Forest Research

Forest Development Types:

A guide to the design and management of diverse forests in Britain

Version 1.1

Jens Haufe

Gary Kerr

Victoria Stokes

Stephen Bathgate

The Research Agency of the Forestry Commission

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About this guide

This guide aims to help forest managers understand and apply the concept of Forest Development Types (FDTs). It is intended as a technical document, so the reader is expected to be familiar with standard forest terminology. Non-standard terms, and terms which are deemed to be essential for the understanding of the guide, are preceded by → where they appear for the first time and explained in the Glossary. Acronyms and abbreviations have been used to a wide extent.

The introduction of the Forest Development Type concept is a gradual process. Currently 69 FDTs have been defined, more will follow over time and the guide will be updated accordingly.

Forest Development Types: a guide to the design and management of diverse forests in Britain

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1 Managing change in British forestry

Forestry in Britain relies to a great extent on even-aged monocultures, managed by clearfelling and restocking. While this is likely to remain an important management approach, managers are increasingly starting to create mixed-age and / or mixed-species forests to increase resilience to climate change and to pests and diseases.

There are several potential benefits of moving away from the default use of even-aged monocultures. Mixed forests are often better able to meet the different management objectives of multi-purpose forestry. Different tree species make use of different resources in terms of nutrients, water, light and growing space, and mixtures may therefore be more resilient to climatic hazards. They are also likely to benefit biodiversity and can better maintain soil properties.

British 'native woodland types' are described by the National Vegetation Classification (NVC). This is a detailed phytosociological classification, which assesses the full suite of plant, bryophyte and lichen species within a certain natural vegetation type. There are 25 major woodland vegetation types (W1-25) described by Rodwell and Patterson [1] which, in general, are mixed-species stands of native species.

However, the →NVC system is confined to native species, and there is no equivalent system in Britain that covers mixtures or woodland types that include native and non-native tree species. Due to the long history of even-aged, single species and non-native species forestry in Britain, current systems of describing and managing forests are not appropriate for the wider range of forest structures now being considered.

A Forest Development Type is a long-term vision outlining the development of the species composition and structure of a forest stand. FDTs provide guidance and should not be used in an overly prescriptive manner.

The concept encourages the greater use of mixed-species stands and a wider variety of stand structures than presently deployed in British forests.

During a period of change in British forestry, FDTs provide a framework to help managers achieve their objectives and increase forest resilience, meeting the challenges of climate change and forest health.

2 Experience from other countries

Several European countries have developed 'NVC-like' classification systems that cover all the species and species-mixtures that are grown within their forests. One of the earliest of these systems, called 'Forest Development Types' (FDTs) was developed in Lower Saxony, Germany in 1987 [2]. This consists of a suite of FDTs, each one describing a target stand structure and composition, and with defined climatic and site suitability. They cover all types of sites and →management objectives, and all native and non-native species options, managed as coppice, even-aged plantations or continuous cover forestry (→CCF).

In Lower Saxony, the forest estate is divided into geographically defined climatic site units which are relatively uniform areas with similar climatic conditions based on their location, topography and altitude. For each climatic site unit a range of FDT options is possible and the forest manager may select the most appropriate one depending on the site-specific soil conditions, management objectives and risk factors.

The concept has been widely used in some parts of Europe (e.g. in Denmark, the Czech Republic, Germany and Poland) for several decades and appears to be growing in popularity as forest managers tackle the need for increased resilience in forests.

A note of caution

FDTs are a proven concept having successfully been used in continental Europe for decades, *i.e.* in a slightly different forestry context.

The use and management of FDTs is based on the principle that all interventions are led by silvicultural best practice. Wherever operational necessities or short-term economic considerations take priority over the above principle there is a risk that FDTs may not deliver the envisaged longer-term benefits. This is particularly true for ambitious plans to change to more complex FDTs involving multiple species and diverse stand structures. In such cases the user would be well advised to choose from simpler FDTs which are more akin to conventional forestry practice in Britain.

3 Key features and benefits of the FDT framework

An FDT represents a *long-term vision of how the species composition and structure of a forest stand (or a group of similar stands) will develop*. It is not a description of the stand(s) at the current point in time, which may differ considerably. FDTs reflect the long-term nature of forestry, and they function as a framework and general target for all activities of forest management. Forest Development Types:

1. are a **comprehensive list of the silvicultural options for a site**, including feasible species, species combinations and stand structures;
2. provide a **framework and common language** for managers helping them to describe a long-term vision of how the species composition and structure of a forest is intended to develop in the future;
3. **challenge silvicultural practice** in terms of species combinations and where to plant species;
4. aid **planning and long-term management** of resilient forests, helping to ensure that consecutive managers work towards the same goal, even if a long transition phase is needed to achieve the target structure;
5. **promote the trend towards mixed stands and diverse forest structures**, which is widely regarded as an important measure to address the risks associated with climate change and tree health;
6. **facilitate multi-purpose forest management** as economic, environmental and social management objectives are all embedded in the design of FDTs.

FDTs offer a management framework for the lengthy process of change that British forestry must go through to become more resilient. They will help users to identify the most appropriate and practical options, and to follow a consistent management pathway to achieve the desired forest structure and tree species composition. Perhaps most importantly, they will provide a common language for practitioners talking about species, mixtures and structural changes in British forests.

Conceptual change

The key conceptual change in using FDTs is the commitment to a clear *long-term vision of the future forest structure*, which is compatible with delivering the site management objectives.

Achieving the target structure may sometimes require a long transition phase, but the use of FDTs, if recorded and integrated into management processes, will help to ensure that consecutive managers work progressively towards the same goal.

4 Designing FDTs for use in Britain

As the Ecological Site Classification (→ESC) system [3] is already used to describe the climatic and site variability of British forests, the FDT system has been designed to be compatible with, and to complement ESC.

The systems used in Germany and Denmark were reviewed, and the approach used in Lower Saxony, Germany, identified as the most suitable template for developing an FDT framework applicable to the wide range of conditions and requirements of British forestry.

A preliminary suite of FDTs was proposed to cover all forest types commonly found in British forestry, including mixed-species stands, those with non-uniform structures, non-native species and native woodlands. These were then tested and developed based on detailed consultation throughout Britain to ensure that the framework of FDTs would be a useful tool for forest managers and planners.

Individual FDTs are presented in the form of →flashcards, designed to summarise the main details of each type including management guidance. The structure of flashcards is explained in Section 5; a summary list of the FDTs is shown in Appendix 1 and the current suite of 69 FDTs can be found in a separate document: **Forest Development Types: Flashcards.**

4.1 Key features of FDTs

- The FDT framework described here has been designed as an open, expandable system where new FDTs can be added when required.
- FDTs can be applied at different scales (stand, coupe, block level) depending on the variability of climate and soil, and on the management objectives.
- Flashcards form the core of the FDT framework, providing clear guidance on species composition, stand structure, site suitability, management options and objectives as well as silvicultural treatment.
- The FDT framework is fully compatible with the existing NVC and ESC systems and will be embedded into →ESC DSS.
- The FDT framework is committed to the principle of sustainable forest management as defined by the UK Forestry Standard (UKFS), ensuring forests deliver an appropriate balance of economic, ecological and social benefits.
- The FDT framework adheres to the paradigm of multi-purpose forestry, encompassing economic, environmental and social functions of sustainable forestry.

4.2 Terminology

Each FDT has been given a 3-digit ID code, *e.g.* 1.2.6, which is defined by:

- 1st digit: →FDT categories,
- 2nd digit: →primary tree species, and
- 3rd digit: →secondary tree species or →stand structure.

4.2.1 FDT category

Ten different FDT categories have been defined. Categories 1 to 9 are designed for multi-purpose forestry where economic, environmental and social management objectives co-exist and are characterised by the primary tree species group; category 10 contains FDTs with special management objectives. Table 1 provides a summary of FDT categories.

Table 1: FDT categories

1st FDT digit	Description
1	FDTs dominated by spruce
2	FDTs dominated by light demanding conifers (→XCLD)
3	FDTs dominated by other conifers from the →Pacific Northwest of America
4	FDTs dominated by other conifers
5	FDTs dominated by oak
6	FDTs dominated by beech
7	FDTs dominated by birch
8	FDTs dominated by long-lived broadleaves (→XBLL) other than oak or beech
9	FDTs dominated by short-lived broadleaves (→XBSL) other than birch
10	FDTs with specific management objectives

4.2.2 Primary tree species

The primary tree species is the dominant species in the FDT, usually contributing ≥ 50 % of stand basal area. (*NB* that in →transitional and →FDTs with loosely defined species lower basal area proportions are possible.) The primary tree species is also essential for achieving the management objectives of the FDT. There is usually just one primary tree species for each FDT, except for FDTs with loosely defined species where several are possible. An overview is shown in Table 2.

Table 2: FDTs by primary species

1st FDT digit	2nd FDT digit	Description and primary tree species
1	1	Sitka spruce FDTs
1	2	Norway spruce FDTs
2	1	Scots pine FDTs
2	2	Corsican pine FDTs
2	3	Lodgepole pine FDTs
2	4	Larch FDTs
3	1	Douglas-fir FDTs
3	2	Pacific North-West American fir FDTs
5	1	Pedunculate oak FDTs
5	2	Sessile oak FDTs
5	3	Pedunculate oak or Sessile oak FDTs
6	1	Beech FDTs
7	1	Silver birch or Downy birch FDTs
7	2	Silver birch FDTs
8	1	Sweet chestnut FDTs
8	2	Ash FDTs
8	3	Sycamore FDTs
9	1	Alder FDTs
9	4	Willow FDTs

4.2.3 Secondary tree species and age structure

Most FDTs have a secondary tree species, which normally contributes ≤ 50 % of stand basal area. This is usually one species but can also be a group such as 'long-lived broadleaves' (XBLL). (*NB* in transitional FDTs the secondary species can contribute a higher basal area proportion.) For selected FDTs without secondary tree species a distinction between even-aged and uneven-aged →age structures has been made. Examples of both are shown in Table 3.

Table 3: Examples of FDTs defined by secondary species or age structure

1st FDT digit	2nd FDT digit	3rd FDT digit	Description
1	1	1	Sitka spruce as primary species, even-aged
1	1	2	Sitka spruce as primary species, uneven-aged
1	1	3	Sitka spruce as primary species, with Douglas-fir as secondary species
1	1	4	Sitka spruce as primary species, with light demanding conifers (XCLD) as secondary species
1	1	5	Sitka spruce as primary species, with shade tolerant conifers (→XCST) as secondary species
1	1	6	Sitka spruce as primary species, with beech as secondary species

Please note that the 3rd digit in the FDT ID code is not used in a species-specific way, *e.g.* whilst the figure *3* in FDT 1.1.*3* denotes Sitka spruce with *Douglas-fir*, in FDT 1.2.*3* it denotes Norway spruce with *Sitka spruce*.

Tree species are henceforth described using familiar abbreviations wherever possible. An overview of abbreviations used is shown in Appendix 2. Species with similar growth behaviour and silvicultural characteristics have also been compiled into broader categories. A summary of these is shown in Table 4.

Table 4: Tree species acronyms used and common examples

General categories	Acronym	Example species which may be included
Shade tolerant conifers*	XCST	SS, NS, DF, GF, NF, WH, WRC, JRC, RSQ, WSQ, LC
Light demanding conifers	XCLD	SP, LP, CP, JL, HL, EL
Long-lived broadleaves	XBLL	OK, BE, SY, AH, LI, HBM, SC, AR, WCH
Short-lived broadleaves	XBSL	BI, ASP, PO, WIL, ROW

* Species with intermediate shade tolerance are included in this group.

The FDT system has been designed to be expandable, as other species combinations may become more common, such as FDTs for →emerging tree species [4]. For example, FDTs 1.3 to 1.9 may later be allocated to any additional FDTs dominated by spruces other than SS and NS. Similarly, FDTs 3.3 to 3.9 are reserved for shade tolerant conifers (XCST) from the Pacific Northwest of America such as WH, WRC and RSQ (excluding SS); FDTs 5.4 to 5.9 are reserved for stands dominated by non-native oak species. Hence gaps in the numbering system are intended to allow for the future expansion of the FDT range.

4.2.4 Minor tree species

A feature of all FDTs is that they also contain →minor tree species. These may contribute ≤ 30 % of stand basal area but are not used for FDT classification.

However, minor species may play an important role by increasing landscape value, biodiversity, improving species habitats and soil properties, and are therefore included in all FDTs. In order to comply with the management objectives of the FDT they have been categorised as follows:

- Category A is the widest definition of minor tree species. Species must be suited to site conditions (according to ESC) and site-specific management objectives, and be non-invasive.
- Category B minor tree species must meet the criteria for Category A but also be unlikely to interfere with the crowns of any light demanding overstorey trees. Category B minor species are generally present in the understorey.
- Category C minor tree species must meet the criteria of Category A but must also be native to the area, effectively ruling out all conifers except SP, YEW and JUN.

4.3 Special FDTs

4.3.1 Transitional FDTs

In light of *Dothistroma* Needle Blight (DNB) stands of CP have been designed as transitional FDTs, *i.e.* they are expected to change into an FDT with a different primary tree species at the end of the current rotation. Thus, FDTs 2.2.1 and 2.2.3 offer options for managing the transition to the next FDT by CCF, introducing shade tolerant conifer (XCST) or long-lived broadleaved (XBLL) species respectively, by underplanting. FDT 2.2.2 is intended for CP stands where a transition to XCLD is envisaged.

4.3.2 FDTs with loosely defined species

The FDT framework leaves room for practitioners to experiment with their own ideas about creating resilient forests. This may involve emerging species, either in mixture or grown on their own, or rare and unusual mixtures. Such areas should be recorded as one of the following four FDTs:

4.8.1 XCST – for stands dominated by any XCST not currently covered

4.9.1 XCLD – for stands dominated by any XCLD not currently covered

9.8.1 XBLL – for stands dominated by any XBLL not currently covered

9.9.1 XBSL – for stands dominated by any XBSL not currently covered.

Generic silvicultural guidance has been provided on the flashcards for these FDTs. If use of these species or mixtures becomes more common they will be integrated in the list of established FDTs and specific management guidance will be issued.

4.3.3 Category 10 FDTs

FDTs in category 10 are provided for scenarios where timber production is not seen as an important management objective. Type 10 FDTs exist for peat edge woodland (FDT 10.1.1) and slope stabilisation woodland (10.1.2). Type 10 FDTs may also include sites which are primarily managed as habitats, →SSSI, for wood pasture, amenity value or research purposes.

5 FDT flashcard structure

5.1 General layout

Detailed information for each FDT is presented in a compact, double-sided flashcard to enable their use in the field. The purpose of these flashcards is to provide an overview of the main characteristics of each FDT whilst their single page format means that they can be used as a compilation of leaflets for quick reference where individual cards may be easily exchanged if updated, or new cards added.

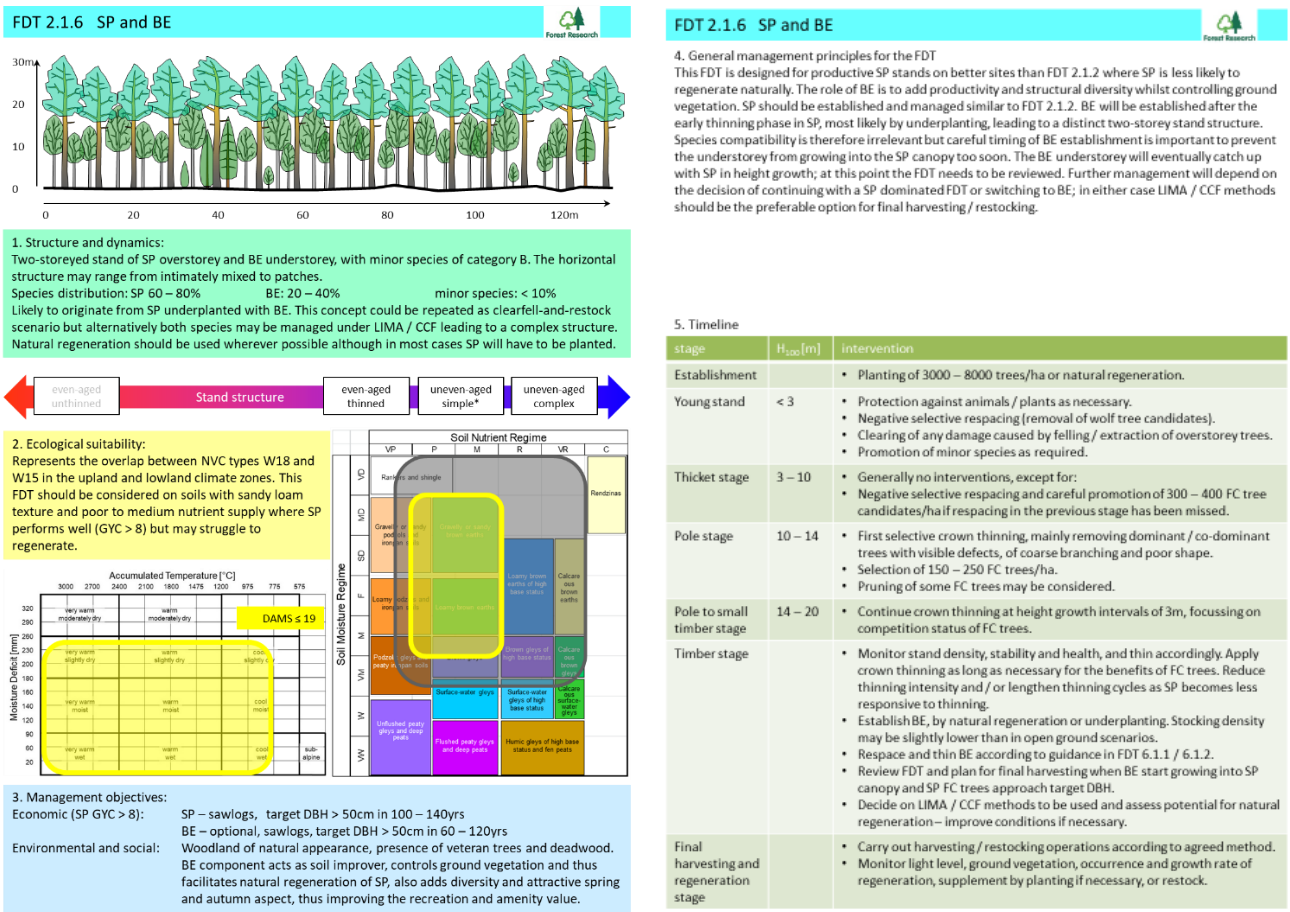
The compact format of the flashcards and the amount of information contained meant that certain compromises have had to be made in terms of style and language; for example acronyms for tree species and common forest management terms are used throughout and brevity of the text has been prioritised over style.

Each flashcard consists of the header and five parts:

1. Structure and dynamics
2. Ecological suitability
3. Management objectives
4. General management principles for the FDT
5. Timeline.

An example of the general flashcard layout is shown in Figure 1; details are explained in Sections 5.2 to 5.7. The full suite of FDT flashcards can be found in the supplementary document **Forest Development Types: Flashcards**.

Figure 1: General flashcard layout, example for FDT 2.1.6

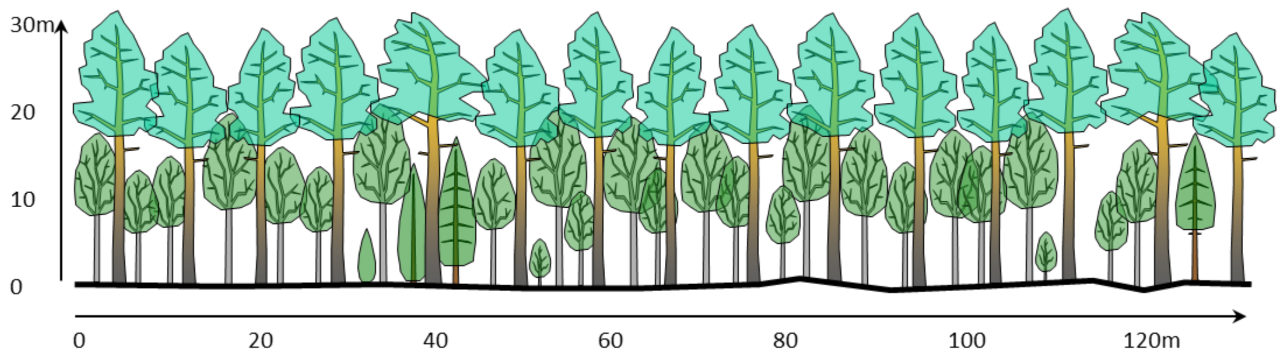


5.2 Header

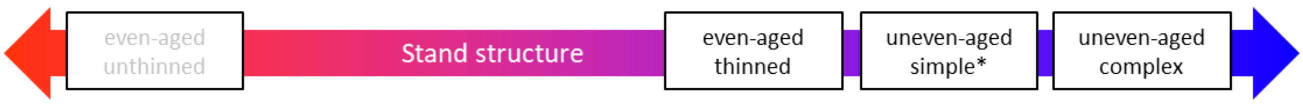
FDT 2.1.6 SP and BE

The header shows the FDT ID code according to the principles explained in Section 4.2 followed by the FDT title, usually detailing the primary and secondary tree species. For category 10 FDTs brief descriptive titles will be used. The band behind the header is colour coded according to the primary tree species, *i.e.* the 2nd digit of the ID code. The header is displayed on both the front and the rear side of the flashcard.

5.3 Structure and dynamics



1. Structure and dynamics:
Two-storeyed stand of SP overstorey and BE understorey, with minor species of category B. The horizontal structure may range from intimately mixed to patches.
Species distribution: SP 60 – 80% BE: 20 – 40% minor species: < 10%
Likely to originate from SP underplanted with BE. This concept could be repeated as clearfell-and-restock scenario but alternatively both species may be managed under LIMA / CCF leading to a complex structure. Natural regeneration should be used wherever possible although in most cases SP will have to be planted.



A visualisation of the envisaged stand structure of the FDT *at maturity* is shown at the top of Part 1. Tree diagrams are species specific and approximately to scale, although the main purpose of this illustration is to provide a visual impression of what the FDT might look like.

The green text box gives a brief description of the stand structure, shows the proportions of primary, secondary and minor tree species by basal area, and provides information on likely management scenarios for the FDT. Horizontal structure types are defined according to Table 5 below.

Table 5: Terms used to describe horizontal structure

Mixture type	Group area [ha]	Group diameter [m]
Intimate / individual tree	n.a.	n.a.
Small group	< 0.03	< 20
Large group	0.03 – 0.5	20 – 80
Small area, patch	0.5 – 1.0	80 – 113

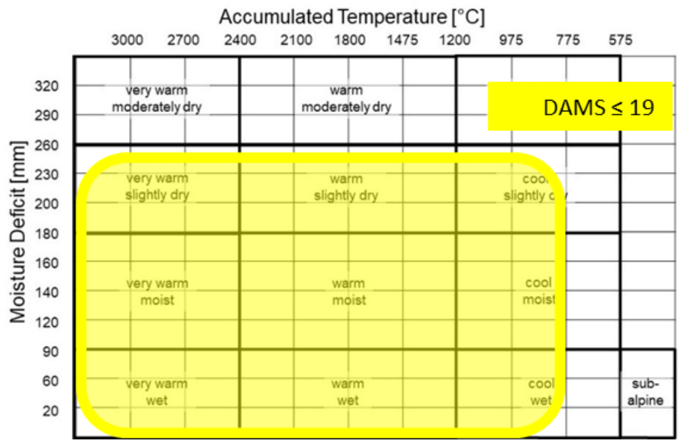
The arrow underneath the green text box in part 1 of the flashcard shows a range of possible stand structures. Options which are not suitable for the FDT are greyed out, all others are shown in a black font. The option marked with * denotes the recommended stand structure to which the visualisation, green text box and Timeline (see Section 5.7) refer. The stand structure options should be interpreted as shown in Table 6 below:

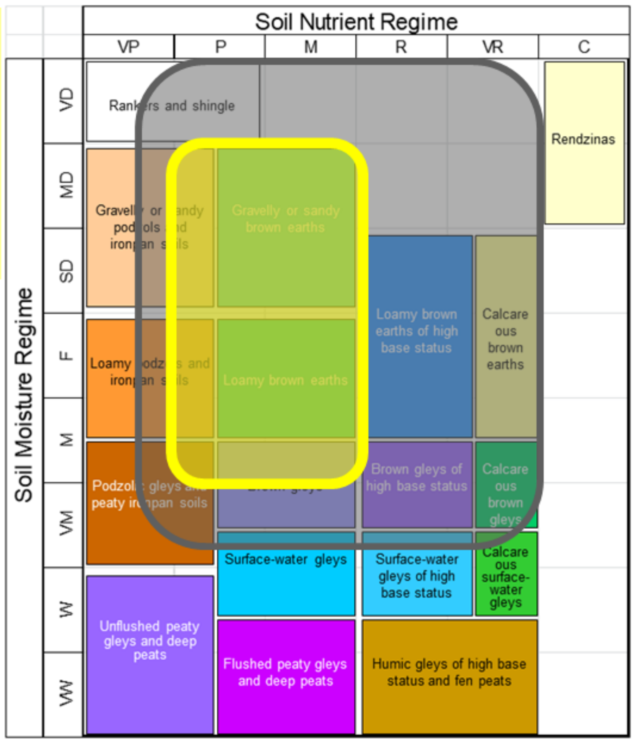
Table 6: Range of possible stand structures

Stand structure	Description
even-aged unthinned	This option includes clearfell-and-restock scenarios without thinning interventions. Rotation length and opportunities to develop stand structure and species composition are limited.
even-aged thinned	Clearfell-and-restock scenarios including thinning interventions, therefore offering greater opportunities to develop structural and species diversity and to use natural regeneration.
uneven-aged simple	Mainly →LIMA and →simple CCF scenarios, using natural regeneration, underplanting as well as small-scale restocking.
uneven-aged complex	Includes →complex CCF scenarios such as group and single tree selection systems, using natural regeneration and small-scale planting.

5.4 Ecological suitability

2. Ecological suitability:
Represents the overlap between NVC types W18 and W15 in the upland and lowland climate zones. This FDT should be considered on soils with sandy loam texture and poor to medium nutrient supply where SP performs well (GYC > 8) but may struggle to regenerate.





Part 2 of the flashcards describes the types of sites where the FDT is likely to be a good silvicultural choice. Site suitability for FDTs has, predominantly, been derived from ESC DSS values for primary and secondary tree species. However, in many cases there is a slight 'steer' to make silvicultural best use of the site, meaning that the suitability range of an FDT does not always match that of the primary species.

The yellow text box provides information about how the FDT is linked to the existing NVC system (all NVC woodland types are covered by at least one FDT) and suggests suitable site conditions, such as soil texture.

The chart in the bottom left corner of part 2 shows climatic suitability with regard to the ESC parameters →Accumulated Temperature (AT), →Moisture Deficit (MD) and →Exposure (DAMS). The chart includes climatic conditions which are not yet present in Britain but which need to be considered because of projected climate change. The yellow area represents the range of climate conditions where all primary and secondary tree species are at least 'suitable' according to the definition used in ESC DSS, *i.e.* capable of growing at ≥ 50 % of their maximum GYC. For FDTs without secondary tree species and those where undefined secondary species have been grouped in a category (*i.e.* XCST, XCLD, XBLL and XBSL) the yellow area applies to the primary tree species only. The same principle applies to the maximum DAMS score, however, additional modifications have been made in cases where the secondary tree species is intended to occupy the understorey of a stand only, or is introduced by underplanting, and can therefore be expected to grow under more sheltered conditions than the overstorey.

The chart on the right-hand side shows the suitability of the FDT with regard to soil fertility (→SNR) and soil moisture (→SMR). The yellow area represents the range of soil conditions where the FDT is a good silvicultural choice for the primary and secondary tree species and is making good use of the site's productive potential. This is somewhat different from the criteria used in ESC DSS for even-aged and single-species stands, and the primary species' suitability according to ESC DSS ('suitable') is shown as a grey area to illustrate the differences between the two systems.

In the example of FDT 2.1.6 shown above, ESC DSS would return a 'suitable' score for SP from SNR 'Very Poor' to 'Very Rich', and from SMR 'Very Moist' to 'Very Dry' – this range is shown in grey. In FDT 2.1.6 (yellow), however, the suitability is limited to SNR 'Poor' to 'Medium' because more fertile sites could be better used for more productive FDTs, and less fertile sites are unlikely to be suitable for BE. The restriction to SMR 'Moist' to 'Moderately Dry' is due to the requirements of BE as the secondary species.

Other reasons why the soil suitability of an FDT may differ from that shown by ESC DSS for the primary tree species include:

- The suitability range of some FDTs may have been restricted to ensure the growth rates of primary and secondary tree species are appropriately matched. For example, in FDT 1.2.3 (NS and SS) the SMR range has been limited to 'Slightly Dry' to 'Moist' compared to 'Slightly Dry' to 'Very Moist' in FDT 1.2.2 (NS) in order to favour NS over SS, which is likely to thrive under higher soil moisture conditions.
- The suitability range of some FDTs may have been extended beyond that of the primary species, due to the beneficial effect of the secondary species in the FDT. Examples include FDTs 1.1.4 (SS with XCLD) and 1.1.8 (SS with XBSL) which are able to tolerate sites of lower fertility than pure stands of SS.
- The SMR suitability range of some FDTs has been restricted where wetter soil conditions are likely to reduce rooting depth and therefore stability of the trees. Many FDTs dominated by conifers fall into this category.
- The suitability range of some FDTs may have been extended beyond that of the primary tree species in cases where timber production is of secondary importance and few or no alternatives for extreme soil conditions are available, for example FDTs 2.3.1 (LP) and 2.3.2 (LP and DBI).

Criteria for FDT suitability differ from those for single species

FDT suitability will not always match that of the primary species in ESC DSS because of built-in guidance to make good silvicultural use of the site, and slight modifications made for mixtures and for establishment methods described above.

5.5 Management objectives

3. Management objectives:	
Economic (SP GYC > 8):	SP – sawlogs, target DBH > 50cm in 100 – 140yrs
	BE – optional, sawlogs, target DBH > 50cm in 60 – 120yrs
Environmental and social:	Woodland of natural appearance, presence of veteran trees and deadwood. BE component acts as soil improver, controls ground vegetation and thus facilitates natural regeneration of SP, also adds diversity and attractive spring and autumn aspect, thus improving the recreation and amenity value.

Part 3 of the flashcard provides an overview of potential management objectives the FDT is capable of delivering; not all of them need necessarily apply in any given situation.

Economic objectives are broken down by species and the following product categories:

- Joinery grade (conifers) or veneer / planking grade (broadleaves). These are to be used synonymously for →high-quality timber which exceeds ordinary sawlog standards.
- Sawlogs – green logs of large enough size for sawmill processing.
- Other categories used such as pulp, fencing material, fuelwood, biomass etc. are often used together to indicate that the choice of main produce may depend more on local circumstances rather than the productive potential of the FDT.

Where the term 'optional' is used it indicates that economic objectives may be subject to special risk factors (*e.g.* grey squirrel damage) or circumstances (*e.g.* for native woodlands managed primarily for environmental and social benefits).

For high-quality timber and sawlog categories a target DBH and estimated timespan have been suggested. The values for both are based on current British yield models [5], with lower relative GYC being used for poorer, and higher GYC for more fertile sites. The timespan given may be interpreted as a guidance figure for estimated stand rotation or applied to individual trees in selection systems. For scenarios where the use of natural regeneration is likely, the timespan has also been chosen to ensure the parent trees will produce a sufficient amount of seed.

Environmental and social management objectives include benefits the FDT is likely to deliver for conservation and species protection, sustainable use of natural resources, forest diversity and resilience, amenity, recreational, landscape and cultural value of the forest. They are largely described in subjective terms and specific objectives not mentioned will be appropriate on many sites.

Forests or stands which are expected to be managed *entirely* for environmental and / or social objectives should be allocated as Type 10 FDT and are covered in Section 4.3.3.

5.6 General management principles for the FDT

Part 4 of the flashcards provides a concise summary of the key features of the FDT, including the general purpose, species contributions and compatibility, likely scenarios for establishment and further development of the FDT, silvicultural management concepts, character of interventions and options for harvesting and regeneration.

> 4. General management principles for the FDT
> This FDT is designed for productive SP stands on better sites than FDT 2.1.2 where SP is less likely to regenerate naturally. The role of BE is to add productivity and structural diversity whilst controlling ground vegetation. SP should be established and managed similar to FDT 2.1.2. BE will be established after the early thinning phase in SP, most likely by underplanting, leading to a distinct two-storey stand structure. Species compatibility is therefore irrelevant but careful timing of BE establishment is important to prevent the understorey from growing into the SP canopy too soon. The BE understorey will eventually catch up with SP in height growth; at this point the FDT needs to be reviewed. Further management will depend on the decision of continuing with a SP dominated FDT or switching to BE; in either case LIMA / CCF methods should be the preferable option for final harvesting / restocking.

In order to accommodate this information in the space available certain terminology and conventions have been used, some of which may not be commonly known and so are introduced and explained in Sections 5.6.2 to 5.6.5.

5.6.1 General purpose of the FDT

Summarises the rationale for choosing this FDT for a particular site.

5.6.2 Tree species compatibility

In mixed stands, it is important that the light requirements and growth rates of the species are compatible, to prevent one species outcompeting the other. The existing FDTs have been designed to take this into account, using only compatible primary and secondary species, and mixture types that allow both species to thrive. For species combinations using the general categories (XCLD, XCST, XBLL and XBSL) it is important to check the compatibility. This can be done by determining the →Compatibility Score [6] which indicates how well matched the species are and therefore how easily they can be managed in mixture. Possible scoring values are shown in Table 7.

Table 7: Compatibility score values

Compatibility score	Advice on design of robust mixtures
1	Species are most compatible; any mixture design possible.
2	Species are quite compatible; mixture in small groups is recommended.
3	Species are less compatible; mixture in large groups is necessary.
4	Species are least compatible; mixture in small areas or patches is necessary.

The Compatibility Score had been developed as guidance for establishing mixed stands but more generic conclusions for further forest management may be drawn from it. More compatible mixtures will, in general, require less frequent monitoring and be more resilient to temporary neglect than less compatible ones. This is the main reason for the larger group size required with decreasing species compatibility (horizontal structures are defined in Table 5). Where appropriate, the role and importance of the secondary tree species for the functionality of the entire FDT is outlined.

5.6.3 Silvicultural management concepts

These are generic concepts outlining the silvicultural approach to achieving the envisaged management objectives for the FDT, mainly, but not entirely, in terms of timber quality and produce size.

5.6.3.1 Negative and positive tree selection

These refer to respacing and thinning interventions.

- →negative selection means the removal of undesirable individuals which do not contribute to the envisaged stand structure and management objectives (*e.g.* poorly shaped, damaged and diseased trees).
- →positive selection means the promotion of desirable individuals (*i.e.* those which do contribute to the envisaged stand structure and management objectives) by removing their immediate competitors. The concept of positive tree selection is closely linked to that of Final Crop trees (→FC trees).

5.6.3.2 Final crop tree (FC tree) concept

This is a silvicultural concept whereby trees that are likely to form the main stand at the time of final harvesting are selected early and continuously promoted by positive selection to achieve the desired timber quality and produce size. In CCF scenarios, a proportion of Final Crop Trees are usually chosen as Seed Trees or Frame Trees before the transformation stage. Final crop trees are usually selected according to the following criteria:

1. Healthy appearance and vigorous growth;
2. Good timber quality;
3. Even distribution across the area.

The Final Crop Tree concept offers additional benefits to forest management and its use is generally encouraged, particularly where sawlogs or high-quality timber are to be produced. For practical reasons Final Crop Trees in conifers should be selected after the first thinning has created sufficient space to assess the form and health of individual trees. In broadleaved stands Final Crop Trees should be selected before the first thinning. The concept may also be applied to scenarios where environmental and social management objectives take priority over economic ones; in such cases the selection criteria for Final Crop Trees may have to be re-defined.

5.6.3.3 Developing tree stability

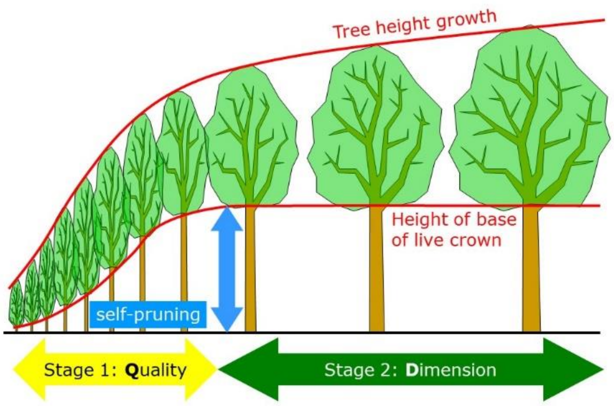
Tree stability with regard to wind (and to a lesser degree snow) is particularly important for conifers. The stability of individual trees can be improved by encouraging diameter growth in relation to height growth, *i.e.* by thinning interventions. The ratio of tree height to tree dbh, commonly known as H/D ratio, is often used as an indicator for conifers whereby values of > 80 indicate poor, and values of < 80 good stability. Similarly, the relative length of the live crown of trees may be used for this purpose, with > 50 % live crown length indicating good stability. The concept of developing individual tree stability is based upon systematic respacing of overly dense natural regeneration and heavy and frequent thinning interventions beginning at a stand top height of about 10 – 12 m. Delaying early thinnings will encourage height growth over diameter growth and produce less stable trees. If thinning is delayed long enough such stands may eventually become “unthinnable”, *i.e.* the risk of severe wind damage following a delayed intervention becoming too high. The concept of developing individual tree stability is primarily applied to the Final Crop Trees of a stand.

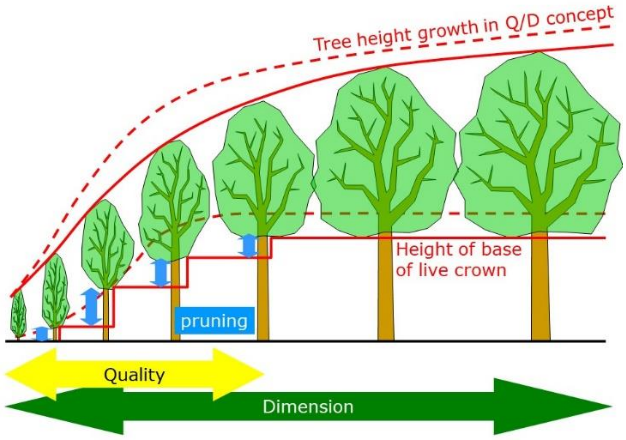
5.6.3.4 The ‘Q/D’ and ‘fast diameter growth’ concepts

In contrast to conifers, most broadleaved tree species lack apical dominance and show a more or less pronounced phototropic growth pattern; therefore timber quality in terms of single, straight and clean stems is more difficult to achieve. Silvicultural concepts for broadleaved species can be roughly divided into two groups.

The first concept favours establishment at relatively dense spacing and seeks to benefit from the self-pruning ability of most broadleaved species. Once quality stems have been produced then rapid growth of selected trees is promoted by thinning. The second concept advocates planting at a relatively wide spacing and seeks to achieve fast diameter growth from early on, often using green pruning to achieve the desired length of clean bole; this approach is often used with poplars. Both concepts are illustrated in Figure 2.

Figure 2: Q/D and fast diameter growth concept





The →Q/D (**Q**uality/**D**imension) concept works in two clearly distinguishable stages: in stage 1 the objective is to achieve timber quality, *i.e.* a clean straight bole of defined length, stage 2 is designed to obtain the desired stem diameter. Tight spacing at stand establishment boosts early height growth, improves stem straightness and facilitates self-pruning. The high stocking density is maintained until the desired length of clean bole has been achieved. At this point stage 2 of the concept starts with thinning interventions, aiming to maximise diameter growth until the target DBH is reached. The base of the live crowns in Final Crop Trees should ideally stay at the same level throughout stage 2, leading to the development of large tree crowns required for high growth rates. The timing of the switch-over from stage 1 to stage 2 will determine the length of the clean bole; however, this needs to be balanced against achievable target DBH and rotation length.

The →fast diameter growth concept aims to achieve a large dbh as fast as possible. Stands are established at wider spacing than in the Q/D concept to encourage early fast diameter growth. To achieve high timber quality (clean straight boles) the concept relies much more on the use of genetically improved material than the Q/D concept, and on silvicultural interventions such as formative shaping and green pruning. While the Q/D concept is only suitable for broadleaved species with good ability to self-prune, the fast diameter growth concept may be applied to all tree species. Target DBHs are achieved faster than in the Q/D concept, however the achievable length of branch free boles is limited and sawlog as well as total volume production will be lower. The risk of failing to achieve timber quality objectives is also higher than in the Q/D approach. The intermittent lines in the image above show the tree height and height of the base of live crown achieved with the Q/D concept for comparison.

Q/D or fast diameter growth?

The decision whether to use the Q/D concept or the fast diameter growth concept is partly driven by the characteristics of the tree species involved. Species which are naturally short-lived or where the risk of disease dictates short rotations are generally managed by the fast diameter concept, whereas for other species the choice of approach may depend more on the management objectives. Table 8 provides examples.

Table 8: Management objectives and planting densities for Q/D and fast diameter growth concept.

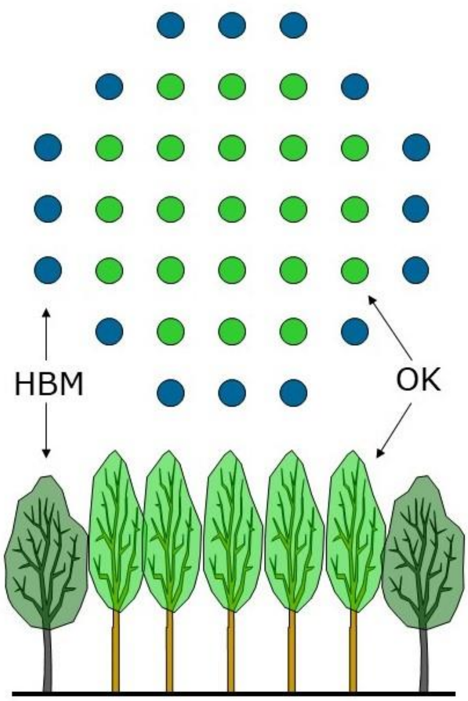
Tree species	Q/D concept	Fast diameter growth concept
OK	Planted at 5000 – 10000 trees/ha, managed for long clean boles	Planted at 1500 – 2500 trees/ha, managed for short thick boles
BE	Planted at 8000 – 10000 trees/ha, managed for long clean boles	Planted at 1500 – 2500 trees/ha, managed for biomass
SY / AH / AR	Planted at 3000 – 5000 trees/ha, managed for long clean boles	Planted at 1500 – 2500 trees/ha, managed for short thick boles
BI / ASP / PO	Not applicable	Planted at 1500 – 2500 trees/ha, managed for sawlogs or veneer
WCH	Not applicable	Planted at ≤ 500 trees/ha, managed for high-quality timber

Part 4 of the FDT flashcards for broadleaved species indicates which of the approaches above is appropriate, with detailed guidance being given in Part 5.

5.6.3.5 Cluster planting

→Cluster planting is an establishment method designed for broadleaved species, mainly OK and BE, where high stocking densities (*i.e.* in the region of 5,000 to 10,000 trees/ha) can be used to achieve straight stem growth and the development of clean boles. Cluster planting aims to achieve these conditions but only on small, discrete areas to ensure costs are minimised. Figure 3 gives more information and an example application.

Figure 3: Schematic representation of OK / HBM cluster



The method is based on the establishment of discrete clusters of 20 to 30 trees each at tight spacing, thus providing the benefits of fast establishment and quick weed suppression, accelerated height growth, improved stem straightness, early canopy closure and better self-pruning. The idea is that only one tree per cluster will remain by the time of final harvesting, the number of clusters per hectare will therefore correspond to the envisaged number of Final Crop Trees and the clusters will need to be spaced according to the expected crown dimensions. Several variations with regard to cluster design exist [7]; the most complex ones include a ring of suitable nurse species planted around the cluster. Tree spacing within the cluster varies from 0.25 – 1 m, clusters are therefore between 1.5 and 6 m in diameter. Cluster planting is ideally suited to fill gaps in natural regeneration but can also be applied across large areas where the space between clusters is usually planted with a 'cash crop' managed on a considerably shorter rotation than OK or BE.

5.6.3.6 Management of light level for underplanting and natural regeneration

In underplanting and natural regeneration scenarios suitable light levels for the understorey must be created by adjusting the degree of canopy cover provided by the overstorey. The required light level will depend on the shade tolerance of both over- and understorey species. Guidance figures for overstorey basal area in order to achieve appropriate light levels for underplanting and natural regeneration under canopy have been derived from Kerr and Haufe [8] and are shown in Table 9. Adjustments will be necessary depending on local site conditions such as aspect, slope or envisaged growth rate of the understorey; frequent monitoring is essential. For information on the shade tolerance of tree species please see Appendix 2.

Table 9: Shade tolerance and basal area ranges for seedling establishment

Likely success of option and maximum Basal Area of canopy trees [m^2/ha]				
		overstorey trees (primary species)		
		shade tolerant	intermediate	light demanding
Understorey trees (secondary species)	shade tolerant	30	30 – 35	35 – 40
	intermediate	20	25	30 – 35
	light demanding	10	15	20

Key	
Green	Species are well matched in light demand, underplanting may well work at Basal Areas above those indicated. Natural regeneration is likely to establish.
Yellow	Underplanting should only be applied at or below Basal Area shown. If this is not possible group planting should be considered. Natural regeneration may struggle and require further reduction of the canopy cover.
Red	In most circumstances group planting will be a better option. Natural regeneration under canopy is unlikely and should focus on gaps.

5.6.4 Character of interventions

The vast majority of FDTs rely on regular thinning to steer species composition and to achieve the envisaged management objectives and stand structure; where non-thinning options are possible this is mentioned explicitly. Another implication is that thinnings will be selective in character, systematic interventions such as line thinning should only be applied to establish the necessary infrastructure for machine access and timber extraction. The need for, and the frequency and intensity of thinning interventions should take account of individual tree stability and the ability of trees to respond to the changed environment over time. It is generally recommended to begin with crown thinnings although in many FDTs low thinning is also appropriate, usually later in the rotation.

Underplanting is mentioned explicitly where it is required to achieve the desired stand structure and species composition, it should therefore not be interpreted as an option but as a necessity to meet the envisaged management objectives.

Pruning is mentioned only where the management objectives include the production of high-quality timber. Pruning is linked to the Final Crop Tree concept and, if applied, only Final Crop Trees, or a proportion of them, should be pruned.

5.6.5 Silvicultural approaches

Not all silvicultural approaches are suitable for all FDTs, and some may be theoretically possible but very challenging to achieve, therefore some guidance is included on particularly suitable concepts. Terms and conventions are shown in Table 10 and reference should be made to Table 6 in Section 5.3. Further guidance on approaches to diversify stands and achieve the target FDT is given in Haufe et al. [9].

Table 10: Silvicultural approaches

Term	Description
Rotational (Clearfell-and-restock)	Includes areas of > 2 ha that are clearfelled periodically and restocked by planting, with or without a fallow period.
Lower Intensity Management Approaches (LIMA)	Includes areas of 0.25 – 2 ha which are clearfelled and restocked, areas of any size where restocking is largely achieved by natural regeneration or coppicing, seed tree and other methods which do not maintain continuity of the forest microclimate.
Continuous Cover Forestry (CCF)	An approach to forest management which seeks to develop diverse forests of a range of species and therefore well suited to delivering the FDT framework. One element of the approach is to maintain the continuity of the forest microclimate during stand renewal, which in practice means that most regeneration occurs in gaps of 0.25ha or less, although larger gaps can occur. Planting can be used to compensate for regeneration failure or to introduce desired species. A CCF approach can be implemented using a range of silvicultural systems: some such as uniform and strip shelterwood will produce simple stand structures while others such as group and single stem selection result in more complex structures. The simple structures can serve in making the transition from an even-aged monocultures to a FDT composed of mixed species in an irregular structure.

5.7 Management timeline

stage	H_{100} [m]	intervention
Establishment		• Planting of 3000 – 8000 trees/ha or natural regeneration.
Young stand	< 3	• Protection against animals / plants as necessary. • Negative selective respacing (removal of wolf tree candidates). • Clearing of any damage caused by felling / extraction of overstorey trees. • Promotion of minor species as required.
Thicket stage	3 – 10	• Generally no interventions, except for: • Negative selective respacing and careful promotion of 300 – 400 FC tree candidates/ha if respacing in the previous stage has been missed.
Pole stage	10 – 14	• First selective crown thinning, mainly removing dominant / co-dominant trees with visible defects, of coarse branching and poor shape. • Selection of 150 – 250 FC trees/ha. • Pruning of some FC trees may be considered.
Pole to small timber stage	14 – 20	• Continue crown thinning at height growth intervals of 3m, focussing on competition status of FC trees.
Timber stage		• Monitor stand density, stability and health, and thin accordingly. Apply crown thinning as long as necessary for the benefits of FC trees. Reduce thinning intensity and / or lengthen thinning cycles as SP becomes less responsive to thinning. • Establish BE, by natural regeneration or underplanting. Stocking density may be slightly lower than in open ground scenarios. • Respace and thin BE according to guidance in FDT 6.1.1 / 6.1.2. • Review FDT and plan for final harvesting when BE start growing into SP canopy and SP FC trees approach target DBH. • Decide on LIMA / CCF methods to be used and assess potential for natural regeneration – improve conditions if necessary.
Final harvesting and regeneration stage		• Carry out harvesting / restocking operations according to agreed method. • Monitor light level, ground vegetation, occurrence and growth rate of regeneration, supplement by planting if necessary, or restock.

Part 5 of the flashcard provides a concise 'management timetable' listing important interventions in chronological order from stand establishment onwards. The Timeline has been designed for the stand structure option marked with * (compare Section 5.3) and needs to be adjusted if a different stand structure is to be achieved.

The management timeline describes establishment of the FDT on a restock or afforestation site; ways of achieving an FDT from different starting conditions are described in Section 6.4.

The information provided is as detailed as possible given the space available. The user should also consider that specific silvicultural guidance usually applies to individual tree species, whereas the FDTs in many cases are mixed stands. It may therefore be necessary to refer to more than one FDT when designing the most appropriate operational plan for a particular stand. Despite the 'instructive' language style all information is intended as guidance and needs to be reviewed, and possibly modified, in the context of the actual situation and management objectives of the site in question.

The chronological order of the interventions is described broadly by the development stages of even-aged forests; in some FDTs with an uneven-aged structure these terms may have to be applied to cohorts of trees, or even to individual trees. Stand top height is denoted by the acronym →H_{100} and used to provide further detail on the timing of interventions. Stand top height is preferable to age for this because it takes account of the yield class-specific differences in growth rate, and therefore is better suited to adjust timing, frequency and intensity of thinning interventions to the response potential of the trees. For operational planning purposes top height can easily be converted into stand age via GYC. Conventions on terminology and further details on the information included in the Timeline are given in Table 11.

Table 11: Timeline content

Stage	Comments
Establishment (by planting, natural regeneration or direct seeding)	• Figures for suggested densities are given in trees/ha. In FDTs with secondary species these figures must be split according to the proportions of species in the mixture. Some adjustment will also be required for species combinations with different light demand and growth rate, *e.g.* if a 70/30 BA mix of SS and BE is envisaged in FDT 1.1.6, establishment may actually have to start with a 60/40 mixture by plant numbers. • The suggested planting densities have been derived from European guidance. Higher densities usually indicate the use of the Q/D concept in broadleaved species, whereas lower densities mean that the fast diameter growth concept is applied. • For mixtures of less compatible species and FDTs with broadleaved species group mixtures are often recommended. For guidance on group size refer to Table 5 in Section 5.3. • Cluster planting is covered in Section 5.6.3.5. • Direct seeding has been included as an establishment option on some FDTs; however, success is highly dependent on site conditions and specific guidance should be sought [10].

Young stand (from establishment to ~ 3 m height)	• Most interventions mentioned here will only need to be carried out if required by the local situation, thus frequent monitoring is advised. • Essential interventions in this stage include the respacing of conifer and BI stands originated from dense natural regeneration, regulation of species mixture in all stands originated from natural regeneration, and formative pruning of broadleaved stands which are managed under the fast growth concept and where the production of high-quality timber is an objective.
Thicket stage (from ~ 3 m height to 10 cm DBH)	• Interventions in this stage are mostly applicable to FDTs dominated by broadleaved species. • Interventions in most conifer FDTs are only recommended under certain circumstances, *e.g.* if the respacing of dense natural regeneration in the previous stage has been missed.
Pole stage (10 to 20 cm DBH)	• A line thinning will usually be required in order to establish the necessary thinning and extraction infrastructure. Line thinning may be carried out before, or in combination with the first selective thinning and is not specifically mentioned in the timeline of any FDT – however this does not mean that they won't be required. • For both silvicultural and operational reasons crown thinning is generally recommended for early interventions. • The use of Final Crop Trees is encouraged for all FDTs where the production of sawlogs is an objective, although in FDTs where Final Crop Trees would primarily serve operational rather than silvicultural purpose it has been marked as '(optional)'. • Final Crop Tree numbers have been derived from Kerr and Haufe [11], taking into consideration the suggested target DBH for each species. A range is given in order to allow for some flexibility but numbers should be interpreted as upper limits rather than average values. Where Final Crop Trees may be chosen from more than one species their number should be divided according to species proportions.
Pole to small timber stage (10 to 35 cm DBH)	• This stage marks the silviculturally important 'early thinning phase' and has therefore been emphasised. • In broadleaved stands managed under the Q/D concept the first thinning also falls in this stage. The development of the desired length of clean

	bole should be the trigger for the beginning of the thinning phase; the exact timing may therefore vary (see Section 5.6.3.4).
Timber stage (from 20 cm DBH to final harvesting)	• Silvicultural interventions will become more situation-dependent at this stage; therefore frequent monitoring is advised. • The exact timing of underplanting needs to be chosen according to the expected growth rate of the understorey species and the role it needs to fulfil (*e.g.* suppression of epicormic growth in the primary species). • For many FDTs the later phase of this stage is a good time to decide on harvesting and regeneration approach (*e.g.* LIMA or CCF) or to review the FDT itself (*e.g.* for transitional FDTs or cases where several scenarios are possible). If the use of natural regeneration is envisaged monitoring of ground conditions and other relevant factors should start.
Final harvesting and regeneration stage (from target DBH if applicable)	• Although a general decision of how to harvest and restock the site should have been made earlier it may still require review and adjustment if conditions have changed. • Regular monitoring of site conditions is required, in particular where LIMA or CCF methods are to be used. • General guidance on the suitability of LIMA and CCF methods and guidance figures for stand basal area are given; for further information please refer to Section 5.6.5.

For FDTs which offer a wide range of possible management approaches with no obvious silvicultural preference for any particular option (*i.e.* FDT 1.1.1), and for FDTs with loosely defined tree species (*i.e.* FDTs 4.8.1, 4.9.1, 9.8.1 and 9.9.1) the above Timeline is not used; a more generic overview of possible options is given instead.

6 Using FDTs in forest management

6.1 Levels of application

The hierarchical system means that FDTs can be applied at different scales. For example, FDT 1 simply specifies that the forest is 'spruce type' and could be applied at forest or landscape scale, describing all spruce-dominated stands. Using the first two digits of the FDT ID code allows the user to specify the primary species, *e.g.* FDT 1.2 covers all forests dominated by NS. The highest resolution, using all three digits of the ID code could be applied at compartment or stand level.

The resolution at which the FDT system is applied depends firstly on the level of planning and needs to take into account the uniformity of the landscape, the variability of the climatic and soil conditions, and the general and site-specific management objectives.

6.2 Identifying and narrowing down the FDT options

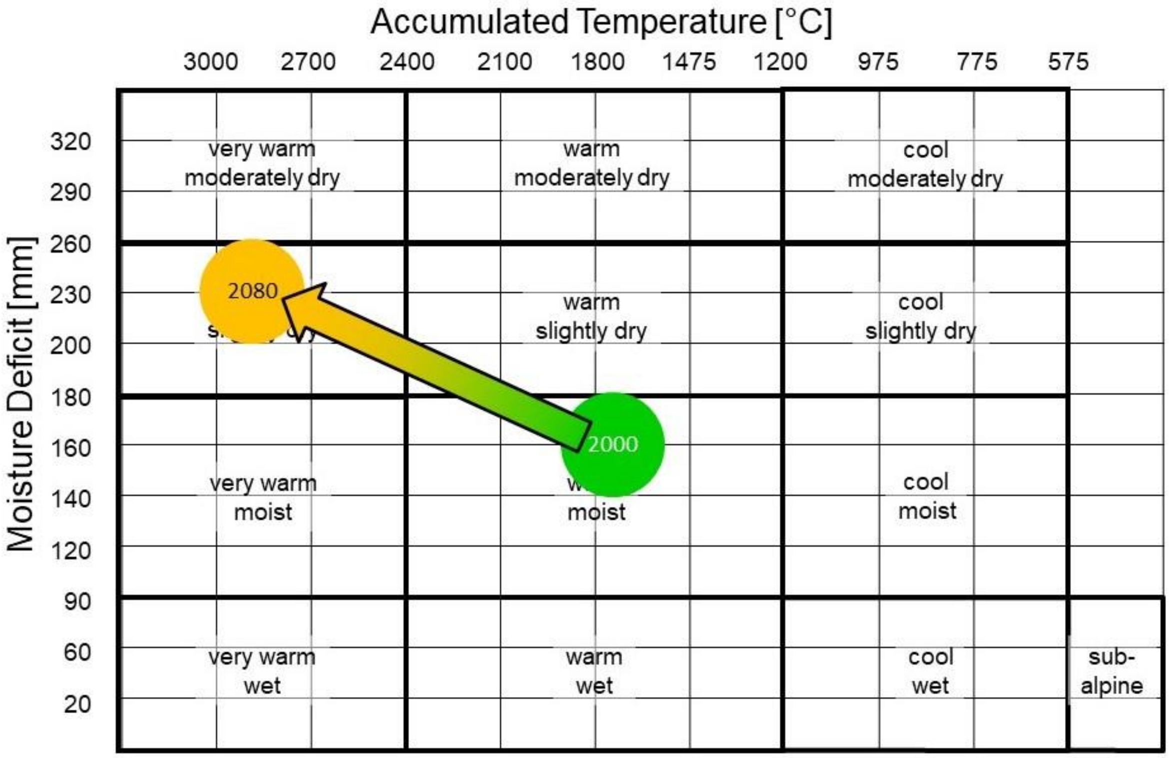
6.2.1 Step 1: Identify the current and future climate zone

In order to increase the resilience of forests to climate change, FDTs will need to be suitable for both the current climate and that projected for the future. ESC DSS currently provides climate projection scenarios for 2050 and 2080. Whilst the former comes with a higher level of certainty the latter must also be considered due to the long-term nature of forest management. In general, but definitely for LIMA and CCF management scenarios, the →AWC method should be chosen when obtaining climate figures by ESC DSS. Figure 4 shows climate zones for the whole of Britain, defined by Accumulated Temperature (AT) and Moisture Deficit (MD). As an example, current and future climatic conditions for the Forest of Dean in the 2080s are indicated by the green and orange markers respectively, with a vector-like arrow indicating the direction of climatic change.

Climate is also influenced by Exposure and →Continentality, and estimates may be obtained from ESC DSS. Whilst Exposure is considered in Section 6.2.4, the variability of Continentality in the British climate is relatively small and its effects on tree species, or FDT selection, is negligible.

A FDT selected for any location must be suitable for both the current and future climatic conditions. In due course FDTs will be incorporated into ESC DSS and →Forester Web.

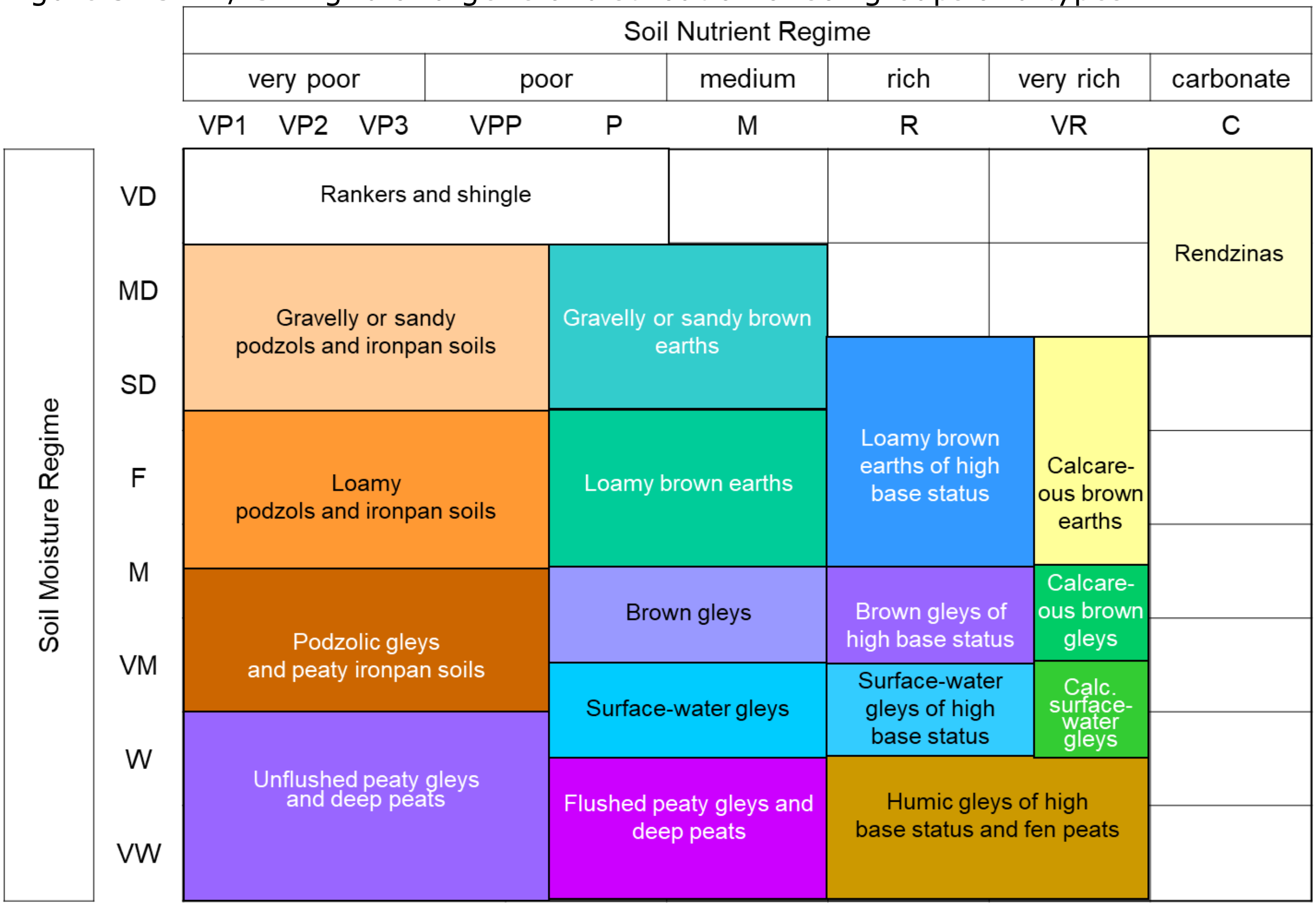
Figure 4: Climate zones and climate projection example for the Forest of Dean



6.2.2 Step 2: Identify the soil conditions of the site

Soil conditions are largely, but not entirely, characterised by moisture and fertility, which are both continuous variables. The SMR / SNR grid has been refined by distinguishing three sub-categories within the 'very poor', and two sub-categories within the 'poor' SNR category, in order to allow for finer differentiation of marginal sites. Figure 5 illustrates the distribution of important soil groups and types within the SMR / SNR grid. Due to the limited space available these sub-categories are not shown on the Flashcards, although the diagram illustrating the suitability of tree species does reflect this sub-division.

Figure 5: SMR / SNR grid and general distribution of soil groups and types



An accurate assessment of soil type, and therefore SMR and SNR for the site is essential. Forest managers must bear in mind that default values returned by ESC DSS may be based on models rather than actual data. In addition, drainage, ground preparation, fertilisation and the impact of the previous crop may all have significantly affected the original soil characteristics. *Estimates of soil fertility and moisture obtained from ESC DSS should in any case be verified on site.* Soil texture also needs to be considered; guidance is given in Part 2 of the flashcards where this is important.

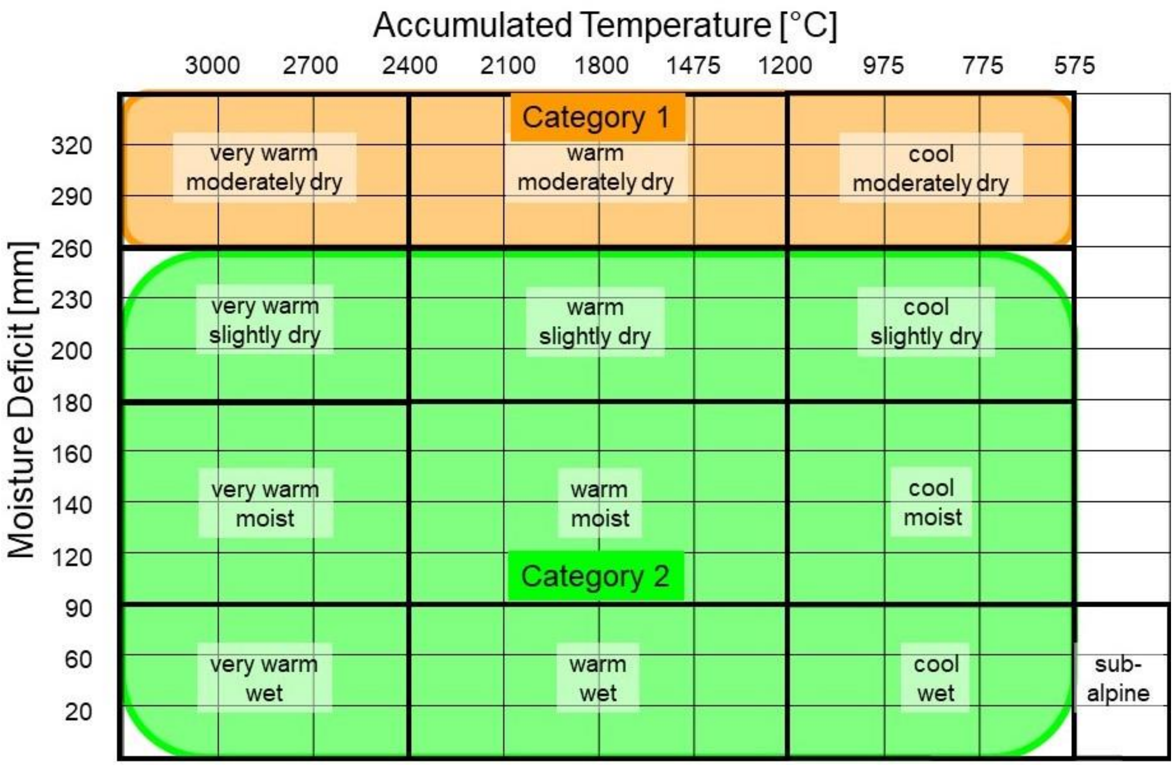
Figure 6: Understanding the underlying soil conditions is key to success

6.2.3 Step 3: Linking climate zone with soil conditions

FDT options that are suitable for the climate zone and soil characteristics can now be identified. For ease of application climate zones have been divided into just two categories, as shown in Figure 7:

- Category 1 covers all zones with a Moisture Deficit of 'moderately dry'.
- Category 2 covers all other zones.

Figure 7: Climate zone categories



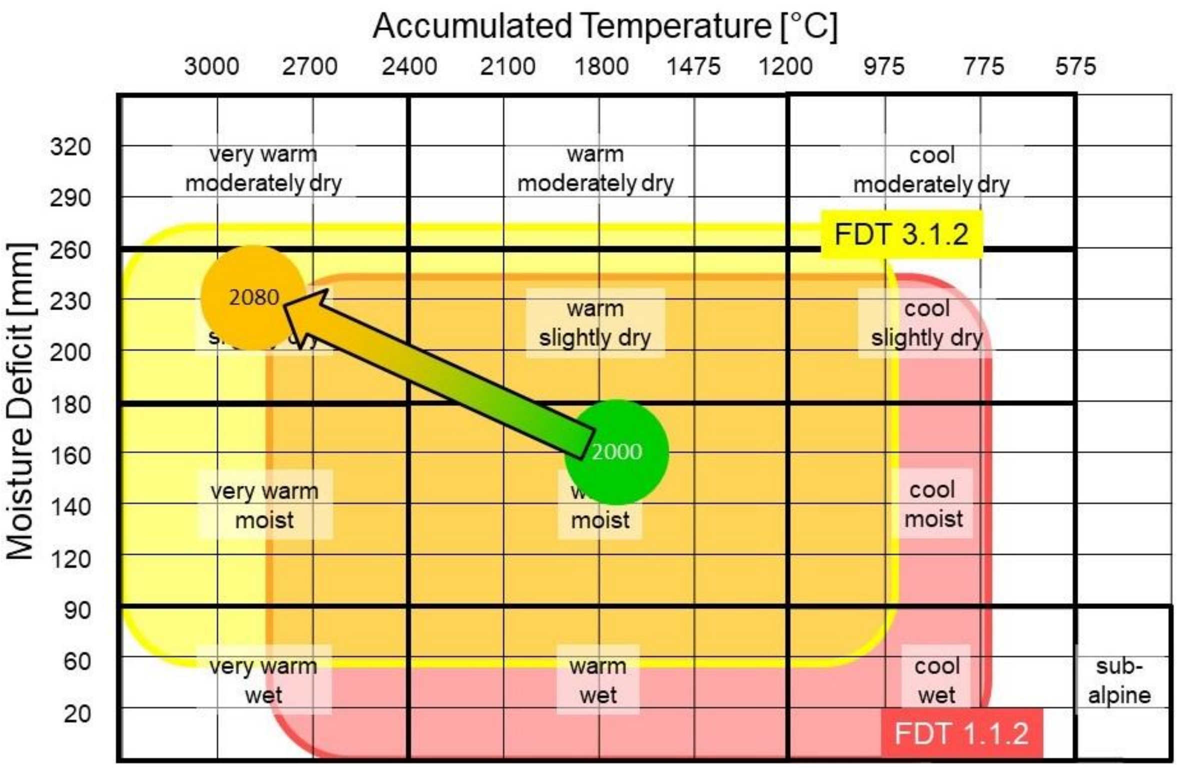
Appendix 3 contains two →FDT selection grids showing the suitability of FDTs with regard to climate zone category, SMR and SNR. The number of potential FDT options shown in Appendix 3 may appear daunting at first, however within each region or forest only a few will be relevant and suitable. Therefore, forest managers will quickly become able to shortlist FDTs which are applicable in their area and for their management objectives.

Checking the suitability of FDTs for future climate

It should also be stressed that the FDT selection grids in Appendix 3 list all FDTs which are suitable for *any* part of the climate zone, whereas a particular FDT may not necessarily be suitable for the entire range of Accumulated Temperature and Moisture Deficit within that zone. FDTs shortlisted as suitable from the selection grids in Appendix 3 must therefore be checked against *individual* site conditions, for both current and projected future climates.

For the example shown in Figure 8 the climate zone is expected to change from 'warm and moist' in the year 2000 to 'very warm and slightly dry' in 2080 (Appendix 4). Both FDT 1.1.2 (NS, red) and FDT 3.1.2 (DF, yellow) will be listed as suitable for the 'very warm and slightly dry' climate zone, however, for the Accumulated Temperature of > 2800°C projected for the year 2080 only FDT 3.1.2 will remain suitable.

Figure 8: Suitability of FDTs 1.1.2 and 3.1.2 for climate projection example in the Forest of Dean



6.2.4 Step 4: Narrowing down the FDT options

The shortlisted FDT options for a site should then be reviewed, bearing in mind that the FDT is a long-term vision and that FDTs are flexible guides. The following points are likely to require special consideration when choosing an FDT:

Exposure: For reasons of simplicity exposure has not been included in the climate zones but needs to be taken into account. In addition to the suitability of the component species and therefore the FDT, site exposure may restrict the achievable yield class, stand structure options, or make it difficult to establish certain tree species in clearfell-and-restock scenarios.

Minor species: An underlying principle of the FDT framework is that minor species are generally desirable in all FDTs for diversity reasons. The suggested proportion of minor species varies by FDT and may be over 30 % in the most diverse FDTs. Minor species are only loosely defined by category (A, B or C, see Section 4.2.4), leaving forest managers to decide on the desirability of minor species according to site suitability and their contribution to site-specific management objectives.

PAWS restoration: FDTs can be used to manage →PAWS restoration and ensure that consecutive managers continue to intervene as appropriate to ensure that the desired species composition and structure is eventually achieved. FDTs can either be interpreted and managed as NVC types or can at least accommodate PAWS elements as secondary tree species. For example, an even-aged plantation of SP could be designated as FDT 2.1.7 (SP and SBI) which is equivalent to NVC W18, or to FDT 2.1.5 (SP and SOK) which contains substantial elements of W16 and W17. The management timelines for these FDTs provide a framework that assists managers to introduce additional secondary and minor tree species, and to manage the stand to maintain the correct proportions of these. If PAWS elements are part of the management objectives it may be necessary to restrict the choice of minor species which are likely to conflict with this; in the above examples minor species might be limited to category C (see Section 4.2.4).

Resources: Realistic consideration should be given to the likely resource requirements, costs and time horizon of achieving a particular FDT. If this can be achieved using working methods that local teams are familiar with, it may be a reliable way to ensure that management objectives are delivered and the effects of a missed intervention or a period of neglect can be quickly recovered. In contrast, if an 'ambitious' FDT is selected that requires a major shift in species composition quickly and / or a very different stand structure, this could be very demanding and may be more vulnerable to missed interventions or periods of neglect.

Riparian zones: Many forest sub-compartments will include watercourses and →riparian zones. All FDTs allow for at least 10 % minor species (or an even higher proportion), the idea being that the particular species and stocking requirements for riparian zones could normally be accommodated within any FDT. Exceptions may apply to particularly large riparian zones where it is more appropriate to specify a separate FDT such as 5.3.2 (OK and XBLL), 8.2.1 (AH and CAR), or 9.1.1 (CAR).

Sites without economic management objectives: Areas managed entirely for environmental, social or research objectives should be allocated as category 10 FDTs.

Species suitability: FDTs have been designed to ensure that both the primary and secondary tree species are suitable under current and future climate and soil conditions of the site, as shown on the FDT selection grids in Appendix 3. However, it is important to check species suitability of the secondary species in ESC DSS, particularly if the FDT includes the broad categories XCST, XCLD, XBLL and XBSL which are difficult to generalize, or emerging species where requirements are less well-known.

6.2.5 Step 5: Selecting an FDT

The final choice of FDT should be driven by its ability to deliver the **site-specific management objectives**.

6.3 Choosing a stand structure

As described in Section 5.3, most FDTs can be managed towards different stand structures using a range of silvicultural approaches. The recommended stand structure option is marked by * in Part 1 of the flashcard but forest managers may choose one of the other possible options. It is, however, important that the target stand structure is identified at the same time as selecting the FDT itself, as this may affect the delivery of management objectives. Changing the stand structure option of an FDT during management may be possible, or even required, in some circumstances.

The selected stand structure should be recorded and documented as part of the FDT decision, as this influences the management path taken. This could be done by attaching a suffix to the FDT ID code, *e.g.*:

- FDT 2.1.1U for stand structure option 'even-aged **U**nthinned';
- FDT 2.1.1T for stand structure option 'even-aged **T**hinned';
- FDT 3.1.2S for stand structure option 'uneven-aged **S**imple';
- FDT 3.1.2C for stand structure option 'uneven-aged **C**omplex'.

6.4 Achieving the FDT on different site types

Whilst FDTs provide a clear vision of how a stand should develop, the starting point may vary widely, including afforestation sites, restock sites and sites where an existing stand is being transitioned to a particular FDT. For the latter scenario it should be noted that, with the exception of designated transitional FDTs covered in Section 4.3.1, overly 'ambitious' changes of species and stand structure may be difficult to achieve and should therefore be avoided. For example, whilst a stand of SP at thicket stage with a 20 % OK component could be managed towards an OK FDT such as 5.2.1 (SOK and BI) or 5.2.2 (SOK and SP), a similar transition would be very difficult to achieve from a thicket stage SS stand with OK component. If such a transition were required this could better be achieved in two steps, *i.e.* by identifying a suitable SS FDT for the current stand and re-assigning a final OK FDT at restocking.

On afforestation and restock sites some consideration needs to be given to species proportions. They are expressed in % basal area at maturity for each FDT, which may not necessarily translate into % transplants per hectare or even % planted area. For instance, if a site envisaged to develop towards FDT 2.1.5 (SP and SOK) should be stocked with 60 % SP and 30 % SOK by basal area at the age of 80 years, planting and early management of the stand should aim to achieve a 50/50 mix of SP and SOK by number of trees at 20 years. This means that transplant numbers required for SOK may actually be higher than those for SP, although the basal area proportions for both species suggest differently.

One of the principles of the FDT framework is to use site adapted tree species only, therefore natural regeneration may occur and its suitability needs to be considered on restock sites.

6.5 What if things change?

A key benefit of using FDTs is that there is a clearly defined long-term target structure and composition to guide future managers. However, FDTs should be reviewed at intervals, and under certain circumstances it may be necessary to change the FDT, for example, if a primary or secondary tree species is affected by a pest or disease, or if catastrophic wind damage occurs. Occasionally the management objectives themselves may change, for example to conserve a newly identified protected species, or to deliver an increased demand for recreation. In these situations, there are various ways to change FDTs:

- ***A gradual change by thinning to favour one species over another.*** For example, FDT 1.1.3 (SS and DF) could be converted to FDT 3.1.3 (DF and SS) by repeatedly thinning to remove SS and favour DF.
- ***By changing the thinning type and stand structure.*** For five commonly grown species (SS, NS, SP, DF, BE) there are separate FDTs for even-aged and uneven-aged stands. Therefore, FDT 1.2.1 (even-aged NS) could be re-allocated as FDT 1.2.2 (uneven-aged NS) if this better delivers the management objectives, signalling a permanent change in the thinning regime and a different target structure. Despite best efforts, it may sometimes prove impractical to pursue the original stand structure, for example if deer populations cannot be controlled sufficiently to allow establishment of natural regeneration. In this case it may be best to change to an even-aged target structure, provided this still delivers the management objectives.
- ***By underplanting with a different species.*** For example, if the appearance of a forest in the landscape becomes more important due to increasing recreational

use, FDT 1.2.1 (even-aged NS) could be re-allocated as FDT 1.2.5 (NS and BE) or FDT 1.2.6 (NS and XBLL). This would require underplanting with BE or XBLL species. For guidance on underplanting see Kerr and Haufe [8].

- ***By taking opportunistic advantage of natural regeneration.*** Unexpected natural regeneration of a desirable and compatible species may be welcome and help to deliver additional ecosystem services. For example, FDT 1.1.1 (even-aged SS) may be re-allocated as FDT 1.1.8 (SS and XBSL) if a significant quantity of short-lived broadleaved species such as BI, ROW, ASP and WIL become established through natural regeneration, adding to the landscape value, increasing biodiversity, and with the potential to improve soil quality.
- ***By clearfelling and restocking with a new FDT.*** Some transitional changes are biologically impractical, for example introducing a light demanding species into an existing stand dominated by shade tolerant species. If an existing FDT is no longer suitable, for example due to catastrophic disease, or extreme wind damage, the best option may be to clear the remaining crop and establish a new FDT by restocking.

7 Monitoring and record keeping

Making British forests more site-adapted and resilient will be a gradual process. Adopting the FDT framework will help with this by providing a clear pathway to increase species and structural diversity. In order to be successful this process must be monitored and recorded, so that future foresters can learn from experiences.

FCIN 45 [12] is recommended for monitoring as it provides detailed information on development of stand composition and structure, it can also be used for inventory and tariffing purposes. Basic stand and site information, and target FDT should be recorded in the sub-compartment database or similar but supplementary records of decision-making processes and management interventions should also be kept.

8 Case studies

The following examples illustrate how FDTs could be allocated to situations in forest management in Britain.

8.1 FDT 2.4.2 (LA and XCST)

60-year-old JL stand underplanted with 35-year-old NS at Craigvinean forest, Perth and Kinross (NO 001 419), on upland brown earth soils. FDT 2.4.2 reflects the current situation. Both JL and NS are suited to current site conditions and will remain suitable under the climate projection scenario for 2080, however the progress of *Phytophthora ramorum* may exclude JL as primary species in the future. In this case the FDT could be easily transitioned into a 1.2 (NS) type.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	warm and moist	1223	111	9		
Climate 2080 (UKCP09)	warm and moist	2104	120	9		
Soil					medium	fresh

8.2 FDT 1.1.5 (SS and XCST)

70-year-old SS stand underplanted with 10-year-old ESF at Clocaenog forest, Denbighshire (SJ 040 542), on a complex of upland brown earths, peaty gleys and ironpan soils. The stand will be managed towards FDT 1.1.5 which is suited to current site conditions and will also remain suitable under the climate projection scenario for 2080. The addition of shade tolerant ESF to the stand of SS will mitigate the disease risk and benefit forest diversity. The exposed nature of the site may make it an unlikely choice for CCF at first glance, however frequent thinning interventions have developed good individual tree stability and thus reduced the risk of wind damage.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	cool and wet	1127	70	18		
Climate 2080 (UKCP09)	warm and moist	2199	143	18		
Soil					poor	fresh

8.3 FDT 2.1.4 (SP and XCLD)

About 75-year-old stand of SP and EL at Glen Dye estate, Aberdeenshire (NO 658 898), on podzol over induration. Whilst sporadic EL regeneration is already present on site, ground scarification is used to encourage SP to regenerate. Both SP and EL are suited to current site conditions and will remain suitable under the climate projection scenario for 2080. If the progress of *Phytophthora ramorum* excludes EL as primary species in the future the FDT could be transitioned into any 2.1 (SP) type.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	cool and moist	1142	115	11		
Climate 2080 (UKCP09)	warm and moist	2038	136	11		
Soil					very poor	slightly dry

8.4 FDT 5.3.2 (OK and XBLL)

85-year-old stand of OK and SY at Cuckoo wood, Monmouthshire (SO 531 048), on fertile loamy brown earth. The SY is managed as coppice to provide an understorey for OK as the primary species. FDT 5.3.2 provides high amenity and conservation value as well as options for high-quality timber production and is likely to remain suitable under the climate projection scenario for 2080.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	warm and moist	1696	153	10		
Climate 2080 (UKCP09)	very warm and slightly dry	2806	224	10		
Soil					rich	fresh

8.5 FDT 7.1.1 (BI)

About 30-year-old SBI stand at Ladywell plantation, Perth and Kinross, (NO 028 417), on a complex of podzols and brown earths. The stand originated from prolific SBI natural regeneration on a SS restock site. Due to its poor performance SS (remnants of which can be seen on the left) was removed and SBI is now managed towards FDT 7.1.1. Although this FDT is likely to remain suitable under the current climate projection scenario for 2080 it could be easily transitioned to alternative FDTs (*e.g.* SP or OK types) if desirable.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	warm and moist	1297	126	7		
Climate 2080 (UKCP09)	warm and moist	2195	130	7		
Soil					very poor	slightly dry

8.6 FDT 8.1.1 (SC coppice)

42-year-old stand of SC in the Forest of Dean, Gloucestershire (SO 646 093), on brown earth. The stand is managed under a coppice system; at this stage individual stems have already been singled and are managed for sawlog production. FDT 8.1.1 is likely to remain suitable under the climate projections for 2080.

	Climate zone	AT [°C]	MD [mm]	DAMS	SNR	SMR
Climate 1961 - 1990	warm and moist	1610	144	12		
Climate 2080 (UKCP09)	very warm and slightly dry	2756	222	12		
Soil					medium	slightly dry

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10 Further information and training

Further information of relevance, but not included in the list of references, includes:

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For general enquiries, please contact the authors at:

Victoria Stokes

Stephen Bathgate

Forest Research
Northern Research Station
Roslin, Midlothian
EH25 9SY
Tel.: 0300 067 5738 (VS) / 0300 067 5911 (SB)
Email: victoria.stokes@forestresearch.gov.uk
Email: stephen.bathgate@forestresearch.gov.uk

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12 Glossary

Term	Definition
Accumulated Temperature (AT)	Annual temperature sum of day degrees above 5 °C, used to describe the climate in terms of warmth.
Age structure	A general distinction is made between even-aged and uneven-aged structures. See Section 4.2.3 for details.
AWC	**A**vailable **W**ater **C**apacity is an option for projecting future climate conditions in ESC DSS, based on the assumption that maintaining forest canopy will maintain SMR better after harvesting.
CCF	**C**ontinuous **C**over **F**orestry. Includes all harvesting/restocking methods where patch clearfelling is limited to areas < 0.25 ha in size. See Section 5.6.5 for details.
Cluster planting	An establishment method, predominantly used for broadleaved species, whereby groups (clusters) of trees are planted at tight spacing. See Section 5.6.3.5 for details.
Compatibility Score	Numeric value describing the compatibility of different tree species with regard to growth rate and light demand. See [6] for reference.
Complex structure	A CCF stand structure with three or more canopy layers.
Continentality	Describes the seasonality of the climate, where oceanic climates have a smaller range in annual variation of temperature and precipitation than those with continental character.
DAMS	**D**etailed **A**spect **M**ethod of **S**coring, scale for measuring exposure.
Emerging tree species	Species and provenances that have been identified as having potential for more extensive planting, usually considered to be Secondary species and Plot-stage species as defined by [4].

ESC	**E**cological **S**ite **C**lassification. Classification system to describe the climatic and soil conditions in British forestry. See [3] for reference.
ESC DSS	ESC **D**ecision **S**upport **S**ystem. Computer based support tool to aid management decisions related to site conditions. http://www.forestdss.org.uk/geoforestdss/
Exposure	Describes the climate in terms of windiness, taking into account the average windspeed and the likelihood of gales.
Fast diameter growth concept	A silvicultural concept for achieving large bole diameters of broadleaved species in a short amount of time. See Section 5.6.3.4 for details.
FC tree concept	**F**inal **C**rop tree concept. A silvicultural concept where the best trees of a stand are identified early and continuously promoted through thinning until final harvesting. FC trees can be Seed Trees or Frame Trees in CCF scenarios.
FDT category	Broad categorisation of FDTs according to primary tree species group and management objectives, defining the 1st digit of the FDT ID code. See Section 4.2.1 for details.
FDT selection grid	A grid matrix showing FDT suitability with regard to SMR and SNR for a certain climate zone category.
FDT with loosely defined species	An FDT which allows forest managers to trial unusual mixtures and novel species. See Section 4.3.2 for details.
Flashcard	A double-sided A4 page summarising key features of each FDT. See Section 5 for details.
Forester Web	Online GIS application for forest management.
Group planting	The planting of trees in canopy gaps of a forest stand.
H_{100}	Stand top height, *i.e.* the average height of the 100 largest trees/ha by dbh.
High-quality timber	Timber which exceeds ordinary sawlog standards.

LIMA	**L**ower **I**ntensity **M**anagement **A**pproaches. Includes all harvesting/restocking methods where patch clearfelling is limited to areas < 2 ha in size. See Section 5.6.5 for details.
Management objectives	The particular economic, environmental and social benefits a fully functional forest is expected to deliver.
Minor tree species	One or several tree species which may not be specified and do not directly contribute to the economic management objectives. See Section 4.2.4 for details.
Moisture Deficit (MD)	Difference between evaporation and rainfall, used to describe the climate in terms of wetness.
Negative tree selection	An approach to thinning whereby the least desirable trees of a stand are selected for removal.
NVC	**N**ational **V**egetation **C**lassification. See Section 1 and [1] for details.
Pacific Northwest of America	This part of North America is similar in climate to Britain and many species used in British forestry originated from here; species from this area have therefore been singled out into a separate primary tree species group.
PAWS	**P**lantation on **A**ncient **W**oodland **S**ites.
Positive tree selection	An approach to thinning whereby the best trees of a stand (positive trees) are identified first and their competing neighbour trees are selected for removal.
Primary tree species	The main species of an FDT. See Section 4.2.2 for details.
Q/D concept	**Q**uality/**D**imension, a silvicultural concept for growing high-quality broadleaved timber. See Section 5.6.3.4 for details.
Riparian zone	The zone relating to or situated adjacent to a water course or water body.

Secondary tree species	One or several tree species which contribute ≤ 50 % of the stand basal area but are not minor species. See Section 4.2.3 for details.
Simple structure	Stand structure with one or two canopy layers.
SMR	**S**oil **M**oisture **R**egime, describes the wetness of a soil.
SNR	**S**oil **N**utrient **R**egime, describes the fertility of a soil.
SSSI	**S**ite of **S**pecific **S**cientific **I**nterest.
Stand structure	The term is used generally in the guide but also refers to the options described in Section 5.3: even-aged unthinned, even-aged thinned, uneven-aged simple and uneven-aged complex.
Transitional FDT	An FDT which is designed to facilitate a change in tree species. See Section 4.3.1 for details.
Underplanting	The planting of trees under the canopy of a forest stand.
XBLL	Unspecified long-lived broadleaved species, see Section 4.2.3 for details
XBSL	Unspecified short-lived broadleaved species, see Section 4.2.3 for details.
XCLD	Unspecified light demanding conifers, see Section 4.2.3 for details
XCST	Unspecified shade tolerant conifers, see Section 4.2.3 for details.

13 Appendices

Appendix 1. Summary of FDTs

FDT ID code			primary species	primary species proportion [%]	secondary species.	secondary species proportion [%]	Stand structure				Short title
							even-aged unthinned	even-aged thinned	uneven-aged simple	uneven-aged complex	
1	1	1	SS	90-100			x	x*			Sitka spruce
1	1	2	SS	80-90					x*	x	Sitka spruce LIMA/CCF
1	1	3	SS	60-80	DF	20-40		x	x*	x	Sitka spruce and Douglas-fir
1	1	4	SS	60-80	XCLD	20-40	x	x*	x	x	Sitka spruce and pine/larch
1	1	5	SS	60-80	XCST	20-40		x	x*	x	Sitka spruce and shade tolerant conifers
1	1	6	SS	70-90	BE	10-30		x*	x	x	Sitka spruce and beech
1	1	7	SS	50-90	XBLL	10-50		x	x*	x	Sitka spruce and long-lived broadleaves
1	1	8	SS	50-90	XBSL	10-50	x	x*			Sitka spruce and short-lived broadleaves
1	2	1	NS	90-100			x	x*			Norway spruce
1	2	2	NS	80-90					x*	x	Norway spruce LIMA/CCF
1	2	3	NS	70-90	SS	10-20	x	x*	x	x	Norway spruce and Sitka spruce
1	2	4	NS	60-80	XCST	20-40	x	x	x*	x	Norway spruce and shade tolerant conifers
1	2	5	NS	50-70	BE	20-40		x	x	x*	Norway spruce and beech
1	2	6	NS	60-80	XBLL	20-40		x	x*	x	Norway spruce and long-lived broadleaves
1	2	7	NS	70-90	XBSL	10-30	x	x*			Norway spruce and short-lived broadleaves
2	1	1	SP	80-100			x	x*			Scots pine
2	1	2	SP	70-90				x	x*	x	Scots pine LIMA/CCF
2	1	3	SP	60-80	XCST	20-40			x*	x	Scots pine and shade tolerant conifers
2	1	4	SP	60-90	XCLD	10-40		x*	x		Scots pine and light demanding conifers
2	1	5	SP	50-70	SOK	20-40				x*	Scots pine and oak
2	1	6	SP	60-80	BE	20-40		x	x*	x	Scots pine and beech
2	1	7	SP	60-90	SBI	10-40		x	x	x*	Scots pine and birch
2	2	1	CP	30-70	XCST	30-70			x*		Corsican pine transition to shade tolerant conifers
2	2	2	CP	30-70	XCLD	30-70		x*	x	x	Corsican pine transition to pine/larch
2	2	3	CP	30-70	XBLL	30-70			x*		Corsican pine transition to broadleaves
2	3	1	LP	90-100			x	x*			Lodgepole pine
2	3	2	LP	50-70	DBI	30-50	x	x*			Lodgepole pine and birch
2	4	1	LA	60-90	SP	10-40		x*			Larch and Scots pine
2	4	2	LA	60-80	XCST	20-40			x*	x	Larch and shade tolerant conifers
2	4	3	LA	50-80	BE	10-40			x*		Larch and beech
2	4	4	LA	50-70	OK	20-40				x*	Larch and oak
3	1	1	DF	90-100				x*			Douglas-fir
3	1	2	DF	80-90					x	x*	Douglas-fir LIMA/CCF
3	1	3	DF	60-80	XCST	20-40		x	x*	x	Douglas-fir and shade tolerant conifers
3	1	4	DF	70-90	XBLL	10-30		x	x*	x	Douglas-fir and broadleaves

FDT ID code			primary species	primary species proportion [%]	secondary species.	secondary species proportion [%]	Stand structure				Short title
							even-aged unthinned	even-aged thinned	uneven-aged simple	uneven-aged complex	
3	2	1	PNWAF	90-100			x	x*			Pacific North-West American firs
3	2	2	PNWAF	80-90					x*	x	Pacific North-West American firs LIMA/CCF
3	2	3	PNWAF	50-70	XCST	30-50			x	x*	Pacific North-West American firs and XCST
3	2	4	PNWAF	60-80	SS	20-40	x	x*	x		Pacific North-West American firs and Sitka spruce
3	3-9		placeholder for any other Pacific North-West American conifers								
4	1-7		placeholder for any other shade tolerant conifers except spruces								
4	8	1	XCST	80-100			x	x	x*	x	Other shade tolerant conifers
4	9	1	XCLD	80-100				x*			Other light demanding conifers
5	1	1	POK	70-90	HBM	10-30			x*	x	Oak and hornbeam
5	2	1	SOK	50-80	BI	20-50		x	x	x*	Oak and birch
5	2	2	SOK	50-70	SP	20-40		x	x	x*	Oak and Scots pine
5	3	1	OK	60-80	BE	20-40			x*	x	Oak and beech
5	3	2	OK	50-70	XBLL	30-50			x	x*	Oak and long-lived broadleaves
5	3	3	OK	80-100	HAZ	n.a.			x*		Oak and hazel coppice
5	4-9		placeholder for other oak species								
6	1	1	BE	90-100			x	x*			Beech
6	1	2	BE	80-90					x	x*	Beech LIMA/CCF
6	1	3	BE	50-70	XCST	30-50			x	x*	Beech and shade tolerant conifers
6	1	4	BE	50-70	XBLL	30-50			x	x*	Beech and long-lived broadleaves
7	1	1	BI	70-100			x	x*			Birch
7	1	2	BI	50-70	XBSL	30-50	x	x*			Birch and short-lived broadleaves
7	2	1	SBI	60-90	SP	10-40		x	x*	x	Birch and Scots pine
7	2	2	SBI	50-80	SOK	20-50			x	x*	Birch and oak
8	1	1	SC	80-100					x	x*	Sweet chestnut coppice
8	1	2	SC	50-80	XBLL	20-50		x	x*	x	Sweet chestnut and long-lived broadleaves
8	2	1	AH	50-70	CAR	30-50			x	x*	Ash and alder
8	2	2	AH	50-70	XBLL	30-50				x*	Ash and long-lived broadleaves
8	3	1	SY	80-100				x	x*	x	Sycamore
8	3	2	SY	50-70	XBLL	30-50			x	x*	Sycamore and long-lived broadleaves
8	4	1	LI	50-90	XBLL	30-50		x	x	x*	Lime and long-lived broadleaves
8	5-9		placeholder for other long-lived broadleaved species								
9	1	1	CAR	80-100				x*			Alder
9	2-3		placeholder for other short-lived broadleaved species								
9	4	1	WIL	50-100			x			x	Willow
9	8	1	XBLL	30-100				x	x	x	Other long-lived broadleaves
9	8	2	XBLL	50-80	XC	20-50		x	x*	x	Long-lived broadleaves with conifers
9	9	1	XBSL	30-100			x	x			Other short-lived broadleaves
10	1	1	PEW								Peat edge woodland
10	1	2	SSW								Slope stabilisation woodland
10	2-9		placeholder for any other special FDTs								

For tree species acronyms see Appendix 2; for stand structure see Section 5.3.

Appendix 2. Tree species abbreviations and shade tolerance

Acronym	Common name	*Latin name*	Light demand	Category
ESF	European silver fir	*Abies alba*	shade tolerant	XCST
GF	Grand fir	*Abies grandis*	shade tolerant	XCST
NF	Noble fir	*Abies procera*	intermediate	XCST
LC	Lawson cypress	*Chamaecyparis lawsoniana*	intermediate	XCST
JUN	Juniper	*Juniperus communis*	intermediate	XCST
EL	European larch	*Larix decidua*	light demanding	XCLD
JL	Japanese larch	*Larix kaempferi*	light demanding	XCLD
LA	Larch	*Larix* spp.	light demanding	XCLD
HL	Hybrid larch	*Larix x marschlinsii*	light demanding	XCLD
NS	Norway spruce	*Picea abies*	shade tolerant	XCST
SS	Sitka spruce	*Picea sitchensis*	intermediate	XCST
LP	Lodgepole pine	*Pinus contorta*	light demanding	XCLD
CP	Corsican pine	*Pinus nigra* subsp. *laricio*	light demanding	XCLD
SP	Scots pine	*Pinus sylvestris*	light demanding	XCLD
DF	Douglas-fir	*Pseudotsuga menziesii*	intermediate	XCST
RSQ	Coast redwood	*Sequoia sempervirens*	shade tolerant	XCST
YEW	Yew	*Taxus baccata*	shade tolerant	XCST
WRC	Western red cedar	*Thuja plicata*	shade tolerant	XCST
WH	Western hemlock	*Tsuga heterophylla*	shade tolerant	XCST
XCLD	Light demanding conifers		light demanding	XCLD
XCST	Shade tolerant conifers		shade tolerant	XCST
SY	Sycamore	*Acer pseudoplatanus*	shade tolerant	XBLL
CAR	Common alder	*Alnus glutinosa*	light demanding	XBSL
AR	Alder	*Alnus* spp.	light demanding	XBSL
SBI	Silver birch	*Betula pendula*	light demanding	XBSL
DBI	Downy birch	*Betula pubescens*	light demanding	XBSL
BI	Birch	*Betula* spp.	light demanding	XBSL
HBM	Hornbeam	*Carpinus betulus*	shade tolerant	XBLL
SC	Sweet chestnut	*Castanea sativa*	intermediate	XBLL
HAZ	Hazel	*Corylus avellana*	shade tolerant	XBLL
BE	Beech	*Fagus sylvatica*	shade tolerant	XBLL
AH	Ash	*Fraxinus excelsior*	intermediate	XBLL
PO	Poplar	*Populus* spp.	light demanding	XBSL
ASP	Aspen	*Populus tremula*	light demanding	XBSL
WCH	Wild cherry	*Prunus avium*	light demanding	XBSL

SOK	Sessile oak	*Quercus petraea*	intermediate	XBLL
POK	Pedunculate oak	*Quercus robur*	intermediate	XBLL
OK	Oak	*Quercus* spp.	intermediate	XBLL
WIL	Willow	*Salix* spp.	light demanding	XBSL
ROW	Rowan	*Sorbus aucuparia*	light demanding	XBSL
LI	Lime	*Tilia* spp.	shade tolerant	XBLL
XBLL	Long-lived broadleaves			XBLL
XBSL	Short-lived broadleaves			XBSL

Appendix 3. FDT selection grids for different climate zones

Climate zones (see Appendix 4) have been divided into two categories. Category 1 covers the following zones:

- very warm / warm / cool and *moderately dry*, *i.e.* the driest climates currently found in Britain.

Category 2 covers all other zones, *i.e.*:

- very warm / warm / cool and *slightly dry*,
- very warm / warm / cool and *moist*,
- very warm / warm / cool and *wet*.

SMR / SNR grids showing the suitability of FDTs within both categories are shown in the tables overleaf. The following conventions apply:

- FDTs shown as 2.2.1-3 means *all* FDTs in the range, *i.e.* 2.2.1, 2.2.2 and 2.2.3.
- FDTs shown as 2.2.1/3 means FDTs 2.2.1 and 2.2.3 *only*.
- Conifer-dominated and broadleaved-dominated FDTs are shown in different colours.
- Climatic suitability of FDTs is as shown on the flashcards; an FDT is included in the grid *even if it is only suitable in a small part of the climate zone* category.
- SMR / SNR suitability of FDTs is also as shown on the flashcards. Where, on the flashcard, the FDT is shown as suitable for part of an SMR or SNR category only, it has been included in the entire category here.
- FDTs 4.8.1, 4.9.1, 9.8.1, 9.8.2, 9.9.1 and 10.1.2 are not shown.

Baseline and future (2080s) climate zone maps are shown in Appendix 4.

Category 1: climate zones very warm / warm / cool and moderately dry

(*5.1.1, 8.1.1, 8.1.2 only borderline suitable in cool and moderately dry; 8.4.1 only borderline suitable in very warm / warm and moderately dry climate zones)

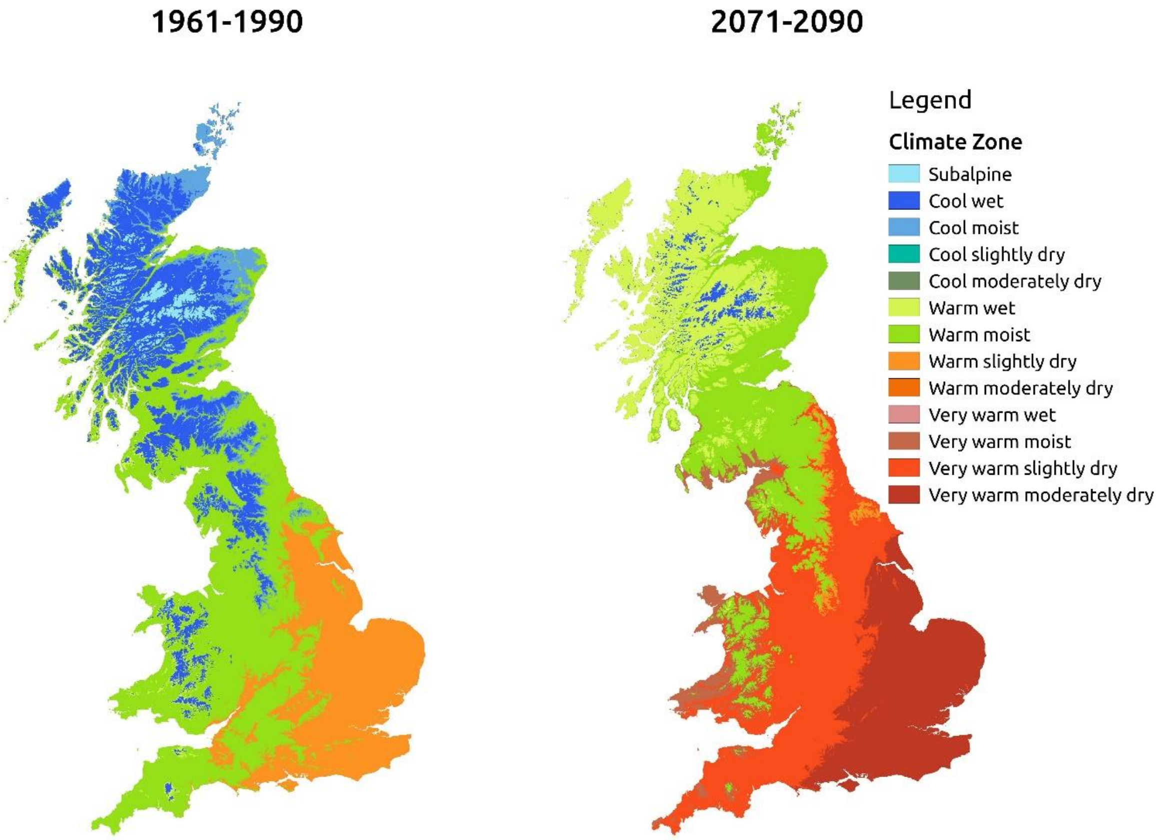
		Soil Nutrient Regime							
		VP2	**VP3**	**VPP**	**P**	**M**	**R**	**VR**	**C**
Soil Moisture Regime	**VD**	2.1.7 10.1.1	2.1.1/2/7 2.2.2 10.1.1	2.1.1/2/7 2.2.2 10.1.1	2.1.1/2/7 2.2.2	2.2.2	2.2.2		
	MD	2.1.7 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/3/7 2.2.1-3 3.1.1/3 7.2.1 8.1.2*	2.1.3 2.2.1-3 3.1.1-4 8.1.2*	2.2.1-3 3.1.1-4 8.1.2*	2.2.1/3 3.1.2/4 8.1.2*	
	SD	2.1.7 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/3/7 2.2.1-3 3.1.1/3 7.2.1 8.1.2*	2.1.3 2.2.1-3 3.1.1-4 5.1.1* 5.3.1/3 8.1.1/2* 8.3.1 8.4.1*	2.2.1-3 3.1.1-4 5.1.1* 5.3.1/3 8.1.1/2* 8.3.1 8.4.1*	2.2.1/3 3.1.2/4 5.1.1* 5.3.1 8.1.1/2* 8.3.1 8.4.1*	8.4.1*
	F	2.1.7 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.2.1 10.1.1	2.1.1/2/3/7 2.2.1-3 3.1.1/3 7.2.1 8.1.2*	2.1.3 2.2.1-3 3.1.1-4 5.1.1* 5.3.1-3 8.1.1/2* 8.3.1 8.4.1*	2.2.1-3 3.1.1-4 5.1.1* 5.3.1-3 8.1.1/2* 8.3.1 8.4.1*	2.2.1/3 3.1.2/4 5.1.1* 5.3.1/2 8.1.1/2* 8.3.1 8.4.1*	8.4.1*
	M	2.1.7 2.3.1 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 2.3.1 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 2.3.1 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 3.1.1/3 7.2.1 8.1.2*	2.1.3 2.2.1-3 3.1.1-4 5.1.1* 5.3.1-3 8.1.1/2* 8.3.1 8.4.1* 9.1.1	2.2.1-3 3.1.1-4 5.1.1* 5.3.1-3 8.1.1/2* 8.3.1 8.4.1* 9.1.1	2.2.1/3 3.1.2/4 5.1.1* 5.3.1/2 8.1.1/2* 8.3.1 8.4.1* 9.1.1	8.4.1*
	VM	2.1.7 2.3.1 7.2.1 10.1.1	2.1.7 2.2.1-3 2.3.1 7.2.1 10.1.1	2.1.7 2.2.1-3 2.3.1 7.2.1 10.1.1	2.1.7 2.2.1-3 2.3.1 7.2.1	2.2.1-3 5.1.1* 5.3.1-3 8.3.1 8.4.1* 9.1.1	2.2.1-3 5.1.1* 5.3.1-3 8.3.1 8.4.1* 9.1.1	2.2.1/3 5.1.1* 5.3.1/2 8.3.1 8.4.1* 9.1.1	8.4.1*
	W	2.3.1 10.1.1	2.3.1 10.1.1	2.3.1 10.1.1	2.3.1	9.1.1	9.1.1	9.1.1	
	VW	2.3.1 10.1.1	2.3.1 10.1.1	2.3.1 10.1.1	2.3.1	9.1.1.	9.1.1.	9.1.1.	

Category 2: climate zones very warm / warm / cool and slightly dry / moist / wet (*5.1.1 not suitable in wet; 8.4.1 borderline suitable in cool or wet)

Soil Moisture Regime	Soil Nutrient Regime							
	VP2	**VP3**	**VPP**	**P**	**M**	**R**	**VR**	**C**
VD	2.1.7 10.1.1	2.1.1/2/7 2.2.2 10.1.1	2.1.1/2/7 2.2.2 10.1.1	2.1.1/2/7 2.2.2	2.2.2	2.2.2		
MD	2.1.7 7.1.1/2 7.2.1 10.1.1	2.1.1/2/7 2.2.1-3 7.1.1/2 7.2.1 10.1.1	2.1.1/2/4/7 2.2.1-3 5.2.1/2 7.1.1/2 7.2.1 10.1.1	2.1.1-7 2.2.1-3 3.1.1/3 5.2.1/2 7.1.1/2 7.2.1/2 8.1.2	2.1.3-6 2.2.1-3 3.1.1-4 5.2.1/2 6.1.1-4 7.1.1/2 7.2.2 8.1.2	2.2.1-3 3.1.1-4 6.1.1-4 8.1.2	2.2.1/3 3.1.2/4 6.1.1/2/4 8.1.2	6.1.1/2/4
SD	2.1.7 7.1.1/2 7.2.1 10.1.1	1.1.4 2.1.1/2/7 2.2.1-3 2.4.1 7.1.1/2 7.2.1 10.1.1	1.1.4/8 2.1.1/2/4/7 2.2.1-3 2.4.1 5.2.1/2 7.1.1/2 7.2.1 10.1.1	1.1.1/2/4-8 1.2.1-7 2.1.1-7 2.2.1-3 2.4.1-4 3.2.3/4 3.1.1/3 5.2.1/2 7.1.1/2 7.2.1/2 8.1.2	1.1.1-8 1.2.1-7 2.1.3-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.3/4 5.1.1* 5.2.1/2 5.3.1/3 6.1.1-4 7.1.1/2 7.2.2 8.1.1/2 8.3.1/2 8.4.1*	1.1.3/6/7 1.2.4-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.2/3 5.1.1* 5.3.1/3 6.1.1-4 8.1.1/2 8.2.2 8.3.1/2 8.4.1*	2.2.1-3 3.1.2/4 5.1.1* 5.3.1 6.1.1/2/4 8.1.1/2 8.2.2 8.3.1/2 8.4.1*	6.1.1/2/4 8.2.2 8.4.1*
F	2.1.7 7.1.1/2 7.2.1 10.1.1	1.1.4 2.1.1/2/7 2.2.1-3 2.4.1 7.1.1/2 7.2.1 10.1.1	1.1.4/8 2.1.1/2/4/7 2.2.1-3 2.4.1 5.2.1/2 7.1.1/2 7.2.1 10.1.1	1.1.1/2/4-8 1.2.1-7 2.1.1-7 2.2.1-3 2.4.1-4 3.1.1/3 3.2.1-4 5.2.1/2 7.1.1/2 7.2.1/2 8.1.2	1.1.1-8 1.2.1-7 2.1.3-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.1-4 5.1.1* 5.2.1/2 5.3.1-3 6.1.1-4 7.1.1/2 7.2.2 8.1.1/2 8.3.1/2 8.4.1*	1.1.3/6/7 1.2.4-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.2/3 5.1.1* 5.3.1-3 6.1.1-4 8.1.1/2 8.2.1/2 8.3.1/2 8.4.1*	2.2.1/3 3.1.2/4 5.1.1* 5.3.1/2 6.1.1/2/4 8.1.1/2 8.2.1/2 8.3.1/2 8.4.1*	6.1.1/2/4 8.2.2 8.4.1*
M	2.1.7 2.2.1-3 2.3.1/2 7.1.1/2 7.2.1 10.1.1	1.1.4 2.1.1/2/7 2.2.1-3 2.3.1/2 2.4.1 7.1.1/2 7.2.1 10.1.1	1.1.4/8 2.1.1/2/4/7 2.2.1-3 2.3.1/2 2.4.1 5.2.1/2 7.1.1/2 7.2.1 10.1.1	1.1.1/2/4-8 1.2.1-7 2.1.1-7 2.2.1-3 2.3.1/2 2.4.1-4 3.1.1/3 3.2.1-4 5.2.1/2 7.1.1/2 7.2.1/2 8.1.2	1.1.1-8 1.2.1-7 2.1.3-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.1/4 5.1.1* 5.2.1/2 5.3.1-3 6.1.1-4 7.1.1/2 7.2.2 8.1.1/2 8.3.1/2 8.4.1* 9.1.1	1.1.3/6/7 1.2.4-6 2.2.1-3 2.4.1-4 3.1.1-4 3.2.2/3 5.1.1* 5.3.1-3 6.1.1-4 8.1.1/2 8.2.1/2 8.3.1/2 8.4.1* 9.1.1	2.2.1/3 3.1.2/4 5.1.1* 5.3.1/2 6.1.1/2/4 8.1.1/2 8.2.1/2 8.3.1/2 8.4.1* 9.1.1	6.1.1/2/4 8.2.2 8.4.1*
VM	2.1.7 2.3.1/2 7.1.1/2 7.2.1 10.1.1	1.1.4 2.1.7 2.2.1-3 2.3.1/2 2.4.1 7.1.1/2 7.2.1 10.1.1	1.1.4/8 2.1.7 2.2.1-3 2.3.1/2 2.4.1 7.1.1/2 7.2.1 10.1.1	1.1.1/2/4-8 1.2.1/2/4-7 2.1.7 2.2.1-3 2.3.1/2 2.4.1-4 3.2.1-4 7.1.1/2 7.2.1	1.1.1/2/4-8 1.2.1/2/4-7 2.2.1-3 2.4.1-4 3.2.1-4 5.1.1* 5.3.1-3 6.1.3/4 7.1.1/2 8.3.1/2 8.4.1* 9.1.1	1.1.6/7 1.2.4-6 2.2.1-3 2.4.1-4 3.2.2/3 5.1.1* 5.3.1-3 6.1.3/4 8.2.1 8.3.1/2 8.4.1* 9.1.1	2.2.1/3 5.1.1* 5.3.1/2 6.1.4 8.2.1 8.3.1/2 8.4.1* 9.1.1	6.1.4 8.4.1*
W	2.3.1/2 7.1.1/2 10.1.1	1.1.4 2.3.1/2 7.1.1/2 10.1.1	1.1.4/8 2.3.1/2 7.1.1/2 10.1.1	1.1.1/4/7/8 1.2.6 2.3.1/2 7.1.1/2 9.4.1	1.1.1/4/7/8 1.2.6 7.1.1/2 9.1.1 9.4.1	1.2.6 8.2.1 9.1.1 9.4.1	8.2.1 9.1.1 9.4.1	
VW	2.3.1/2 7.1.1/2 10.1.1	2.3.1/2 7.1.1/2 10.1.1	2.3.1/2 7.1.1/2 10.1.1	2.3.1/2 7.1.1/2 9.4.1	7.1.1/2 9.1.1 9.4.1	9.1.1 9.4.1	9.1.1 9.4.1	

Appendix 4. Climate zone maps

Climate zone maps of Great Britain for the baseline period of 1961-1990 and the predicted future climate zone in the 2080s (2009 A1b medium emissions scenario, equivalent to UKCP18 RCP6).



Forest Research

Alice Holt Lodge
Farnham
Surrey GU10 4LH, UK

Tel: 0300 067 5600

Fax: 01420 23653

Northern Research Station
Roslin
Midlothian EH25 9SY, UK

Tel: 0300 067 5900

Fax: 0131 445 5124

Forest Research in Wales
Environment Centre Wales
Deiniol Road
Bangor
Gwynedd
LL57 2UW

Tel: 0300 067 5774

www.forestresearch.gov.uk