forest Research website under climate change, species selection. One of the most significant changes is likely to be our selection of provenances, which will be addressed in future guidance. Examples of this may be the selection of beech provenances that will be more resistant to drought.

[5] Rodwell & Patterson, 1994.
[6] Ray, 2008.

Where creation of native woodland habitat is an objective then appropriate assemblages of species as identified within FC Bulletin 112 *Creating new native woodlands* should be the starting point for species choice.

However you should also take into account:

- the full range of objectives that can be delivered from native woodlands (not just the environmental outcomes). Identifying timber / biomass production as objectives does not necessarily conflict with environmental outcomes, and should be considered on the majority of native woodland sites.
- that resilience to climate change is part of the decision process
- options for creating mixed native or non-native species woodlands or using nurse species as a way of meeting multiple objectives for stands. Species need to be compatible and future management must be considered (See Section 4.6).

We do *not* recommend that entirely native-species woodlands should have non-natives introduced for the purposes of diversification. However it may be appropriate to reconsider the assemblage or distribution of native species in the woodland.

5. Species guidance

5.1 Species tables

The species tables are divided into four parts as follows:

Climatic zone	Forest type	Exposure	Species table
Predominantly cool & wet	Upland Wales	Exposed (DAMS score >18) / Moderately exposed (DAMS 16-17)	***PART ONE***
		Moderate or sheltered (Dams score ≤15)	***PART TWO***
Warm moist	Mixed woodland		***PART THREE***
Warm dry	Mixed forest / pine	Moderate or low	***PART FOUR***

Larch and *Phytopthora ramorum*

Phytopthora ramorum is currently spreading to larch sites throughout Wales. This is clearly an important consideration when choosing species. At the time of writing there are restrictions on grant aid for the establishment of larch in new planting and restock sites. Please check the FCW website for up-to-date information.

PART ONE

Climatic zone: ***Predominantly cool & wet***

Forest type: ***Upland Wales***

Exposure: ***Exposed*** (DAMS score >18) / ***Moderately exposed*** (DAMS 16-17)

Comments:

- Due to the very limited opportunities in these exposed peaty gley dominated uplands the presumption is that ALL opportunities will be taken to diversify species choice where better soils occur even where these are isolated pockets.
- Sitka spruce will remain the most productive conifer on these sites. Other suitable conifers primarily have fibre rather than timber potential but this should not deter their selection if site opportunities allow.
- Pines can be used as nurse species in line mixtures. If they are required as a permanent component within spruce crops, groups must be greater than 25 trees.
- The presumption is that all areas with deep peat will be reverted to open habitat as part of priority habitat restoration. Where the peat is so modified, native woodland may be appropriate.

Primary soil types	***Soil categories***	***Species choice***	
		Broadleaf	***Conifer***
Peaty gley Other than brown earth, these are some of the most common soils found, particularly at higher elevation.	6, 5p	Downy birch Silver birch Sycamore Rowan Grey alder	Sitka spruce Lodgepole pine Serbian spruce Scots pine Macedonian pine Pacific silver fir Noble fir
Ironpan/intergrade (Most of Wales is classed as Intergrade rather than full ironpans which allows a wider range of species to be suitable)	4	Downy birch Grey alder Sycamore Rowan	Sitka spruce Pacific silver fir Serbian spruce Noble fir Macedonian pine Lodgepole pine
Surface water gley	7	Downy birch Grey alder Sycamore Rowan	Sitka spruce Pacific silver fir Serbian spruce Noble fir Macedonian pine Lodgepole pine
Brown earth (At this elevation are *more likely* to be at the poorer end of the scale and classed as upland brown earth)	1, 1u	Downy birch Sycamore Grey alder Sycamore Beech Rowan	Sitka spruce Pacific silver fir Serbian spruce Noble fir Japanese larch Macedonian pine Lodgepole pine Pines, various
Skeletal/Rankers	13	Downy birch Sycamore Grey alder Rowan	Macedonian pine Lodgepole pine Scots pine Pines, various

PART TWO

Climatic zone: ***Predominantly cool & wet***

Forest type: ***Upland Wales***

Exposure: ***Moderate*** or ***sheltered*** (DAMS score ≤15)

Comments:

- These sites have increased opportunity for species diversity and a wider range of species may be used as major components at a catchment/forest scale.
- A number of the species identified here are shade bearers that should be utilised for underplanting to increase diversity in single species plantations undergoing transformation to non-clearfell management. Some species such as ESF are suitable only for underplanting in non-clearfell systems.
- On better soils, Redwoods including (in priority order) Douglas fir, Western Red Cedar and Sequoias in priority order should all be favoured when exposure allows.
- Where suitable Grand and Noble fir will prove useful choices for fibre rather than timber production as an alternative to Sitka spruce.
- Many of these sites will have potential for biomass through short rotation forestry management.
- The presumption is that all areas with deep peat will be reverted to open habitat as part of priority habitat restoration. Where the peat is so modified, native woodland may be appropriate.

Primary soil types	***Soil categories***	***Species choice***	
		Broadleaf	***Conifer***
Peaty gley	6, 5p	Downy birch Sycamore Ash (where more fertile) Silver birch Aspen Common alder Grey alder	Sitka spruce Norway spruce European silver fir (ESF) Grand fir (Less exposed areas) Noble fir Pines, various
Ironpan/intergrade (Most of Wales is classed as Intergrade rather than full ironpans which allows a wider range of species to be suitable)	4	Birch Rowan Sycamore Silver birch Aspen Common alder Grey alder	Sitka spruce Larch Douglas fir (Limited by exposure) Norway spruce Western Hemlock European silver fir Grand fir (Less exposed areas) Noble fir Pines, various
Surface water gley	7	Downy birch Sycamore Common alder Silver birch Aspen Grey Alder	Sitka spruce Norway spruce Western red cedar (limited by exposure) Pacific Silver fir Serbian spruce Noble fir Macedonian pine Lodgepole pine Scots pine

Primary soil types	Soil categories	Species choice	
		Broadleaf	Conifer
Brown earth	1, 1u	Downy birch Sycamore Ash(on best none acidic sites) Oak (sessile) Southern beech Beech (Only in nurse crops or as understory) Red oak	Scots pine Larch Douglas fir Western red cedar Sitka spruce Western Hemlock Pines, various Norway spruce Grand fir European silver fir Pacific silver fir Serbian spruce
Skeletal/Rankers	13	Downy birch	Pines, various

PART THREE

Climatic zone: ***Warm moist*** (currently mainly below 400m but predicted to increase from the east. This area include some "warm wet" (in the west) and "cool moist" (in the east)

Forest type: ***Mixed woodland***

Exposure: ***Moderate*** or ***sheltered*** (DAMS score ≤15)

Comments:

- Where conifers are chosen the presumption is that Douglas fir and other redwoods in priority order will be the preferred conifer species where site and exposure allow.
- On brown earth sites a wide variety of species are suitable. We strongly recommend that you consider alternative species to Sitka Sprice where they will meet management objectives.
- The presumption in this zone is that non-clearfell management options will be possible in future and therefore a range of mixtures at intimate and matrix scales should be established to facilitate this.
- Managers should look for all opportunities to establish mixed conifer/broadleaf stands with species such as redwoods, oak, ash and sweet chestnut. Where intimate mixtures are used careful selection of compatible species is necessary.
- Soil fertility and exposure will be the main factors constraining species choice.
- Drought will become an issue for some species particularly in the east and south of Wales.
- Most sites below 400m have moderate or low exposure: ***where exposure is high some species listed here will be unsuitable***. Always check species suitability in the context of the local exposure.

Primary soil types	***Soil categories***	***Species choice***	
		Broadleaf	***Conifer***
Peaty gley	6, 5p	Downy birch Common Alder Grey alder	Sitka spruce Omorikan Spruce Pines, various Norway spruce
Ironpan/intergrade (Most of Wales is classed as Intergrade rather than full ironpans which allows a wider range of species to be suitable)	4	Downy birch Pendunculate oak Common alder Hornbeam Southern beech Silver birch	Sitka spruce Larch Western hemlock Serbian spruce Oriental spruce
Surface water gley	7	Downy birch Pedunculate oak Common alder Red alder Grey alder Hornbeam	Norway spruce Western red cedar Sitka spruce Serbian spruce Pacific silver fir Pines, various
Skeletal/Rankers	13	Downy birch	Pines, various Douglas fir
Brown gley, brown earth	1, 1u	Sessile/Pendunculate oak Ash Sweet chestnut Southern beech Wild cherry Beech Lime Hazel	Douglas fir Larches Western red cedar Cypresses Silver firs Pines, various Japanese cedar Redwoods (Coast)

Primary soil types	Soil categories	Species choice	
		Broadleaf	Conifer
		Eucalyptus Norway Maple Aspen Poplars Red oak Sycamore Italian alder	
Calcareous (Where the Ph is high or soils shallow) Deeper soils where the Ph is relatively low will support a wider variety of species, see brown earth above.	12	Ash Silver birch Beech Sycamore Cherry Pendunculate oak Whitebeam Norway maple	Western Red Cedar European Silver Fir Leyland cypress

PART FOUR

Climatic zone: ***Warm dry*** (currently mainly under 50m, mainly in the south east of Wales but predicted (depending on CC scenario applied) to increase from the south and east to cover mos of southern and eastern Wales)

Forest type: ***Mixed forest / pine***

Exposure: ***Moderate*** or ***low***

Comments:

- The presumption in this zone is that non-clearfell management options will be possible in future and therefore a range of mixtures at intimate and matrix scales should be established to facilitate this.
- Managers should look for all opportunities to establish mixed conifer/broadleaf stands with species such as redwoods, oak, ash and sweet chestnut
- A wide range of broadleaves including some with growth rates compatible to conifers have significant potential for increased use such as Sweet chestnut and Southern beech
- ***Susceptibility to drought*** will be the most limiting factor in this zone and the extent is predicted to increase significantly to the North and West in the future climate change predictions. Spruce should not be selected and the use of beech and ash may be limited.

Primary soil types	***Soil categories***	***Species choice***	
		Broadleaf	***Conifer***
Ironpan/intergrade (Most of Wales is classed as Intergrade rather than full ironpans which allows a wider range of species to be suitable)	4	Silver birch Pendunculate oak Common alder Hornbeam Southern beech	Western red cedar Douglas fir Western hemlock Pines, various
Surface water gley	7	Silver birch Pendunculate oak Sweet chestnut Red alder Grey alder Hornbeam	Western red cedar Pines, various Douglas fir Pacific silver fir
Littoral/dune	15		Pines
Brown earth	1	Silver birch Pendunculate/sessile oak Sweet chestnut Wild cherry Hazel Beech Walnut Red alder Grey alder Hornbeam Red oak	Douglas fir Cypresses Pines
Calcareous	12	Beech Ash Silver birch	Western red cedar European Silver Fir Cypresses

Primary soil types	Soil categories	Species choice	
		Broadleaf	Conifer
		Sycamore Walnut Wild cherry Pendunculate oak Whitebeam Norway maple Italian alder	Pines

5.2 Species notes

Note

This is not an exhaustive list of species notes: if a species is not included, it should not be infered that it is considered unsuitable for use in Wales. Forest Research are currently compiling more comprehensive species notes on a wide range of species including those identified within this guidance (to be available late 2010). The notes below are mainly Wales-specific and should be used in conjunction with the guidance material in this document, and other relevant silvicultural publications.

Risk

In introducing new species to sites, some of which have rarely used to date within Wales, there needs to be an assessment of the level of risk associated with that species. For many sites and many species this risk will be low, however where species are known to be particularly invasive (e.g. western hemlock) or where that species might have other environmental impacts (e.g. water/fire issues related to eucalyptus), strategic and local evaluations will be necessary before widespread use of such species will be considered appropriate.

Provenance choice

This section does not identify suitable provenances. FCW will make more guidance available on the subject as soon as possible (2010 onwards). Appropriate selection of provenance is critical to the successful establishment and use of ALL species whether the objectives are environmental, social or economic. Some comments on seed sources for native tree species have been made here. Sourcing material from seed collected at comparable elevations to those where planting is proposed, is critical for a range of native species.

5.2.1 Conifers

Douglas fir

There is significant potential for increased use of Douglas fir in Wales. Its main restriction is by exposure, which is not predicted to alter in Wales. Opportunities exist particularly in East Wales where spruce will become less suitable. Little change is predicted to the suitability of DF except in the highest case scenario for climate change.

Grand and Noble fir

Both species are known to have potential within Wales and Noble fir in particular is of potential value as an alternative to spruce in exposed areas of Wales at high elevation. However both species have well documented problems with timber quality (related to drought crack) and primarily have wood fibre rather than timber value but this should not deter their selection if site opportunities allow.

Larches

Larch suitability will increase in parts of west Wales where water deficit is not predicted to be a major issue. In eastern Wales there is a risk that larch will become increasingly prone to drought on the dryer sites. See note on Phytopthora ramorum, p.26.

Pines

Climate change is predicted to reduce the suitability of Lodgepole and Scots pine but suitability of Corsican pine will increase. There is currently a moratorium on the use of Corsican pine in Wales due to its susceptibility to Red Band Needle Blight (RBNB). The susceptibility of all other pines to RBNB is currently unclear and latest information must be sought. Regular updates of information are available via Forest Research or FC England. Currently FCW will continue to plant Scots pine.

Use of pines as nurse species is recommended in some circumstances particularly where it can reduce the need for chemicals and fertilisers. At elevation, pine offers opportunities for diversification.

There is a wider range of pines that could be in utilised in Wales and the main possibilities are mentioned within the Species Tables (Annex 1). Information on some of these is limited. Macedonian pine is known to grow well in Wales and can be of good form but difficulty in establishment is an issue.

Silver firs – (Pacific, Nordmann and European)

These species are shade bearing and have significant potential for planting as understories to diversify existing CCF crops. They are not recommended as pure crops for new planting or restocking at this stage.

Spruce

Spruce (mainly Sitka) has been planted by foresters in Wales over the past century for very good reasons: ease of establishment, resilience and suitability to the Welsh climate, as well as its timber qualities. These factors will ensure it still has a future in parts of Wales.

Climate change predictions for the suitability of spruce in Wales currently indicate a significant reduction in suitability (due to moisture deficit) of both Sitka and Norway spruce in the future, particularly in the east and south of Wales.

Increased growth and suitability is predicted for the western uplands of Wales (Upland Wales). There should be a presumption against planting of significant areas of pure spruce in the east and far south of Wales.

Other opportunities exist to diversify using traditionally minor spruce species such as Serbian and Oriental spruce.

Western Hemlock

There has been a recent programme to remove much of the western hemlock that was planted throughout the twentieth century. This is largely due to its invasive tendency especially where native woodland restoration is an objective. Western hemlock could still be considered where its ability to seed will not threaten habitats and wood fibre is the objective rather than timber.

Western Red Cedar/Coast Redwood

Both species are known to grow well on certain sites within Wales and can produce durable timber but the thick fibrous bark can be a problem to the processing industry. Both are heavily shade bearing. Coast redwood can suffer frost damage. There is potential for increased use of both species, particularly in mixtures of compatible species and for diversifying existing mature CCF crops.

Other potential conifers (Cypress and Japanese cedar)

There are other species identified within the species tables that will have potential for use in Wales. For some information is limited and managers should ensure they have an understanding of the silviculture and utilisation of these species before using them but this should not deter their selection if opportunities allow.

5.2.2 Broadleaves

Alders

A wide range of alder species is identified as having potential including the native common alder. They have a wide range of uses including use on infertile brown field sites. Forest managers need to be clear on the specific values of the alder used.

Phytophthora is an issue with alder.

Ash

Little change to its distribution is expected within Wales. Ash has the potential for greater usage within Wales. It has good growth potential and can meet a wide range of objectives. It is relatively resistant to grey squirrel damage.

Aspen

Versatile species with good potential growth. Attractive species.

Beech

Beech is on the edge of its current climatic suitability in Wales. Although under most climate change scenarios it is predicted to increase in suitability, beech is prone to drought and this will become of increasing concern in Wales. Southern provenances of beech with more potential for drought resistance could be considered.

Birch (Downy and Silver)

Silver birch should be increasingly used in areas predicted to become dryer and warmer in the east and the south, replacing downy birch. Choice of provenance is critical; stock should be sourced from seed collected at comparable elevations to proposed planting.

Eucalyptus (Gunnii and Nitens)

Is being considered because of its exceptional growth rates and potential value for Short Rotation Forestry. Its ability to coppice will reduce future establishment to minimum. There have been concerns about the impact eucalypts have with their uptake of water. It is also highly flammable.

Hornbeam

Utilisable as a component within wider assemblages of species. Valuable as an understorey.

Oak (Sessile and Pendunculate)

Neither of these major native species is predicted to change its distribution within Wales under most climate change predictions. Should be used as part of an assemblage of species related to the Priority Native Woodland Habitat. Provenance choice will become increasingly important as a tool to create resilience to climate change within our oak woodlands.

Southern Beech (Roble and Rauli)

Potential for high growth rates in Wales. Potential for Short Rotation Forestry larger timber. Some resilience to grey squirrel and potential to achieve woodland condition quickly.

Sweet chestnut

Is predicted to increase its range of suitability in Wales. It has the potential for good growth and to be used for both short rotation forestry and larger diameter durable timber.

Sycamore

Will grow in most conditions. Potential for use at exposed high elevations.

Willows

Choice of provenance is critical (see comments for birch re. elevation).

6. Further reading and references

Please refer to the Forestry Commission's website is regularly updated with the latest news and guidance on climate change and diversification:

Forestry Commission Wales webpage

Forestry Commission Wales Land Information Search

Forest Research webpage

Forest Research Decision Support webpage[7]

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7. Glossary

BWW	Better Woodlands for Wales – the management plan-based grant scheme run by FCW since 2006. The closure of this scheme was announced in July 2010, with effect from January 2011.
CCF	Continuous Cover Forestry
DAMS	Detailed Aspect Method of Scoring. A measure of windiness – the greater the value, the windier the site.
ESC	Ecological Site Classification – a PC-based decision support tool produced by the Forestry Commission, designed to match site factors with the ecological requirements of different tree species and woodland communities. Developed since 1992, the most recent version was launched in 2001.
FCW	Forestry Commission Wales
GLOS	Grants and Licences Online System – the FC's computer system for delivering woodland grants (including Better Woodlands for Wales).
LISS	Low Impact Silvicultural System, defined as a system in which no clearfell larger than 2ha is permitted. LISS may include a range of silvicultural systems commonly used in CCF, and also systems involving small-scale clearfells.
SRF	Short Rotation Forestry