Forest Research

25-year forecast of softwood timber availability (2022)

NFI Forecast Report

The Research Agency of the Forestry Commission

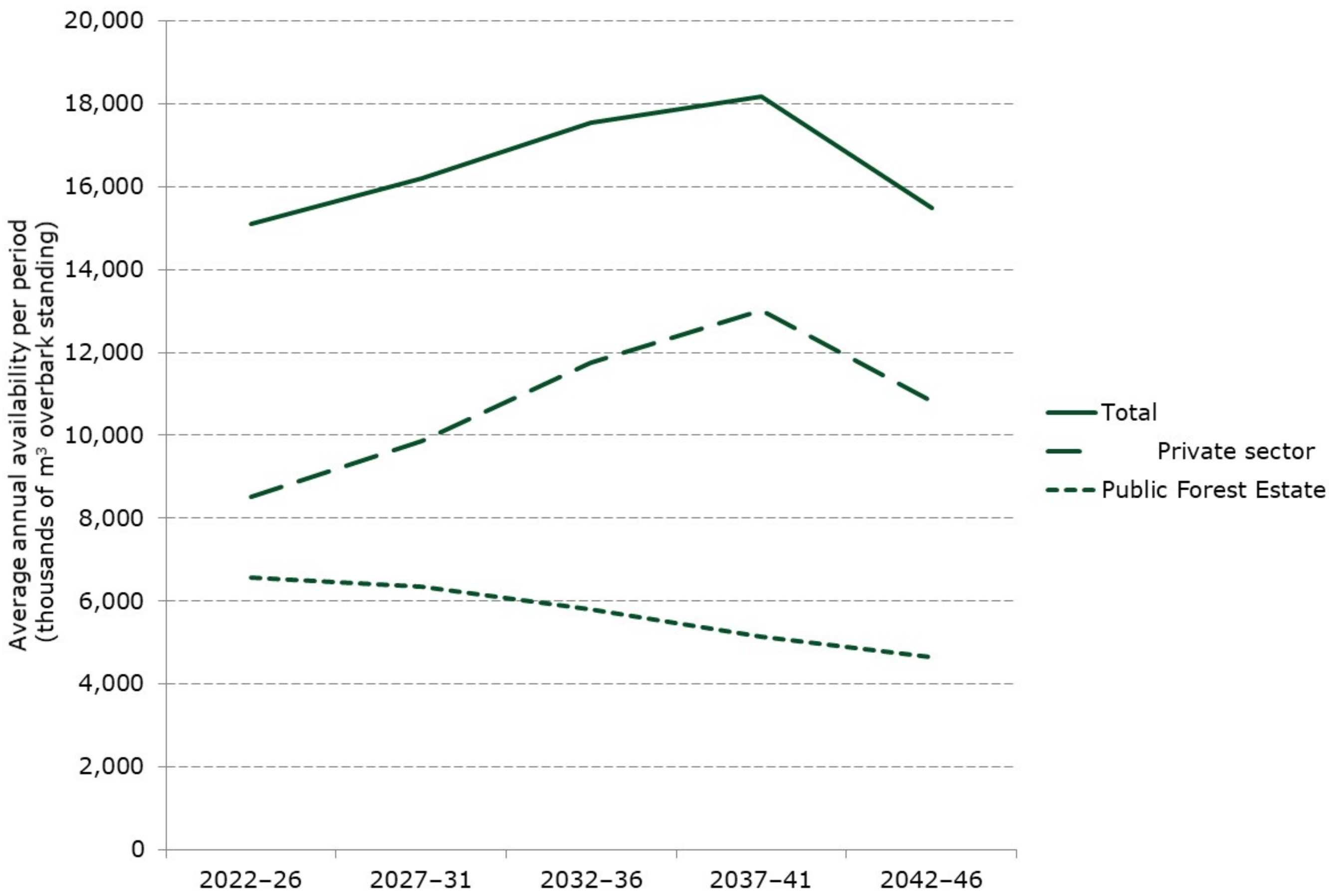
Forest Research is the Research Agency of the Forestry Commission and is the leading UK organisation engaged in forestry and tree related research.

The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high quality scientific research, technical support, and consultancy services.

Summary

This report provides a 25-year forecast of softwood timber volume that could potentially be produced from conifers growing in forests and woodlands in the United Kingdom, assuming certain timber harvesting scenarios are followed. It includes estimates for potential timber production on land managed by Forestry England (FE), Forestry and Land Scotland (FLS), Natural Resources Wales (NRW) and the Forest Service of Northern Ireland (FS), and under private sector ownership. In this report, FE/FLS/NRW/FS will be referred to as 'public forest estate'. FE/FLS/NRW will be referred to as 'GB public forest estate'. The reporting period runs from 2022 to 2046.

Figure 1. Summary of the 25-year forecast of softwood timber availability for the public forest estate and private sector estate in the UK



This report supersedes the previous *25-year forecast of softwood timber availability* published in 2016. Some comparison is made between the two reports. Reference is also made to the *50-year forecast of softwood timber availability* (2014) and the *25-year forecast of softwood timber availability* (2012).

Key findings

- The forecast of potential softwood availability for the UK forest estate is an average of 16.5 million m^3 of softwood timber per annum over the 25-year period. The forecast for England is an average of 3.5 million m^3 per annum; for Scotland 10.7 million m^3; for Wales 1.7 million m^3; and for Northern Ireland 0.6 million m^3.
- Softwood availability changes over the period of the forecast; it increases from 15.1 million m^3 per annum in 2022–26 to 18.2 million m^3 per annum in 2037–41 before reducing to 15.5 million m^3 per annum in 2042–46.
- The profiles for the public forest estate and private sector estate are different. Over the forecast period, the public forest estate shows an overall reduction in forecast availability while the private sector estate shows an overall increase. Private sector softwood availability is forecast to increase for the first 20 years of the forecast period followed by a decline from 2042-46, with annual availability in the last 5 years (2042–46) returning to a level similar to the 2027–31 period.
- The GB public forest estate is projected to generate an average of 5.1 million m^3 of softwood timber per annum for the next 25 years if existing forest plans are followed and production is not constrained. In the first five-year period (2022–26) 6.1 million m^3 per annum would be potentially available and this will reduce to an average of 4.1 million m^3 per annum in the final five-year period (2042–46). In addition, availability from the Forest Service estate in

Northern Ireland is forecast to average 0.6 million m^3 per annum over the same 25 years. However, it should be noted that the published intention in Scotland is to constrain production, and this will reduce availability overall.

- The potential availability of softwood timber from the private sector estate for the UK is forecast to average 10.8 million m^3 per annum for the next 25 years. This assumes a management scenario of, where viable, felling at a specified target diameter. The forecast for England is an average of 2.4 million m^3 per annum; for Scotland 7.6 million m^3 per annum; for Wales 0.8 million m^3 per annum; and for Northern Ireland 0.035 million m^3 per annum. Potential availability amounts to 8.5 million m^3 per annum in the first five-year period, with maximum annual availability of 13.0 million m^3 per annum occurring in the period 2037–41.

The private sector forecast in this report represents potential availability of softwood timber under the assumption of a management scenario of felling at a specified target diameter where viable. The actual levels of timber that will be produced will vary from the results reported here as production depends on the harvesting choices made by forest and woodland owners, and owners are unlikely to consistently choose to fell at a specified target diameter over the forecast period. Previous forecasts have been run under the different assumption of harvesting to maximise timber production by felling at age of maximum mean annual increment (MAI). The change from utilising age of maximum MAI was made to mitigate the impacts of applying M1v2 growth and yield models, which greatly extended age of maximum MAI and rotation length for most species, much beyond current harvesting practice. With such it was thought such long rotations were impractical for a forecast aimed to signal likely levels of production and a target diameter scenario was devised in conjunction with the timber industry.

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1 Introduction

National forest inventories are carried out by Forest Research to provide accurate, up-to-date information about the size, distribution, composition and condition of the forests and woodlands in Great Britain (GB). This information is essential for developing and monitoring policies and guidance to support sustainable forest management.

The current National Forest Inventory (NFI), which began in 2010, is a multipurpose operation that has involved the production of a forest and woodland map for Britain and a continuing programme of field surveys of the mapped forest and woodland areas. The first cycle of field surveys completed in late 2015 and the second cycle completed in late 2020. The third cycle is underway.

Information and data collected by the National Forest Inventory is used for a number of purposes, including estimates and 25-year forecasts of forest metrics such as:

- standing volume
- timber availability
- tree growth and increment
- carbon stocks
- biomass

Estimates of the ecological condition, biodiversity and social value of forests and woodlands are also provided by the NFI.

This report sets out the results of a 25-year forecast of softwood availability for all forests and woodlands in the United Kingdom (UK). For the public sector in the United Kingdom this comprises Forestry England (FE), Forestry and Land Scotland (FLS), Natural Resources Wales (NRW) and the Forest Service of Northern Ireland

(FS), an agency within the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland. The private sector covers all other woodland in the UK.

Timber is defined in this report as the volume in m^3 (obs) of stemwood to 7 cm top diameter overbark, including stump (above ground) and usable branchwood (of minimum 3 m in length and 7 cm top diameter).

It should be noted that this report assesses the potential amount of timber that could arise from UK forests under the specified scenarios, and any references to volume, production or availability must be taken in that context.

A forecast of hardwood availability was published in 2014. Further information on this and other NFI outputs is available from the NFI web pages.

2 Methodology used in the derivation of the forecast of softwood availability

This report provides the latest overall softwood timber availability forecasts, giving a breakdown of forecast volume by size class and by country, shown in **Table 3** and **Table 4**.

The forecasts of softwood availability for Great Britain are based on the GB public forest estate's sub-compartment database for public sector woodland and on the National Forest Inventory assessment of the current state of woodland in the private sector. Recent estimates of standing timber volume and other attributes of coniferous stands in Britain can be found in the published NFI report *Standing timber volume for coniferous trees in Britain* (2012) which was updated in 2013. Revised estimates were included in the NFI report *25-year forecast of softwood timber availability* (2016). The forecast of softwood availability for Northern Ireland is derived from data sourced by DAERA.

The previous 25-year forecast of softwood availability in the UK was published in the NFI report entitled *25-year forecast of softwood timber availability* (2016).

2.1 How forecasts are derived

Forecasts of softwood availability are derived by assessing:

- woodland area;
- woodland characteristics (e.g. age, species and stocking) within this area;
- how quickly the trees are growing (yield class);
- when the trees will be harvested.

The forecast of softwood availability for the UK is composed of four separate forecasts derived under different methodologies: a forecast for the Forestry England/Forestry and Land Scotland/Natural Resources Wales estates retains a common methodology with previously published forecasts; a forecast for the private sector estate in Britain; a forecast for the Forest Service (FS) estate in Northern Ireland; and a forecast for the private sector estate in Northern Ireland. The forecasts are based upon the same principles but use different data sources.

For the GB public forest estate, information on woodland area and woodland characteristics has been extracted from the long-established sub-compartment database (SCDB). For the private sector estate in Britain, the estimates were derived from results from the National Forest Inventory. The same principles were used in the Northern Ireland forecast with the data source for the FS estate being the Northern Ireland inventory database. For the private sector in Northern Ireland the forecast was derived from historical establishment and management grant data and the Northern Ireland woodland map.

The *National Forest Inventory forecasts methodology overview* (2012) and the technical documentation on *Felling and removals forecasts* (2012) give more information on the approaches used to derive the forecasts (see the National Forest Inventory internet webpages: https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory).

2.2 Sub-compartment database

The sub-compartment database is a record of all land managed by Forestry England, Forestry and Land Scotland, and Natural Resources Wales. Each stand of trees is represented spatially, together with information on individual stand characteristics (e.g. species, planting year, spacing and yield class) which is periodically updated. As new surveys of stands are conducted (e.g. for operational purposes), survey results are also recorded against the stands. In addition, the database contains details of planned stand management – in particular, the planned frequency and type of thinning and a date for felling, as recorded in the forest plans. Forest plans are prepared and maintained by staff throughout Britain. These plans form the basis of the harvesting regimes used to derive the estimates for the forecasts.

2.3 National Forest Inventory

The National Forest Inventory is composed of two elements: a woodland map and a field survey. The woodland map covers all forests and woodlands of over 0.5 hectare with a minimum width of 20 metres and a minimum of 20% canopy cover (or the potential to achieve it), including new planting, clearfelled sites and restocked sites. It is based on interpretation of 25 cm resolution colour aerial photography for England and Scotland and 40 cm resolution aerial photography for Wales. The map was validated and updated using satellite imagery (available up to 2019), which gave an independent crosscheck of woodland presence. Satellite imagery was also used to identify areas of recently felled forests and woodland. Particular attention was paid to identifying areas of woodland creation and woodland loss, with areas of woodland loss verified as being due to the establishment of wind farms, the restoration of habitats or the impacts of tree diseases and pests.

Field survey work was then used to refine the map-based estimates of woodland and clearfelled areas and to measure detailed aspects of the forest. Field surveys carried out between 2015 and 2020 were used to estimate standing volume (and other forest metrics). This involved the ground surveying of 1 hectare sample squares that were partially or entirely covered by forest, including clearfelled areas, according to the woodland map. Further details of the mapping work and the derivation of forested areas can be found in the 2010 Woodland Area reports on the NFI web pages.

2.4 Estimates for the GB Public Forest Estate

Information from the sub-compartment database was used to estimate standing volume and other attributes of stands on a stand-by-stand basis, at the reference date of 31 March 2020 for FE/FLS and 31 March 2022 for NRW. The impacts of the storms over winter 2021/22 are not accounted for in this forecast.

For each stand, if an operational survey had been carried out close to the reference date, information from that survey was used to estimate the state of the stand at the reference date. Otherwise, an estimate was made of the state of the stand, normally involving the application of standard Forest Research growth and yield models that take into account the past management of the stand. These data formed the basis of the volume forecasts.

Recently revised Forest Research growth and yield models (**Appendix H**) were then used to 'grow' the stands, based upon inventory data and yield class estimates. The stands were grown taking account of harvesting events that either thinned or felled a stand over the forecast period, producing the standing volume, increment and production volumes projected by the forecasts. The timing and scale of thinning and felling events was taken from forest plans, which set prescriptions for harvesting across productive forest area on the estate. This was then aggregated to produce the estimated total production across a defined geographic area for particular types of stand (classified, for example, by species, age or size class). The stands were then restocked according to country-level prescriptions (details on forecast restocking assumptions are described in **Appendix B**). The production forecast is an output of this stand modelling process.

Because the resulting estimates are based on a full record of data from the sub-compartment database, there is no sampling error involved in the estimation process, therefore no sampling standard error is calculated. However, the nature of the estimation process within each individual stand does introduce estimation error, with variable contributions from stand to stand, due to the type, age and accuracy of the information held in the sub-compartment database. These estimation errors have not been quantified in this report.

2.5 Estimates for the private sector estate in Britain

GB Forests on the National Forest Inventory woodland map were first separated into GB Public Forest Estate and private sector estate holdings using spatial records of management boundaries as at 31 March 2020 for FE/FLS, and 31 March 2022 for NRW. Estimates of softwood availability on the private sector estate used a woodland area obtained from the map updated to 31 March 2019 (published in May 2020). This map contained a slightly larger area (around 2.3 million hectares) of private sector woodland than was used in the 2016 forecast. A full account of the National Forest Inventory mapping exercise can be found in the *National Forest Inventory forecasts methodology overview* (2012). The mapped woodland area results can be found in the *National Forest Inventory woodland area statistics* for Great Britain, England, Scotland and Wales.

During the field survey work some 9,000 sample squares were surveyed of which 6,607 were located in private sector woodland and the resulting data have been used to produce the results in this report. These surveyed sample squares are a statistically representative sample covering all woodland in Britain that has been surveyed during the second cycle of the National Forest Inventory field surveys (completed in late 2020).

At each sample square, the area was stratified into forest and non-forest and the forested area was further stratified into different woodland types or stands, where information on species, age, management and a range of other parameters was collected. Typically, sample squares covered parts of different forest stands, resulting in 27,168 stands being assessed (20,529 in private sector woodland). Within each stand, field-based computer systems were used to locate two or three randomly located 100 m^2 (0.01 hectare) circular plots, within which all trees of greater than or equal to 7 cm diameter at breast height (DBH) were mapped, species and age identified, stocking assessed, and diameters measured. A total of 253,467 trees (with a dbh of 7 cm or greater) were measured (173,379 in private sector woodland). For 78,377 of these trees (55,937 on private sector woodland), additional measurements of tree height and crown dimensions were taken for yield class assessment and for other purposes. The resulting data were used to estimate the standing volume of the trees that provided the initial values of timber present in the stand from which forecasts of future timber availability were projected. All squares were marked on the ground with metal pegs and GPS data of their location were recorded for checking and future measurement. All measurements were subject to office-based checks and a small percentage were re-measured in the field by an independent quality assurance team to ensure consistency and high standards of data quality.

The inventory data for the private sector estate was then run against the headline management scenario. **Appendix A** has more explanation on the management scenario. Under this scenario, private sector forests are managed under a regime designed to:

- Fell according to a target stand mean diameter. For conifers other than larches, a target diameter of 30 cm is used; for larches 25 cm is used.
- Take account of thinning and wind constraints, with stands thinned where evidence shows that there has been previous thinning or where they are assessed with a DAMS (Detailed Aspect Method of Scoring) score of less than 16.
- Harvest a proportion of overdue stands (i.e., stands that have exceeded the prescribed target stand mean diameter for felling according to the scenario). Overdue handling is described in **Appendix D**.
- Harvest stands which are slow growing and which forest growth and yield models indicate will not reach the target diameter, according to the age of maximum mean annual increment or (where wind constraints apply) at a terminal height of 25 m (the modified biological potential assumptions described in **Appendix I** used in the 2016 forecast)

- Restock stands which are currently felled, and restock stands which are felled within the forecast period, according to the country level restocking options described in **Appendix B**.

Together these form a management scenario referred to as the ‘target diameter’ scenario which is used as the headline scenario for this forecast. Further details of the assumptions made can be found **Appendix A**. A summary of the modified biological potential scenario used as the basis of the headline results in the 2016 forecast can be found in **Appendix I**.

This scenario, selected after consultation with private sector woodland owners and timber processors, aims to reflect current management practices for conifer felling.

This report concentrates on the target diameter scenario. Alternative harvesting scenarios and their impact on timber availability are explored in **Appendix E** to this report.

The forecast results for individual surveyed squares were aggregated and scaled up to the areas identified by the woodland map, using standard statistical survey methodology, to produce the estimates in this report. Along with these estimates, associated sampling standard errors have also been calculated and reported. The sampling standard error will account for random variation arising from the selection of the sample, and random measurement errors, but not from any systematic biases in the field measurements. However, because of the quality assurance process it is thought unlikely that any substantial biases of this nature are present in the survey data.

There are four classes of error or uncertainty that are not accounted for or contained in the quoted sampling standard errors:

1. Errors in standing volume estimates arising from random variation about, and systematic bias in, the empirical models used to estimate standing volumes

from mensuration data. It is not thought that this will contribute a large source of additional error.

2. Random variation about, and biases in, the growth and yield models used to project the future growth of stands. It is known that biases exist in these models, some of which have recently been corrected, and both these biases and annual random variation about the growth model projections will contribute accumulating errors in the longer-term forecasts such that errors contributed by these sources will eventually become a larger source of error than sampling error.
3. The forecasts are conditional upon future conditions of growth being equal to those experienced in the past. The quoted sampling standard errors do not therefore take account of any major sudden events that significantly impact upon the tree stock, such as meteorological conditions of a type not experienced in the past, or of more gradual deviation from past conditions, such as the possible accumulating impact of climate change. These sources of error will impact more heavily on forecasts further into the future rather than on short-term forecasts.
4. It is important to also note that in the statement above that the forecasts are ‘conditional upon the underlying assumptions'. This means in effect that it is assumed that every stand is managed in the future exactly as prescribed by the future management scenario being analysed. In practice there will be considerable uncertainty and variation in the future management of forest stands. This is a major source of future uncertainty and therefore another major source of error in longer term forecasts.

Incorporation of these unaccounted sources of error in future forecasts would require a different forecasting model that is beyond current capacity to implement. The effect would be that the magnitude of standard errors fully accounting for all sources of variation in the forecasts would be close to the sampling standard errors for short-term forecasts; but would then continuously expand for forecasts further into the future.

However, the advantage of the semi-deterministic forecasts used in this report are that the comparative effects of alternative management scenarios on future production and state of the woodland resource can be easily identified, even if the forecast values themselves are subject to increasing uncertainty the further they project into the future.

2.6 Estimates for the Forest Service estate in Northern Ireland

In Northern Ireland, production forecasting of softwood availability within the DAERA FS estate is based on forest stand inventory measurement combined with aspects of wider forest management planning requirements. This information, as well as informing softwood availability forecasts is also required to verify sustainable forest management and to form the basis of forestry asset valuations for accounting purposes. The policy for sustainable forest management is delivered as a requirement under the Forestry Act (Northern Ireland) 2010. As evidence of this, DAERA FS sustainable forest management practices remain compliant with the UK Woodland Assurance Standard (UKWAS), confirmed through an independent audit accredited by the Forest Stewardship Council® (FSC®) (Licence code: FSC-C084232), and the Programme for Endorsement of Forest Certification (PEFC) (Licence code: PEFC/16-40-1924).

The 2020 DAERA FS estate forecast is based on the most recent sub-compartment dataset, incorporating recent inventory data and refreshed yield class values which use the latest Forest Service planned felling dates and felling coupe geometries. Yield class values are derived using a statistical model, which includes an adjustment to generate a predicted value at felling age, based on historical data indicating a reduction in yield class with increasing age.

The forecast returns annual conifer volume availability averaged across 5-year age bands. The yield models used assume normal growth throughout rotations.

2.7 Estimates for the private sector estate in Northern Ireland

The private sector forecast is based on private woodlands data and includes information on planting year, forest/woodland type, and individual polygon area.

Reference is also made to the updated NI Woodland Basemap[1]. The woodland basemap has been compiled using Geographic Information datasets provided by statutory and non-statutory bodies. The woodland register was published by DAERA FS in April 2020, which replaces an earlier draft woodland register and basemap from 2018.

The private sector dataset does not include owner objectives or a productivity assessment from which rotation or thinning cycles could be inferred therefore the forecast has been based on a number of assumptions. To estimate private sector softwood availability, management models were developed by DAERA FS for conifer stands and conifer components in mixed woodland, which assume rotation lengths, thinning interventions and intensities, clearfell recoveries and re-establishment objectives. Top diameter volumes have been apportioned as per assortment tables.

This methodology has been used in the past three quinquennial forecast publications and has borne reasonable comparison with reported annual private sector removals data gathered by Forest Service and published by Forest Research in *Forestry Statistics*[2].

[1] https://www.daera-ni.gov.uk/publications/woodland-register
[2] https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/

2.8 Assumptions used in the forecast

2.8.1 Ownership

Forests and woodlands are harvested differently under different ownership types. Given that forecasts are largely based on the assumptions made about harvesting prescriptions, the rate of change of ownership between public and private sector is important. For simplicity, this current forecast assumes that there will be no future transfer of ownership, in line with the assumptions made in 2016.

2.8.2 Restocking

The restocking that is applied in this current forecast to both GB public forest estate and private sector woodlands in Britain builds on the approach that was adopted for the *50-year forecast of softwood timber availability* (2014) and the *25-year forecast of softwood availability* (2016), moving away from the scenario that replaced felled stands with exactly the same crop in the subsequent rotation *25-year forecast of softwood availability* (2012), thus restocking in a way that better reflects current practices. These scenarios were developed to reflect the findings of the report *Preliminary estimates of the changes in canopy cover in British woodlands between 2006 and 2015* (2016).

For conifer stands, this includes conifer species diversification and the introduction of 10% open space and 10% broadleaved species. These restocked stands are managed according to the target diameter felling assumptions modified in areas considered to be at high risk from wind damage, as determined by a DAMS score of 16 or more. It is important to note that the impact of restocking on production volumes is minimal during the forecast period, as these stands will mostly only produce timber volume after the forecast period. Even then, only a very small volume will arise in relation to some early thinning from stands of higher yield class late in the period of the forecast. These are included in the volumes presented, but they only have material contribution to harvested volumes from the period 2042–46. This is only one of many possible scenarios for restocking and was formulated in liaison with forest industry representatives. The National Forest Inventory has provided a range of modelled restocking and new planting scenarios to explore the impacts of these assumptions in the 50-year forecast report and the report *Evaluation of alternative harvesting and afforestation scenarios on British softwood timber availability* (2015).

2.8.3 Currently clearfelled areas

In the 2012 25-year forecast, forest area that was clearfelled as of 31 March 2011 was not included in the forecast. It was acknowledged within the report that not including some level of replanting in these areas would create a small underestimate of future production which would be marginally evident in the later years of the forecast. In line with the 2016 forecast, the current forecast assumes that all clearfelled areas are restocked, both within GB Public Forest Estate and the private sector. The restocking assumptions applied differ from the 2016 forecast and are as outlined in **Appendix B**.

To estimate area of clearfell for the GB public forest estate, the sub-compartment database records of clearfelling were used. For the private sector estate, the area of clearfell was first identified by aerial photography and then updated with satellite imagery. This was used in conjunction with the field survey to estimate stocked area (**Table 1**) and area of clearfell (**Table 8**).

2.8.4 Overdue timber

Overdue timber is timber contained within stands that, at the start of the forecast period, are already beyond the timing prescribed for felling according to the management scenario used for the private sector forecast. In the *25-year forecast of softwood timber availability* (2012) overdue timber was set aside from the main forecast volume. In the 50-year forecast (2014) a separate prescription for overdue timber was developed and run as part of the main scenario. This scenario assumed a proportion of overdue timber would come to market over the forecast period. This approach was applied in both the 2016 and the current forecast. For example, in the current forecast, where the target diameter scenario is used, those stands less than target diameter will be felled at the age they achieve that target diameter (according to growth and yield models). However, for those stands with a mean dbh currently larger than the target diameter a separate prescription was used. The proposed prescriptions were developed in consultation with the private sector, and for example, allocate proportions such as 70% of overdue timber to felling over approximately 20 years, dependant on species and age. In detail, the overdue prescriptions take into account tree species, presence and impact of current tree diseases, age of stand in relation to age of maximum Mean Annual Increment (MAI) and historical market trends in harvesting. For a full description of the overdue prescription applied see **Appendix D**.

All areas felled as overdue were restocked in the forecast according to the restock scenario, in common with any other stand felled during the forecast period. This approach will not materially affect the forecast timber volumes as the replacement stands will not mature within the forecast period.

Overdue timber represents a significant amount of total standing volume at the start of the forecast, indicating that a portion of the estate is not currently being managed to either maximum MAI or shorter rotations such as those based on target diameter. This is especially so in the private sector and implies that the current practice on at least a portion of the private sector estate is to leave some stands beyond the age of maximum MAI or the target diameter.

Since such stands are currently being managed differently from the assumed prescription, these, and some other stands that are currently below the age of maximum MAI or target diameter, are also not likely to be managed to these criteria in the future. This forecast assumes they are, but the *Evaluation of alternative harvesting and afforestation scenarios on British softwood timber availability* (2015) report explores the impact of a proportion of all stands, irrespective of current age, becoming overdue.

For more information about the inventory methodology, see the *National Forest Inventory forecasts methodology overview* (2012).

Felling ages for the GB Public Sector forecast are derived from the approved Forest Plans covering the entire Public Sector estate. The overdue timber volume reflects coupes where felling is taking place during the first phase of the approved plan and the cut may be partially complete at the start of the forecast period. It may also include volume arising from changes to the order in which coupes are cut and volume substitution is taking place for operational reasons.

2.9 Yield Models

Following the recommendation in the *25-year forecast of softwood timber availability* (2016) work was undertaken to explore how the underlying growth and yield models used in the forecast may be refreshed to more closely predict future timber yields, especially in improved stock and contemporary silvicultural situations.

A suite of revised models for softwoods has been developed which have been used in the calculation of this forecast. The most significant revisions are in the models for Sitka spruce reflecting the higher growth rates of improved stock.

Full technical details of the work undertaken can be found in **Appendix H** along with references to published documents. A brief summary is presented here.

A new growth model, known as M1v2, has been developed and applied in producing this forecast. The model is an extension of an earlier model (M1), which has been applied in previous production forecasts. The key aim of developing M1v2 was to address and remove major inaccuracies identified in some of the earlier models of growth and yield.

2.9.1 Development of the M1v2 model

A QA exercise was carried out, reviewing a number of models developed and maintained by Forest Research with high-impact applications related to estimating and forecasting forest timber, biomass and carbon. This included the growth and yield models used for predicting the growth and potential production of forests and applied within the FC and private sector Forecast Systems.

There was substantial evidence that the growth relationships referred to in the growth and yield models displayed significant biases. One result is that estimates of yield class ascribed to forest stands based on the yield models in Forest Yield are likely to be inaccurate. The outcome of the QA assessment recommended that, as a minimum response, the growth relationships referred to in the existing growth models should be updated to take account of the data currently available from FR permanent mensuration sample plots. This would make it possible to address apparent issues of bias in the growth patterns represented in the models.

The M1v2 growth model was developed to meet the above aims, and also to allow the 2020 forecast to be based on models with improved growth relationships. M1v2 retains nearly all of the methodology of the original M1 model described earlier, but the growth relationships and yield tables it refers to are completely changed. Keeping the M1 methodology and updating the underlying yield tables offered the most effective way to develop and deliver more accurate yield models in a relatively short timescale with limited resources.

2.9.2 Development of YT2020 model

A completely new model, known as YT2020, was developed to generate a revised suite of yield tables representing standard management prescriptions (consisting of ‘standard thinning’ and no thinning). YT2020 also uses elemental models for predicting tree survival/mortality and the growing stock remaining (numbers of trees, basal area and volume) after different types and intensities of thinning (including after losses from mortality); these were developed for the original M1 model.

The YT2020 model can be used to produce standard yield tables for all of the tree species originally represented in FC Booklet 48 (Edwards & Christie, 1981), including some additional tree species and refined species groups, e.g. new models for “sequoias”, and separate models for alder, “ash and birch” and “sycamore and other maples”, replacing a combined “sycamore, alder, ash and birch” model. Yield tables can be produced for a range of planting spacings from very narrow (e.g. 0.9 m) to very wide (e.g. 8 m) and for yield classes between 1 and 40 m3 per hectare per year. This is a much wider range than available previously and allows extremes of slow growth rates in broadleaves and fast growth rates in conifers (notably Sitka spruce) to be better represented. Yield classes are also defined at a finer scale of intervals of 1 instead of 2 m3 per hectare per year.

For Sitka spruce, the revision of fundamental growth relationships also considered the growth and yield of genetically improved Sitka spruce (Matthews et al., 2020). Data from permanent sample plots on unimproved Sitka spruce stands were supplemented with available data on the growing stock and growth of improved Sitka spruce. These show a greater increase with age for top height, volume, mean annual increment, and mean dbh and higher maxima. The changes for tree species other than Sitka do not follow a consistent pattern.

3 Results

The forecasts are projected from the stocked area and standing volume of conifers summarised in **Table 1** and **Table 2** respectively.

Table 3 gives the 25-year forecast of softwood timber availability for the UK, GB, and each country, broken down by Public Forest Estate and private sector estate. **Figure 2** illustrates the 25-year forecast broken down by country, ownership, and five-year period. **Table 4** shows the forecast of softwood timber availability broken down by country, ownership, size class and five-year period. **Table 5** gives a breakdown of the forecast by the percentage of spruce within overall softwood volumes (spruce comprises Sitka spruce and Norway spruce). These tables are comparable with the tables supplied with the *25-year forecast of softwood timber availability* (2016).

The baseline date for the FE/FLS forecasts is 31 March 2020, and for NRW is 31st March 2022. The FE/FLS forecast projections were run starting in 2021, and for NRW starting in 2022. For the private sector in Britain a baseline of 2021 has been used, which reflects the completion of the assessment of the second cycle of NFI field samples.

To create an even baseline between public and private sector data, harvesting and management scenarios were applied retrospectively to the private sector data between 2016 and 2020 meaning the opening estimates in **Table 1** and **Table 2** are only as accurate as the management assumptions that were applied and how well the scenario applied reflects actual management during that period.

The convention in this report is to define the year 2021 as starting on 1 April 2020 and ending on 31 March 2021. This convention applies to all forecast years or periods quoted. The forecast reports on five-year cycles of production, starting with 2022-2026.

All volumes are given in cubic metres (m^3) overbark standing (obs) and, as in previous forecasts, all volumes available for harvesting include thinnings and fellings. Volumes are presented as average annual volume for each five-year period. The values in the tables have been independently rounded, so may not add to the totals shown. In some breakdowns of private sector estimates, the estimates in the body of the table may not sum to the quoted total because each individual value, including the total, has been estimated independently. Sampling standard errors (SE) attached to private sector estimates are expressed in relative terms (%) to the right of the relevant estimate.

Due to biological and sampling constraints, for example where there is a very small population of a species within a particular region, the estimates may have a high associated standard error. Since this indicates a high level of uncertainty around those estimates, caution should be used when drawing any conclusions from these values as the estimate may not be representative of the real population. Such estimates have been shown in amber in the tables.

Other than the estimates in **Table 1**, **Table 2**, **Table 6**, **Table 7** and **Table 8**, the estimates are forecast values determined by applying growth and yield models to current assessments.

Tables showing the regional estimates for England and Scotland are available in a supplementary spreadsheet.

Table 1. Stocked area of conifers at 31 March 2021

Country	Public Forest Estate	Private sector		Total
	area (000 ha)	area (000 ha)	*SE%*	area (000 ha)
England	124.6	153.0	*2*	**277.6**
Scotland	335.1	513.3	*1*	**848.4**
Wales	70.6	48.7	*3*	**119.4**
Great Britain	**530.4**	**715.1**	***1***	**1,245.4**
Northern Ireland	49.1	5.0		**54.1**
United Kingdom	**579.5**	**720.1**		**1,299.5**

Table 2. Standing volume of conifers at 31 March 2021

Country	Public Forest Estate	Private sector		Total
	volume (000 m^3 obs)	volume (000 m^3 obs)	*SE%*	volume (000 m^3 obs)
England	25,753	65,140	*3*	**90,893**
Scotland	76,143	187,961	*2*	**264,104**
Wales	19,951	19,827	*6*	**39,777**
Great Britain	**121,847**	**272,927**	***2***	**394,775**
Northern Ireland	12,528	1,420		**13,948**
United Kingdom	**134,375**	**274,347**		**408,723**

Table 3. 25-year forecast of softwood availability; average annual volumes within periods

Forecast period	Public Forest Estate	Private sector		Total
	volume (000m³ obs)	volume (000m³ obs)	*SE%*	volume (000m³ obs)
England				
2022–26	1,107	2,570	*6*	**3,677**
2027–31	1,158	2,616	*8*	**3,774**
2032–36	1,097	2,319	*8*	**3,415**
2037–41	1,006	2,495	*8*	**3,501**
2042–46	1,039	2,057	*8*	**3,096**
Scotland				
2022–26	3,674	5,092	*8*	**8,766**
2027–31	3,538	6,529	*8*	**10,067**
2032–36	3,201	8,608	*7*	**11,809**
2037–41	2,699	9,609	*6*	**12,309**
2042–46	2,610	7,965	*6*	**10,575**
Wales				
2022–26	1,284	843	*15*	**2,128**
2027–31	1,017	683	*16*	**1,700**
2032–36	799	773	*15*	**1,572**
2037–41	816	870	*15*	**1,686**
2042–46	457	790	*15*	**1,248**
Great Britain				
2022–26	6,065	8,505	*6*	**14,570**
2027–31	5,713	9,828	*6*	**15,541**
2032–36	5,096	11,700	*5*	**16,796**
2037–41	4,521	12,974	*5*	**17,495**
2042–46	4,107	10,812	*5*	**14,919**
Northern Ireland				
2022–26	498	24		**522**
2027–31	628	42		**670**
2032–36	698	43		**741**
2037–41	635	40		**676**
2042–46	534	25		**558**
United Kingdom				
2022–26	6,563	8,529		**15,092**
2027–31	6,341	9,870		**16,211**
2032–36	5,794	11,743		**17,537**
2037–41	5,157	13,015		**18,171**
2042–46	4,641	10,837		**15,477**

Figure 2. 25-year forecast of softwood timber availability for Public Forest Estate and private sector estates in the UK by country

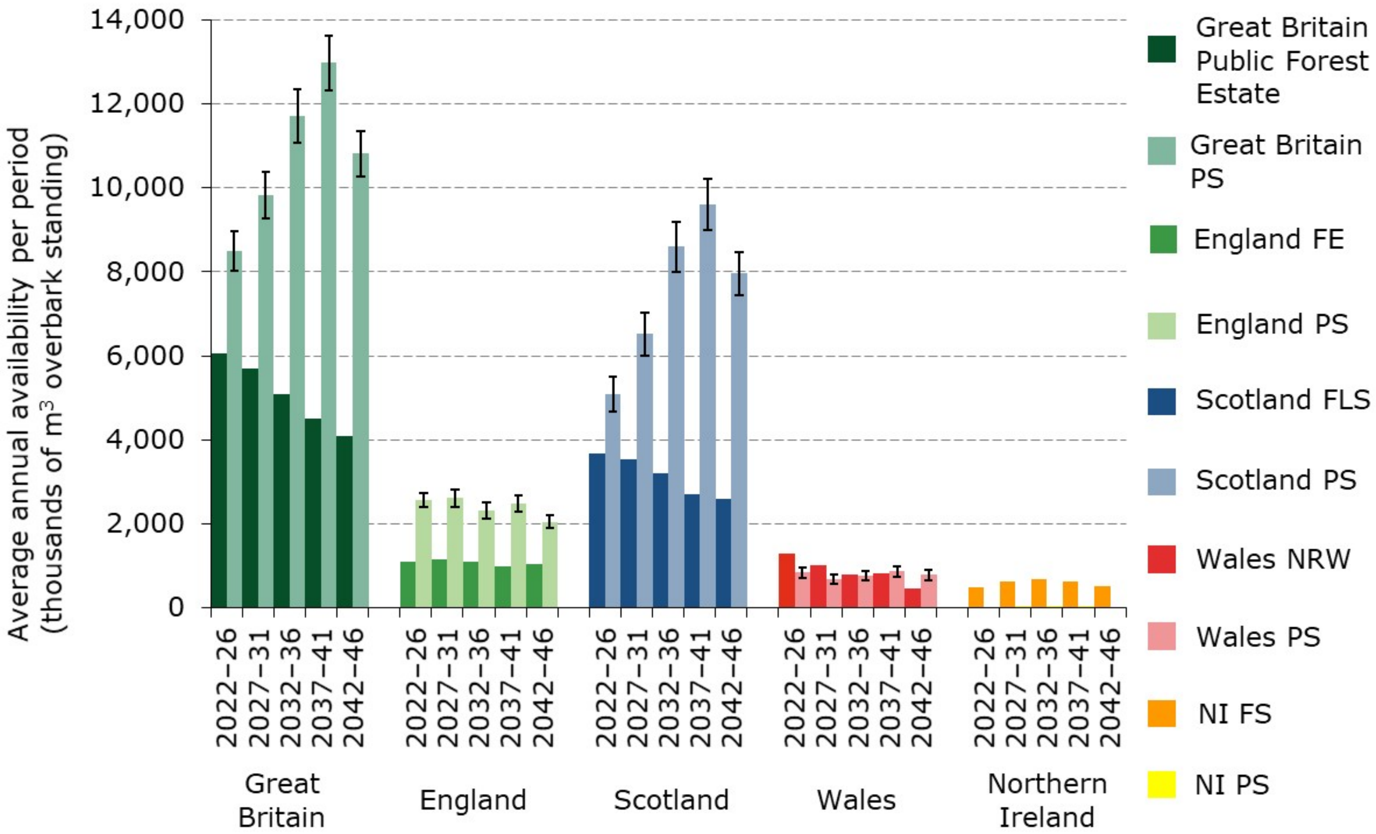


Table 4. Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	FE	Private sector		FE	Private sector		FE	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
England									
7–14	189	120	*9*	174	129	*12*	148	119	*11*
14–16	86	69	*10*	85	74	*14*	75	63	*14*
16–18	92	99	*10*	94	101	*13*	86	82	*13*
18–24	277	508	*9*	292	481	*11*	287	399	*12*
24–34	273	868	*7*	293	852	*8*	290	754	*9*
34–44	106	420	*7*	118	455	*8*	111	425	*9*
44–54	47	206	*8*	52	226	*9*	50	219	*10*
54+	39	279	*10*	50	298	*9*	50	257	*9*
Total	**1,107**	**2,570**	***6***	**1,158**	**2,616**	***8***	**1,097**	**2,319**	***8***

Top diameter class (cm)	2037–41			2042–46		
	FE	Private sector		FE	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
England						
7–14	134	133	*11*	161	102	*11*
14–16	62	74	*13*	67	55	*13*
16–18	72	98	*12*	74	73	*13*
18–24	258	456	*11*	256	339	*12*
24–34	282	786	*9*	285	637	*9*
34–44	106	434	*8*	106	379	*7*
44–54	45	219	*8*	43	198	*7*
54+	48	296	*9*	50	274	*7*
Total	**1,006**	**2,495**	***8***	**1,039**	**2,057**	***8***

Table 4 (continued). Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	FLS	Private sector		FLS	Private sector		FLS	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Scotland									
7–14	668	332	*9*	541	411	*9*	437	583	*7*
14–16	323	197	*10*	285	242	*10*	239	353	*8*
16–18	355	271	*10*	328	336	*10*	286	480	*8*
18–24	1,079	1,221	*9*	1,050	1,491	*9*	975	2,024	*8*
24–34	890	1,731	*9*	921	2,199	*8*	877	2,905	*7*
34–44	247	735	*10*	270	1,005	*9*	255	1,299	*8*
44–54	78	325	*11*	89	474	*10*	86	583	*9*
54+	35	280	*13*	53	372	*13*	46	380	*14*
Total	**3,674**	**5,092**	***8***	**3,538**	**6,529**	***8***	**3,201**	**8,608**	***7***

Top diameter class (cm)	2037–41			2042–46		
	FLS	Private sector		FLS	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Scotland						
7–14	365	656	*7*	454	611	*8*
14–16	193	383	*7*	198	353	*7*
16–18	232	512	*7*	223	451	*7*
18–24	811	2,135	*7*	737	1,854	*7*
24–34	761	3,219	*7*	695	2,610	*7*
34–44	219	1,517	*7*	197	1,181	*8*
44–54	76	702	*8*	66	539	*9*
54+	42	486	*11*	40	365	*9*
Total	**2,699**	**9,609**	***6***	**2,610**	**7,965**	***6***

Table 4 (continued). Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	NRW	Private sector		NRW	Private sector		NRW	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Wales									
7–14	208	55	*24*	156	49	*27*	119	42	*17*
14–16	94	33	*25*	75	28	*31*	58	26	*18*
16–18	103	43	*24*	84	38	*30*	68	35	*19*
18–24	327	173	*19*	269	152	*24*	226	165	*19*
24–34	336	247	*16*	266	203	*16*	208	269	*16*
34–44	129	134	*19*	97	103	*16*	70	128	*15*
44–54	54	71	*22*	41	52	*17*	30	63	*17*
54+	33	87	*26*	29	59	*25*	20	46	*19*
Total	**1,284**	**843**	***15***	**1,017**	**683**	***16***	**799**	**773**	***15***

Top diameter class (cm)	2037–41			2042–46		
	NRW	Private sector		NRW	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Wales						
7–14	122	68	*19*	82	61	*21*
14–16	58	39	*21*	31	31	*24*
16–18	69	50	*21*	34	37	*24*
18–24	242	201	*20*	115	155	*22*
24–34	214	277	*16*	121	243	*16*
34–44	62	127	*14*	41	128	*16*
44–54	25	59	*15*	17	63	*19*
54+	22	49	*17*	18	73	*22*
Total	**816**	**870**	***15***	**457**	**790**	***15***

Table 4 (continued). Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	GB Public Forest Estate	Private sector		GB Public Forest Estate	Private sector		GB Public Forest Estate	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Great Britain									
7–14	1,065	507	*7*	871	589	*7*	705	744	*6*
14–16	503	299	*7*	446	344	*8*	372	442	*7*
16–18	550	413	*7*	506	475	*8*	440	597	*7*
18–24	1,683	1,903	*7*	1,611	2,123	*7*	1,488	2,588	*6*
24–34	1,498	2,845	*6*	1,481	3,254	*6*	1,375	3,928	*6*
34–44	482	1,289	*6*	485	1,563	*6*	436	1,853	*6*
44–54	179	602	*7*	182	752	*7*	166	865	*6*
54+	106	647	*8*	132	728	*8*	116	683	*8*
Total	**6,065**	**8,505**	***6***	**5,713**	**9,828**	***6***	**5,096**	**11,700**	***5***

Top diameter class (cm)	2037–41			2042–46		
	GB Public Forest Estate	Private sector		GB Public Forest Estate	Private sector	
	(000 m^3)	(000 m^3)	*SE%*	(000 m^3)	(000 m^3)	*SE%*
Great Britain						
7–14	622	857	*6*	696	773	*6*
14–16	313	496	*6*	296	438	*6*
16–18	374	660	*6*	331	562	*6*
18–24	1,311	2,792	*6*	1,108	2,349	*6*
24–34	1,256	4,282	*5*	1,100	3,490	*6*
34–44	387	2,078	*5*	344	1,688	*6*
44–54	146	979	*6*	125	800	*6*
54+	112	830	*7*	108	712	*6*
Total	**4,521**	**12,974**	***5***	**4,107**	**10,812**	***5***

Table 4 (continued). Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	FS (000 m^3)	Private sector (000 m^3)	SE%	FS (000 m^3)	Private sector (000 m^3)	SE%	FS (000 m^3)	Private sector (000 m^3)	SE%
Northern Ireland									
7–14	67	3	–	68	6	–	69	6	–
14–16	38	2	–	39	3	–	41	3	–
16–18	53	2	–	55	4	–	57	4	–
18–24	205	9	–	244	16	–	254	17	–
24–34	116	7	–	184	10	–	213	11	–
34–44	11	1	–	21	1	–	36	1	–
44–54	5	0	–	9	1	–	15	1	–
54+	3	0	–	8	1	–	12	0	–
Total	**498**	**24**	**–**	**628**	**42**	**–**	**698**	**43**	**–**

Top diameter class (cm)	2037–41			2042–46		
	FS (000 m^3)	Private sector (000 m^3)	SE%	FS (000 m^3)	Private sector (000 m^3)	SE%
Northern Ireland						
7–14	64	6	–	61	4	–
14–16	35	2	–	33	1	–
16–18	51	4	–	46	2	–
18–24	223	17	–	192	10	–
24–34	197	11	–	146	7	–
34–44	39	1	–	34	1	–
44–54	16	0	–	17	0	–
54+	9	0	–	6	0	–
Total	**635**	**40**	**–**	**534**	**25**	**–**

Table 4 (continued). Breakdown of the softwood forecast volume (000 m^3 obs) by country, top diameter class and forecast period

Top diameter class (cm)	2022–26			2027–31			2032–36		
	Public Forest Estate (000 m^3)	Private sector (000 m^3)	Private sector *SE%*	Public Forest Estate (000 m^3)	Private sector (000 m^3)	Private sector *SE%*	Public Forest Estate (000 m^3)	Private sector (000 m^3)	Private sector *SE%*
United Kingdom									
7–14	1,131	510	–	939	594	–	774	750	–
14–16	541	301	–	485	347	–	413	445	–
16–18	603	415	–	561	479	–	497	601	–
18–24	1,888	1,912	–	1,854	2,140	–	1,742	2,605	–
24–34	1,615	2,851	–	1,665	3,264	–	1,588	3,939	–
34–44	493	1,290	–	506	1,564	–	472	1,854	–
44–54	184	602	–	192	753	–	181	866	–
54+	109	647	–	140	729	–	128	683	–
Total	**6,563**	**8,529**	**–**	**6,341**	**9,870**	**–**	**5,794**	**11,743**	**–**

Top diameter class (cm)	2037–41			2042–46		
	Public Forest Estate (000 m^3)	Private sector (000 m^3)	Private sector *SE%*	Public Forest Estate (000 m^3)	Private sector (000 m^3)	Private sector *SE%*
United Kingdom						
7–14	686	863	–	757	777	–
14–16	348	499	–	329	439	–
16–18	425	663	–	376	564	–
18–24	1,534	2,808	–	1,300	2,359	–
24–34	1,454	4,293	–	1,246	3,496	–
34–44	426	2,079	–	378	1,688	–
44–54	162	979	–	142	800	–
54+	122	830	–	114	712	–
Total	**5,157**	**13,015**	**–**	**4,641**	**10,837**	**–**

Table 5. Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

England		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	FE (%)	63	66	64	59
	PS (%)	41	42	42	38
2027-31	FE (%)	69	69	67	60
	PS (%)	46	47	47	46
2032-36	FE (%)	69	71	69	62
	PS (%)	41	44	43	41
2037–41	FE (%)	61	69	68	64
	PS (%)	46	47	46	44
2042–46	FE (%)	63	70	70	65
	PS (%)	48	51	52	50

England		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	FE (%)	44	34	30	28	**52**
	PS (%)	30	22	19	11	**29**
2027-31	FE (%)	46	37	34	28	**54**
	PS (%)	41	34	31	14	**37**
2032-36	FE (%)	47	37	35	28	**55**
	PS (%)	37	32	29	24	**35**
2037–41	FE (%)	53	44	39	28	**57**
	PS (%)	44	42	40	26	**41**
2042–46	FE (%)	52	41	33	28	**56**
	PS (%)	42	35	32	26	**40**

Table 5 (continued). Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

Scotland		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	FLS (%)	71	75	77	80
	PS (%)	72	74	75	75
2027-31	FLS (%)	74	78	80	81
	PS (%)	75	76	76	75
2032-36	FLS (%)	74	78	80	83
	PS (%)	79	80	80	80
2037–41	FLS (%)	75	80	82	84
	PS (%)	79	80	81	80
2042–46	FLS (%)	81	83	83	84
	PS (%)	78	78	78	78

Scotland		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	FLS (%)	82	82	80	70	**78**
	PS (%)	71	65	62	42	**69**
2027-31	FLS (%)	82	80	76	70	**79**
	PS (%)	74	74	73	57	**74**
2032-36	FLS (%)	83	81	79	70	**81**
	PS (%)	80	81	80	73	**80**
2037–41	FLS (%)	85	83	81	70	**82**
	PS (%)	80	79	77	65	**79**
2042–46	FLS (%)	83	79	74	70	**82**
	PS (%)	78	79	80	72	**78**

Table 5 (continued). Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

Wales		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	NRW (%)	68	70	70	71
	PS (%)	54	59	59	59
2027-31	NRW (%)	75	77	78	79
	PS (%)	76	80	80	75
2032-36	NRW (%)	76	81	83	84
	PS (%)	64	63	63	61
2037–41	NRW (%)	74	81	84	86
	PS (%)	69	68	68	66
2042–46	NRW (%)	63	73	76	80
	PS (%)	69	69	67	62

Wales		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	NRW (%)	72	73	74	66	**71**
	PS (%)	56	53	51	39	**54**
2027-31	NRW (%)	79	80	80	66	**78**
	PS (%)	60	49	45	20	**60**
2032-36	NRW (%)	84	84	84	66	**82**
	PS (%)	56	52	53	45	**57**
2037–41	NRW (%)	87	84	82	66	**83**
	PS (%)	65	65	64	48	**65**
2042–46	NRW (%)	80	74	70	66	**74**
	PS (%)	52	44	40	38	**53**

Table 5 (continued). Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

Great Britain		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	GB Public Forest Estate (%)	69	72	74	75
	PS (%)	63	65	65	64
2027-31	GB Public Forest Estate (%)	73	76	77	77
	PS (%)	68	70	70	69
2032-36	GB Public Forest Estate (%)	73	77	78	79
	PS (%)	72	74	74	72
2037–41	GB Public Forest Estate (%)	72	78	80	81
	PS (%)	73	74	75	74
2042–46	GB Public Forest Estate (%)	75	79	80	79
	PS (%)	73	74	74	73

Great Britain		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	GB Public Forest Estate (%)	73	69	65	54	**72**
	PS (%)	57	50	46	28	**56**
2027-31	GB Public Forest Estate (%)	74	69	65	54	**74**
	PS (%)	65	61	59	36	**63**
2032-36	GB Public Forest Estate (%)	76	71	67	54	**75**
	PS (%)	70	67	65	52	**69**
2037–41	GB Public Forest Estate (%)	78	72	68	54	**77**
	PS (%)	73	71	68	50	**71**
2042–46	GB Public Forest Estate (%)	75	67	60	54	**75**
	PS (%)	70	67	65	51	**69**

Table 5 (continued). Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

Northern Ireland		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	FS (%)	83	86	89	94
2027-31	FS (%)	86	87	90	95
2032-36	FS (%)	82	83	86	92
2037–41	FS (%)	79	80	83	91
2042–46	FS (%)	81	82	84	92

Northern Ireland		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	FS (%)	94	69	76	57	**81**
2027-31	FS (%)	96	86	85	67	**87**
2032-36	FS (%)	96	89	90	82	**88**
2037–41	FS (%)	97	92	93	76	**86**
2042–46	FS (%)	96	91	92	87	**88**

Table 5 (continued). Percentage spruce in the forecast softwood volume by country, sector, top diameter class and forecast period

United Kingdom		Top diameter class (cm)			
		7–14	14–16	16–18	18–24
2022-26	Public Forest Estate (%)	70	73	75	77
2027-31	Public Forest Estate (%)	74	77	78	79
2032-36	Public Forest Estate (%)	74	78	79	81
2037–41	Public Forest Estate (%)	72	78	80	82
2042–46	Public Forest Estate (%)	75	79	80	81

United Kingdom		Top diameter class (cm)				
		24–34	34–44	44–54	54+	All Diameter Classes
2022-26	Public Forest Estate (%)	75	69	65	54	**73**
2027-31	Public Forest Estate (%)	77	70	66	56	**75**
2032-36	Public Forest Estate (%)	78	72	68	55	**77**
2037–41	Public Forest Estate (%)	81	74	71	56	**78**
2042–46	Public Forest Estate (%)	77	69	64	45	**76**

Table 6 gives a breakdown of the amount of overdue timber by ownership and country for Britain arising from the headline harvesting scenario. A proportion of this volume was assumed to have been available for harvesting and has been included in the main forecast of timber availability according to the prescriptions for handling overdue timber set out in **Appendix D**.

To bring the base year of the inventory data to a common year (2021) the headline relevant harvesting scenario for the sector was applied individually to stands in the inventory data, growing and managing each stand from its assessment date through to 2021. For the private sector, this assumed that a proportion of the overdue timber was harvested in this preliminary period through to the base year of the forecast (2021). This will have adjusted the overdue volume, standing volume and clearfell area at the start of the forecast period.

Table 8 gives estimates of clearfelled areas. For GB Public Forest Estate, the area of clearfell is taken from the sub-compartment database as at 31 March 2020. For the private sector, the NFI fieldwork records clearfelled areas and these areas are combined with the areas of clearfell identified in the NFI map based on satellite imagery to provide the estimates.

Currently clearfelled areas are assumed to be restocked within this forecast (see **Appendix B**) and contribute marginally to future production. Clearfelled areas were not included in the 2012 forecast.

Table 6. Overdue timber at 31 March 2021

All conifers	GB Public Forest Estate	Private sector		GB Public Forest Estate	Private sector	
	Volume (000 m^3 obs)		*SE%*	area (000 ha)		*SE%*
England	1,730	36,403	5	5.1	50.8	5
Scotland	2,594	52,800	6	6.4	70.7	6
Wales	1,960	9,349	12	4.3	11.2	11
Great Britain	**6,283**	**98,552**	***4***	**15.8**	**132.7**	***4***

Table 7. Standing volume by country and stand mean dbh class for GB

DBH class	GB Public Forest Estate	Private sector		Total
	volume (000m³ obs)	volume (000m³ obs)	*SE%*	volume (000m³ obs)
England				
0 to 7	126	0	–	**126**
7 to 10	1,661	111	*27*	**1,772**
10 to 15	5,247	1,156	*12*	**6,403**
15 to 20	6,972	3,166	*14*	**10,139**
20 to 30	4,482	15,801	*7*	**20,283**
30 to 40	5,143	18,133	*7*	**23,276**
40 to 60	710	18,915	*6*	**19,625**
60 to 80	196	5,153	*13*	**5,349**
80+	0	2,704	*23*	**2,704**
Scotland				
0 to 7	385	0	–	**385**
7 to 10	5,611	384	*12*	**5,995**
10 to 15	20,618	8,726	*5*	**29,343**
15 to 20	37,674	26,308	*6*	**63,982**
20 to 30	10,509	85,682	*4*	**96,190**
30 to 40	4,558	42,105	*7*	**46,663**
40 to 60	421	19,635	*9*	**20,056**
60 to 80	70	3,466	*15*	**3,536**
80+	0	1,655	*33*	**1,655**
Wales				
0 to 7	94	0	–	**94**
7 to 10	1,054	38	*21*	**1,092**
10 to 15	4,446	805	*16*	**5,251**
15 to 20	8,229	2,521	*17*	**10,750**
20 to 30	3,831	5,708	*13*	**9,538**
30 to 40	2,023	5,372	*16*	**7,396**
40 to 60	223	4,229	*19*	**4,452**
60 to 80	49	1,032	*38*	**1,081**
80+	0	123	*90*	**123**
Great Britain				
0 to 7	605	0	–	**605**
7 to 10	8,326	532	*11*	**8,859**
10 to 15	30,310	10,687	*4*	**40,998**
15 to 20	52,875	31,995	*5*	**84,871**
20 to 30	18,822	107,190	*3*	**126,012**
30 to 40	11,725	65,610	*5*	**77,335**
40 to 60	1,354	42,779	*5*	**44,133**
60 to 80	315	9,651	*10*	**9,966**
80+	0	4,482	*11*	**4,482**

Figure 3. Standing coniferous timber volume by sector and stand mean dbh class for GB

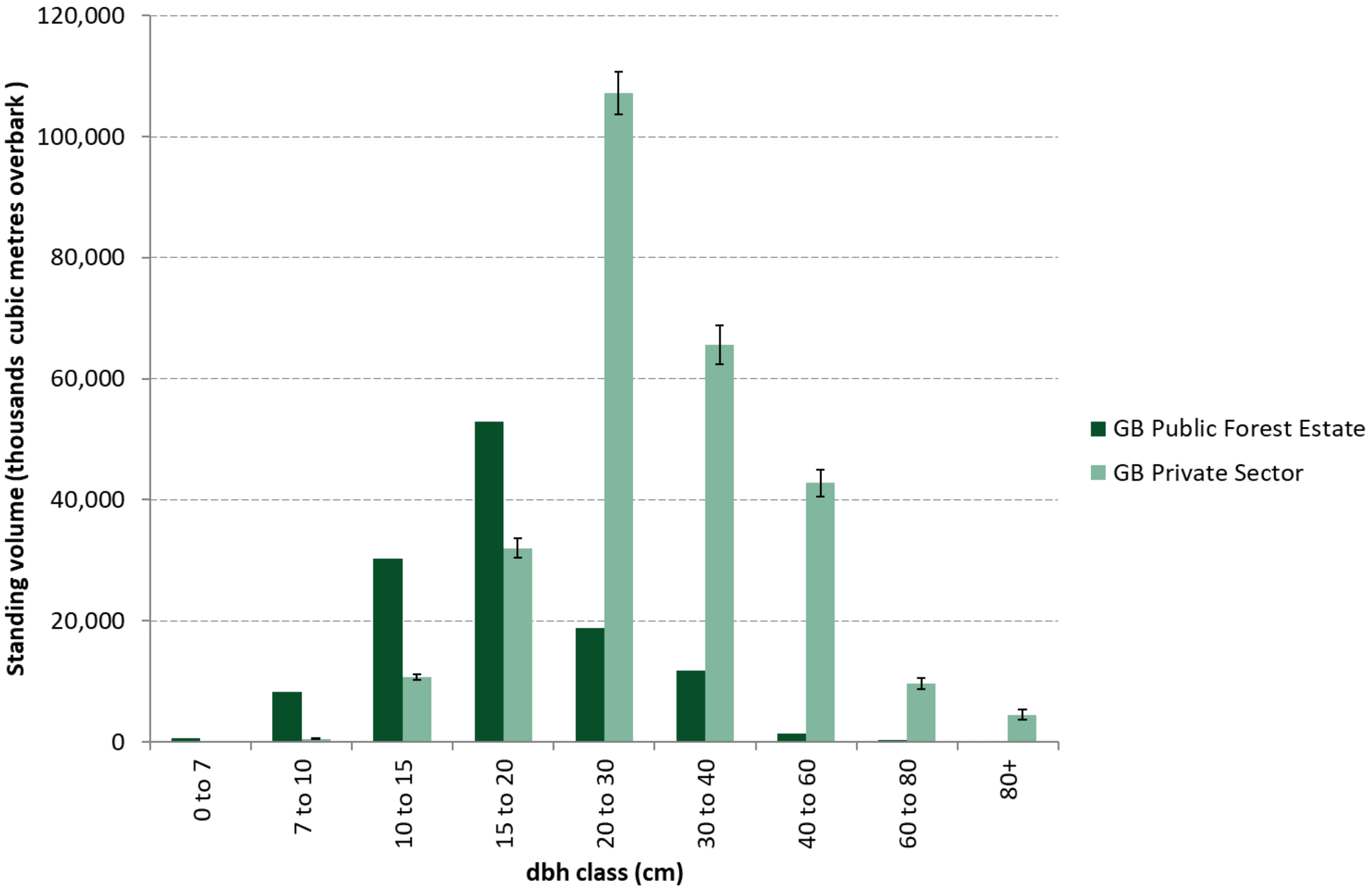


Table 8. Clearfelled area at 31 March 2021

All conifers	GB Public Forest Estate	Private sector		Total
	area (000 ha)		*SE%*	area (000 ha)
England	8.3	8.9	*12*	17.1
Scotland	39.1	42.7	*6*	81.9
Wales	5.0	2.2	*21*	7.2
Great Britain	**52.4**	**53.8**	***5***	**106.2**

Further elaboration on the extent of clearfell can be obtained from the NFI report *Preliminary estimates of canopy cover change in British woodlands* (2017).

Table 9 and **Figure 4** show the evolution of standing volume. **Table 10** and **Figure 5** show the net increment under the headline scenario used to derive the forecast results. The forecast uses the international definitions of gross and net increment as described in **Appendix F**. **Figure 6** and **Figure 7** show the relationship between forecast standing volume, increment (i.e. gain in volume over time) and subsequent timber availability over the forecast period.

Table 9. 25-year forecast of coniferous standing volume; average annual volumes within periods

Forecast period	GB Public Forest Estate	Private sector		Total
	volume (000m^3 obs)	volume (000m^3 obs)	*SE%*	volume (000m^3 obs)
England				
2022–26	26,107	64,288	*3*	**90,396**
2027–31	25,985	60,880	*3*	**86,865**
2032–36	25,599	57,184	*3*	**82,783**
2037–41	25,536	53,420	*3*	**78,956**
2042–46	25,511	51,009	*4*	**76,520**
Scotland				
2022–26	74,166	196,336	*2*	**270,502**
2027–31	68,914	198,778	*2*	**267,693**
2032–36	65,699	192,535	*2*	**258,234**
2037–41	65,159	182,364	*2*	**247,523**
2042–46	65,578	171,933	*2*	**237,511**
Wales				
2022–26	18,812	19,827	*5*	**38,639**
2027–31	17,708	19,089	*6*	**36,797**
2032–36	16,470	18,864	*6*	**35,334**
2037–41	15,655	17,878	*6*	**33,533**
2042–46	16,694	17,190	*6*	**33,884**
Great Britain				
2022–26	119,085	280,451	*1*	**399,536**
2027–31	112,607	278,748	*2*	**391,355**
2032–36	107,768	268,583	*2*	**376,350**
2037–41	106,350	253,662	*2*	**360,012**
2042–46	107,783	240,132	*2*	**347,915**

Figure 4. 25-year forecast of average annual coniferous standing volume

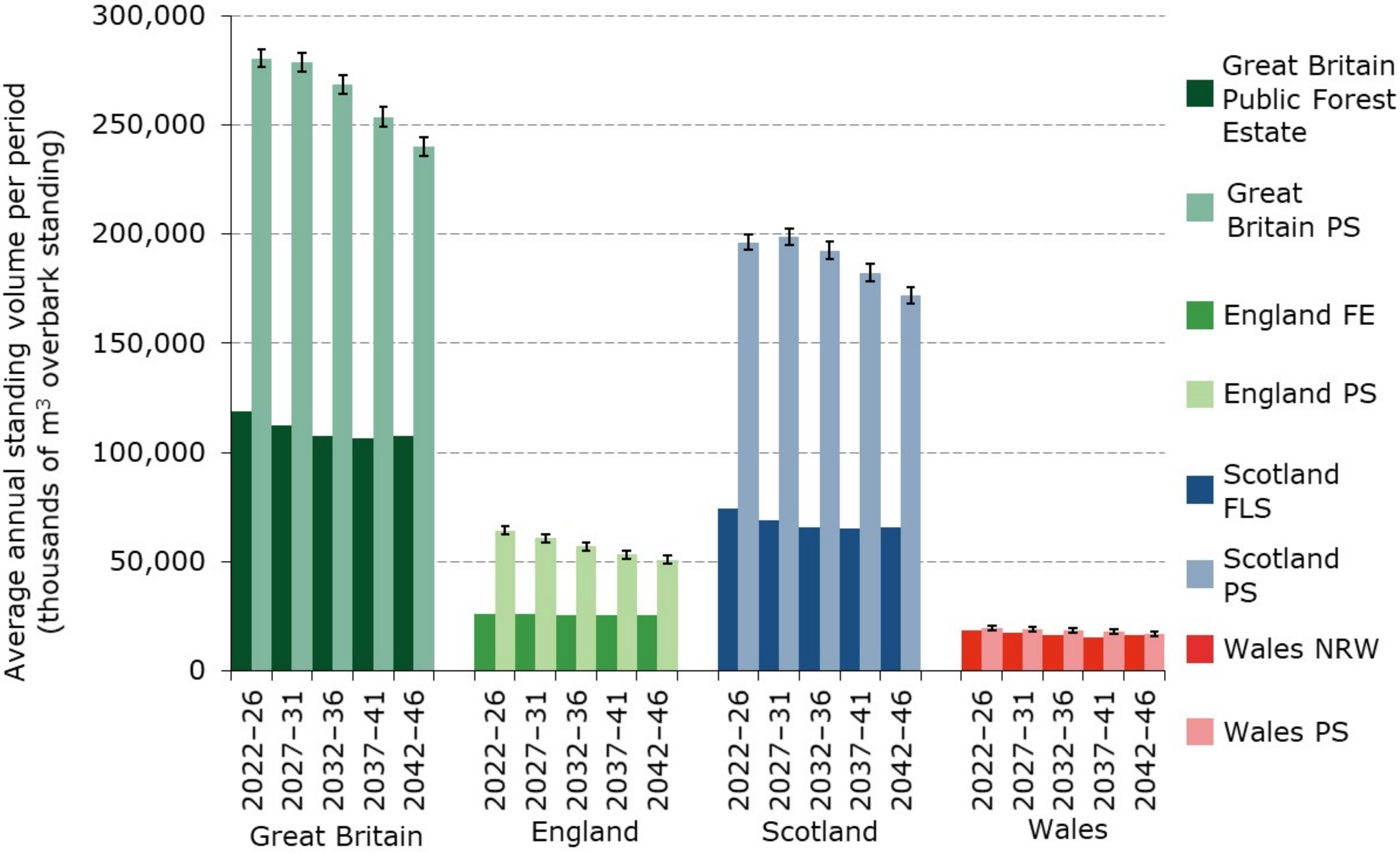


Table 10. 25-year forecast of coniferous net increment: average annual volumes within periods

Forecast period	GB Public Forest Estate	Private sector		Total
	volume (000m^3 obs)	volume (000m^3 obs)	*SE%*	volume (000m^3 obs)
England				
2022–26	1,193	2,074	*3*	**3,267**
2027–31	1,119	1,913	*3*	**3,032**
2032–36	1,072	1,738	*3*	**2,810**
2037–41	1,049	1,660	*3*	**2,709**
2042–46	1,052	1,671	*3*	**2,722**
Scotland				
2022–26	2,915	6,157	*2*	**9,072**
2027–31	2,726	6,318	*2*	**9,044**
2032–36	2,691	6,084	*2*	**8,775**
2037–41	2,820	5,723	*2*	**8,543**
2042–46	2,889	5,419	*2*	**8,308**
Wales				
2022–26	723	726	*5*	**1,449**
2027–31	786	714	*5*	**1,501**
2032–36	740	683	*4*	**1,423**
2037–41	712	659	*4*	**1,371**
2042–46	740	651	*4*	**1,391**
Great Britain				
2022–26	4,831	8,957	*1*	**13,788**
2027–31	4,631	8,945	*2*	**13,576**
2032–36	4,503	8,505	*2*	**13,008**
2037–41	4,581	8,043	*2*	**12,624**
2042–46	4,681	7,740	*2*	**12,421**

Figure 5. 25-year forecast of average annual coniferous net increment

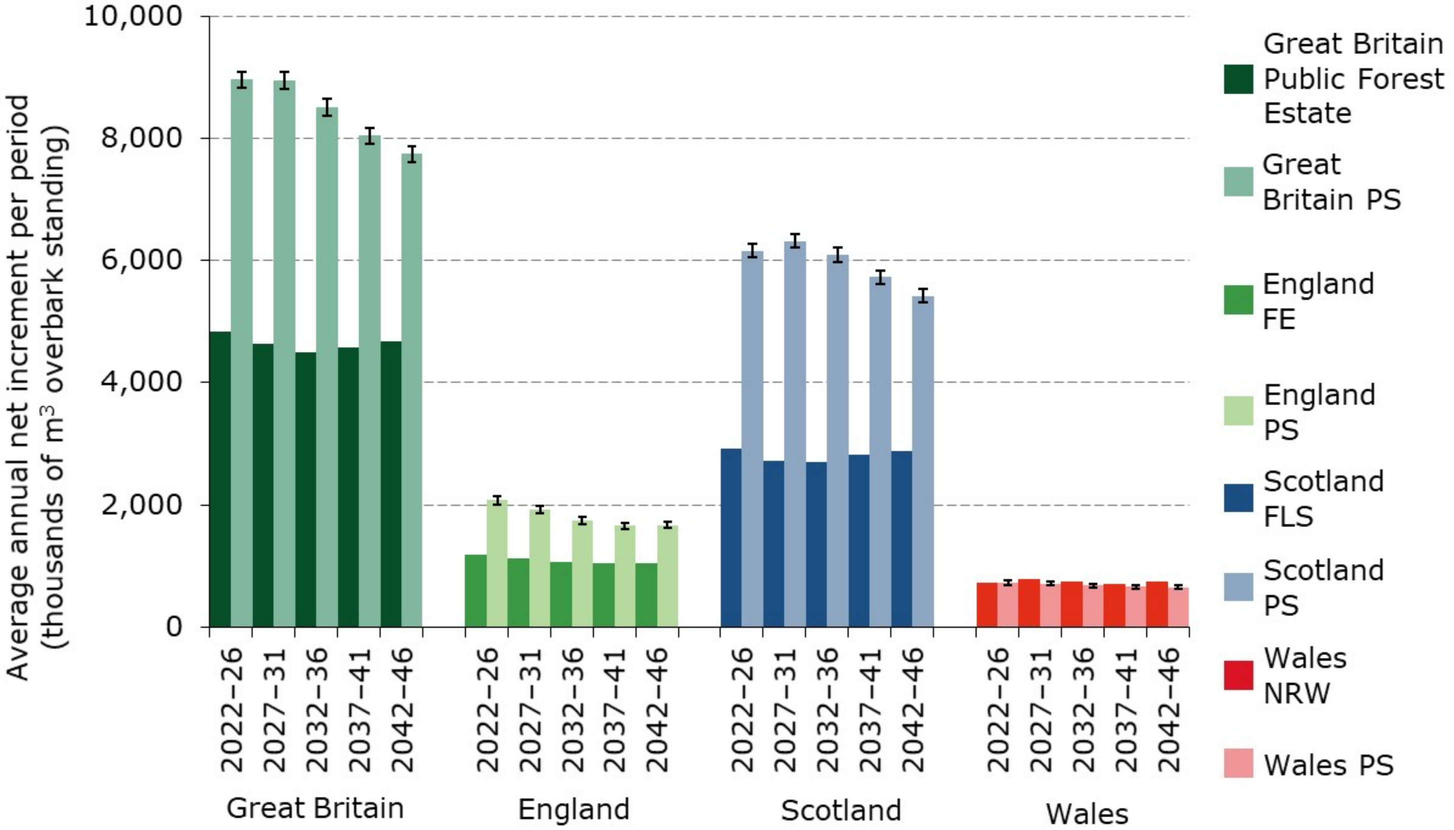
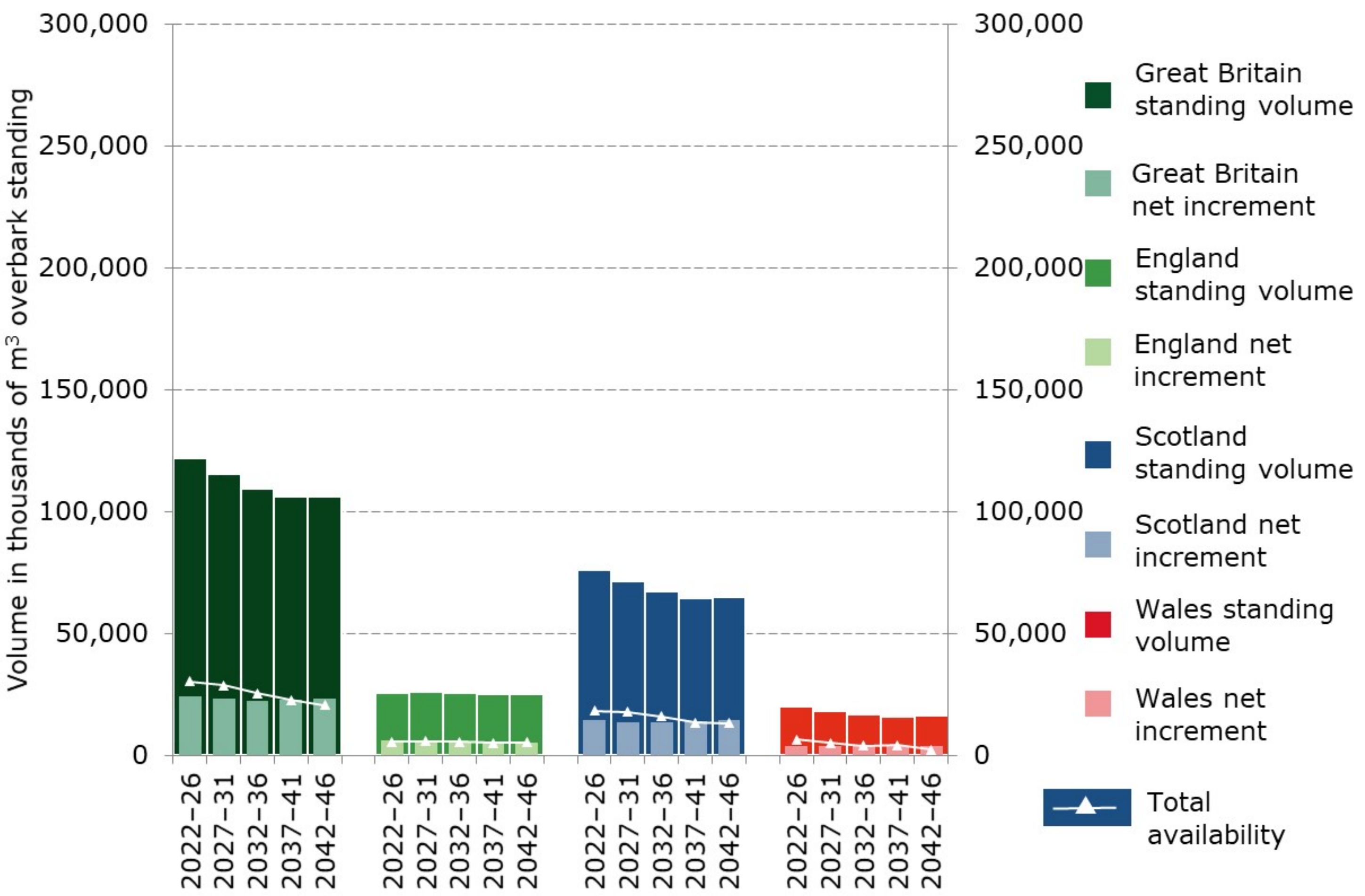
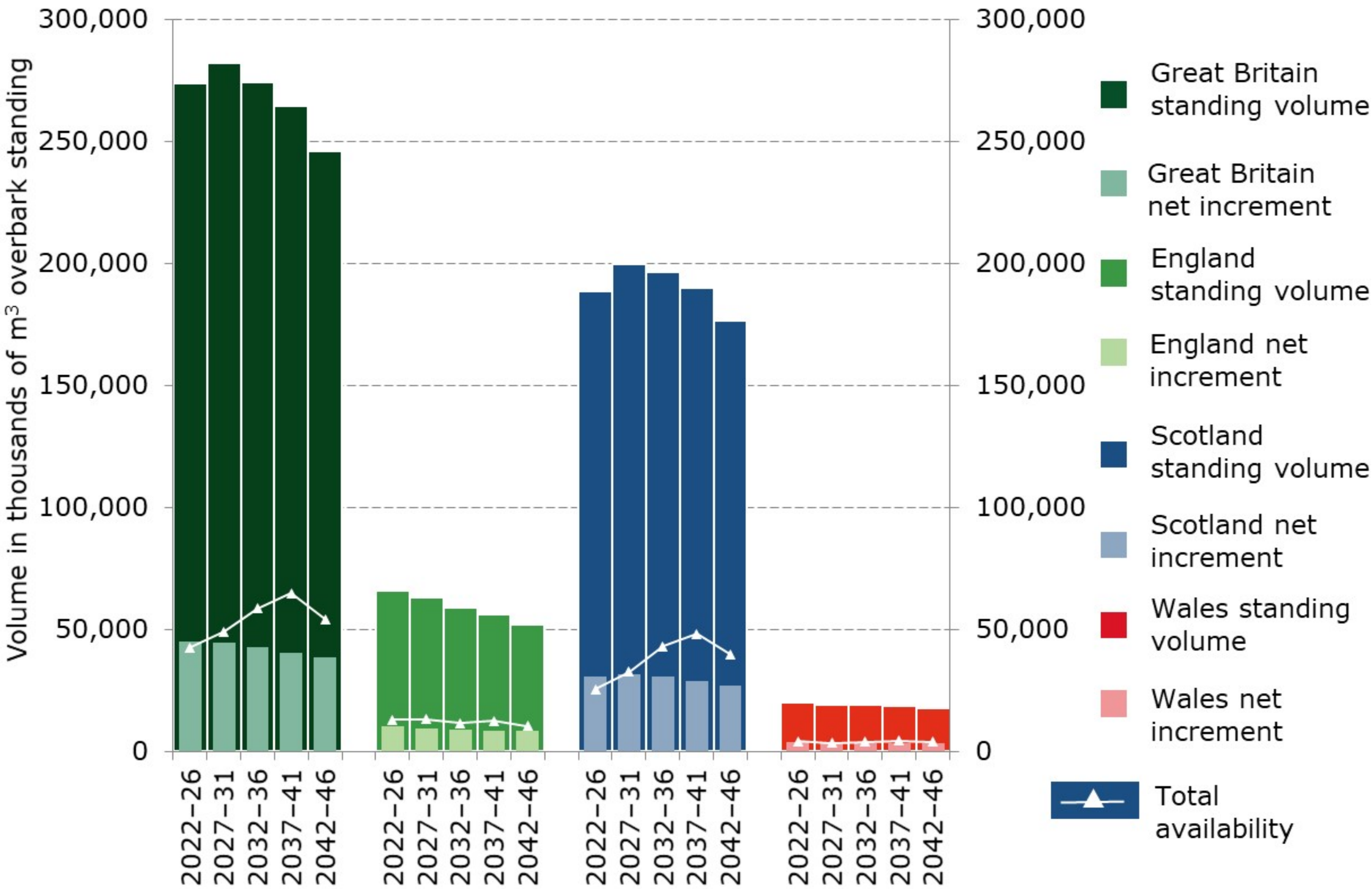


Figure 6. 25-year summary of softwood standing volume, increment and availability by country – GB Public Forest Estate.



Note: Y-axis scaled to allow direct comparison with the private sector **Figure 7**.

Figure 7. 25-year summary of softwood standing volume, increment and availability by country – GB private sector



4 What the results tell us

The current forecast for the GB private sector has been produced from new woodland inventory data taken from the NFI second cycle, where woodland inventory data was collected between 2015 and 2020. This data, collected independently from the first cycle data (collected between 2010 and 2015) confirms the findings of the first cycle on many fronts, primarily in finding internally consistent values in factors such as stocked area, species breakout, age class structure, tree diameter and height distribution. Having these two surveys confirm one another provides a great deal of assurance as to their individual accuracy. This is a good basis for this timber forecast.

On top of this inventory data change the current forecast employs new tree growth and yield models, further improving the results.

This has produced a forecast that has identified an increase in potential timber production and standing volume, and that encompasses the yield gains that arise from the introduction of genetically improved stock. However, the profile of when that timber becomes available has altered between forecasts, in the main due to a change in the harvesting assumptions applied within the forecast.

The modelling work that has been carried out to produce the revised growth and yield models established that for some species, including spruces, the age of maximum MAI is much later than had been indicated in the M1 models, for example up to 20 years later in Sitka spruce. If the forecast were to have been based on these later ages of maximum MAI, this would have diverged significantly from current felling practice and consideration of wind risk. To mitigate this, a new approach to the harvesting regime assumed in the forecast was devised in conjunction with representatives of the timber industry. The harvesting assumption is based on felling stands at a mean stand target diameter, as widely practised.

The change to the basis of the harvesting assumptions has had a significant impact on the production profile outlined above. **Figure 15** in **Appendix E** shows production forecast results based on the assumption of felling at age of maximum MAI (as in the modified biological potential scenario) comparing these with the results for basing the felling age on age at which a target diameter is reached (as in the target diameter scenario), both sets using the M1 rather than the M1v2 models. This demonstrates that the differences that can be seen are due to the change in approach.

Overall, the general trend in softwood availability shown in **Figure 1** is comparable to that of previous forecasts in that volume levels rise to a maximum and then begin to decline to a level lower than the starting point. However, the results are heavily influenced by the change in the softwood availability from the GB private sector resulting from the M1v2 models and the change from basing age of felling on age of maximum MAI to age at which a target diameter is reached. This has resulted in the peak being slightly lower than estimated in the 2016 forecast and coming two five-year periods later.

The assessment of overdue volume has also been affected by changing the approach to defining fell age by age at which a target diameter is reached, and gives higher estimates of overdue timber than using age of maximum MAI would have done. The result is that the volume of overdue timber has approximately doubled since the 2016 forecast for the GB private sector. The increase in overdue timber for the GB Public Forest Estate is not quite as large, at just over 85%.

Overdue timber was reported separately from the availability in the *25-year forecast of softwood timber availability* (2012). In this forecast (as in the forecast published in 2016) a proportion of the volume has been allocated as available for harvest. Between the two forecasts (2016 and 2022) the amount of overdue timber has increased, again due to harvest levels being lower than the volumes assumed in the earlier forecasts. Different trends are forecast for the Public Forest Estate and private sector estates with the former showing a gradual decline, while the latter rises to a maximum in the fourth period of the forecast and subsequently declines.

The trend in total availability across both sectors is driven by the trend in private sector availability.

4.1 Changes in estimated amounts of overdue timber

Some 98.6 million m^3 of softwood timber was estimated to be overdue on the GB private sector estate as of 31 March 2021 (**Table 6**). This is an increase in overdue volume in the private sector compared to the 2016 estimate of 49.6 million m^3. The increase is due to two key factors. The application of a different basis for deriving felling ages, and the continued increment in existing overdue stands. For spruce in particular, the change of management assumptions between the forecasts, results in an earlier felling age thereby classifying more stands as overdue. Additionally there is continued increment in existing overdue timber as more stands reach and pass either the target diameter or age of maximum MAI without being harvested.

Table 11. Overdue area and volume under management scenarios – GB private sector

Target Diameter (Cycle 2 data, M1v2 models)		Modified biological potential (Cycle 2 data, M1v2 models)		Increase	
Stocked area thousand ha	Standing volume Million m^3	Stocked area Thousands ha	Standing volume Million m^3	Stocked area Thousands ha	Standing volume Million m^3
132.7	98.6	98.5	73.1	34.2	25.5

To produce a balanced forecast, woodland inventory data of different ages must be brought to ‘one age’. To bring the base year of the private sector field data (2018) to the same as that of the public sector data (2021) the headline target diameter harvesting scenario was applied individually to stands contained in the NFI second cycle data, growing and managing each stand from its assessment date through to 2021. This assumed that a proportion of the overdue timber was harvested in this preliminary period through to the base year of the forecast (2021). Thus, the forecast assumes that a proportion of the overdue volume has already been harvested prior to the first forecast period of 2022–26. The 25-year forecast for the private sector then continues to assume that a proportion of the remaining overdue volume is harvested over 20 years using the procedure described in **Appendix D** and thus a proportion of the overdue volume is included in the estimates of softwood availability (**Table 3**). Whether or not this overdue timber is harvested will depend on a number of factors, including management objectives and environmental constraints. In practice a wide array of felling and retention practices will apply to these stands, with some being retained and some felled at different points in time in the future. The current standing volume by stand mean dbh of woodland in GB is reported in **Table 7** and **Figure 3**.

For the GB public sector estate, the overdue volume is assumed to be cut in the first period of the forecast.

4.2 Changes in standing volume

Perhaps the most notable result of this forecast when compared to previous forecasts is the circa 25% increase in standing volume per hectare estimated in the forest at present for the private sector in GB, and how this increase in volume per hectare continues into the future. There are several reasons for this:

- The introduction of the M1v2 growth and yield models has led to an overall increase in observed yield class (YC) (**Table 12**). This will raise average standing volume overall. This is especially true for Sitka spruce, where average YC has risen from 14 (2016) to 16 (2020). A significant component of this increase was because Sitka spruce YC was capped to no more than 24 in the M1 models, irrespective of how well it grew on the ground. In the M1v2 model, Sitka spruce can now reach YC 40, if it does so on the ground. Therefore, all such stands above YC 24 will now report more standing volume in the forecast. Additionally, the yield class cap on spruce removed much of the volume benefits arising from the introduction of improved stock in the previous forecasts.

- Under the M1v2 growth and yield models many species, including spruce, continue to grow steadily, into their 70's, 80's and 90's, well beyond the age of maximum MAI derived from the M1 model, whereas the M1 models had a decline in growth in older stands. The M1v2 models therefore reflect that many older stands continue to gain a great degree of volume in later years, hence increasing their standing volume overall.
- Stands will have grown in the 5 year period between the 2016 and current forecast, and this difference would have been forecast as higher with the application of the M1v2 yield models, due to the factors set out above.
- The thinning assumptions used in the forecast management assumptions have lead to an increase in the estimates of the forecast of standing volume. In this forecast, only two thins in the stand's lifetime are assumed, whereas previous forecasts assumed multiple thinning events to management table. As a result of lower thinning volume being removed, higher standing volumes are estimated over time.

Total standing volume has increased due to the factors outlined above. However, this trend alters over time; while standing volume for Britain at the 31st of March 2021 is around 395 million m^3, total standing volume is estimated at an average of around 400 million m^3 per year for the first period of the forecast (2022–26) and by the last period of the forecast (2042–46) the average annual standing volume has decreased to 348 million m^3.

A large determinant in the evolution of total standing volume in Britain is the age class structure of Britain's woodlands (**Figure 8**).

The trend of an increase followed by a decline in standing volume arises primarily as a result of the historical planting profile in the UK, with relatively large amounts of new forest planting between 1960 and 1980, leading to a peak of production and standing volume one rotation length later between 2010 and 2030, followed by relatively lower levels of new planting 1990 to 2010, leading to reduced levels of production and standing volume in the period following 2030.

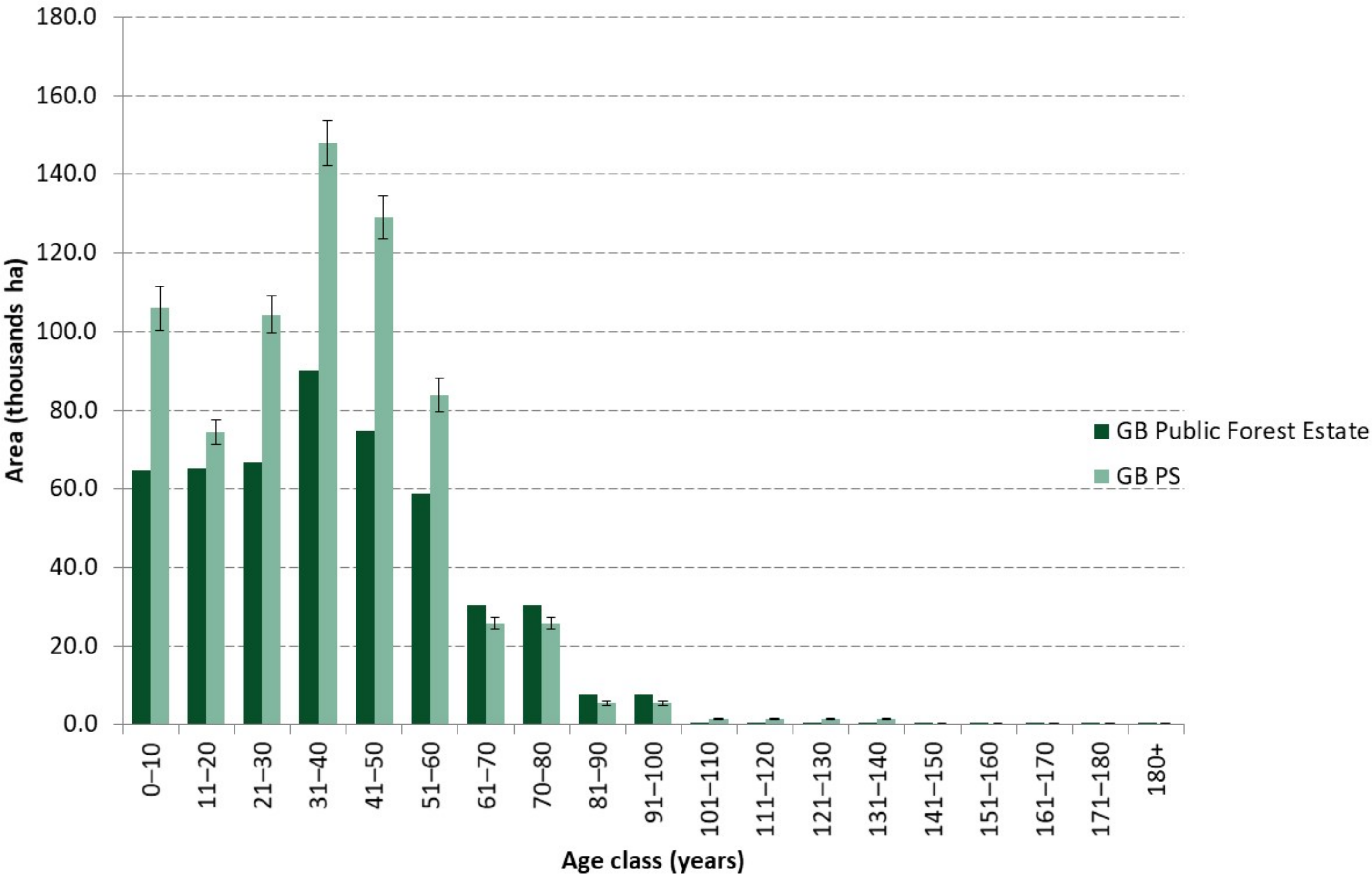
The development of the planted forestry resource in Britain has led to an uneven planting and age profile which, in combination with historical felling and the assumption to fell at the time prescribed in the management scenario applied, is the principal determinant of current and forecast standing volume. This is in contrast with forests of a more evenly distributed age in other countries, which result in a more even development of total standing volume, increment and production through time. The uneven planting profile should be taken into account when making any comparison between level of cut and increment. It should also be noted that this forecast is a limited outlook on the evolution of standing volume, confined to the period of the next 25 years, which represents a fraction of the life cycle of a forest. A 50- or 100-year forecast would give a different perspective; in particular, estimates of increment and harvesting are likely to be closer to being in balance over longer timescales.

However, this trend is contingent on the assumed harvesting scenario. The relationship between the projections of harvest, increment and standing volume is illustrated in **Figure 6** and **Figure 7**.

As noted above, there is an increase in the standing volume between the 2016 and 2020 forecasts which reflects net growth in the intervening period and the application of the M1v2 yield models.

The reports *Standing timber volume for coniferous trees in Britain* (2012), *25-year forecast of standing coniferous volume and increment* (2012) and *Interpreting National Forest Inventory timber volume forecasts* (2012) cover this subject in more detail.

Figure 8. All conifers – area by age class and ownership for GB



4.3 Changes in relative levels of species and of timber

The proportion of spruce contributing to total timber volume is projected to rise from 62 to 72% for GB for both sectors, and then to decrease to 71% by the end of the forecast. This is a modest rise in comparison to the 2016 forecast. This increase is due to the M1v2 growth and yield models better reflecting how spruce is growing on the ground, producing more volume per hectare than other species.

The forecast shows a higher proportion of spruce in larger diameter classes (**Table 5**); this relies on the assumption of owners harvesting and thinning to the ‘target diameter’ prescription. In comparison with the 2016 forecast, the 2020 forecast shows slightly higher proportions of spruce in the larger diameter classes. This is the result of a combination of higher yield classes, less thinning and the handling of overdue timber. Other scenarios would produce different assortments, and if lower levels of thinning were applied, this would produce a different profile of assortments with more smaller diameter material.

4.4 Impact of future events

The impact of future harvesting events on production levels in the private sector has been explored using scenarios in previous forecast reports. Clearly if owners choose to fell later or earlier than assumed in the scenario applied, actual production will vary from the forecast. It is unlikely that the majority of forests and woodlands will be managed to the exact target diameter scenario assumed for this forecast as owners have a wide range of objectives. For example, the target diameter forecast relies on the assumption that all woodland managers fell to the same target diameter and thin twice over the rotation which may not be typical of all current practice. Other drivers contribute to the profile of the forecast, such as the age of trees and their rate of growth. These are fixed factors which cannot be changed in the current crop since the age of the trees and rate of growth will determine the underlying profile of actual production. If future harvesting actions reflect the pattern of the maturity of the crops then a profile of production similar to this forecast and its harvesting assumptions, which reflect the underlying age and growth pattern will evolve. On top of underlying pattern of age and rate of growth, actual harvesting activity might follow a variety of patterns over the next 25 years, reflecting the different and evolving management objectives of woodland owners. Taking all these factors into account, the timing of actual production is expected to vary from the forecast results, but a level of correlation between actual and forecast production can be expected, especially as a target diameter harvesting approach is used by many woodland owners and timber buyers. This pattern of felling choice is also identifiable in the NFI data on age of trees and DBH relationships.

In addition to the impact of harvesting decisions, there are other unpredictable external factors that are likely to have an impact on production over the period of the forecast. For example, pest and disease outbreaks (current risks include Dothistroma needle blight, *Phytophthora* and *Ips typographus*), economic factors, severe weather events (windthrow), changes in land use (habitat restoration and built developments) and changes in government policy (affecting for example grants and regulation, land sales and forest management) all have the potential to affect production levels and timings not only of the current stands but also through species choices made on restocking.

4.5 Afforestation

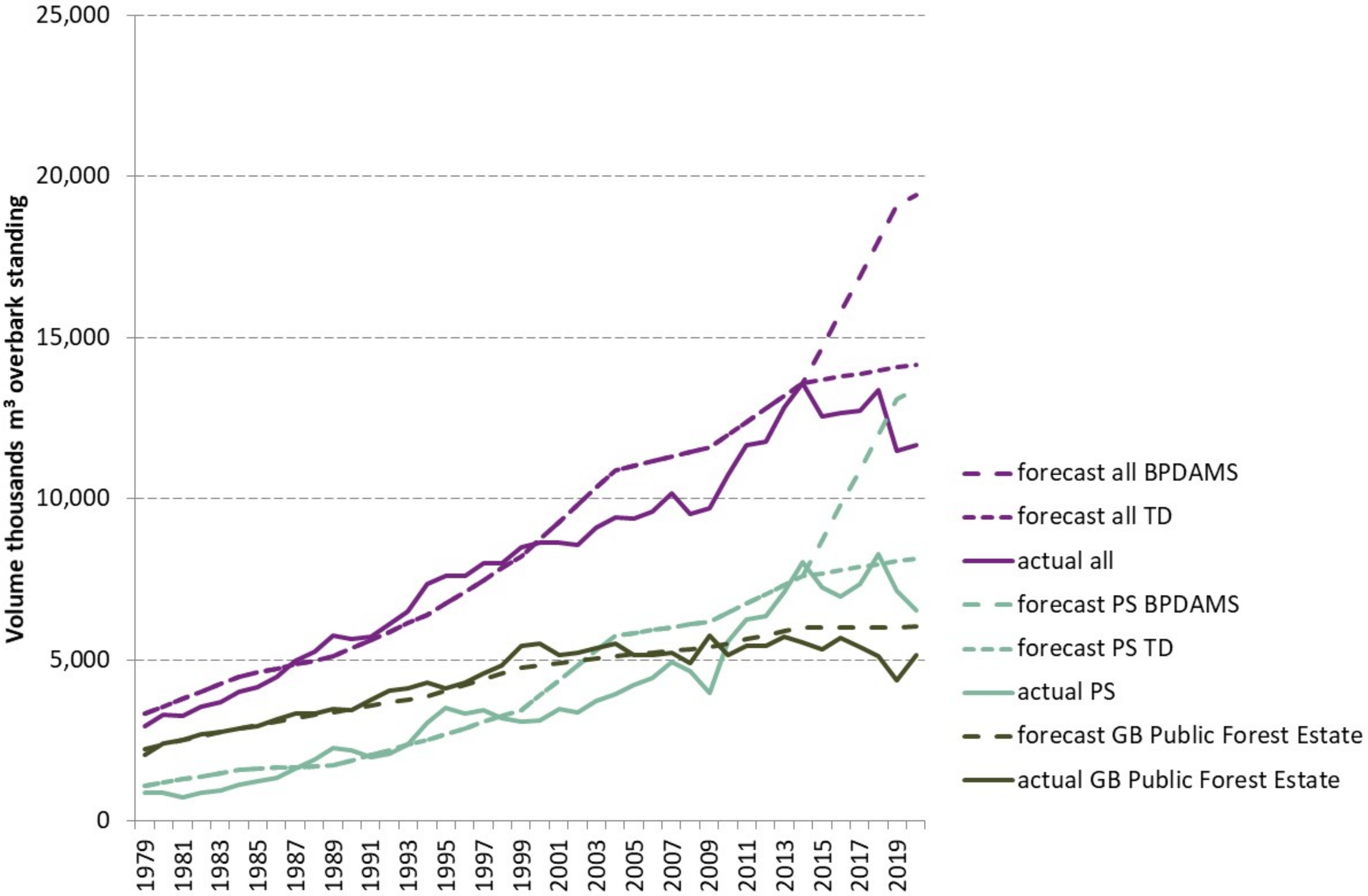
This forecast is conservative in that it does not include an estimate of production from area of woodland area created after 2020. Trees planted up to 2020 are included in the forecast, but provision has not been made for any future new planting. It is acknowledged that not including some level of production resulting from afforestation creates a small underestimate of future production which will be marginally evident in the later years of the forecast. Forecasts that include future afforestation have been published in the NFI report *Evaluation of alternative* *harvesting and afforestation scenarios on British softwood timber availability* (2015) and further such forecasts could be the subject of future work.

4.6 Impact of restocking on results

Restocking stands during the forecast makes only a very small difference to the estimated timber availability. This is principally because the stands restocked within the 25-year period will not have matured within the forecast period. However, for some stands felled in the first period and restocked with high yield class crops, some early thinning volume will begin to arise in the last period, but not to any significant degree. This is illustrated in **Figure 10** of the *50-year forecast of softwood timber availability* (2014). The report *Interpreting National Forest Inventory timber volume forecasts* (2012) explores the impact of adding restocking to the forecast.

4.7 Actual production versus forecast

Figure 9. Actual production of softwood timber volume and forecast of softwood timber availability for GB



Notes:

- This is produced as a GB chart as the first forecast that covered all parts of the UK was the 2005 forecast *New forecast of softwood availability in the UK* (2006).
- Forecast values for past years have been compiled from a number of previously published softwood forecasts.
- Time series data for wood production and roundwood removals are available from Forestry Commission's *Forestry Statistics*.
- There are lines for private sector which diverge after 2014. One based on modified biological potential scenario (labelled forecast PS BPDAMS). The second based on target diameter scenario (labelled forecast PS TD).

4.8 Forecast for the Public Forest Estate

The forecast set out in this report for the Public Forest Estate is broadly comparable to the forecast reported in 2016 both in terms of total production and the shape and timing of the profile of production, which shows a gradual decline in production over the forecast period. This is because they have been derived in a similar way.

However, the 2022-26 period shows a reduction in availability of 0.4% when compared with the 2016 forecast; the following period shows an increase of 1.4% then reductions of 0.7% in 2032-36 and 6.1% in 2037-41. This reflects the evolution of forest plans and policy within the Public Forest Estate in the intervening years. Drivers for this change include the accommodation of sanitation felling in response to *Phytophthora ramorum* and Dothistroma needle blight.

FE, FLS, NRW and FS are committed to harvest most of the forecast volumes within the first five-year period (within a window of tolerance) and to offer most of the resulting harvested volume to market. However, these commitments vary between countries (see below). Beyond 2026 the forecast indicates availability only, and although it is based on existing forest plans, these will change over time to reflect evolving country policies, such as the strategic production volume target set by Forestry and Land Scotland.

- Forestry England is committed to offer to market 1.1 million m^3 per annum (±5%) in the period 2022–2026, through new and existing contracts. This offer sits with the caveats that this will be subject to responding to plant health issues and that there is an aim to constrain the total forecast volume by 20 thousand m^3 per annum to accommodate recently emergent environmental considerations. Dothistroma needle blight has the potential to affect the predicted levels of availability from pine in two ways; firstly, with short-term increases in production from sanitation felling and, secondly, there may be longer term impacts in which stands do not achieve the volumes estimated.

- Forestry and Land Scotland is committed to offer at least 3.2 million m^3 per annum (±5%) to market in the period 2022–2026 (See Marketing & Sales Timber Marketing Framework 2020-2029 (forestryandland.gov.scot) through new and existing contracts. Forestry and Land Scotland's aim is to smooth production in the medium to long term, although management of diseases such as Phytophthora and Dothistroma needle blight may result in production variations in the short term (±10%).
- Potential available volume from the Welsh Government Woodland Estate shows a steady trend over the next two decades, reflecting volume from approved coupes in the current forest resource plans. Following extensive clearance of larch during the last two periods, Natural Resources Wales (NRW) is now revising forest resource plans, to ensure a steady and balanced availability through to the middle of this century. The approval period for 2042-46 currently shows a dip because more coupes remain to be assigned to this period through plan revisions.
- NRW's commitment of 'timber to market' is published in their Timber Sales & Marketing Plan, which can be found on NRW's Internet site.
- In the period 2022–2026 DAERA Forest Service intends to continue to market timber at quantities consistent with recent levels.

When considering the volumes from 2027 onwards, it is worth noting that actual production for the GB Public Forest Estate has historically been closely correlated to forecast production, as shown in **Figure 9**. If this continues, production from this sector will form a comparatively stable element of the forecast. However, in Scotland plans are being gradually modified to align proposed timber production with the commitment to producing up to 3.2 million m^3 per annum (± 5%) and until this exercise is complete (which will take 10 years), the forecast can only indicate availability rather than proposed production.

The mean yield class for the GB Public Forest Estate has risen from 13.6 in the 2016 forecast to 14.1 in the 2020 forecast (**Table 12**). Both estimates were based on the sub-compartment database estimates of yield class made at each stand. This change may reflect differential harvesting of lower yield class crops to higher yield class crops raising the mean yield class, in combination with recent surveys better reflecting actual yield. Note that the forecast for the GB Public Forest Estate has not employed the M1v2 models.

4.9 Forecast for the private sector estate

The forecast results set out in this report for the private sector estate are different from the headline forecast reported in the *25-year forecast of softwood timber availability* (2016), with the change from a forecast based on modified biological potential to one broadly based on target diameter. The forecast softwood availability for the first two periods of the 2020 forecast is over 3 million m^3 lower but with the peak of production falling later, by 2037-41 it is 1.5 million m^3 higher.

Changes made as part of the on-going development for the forecasting system account for marginal differences between the forecasts.

4.9.1 Woodland and stocked area

The overall net change in woodland area between the forecasts is modest, reflecting a modest new planting programme between 2015 and 2020, slightly increasing woodland area. However, coniferous stocked area has declined by 5% over the period from 759 to 720 thousand hectares. This has arisen out of an increase in the average annual rate of harvesting in conifers over the period (some 30,000 ha per annum), coupled with a reduction in the area of restocking with conifer species as conifer stands are restructured to meet the criteria contained in the UK Forestry Standard. However in terms of maintaining woodland area overall this is more than compensated for by the increase in broadleaved area expected in the UK Forestry Standard, increasing the total stocked area. Information on levels of new planting and restocking can be found in [Forestry statistics].

The yield classes applied in this forecast for the private sector estate are higher than those applied in the 2016 forecast (an average of 16.3 for all conifers in this forecast, see **Table 12**, compared with 13.8 in the 2016 forecast). The yield classes used in this report and the 2016 report were based on physical measurements which were taken stand-by-stand, and the differences arise as the 2020 yield classes are taken from the revised age-top height relationships within the M1v2 models.

Table 12. Coniferous mean yield classes for GB

All conifers	GB Public Forest Estate	Private sector
	(m^3 ha^{-1} yr^{-1})	
England	14.5	15.2
Scotland	13.5	16.6
Wales	15.9	17.0
Great Britain	**14.1**	**16.3**

Notes:

- The data in this table are for stands aged between 15 and 50 years old.
- The private sector estimates are derived from NFI measurements of top height and use new top height age relationships that are part of the M1v2 models.
- The GB public forest estate are derived from the sub-compartment database, and whilst some are based on measurements, the majority of them are likely to be based on estimates of yield class from the M1 models.

4.9.2 Harvesting activity

The modified biological potential scenario used in the 2016 forecast represented the volume of timber that would be produced if felling took place at the age of maximum MAI and thinning conformed to management table thinning except in high wind risk areas. The 2020 forecast used for the majority of stands a scenario that was based on target diameter. This is the factor that makes the single biggest difference in the two forecasts. The approach, used in the 2016 forecast, in assuming that a proportion of overdue stands are harvested over the first 25 years of the forecast is continued.

The second largest contribution to increased volume is the expansion of the amount of overdue volume which, due to actual rates of harvesting being lower between 2016 and 2020 than was forecast.

The report *Interpreting National Forest Inventory timber volume forecasts* (2012) discusses how approaches to harvesting influence and constrain the amount of timber that is likely to be harvested in any given period.

4.10 Forecasts for Northern Ireland

DAERA Forest Service intends to continue to bring timber to market at current levels in the period 2022–2026. This programme provides a manageable income derived from current sales contract values and results in an affordable re-establishment obligation. It requires reasonable infrastructure maintenance to support and generates a competitive level of demand from the all-Ireland wood processing sector.

Targets for timber production figures will continue to be set annually in compliance with strategic objectives identified in and met through annual Business Plans.

Strategic objectives and future timber marketing arrangements are subject to successive government policies, priorities, and approvals.

5 Conclusions

The forecast of softwood availability for the UK forest estate is an average of 16.5 million m^3 of softwood timber per annum over the 25-year period. The forecast for England is an average of 3.5 million m^3 per annum; for Scotland 10.7 million m^3; for Wales 1.7 million m^3; and for Northern Ireland 0.6 million m^3. The general trend predicted by this forecast is comparable to that of previous forecasts in that volume levels rise to a peak in 2037-41 and then begin to decline. This rise and fall in the profile is driven by the underlying age class structure of the forests in Britain, which reflects higher levels of planting from the post-war period to the late 1980s.

The Forestry England forecast estimates production of softwood timber at a level lower than previously forecast, with a less than 1% increase in production over the first 20 years of this forecast compared to the 2016 forecast. The volume of timber potentially available over the forecast period varies between 1.16 million m^3 in the second period (2027-31) and 1.00 million m^3 in the period (2037–41). Around 55% of that timber is from spruce.

The Forestry and Land Scotland forecast estimates production of softwood timber at a level lower than previously forecast, with a 3% decrease in production over the first 20 years of this forecast. The volume of timber potentially available over the forecast period falls from 3.67 million m^3 in the first period (2022-26) to 2.61 million m^3 in the final period (2042-46). Around 80% of that timber is from spruce.

The Natural Resources Wales forecast estimates production of softwood timber at just over 1.15 million m^3 for the first ten years of the forecast with an average production of 0.69 million m^3 for the following fifteen years. Around 78% of that timber is from spruce.

Timber availability from the Northern Ireland Forest Service is 0.5 million m^3 in the first period (2022-26), rising to a peak of 0.7 million m^3 in the period 2032–36 and then falling to a value of 0.53 million m^3 in the final period (2042-46). Around 86% of that timber is from spruce.

For the private sector across the UK, the volume of timber potentially available over the forecast period rises from 8.53 million m^3 in the first period (22-26) before peaking at 13.01 million m^3 in the fourth period (2037–41) then falling to 10.84 million m^3 in the final period (2037–41).

The increase in volume forecast for the private sector is due to two main factors:

1. The application of the M1v2 growth and yield models better reflecting the actual timber volumes on the ground and how these will increase over time.
2. Overdue timber – there was a 98% increase in the amount of overdue timber in the private sector between the 2016 forecast and this assessment.

If actual production continues to fall below availability, forecast availability will continue to rise, as increasingly large areas and volumes of overdue timber accumulate in the overall forest estate thereby adding to potential availability.

The actual profile of timber production will be determined by actual harvesting rates. When, and if, timber is harvested will depend on choices made over the coming decades by Forestry England, Forestry and Land Scotland, Natural Resources Wales, the Northern Ireland Forest Service and private sector woodland owners. For example, owners in the private sector are unlikely to consistently manage their forests and woodlands to a target diameter regime throughout the 25-year period as is assumed by this forecast. Their choices will respond to changing environmental, economic and policy drivers, underpinned by the principles of biological potential. Therefore, actual private sector production will vary from these estimates to a greater or lesser extent.

In England, actual public sector production is less likely than private sector production to vary significantly from the forecast, as a larger proportion of its woodlands are under long term policies and plans, and thus are more likely to continue to show a close relationship between forecast availability and actual production.

However in Scotland, plans are being gradually modified to align proposed timber production with the commitment to producing at 3.2 million m^3 per annum (± 5%) and, until that exercise is complete, the forecast can only show availability and not proposed production. Even with its systematic policy and planning processes in place, the public sector estate is subject to the same environmental constraints and changes as the private sector. The impacts of these, together with possible changes to strategic policies and economic conditions, may cause harvesting strategies and plans to evolve and change over time.

When drawing conclusions from this report it should be noted that the 25-year forecast period is only a fraction of the life cycle of forests and therefore the report presents a limited timeframe of production. A 50 or 100-year forecast would give a different perspective on potential production. For example, although availability compared to current production is forecast to increase across the woodlands in GB for the next 20 years, there is a reduction in this availability from 2037–41 to the end of the forecast in 2042–46. As with the previously published 50-year forecast, this trend continues until 2052–56, when availability is forecast to reach 13.4 million m^3, below the peak of actual production in 2021. This low point precedes a period of increasing timber availability resulting in another peak in forecast availability of around 15.2 million m^3 for the period 2062–2066. These longer-term trends can be seen in **Appendix E**. The reports *50-year forecast of softwood timber availability* (2014) and *Evaluation of alternative harvesting and afforestation scenarios on British softwood timber availability* (2015) explore this further. In the latter report, scenarios explore how the dip in availability can be mitigated by modest new planting programmes or extensions to rotation length.

6 Future work

The forecasts for GB in this report have used the information from the 2020 sub-compartment database (FE/FLS) and 2022 sub-compartment database (NRW), the 2019 woodland map and the second cycle of the NFI field survey. The NFI sample comprises a total of approximately 9,000 samples of surveyed one-hectare squares.

Future reports will look at forecasts of different restocking scenarios, based on the comparison of the first and second cycles of NFI fieldwork, which will provide actual levels and types of restocking. An updated forecast of hardwood availability is planned, as is an updated version of the report exploring alternative afforestation and harvesting scenarios.

All such information is an essential part of planning for sustainable forest management.

7 Glossary

Term	Description
Actual production	Timber reported as having been felled and removed from the forest. The Forestry Commission keeps records of actual production for its estate, while estimates for the private sector come from surveys of harvesting companies and timber processors. These figures are available from Forestry Commission Statistics.
Age class	A grouping of trees into specific age ranges for classification purposes.
Annual Increment	The volume growth in a year; often expressed in terms of the mean annual increment – see below.
Area (forest/woodland)	Forest and woodland area can be defined in net or gross terms. Net area is the land actually covered by trees (in the National Forest Inventory that is to the drip line of the canopy). Gross area includes both the area covered by trees and the open spaces (<0.5 hectare) within (e.g., rides, glades, ponds).
Biological potential	A term applied to forecast scenarios with the objective of maximising timber production. It typically involves felling stands in the year of maximum MAI and applying management table thinning. It may not take account of factors that constrain thinning and felling (e.g. wind risk or pest attack).
Broadleaves	Trees and shrubs that belong to the angiosperm division of the plant kingdom (as distinct from the gymnosperm division that includes conifers). Most in the UK have laminar leaves and are deciduous. Sometimes referred to as ‘hardwoods’.
Clearfelling	Cutting down of an area of woodland (if it is within a larger area of woodland it is typically a felling greater than 0.25 hectare). Sometimes a scatter or small clumps of trees may be left standing within the felled area.
Conifers	Trees and shrubs that belong to the gymnosperm division of the plant kingdom (as distinct from the angiosperm division that includes broadleaves). Conifers mostly have needles or scale-like leaves and are usually evergreen. Sometimes referred to as ‘softwoods’.
Coupe	An area of forest that is harvested in a single operation.

Cumulative volume production	The total volume of timber that is forecast to be produced over the entire forecast period, including any overdue timber.
DAMS (Detailed Aspect Method of Scoring)	A measure of exposure at a particular location. Can be used as a proxy indicator of the risk of catastrophic wind damage to a stand of trees. May be used to influence decisions on thinning and timing of clearfelling where wind is a risk factor. See How ForestGALES works - Forest Research
DAERA (Department of Agriculture, Environment and Rural Affairs) (Northern Ireland)	The Department of Agriculture, Environment and Rural Affairs (DAERA) has responsibility for food, farming, environmental, fisheries, forestry and sustainability policy and the development of the rural sector in Northern Ireland.
dbh (diameter at breast height)	The diameter on the stem of a tree at ‘breast height’, defined as 1.3 m from ground level.
Dothistroma needle blight	A disease of conifers (especially pine) which causes defoliation, losses in yield and, in severe cases, tree death. Also known as red band needle blight.
Felling plan	A spatial and temporal plan of harvesting activities within a forest or woodland.
Forest (or woodland)	Land predominately covered in trees (defined as land understands of trees with a canopy cover of at least 20%, or the ability to achieve this, and with a minimum area of 0.5 hectare and minimum width of 20 m), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts).
Forestry Commission	The government department responsible for regulating forestry, implementing forestry policy, and managing state forests in England. Forestry policy is devolved, with the exception of common issues addressed on a GB or UK basis, such as international forestry, plant health and forestry standards.
Forestry Commission (FC) estate	Forests, woodlands, open land, and other property managed by the Forestry Commission.

Forestry England (FE)	The Forestry Commission agency responsible for managing the national forests in England. Prior to April 2019, Forestry England was known as Forest Enterprise England.
Forestry and Land Scotland (FLS)	The Scottish Government agency responsible for managing the national forests and lands in Scotland, created on 1 April 2019.
Forest Plan	A holistic spatial and temporal plan stating the objectives of management together with details of forestry proposals over a period of five years and outlining intentions over a minimum total of 10 years. Such plans allow managers to communicate proposals and demonstrate sustainable forest management. They can be used to authorise thinning, felling and other management operations. FLS use the alternative term ‘land management plan’. NRW use the term ‘forest resource plan’. FE use the term ‘forest plan’.
Forest Service (FS)	An agency within the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland responsible for the regulation of forestry and the management of state forests in Northern Ireland.
Great Britain (GB)	Great Britain includes England, Scotland and Wales.
Global Positioning System (GPS)	A U.S. owned utility that provides users with positioning, navigation, and timing (PNT) services.
Increment	The increase in volume of a tree or a stand over a year or annualised over a specified period measured either in m3 per year or in m3 per hectare per year. See also Mean Annual Increment (MAI).
Ips typographus (European spruce bark beetle)	The larger eight-toothed European spruce bark beetle is a destructive pest of spruce trees (trees in the Picea genus) as well as some tree species in other conifer genera. It is also known as European spruce bark beetle, eight-toothed spruce bark beetle, bark beetle, eight-dentate beetle, engraver beetle, eight-spined beetle, and spruce bark beetle.
Like-for-like (restocking)	The restocking of areas of felled trees with trees of the same species and yield class.

M1 growth and yield model	A dynamic representation of the yield tables originally published as FC Booklet 48. Provides a flexible model for predicting forest growth and yield, in terms of the types of management prescriptions that can be applied and the growing stock that can be represented.
M1v2 growth and yield model	An extension of the earlier M1 model developed with the key aim of addressing and removing major inaccuracies identified in some of the earlier models of growth and yield. Refers to a revised set of yield tables.
Management table thinning	A sequence of thinnings prescribed by Forestry Commission yield tables over the life of a forest stand. Management table thinning refers to the pattern of thinning recommended in these yield tables. In standard yield tables the thinnings are set to an intensity which aims to maximise diameter increment while also maintaining maximum cumulative volume production.
Mean annual increment (MAI)	The average rate of volume production up to a given year, expressed in m^3 per hectare per year. In even-aged stands it is calculated by dividing cumulative volume production by age.
Mensuration	The study of the measurement of lengths, areas, volumes, and related quantities. Forest mensuration is concerned with the measurement of trees, woodlands, and forests, including standing and felled timber.
Modified biological potential	A term applied to a biological potential forecast scenario which takes account of factors that constrain thinning and felling (e.g. wind risk or pest attack).
Natural Resources Wales (NRW)	Natural Resources Wales was formed in April 2013, largely taking over the functions of the Countryside Council for Wales, Forestry Commission Wales, and the Environment Agency in Wales, as well as certain Welsh Government functions.
Net Increment	The volume growth less loss due to mortality, including windthrow, but not subtracting any harvested volume.
Overbark	Used as a qualification when the diameter or volume of wood includes the bark.
Overdue	Timber contained in stands that are beyond the felling age prescribed by the harvesting scenario at the start of the forecast.

Phytophthora	Fungus-like pathogens that can cause extensive damage and mortality to trees and other plants.
Public Forest Estate	In this report, the combined FE/FLS/NRW/FS will be referred to 'Public Forest Estate'. FE/FLS/NRW will be referred to as 'GB Public Forest Estate'.
Private sector estate	Forests and woodlands in the UK not managed by the Forestry England, Forestry and Land Scotland, Natural Resources Wales, or Forest Service. In the context of the National Forest Inventory, 'private sector' is used for convenience although it includes land owned or managed by bodies such as local authorities and charities.
Production forecast	A forecast of softwood volume production based on a firm plan of harvesting.
Restocking plan	A spatial and temporal plan describing how felled areas are to be replanted or regenerated.
Scottish Forestry	The Scottish Government agency responsible for forestry policy, support and regulations.
Softwood	The wood of coniferous trees or the conifers themselves.
Stand	A distinct area of woodland, generally composed of a uniform group of trees in terms of species composition and spatial distribution, and age and size class distribution.
Standard error (SE)	The measure of the margin of error associated with an estimate as a result of sampling from a population with statistical variability. Larger standard errors indicate less precision in the estimate. Standard errors in this report are quoted in relative terms (i.e., as percentages of the value of the estimate).
Standing volume	The live stemwood and usable branchwood of trees (up to 7 cm top diameter). It excludes roots, below ground stump material, small branches, foliage, and deadwood. For private sector woodland only, it also excludes trees in woodlands of less than 0.5 hectare. Usually expressed as m^3 overbark standing (m^3 obs).

Stemwood	The woody material forming the above ground main growing shoot(s) of a tree or stand of trees. The stem includes all woody volume above ground with a diameter greater than 7 cm overbark. Stemwood includes wood in major branches where there is at least 3 m of straight length to 7 cm top diameter.
Sustainable forest management	The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity and vitality and their potential to fulfil, now and in the future, relevant ecological, economic, and social functions at local, national, and global levels, and that does not cause damage to other ecosystems.
Terminal height	The top height of a stand at which wind damage is expected to reach a level necessitating clearfelling.
Thinning	The periodic harvesting of trees in a woodland, involving the removal of some trees for commercial use and the retention of others for future production or long-term retention.
Thinning plan	A spatial and temporal plan of harvesting activities within a forest or woodland.
Top diameter	The diameter of the smaller (top) end of a length of stemwood, branchwood or log, often used to define different categories of wood products (e.g. sawlogs, roundwood, pulp) and merchantable timber.
Top height	The mean total height of the 100 largest dbh trees per hectare.
UK (United Kingdom)	Great Britain and Northern Ireland.
Windthrow	Uprooting of trees by the wind. Windthrow can be endemic – i.e. that caused by frequently recurring peak winds – or catastrophic – an infrequent occurrence associated with exceptionally strong winds where large areas/numbers of trees are blown down.
Woodland	see Forest.
Yield class (YC)	An index used in the UK of the potential productivity of even-aged stands of trees based on age of maximum MAI. It reflects the potential productivity of the site for the tree species growing on it.

8 NFI national reports and papers

This inventory report is one of a series of publications reporting the outputs of the Forestry Commission National Forest Inventory. It forms part of the 25-year forecast of softwood availability series, which includes the following reports:

- Standing timber volume for coniferous trees in Britain (April 2012)
- 25-year forecast of standing coniferous volume and increment (2012)
- 25-year forecast of softwood timber availability (July 2012)
- 25-year forecast of softwood timber availability (2014)
- 25-year forecast of softwood timber availability (2016)

Supporting technical documentation for these reports is available in:

- National Forest Inventory survey methodology
- National Forest Inventory forecasts methodology overview
- Interpreting National Forest Inventory timber volume forecasts

The woodland map and areas derived from it can be found in:

- National Forest Inventory woodland area statistics (for Great Britain, England, Scotland and Wales).

Full details are available from the NFI web pages.

The National Forest Inventory supports sustainable forest management in Great Britain. For more information see The UK Forestry Standard and its supporting Guidelines.

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For more information about Forestry Research publications click this link

More information about the National Forest Inventory publications is available from the NFI web pages.

Links to external sources are valid at the time of this report's publication.

Appendix A Target diameter management assumptions

Under this scenario, private sector forests are managed under a regime designed to:

- Fell according to a target stand mean diameter. For conifers other than larches, a maximum diameter of 30 cm is used; for larches 25 cm is used.
- Take account of thinning and wind constraints, with stands thinned where evidence shows that there has been previous thinning or where they are assessed with a DAMS (Detailed Aspect Method of Scoring) of less than 16.
- Harvest a proportion of overdue stands (i.e., stands that have exceeded the prescribed size for felling according to the scenario, or are older than the age of maximum MAI or, where wind constraints apply, taller than the terminal height of 25 m). Overdue handling is described in **Appendix D**.
- Harvest stands which are slow growing and which forest growth and yield models indicate will not reach the target diameter, according to the age of maximum mean annual increment or (where wind constraints apply) at a terminal height of 25 m. (the 'headline' modified biological potential assumptions used in the 2016 forecast)
- Restock stands which are currently felled, and restock stands which are felled within the forecast period, according to the country level restocking options described in **Appendix B**.

This scenario, selected after consultation with private sector woodland owners and processors, aims to reflect current softwood management practices in a way that involves a relatively straightforward and transparent prescriptions.

The key elements of the target diameter assumptions are that each stand is assessed at the start of the forecast and falls into one of three categories which then determine the age of felling. These criteria for these categories are:

- 'Standard felling':
    - the mean stand diameter is less than 30 cm (25 cm for larch) AND
    - the stand is younger than the model age of maximum mean annual increment AND
    - the stand is shorter than the terminal height (25 m) AND
    - the yield class for the stand is over a given threshold which means that, according to the modelled growth, the stand will achieve the target diameter
- 'Underdue'
    - the mean stand diameter is less than 30 cm (25 cm for larch) AND
    - the stand is younger than the model age of maximum mean annual increment AND
    - the stand is shorter than the terminal height (25 m) AND
    - the yield class for the stand is below a given threshold which means that, according to the modelled growth, the stand will not achieve the target diameter
- 'Overdue'
    - the mean stand diameter is greater than 30 cm (25 cm for larch) OR
    - the mean stand diameter is less than 30 cm (25 cm for larch) AND the stand is older than the model age of maximum mean annual increment OR

    - the mean stand diameter is less than 30 cm (25 cm for larch) AND the stand is younger than the model age of maximum mean annual increment AND the stand is taller than the terminal height (25 m)

The age of felling is taken as:

- ‘Standard felling’ – age at when the growth and yield model indicates that the main stand diameter will reach 30 cm.
- ‘Underdue’ – age is determined as in the modified biological potential with windthrow risk assumptions on which the 2016 forecast was based. Timber is felled at the age of maximum MAI or (where wind constraints apply) at a terminal height of 25 m.
- ‘Overdue’ – a schedule of how felling ages are derived is included in **Appendix D**.

The decision whether and when to thin is similar for ‘standard felling’ and ‘underdue’:

- If the stand has been thinned before, one further thinning will be scheduled in the forecast period.
- If the stand has not been thinned before AND the stand is older than the age of first thin as indicated by the growth and yield model, no thinnings will be scheduled during the forecast period.
- If the stand has not been thinned before AND the stand is younger than the age of first thin as indicated by the growth and yield model the determination of whether and when to thin is based on windthrow risk. if the stand is in an area of low windthrow risk (a threshold DAMS score of 16 is used), a proportional approach is adopted with 85% of the stands receiving two thinnings during the forecast period and 15% of the stands receiving no

thinning. Whilst if the stand is in an area of high windthrow risk, no thinnings are assumed.

For ‘overdue’ stands, no further thinning is assumed.

Decision trees describing the assumptions are shown below in **Figure 10** (felling and thinning), **Figure 11** (felling prescription) and **Figure 12** (thinning prescription).

Figure 10. Overview of decision tree for felling and thinning

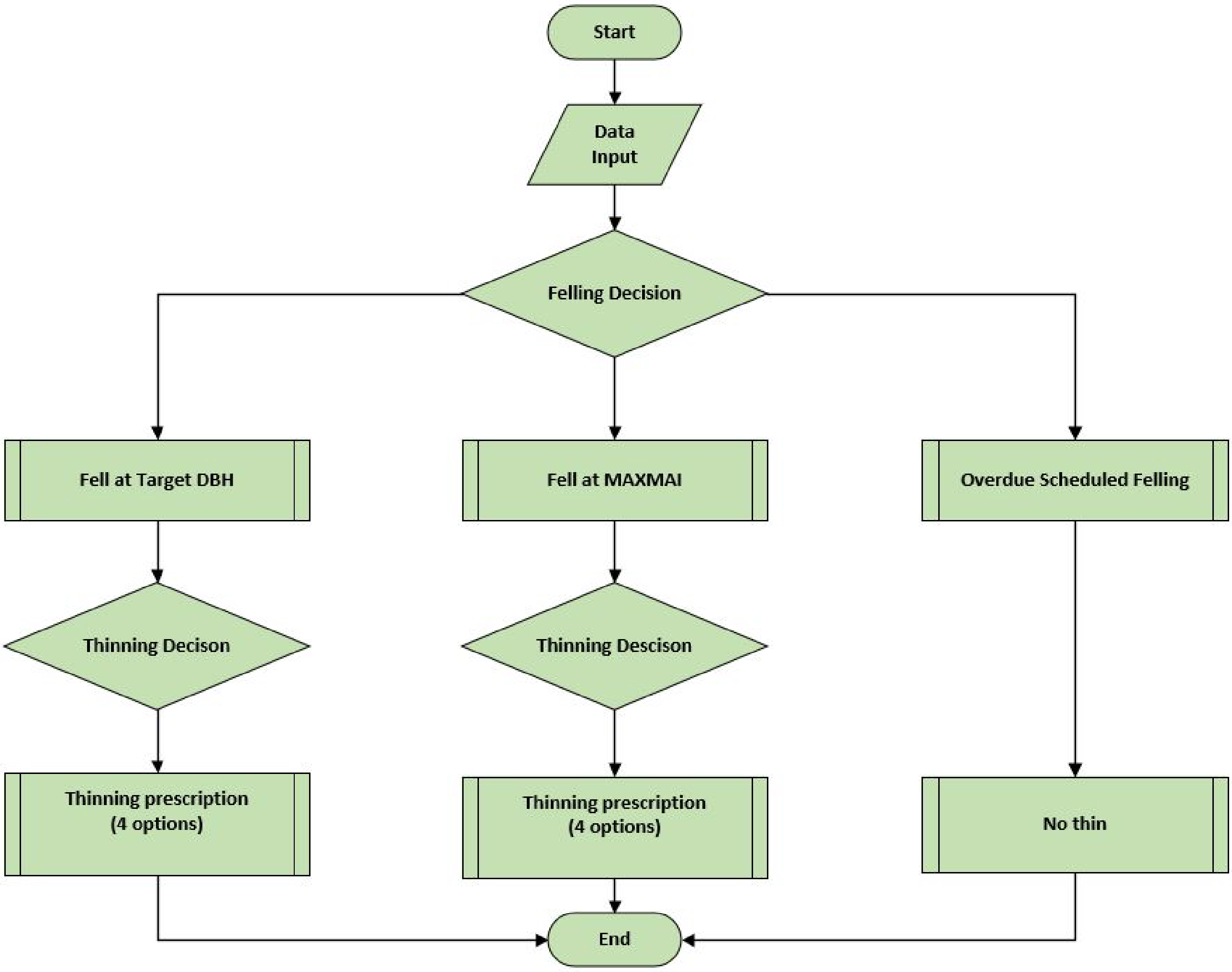


Figure 11. Overview of decision tree for felling prescription

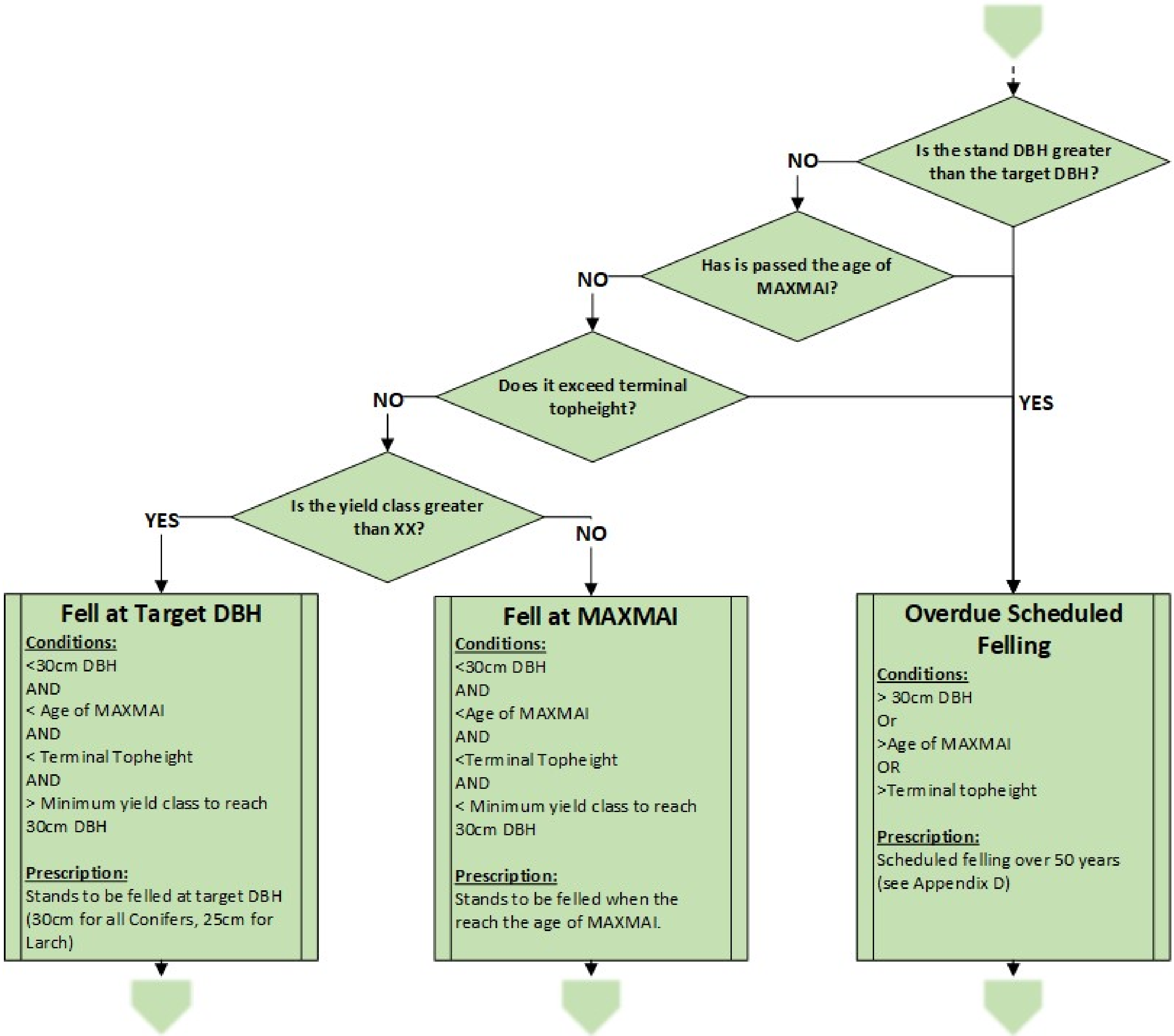
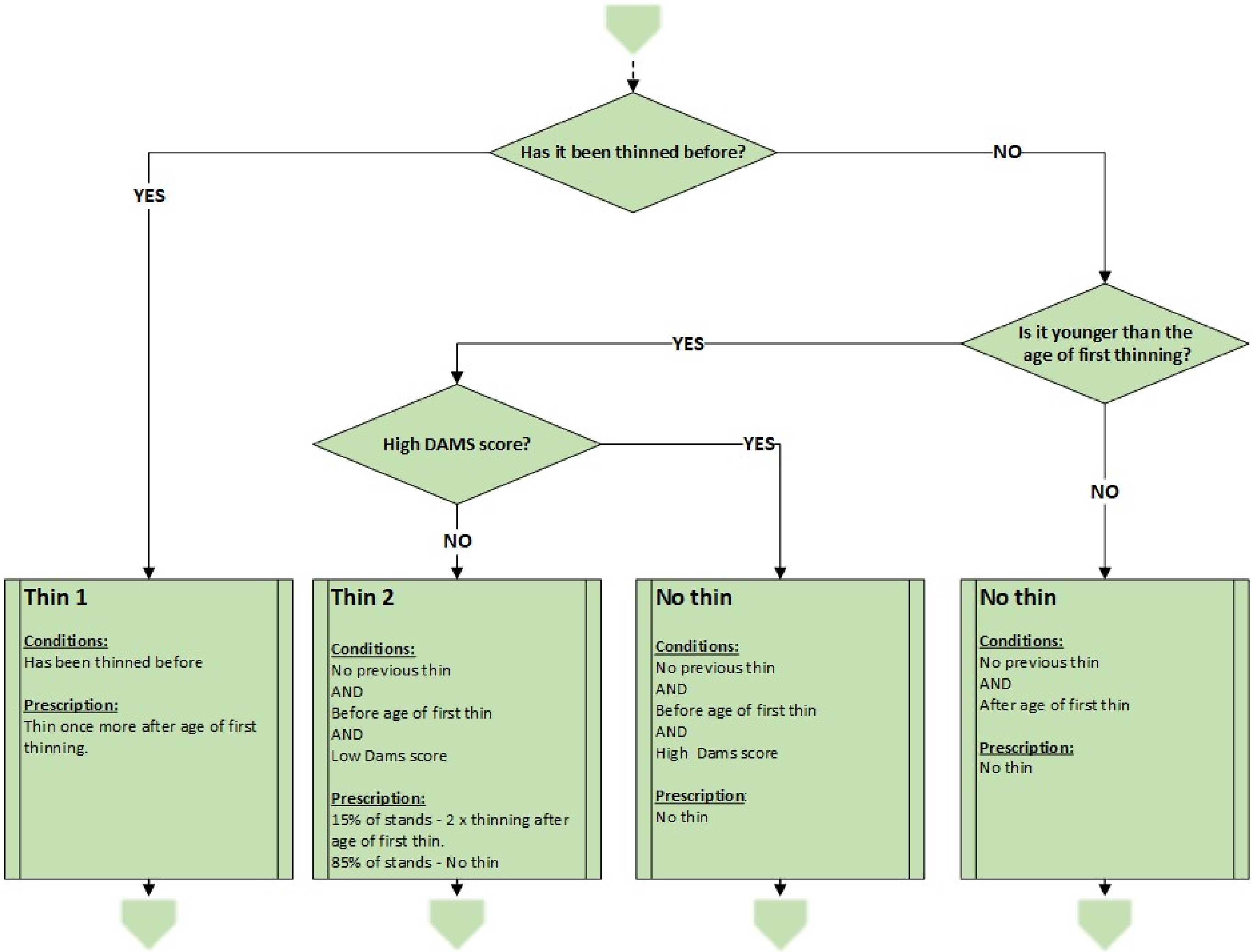


Figure 12. Overview of decision tree for thinning prescription



Appendix B Restocking assumptions

In line with the UK Forestry Standard, assumptions are made about the species choice and the amount of open space introduced when conifer crops are felled during the forecast period.

The following tables describe the restocking assumptions applied in each country following felling of conifer species in the 2020 forecast.

A fallow period of 2 years from clearfelling to restocking is assumed.

Table 13. Restock assumuptions for England

Species	Current stocked area	Conifer species as a % of conifer area	Proposed conifer species as a % of conifer area	Assumed % change to conifer woodland
Sitka spruce	76	27.9	30.0	
Scots pine	54	19.9	25.0	
Corsican pine	33	12.0	0.5	
Norway spruce	24	8.7	10.0	
Larches	30	11.0	2.0	
Douglas fir	23	8.4	14.0	
Lodgepole pine	7	2.7	0.5	
Other conifer species	26	9.3	18.0	
Total	273	100.0	100.0	-20
Areas	Area	% of total woodland area		
Total conifer stocked area	273	21.7		
Total broadleaved stocked area	970	77.0		
Total conifer and broadleaved stocked area	1,243	98.6		
Total unstocked area	17	1.4		
Woodland area at 2021	1,260			
Projected change after one rotation				
Resultant total conifer stocked area	219	17.3		
Resultant total broadleaved stocked area	997	79.1		
Resultant total conifer and broadleaved stocked area	1,216	96.5	Figures assume 50% of the conifer reduction goes to blvd trees and 50% to open	

Table 14. Restock assumptions for Scotland

Species	Current stocked area	Conifer species as a % of conifer area	Proposed conifer species as a % of conifer area	Assumed % change to conifer woodland
Sitka spruce	495	61.2	59.0	
Scots pine	138	17.1	24.5	
Corsican pine	4	0.4	0.0	
Norway spruce	47	5.8	6.0	
Larches	78	9.6	2.0	
Douglas fir	15	1.8	3.0	
Lodgepole pine	82	10.2	0.5	
Other conifer species	17	2.1	5.0	
Total	809	100.0	100.0	-20
Areas	**Area**	**% of total woodland area**		
Total conifer stocked area	809	66.0		
Total broadleaved stocked area	338	27.5		
Total conifer and broadleaved stocked area	1,147	93.5		
Total unstocked area	80	6.3		
Woodland area at 2021	1,226			
Projected change after one rotation				
Resultant total conifer stocked area	647	52.8		
Resultant total broadleaved stocked area	419	34.1		
Resultant total conifer and broadleaved stocked area	1,066	86.9	Figures assume 50% of the conifer reduction goes to blvd trees and 50% to open	

Table 15. Restock assumptions for Wales

Species	Current stocked area	Conifer species as a % of conifer area	Proposed conifer species as a % of conifer area	Assumed % change to conifer woodland
Sitka spruce	74	62.3	60.0	
Scots pine	3	2.5	6.0	
Corsican pine	2	1.8	0.0	
Norway spruce	8	6.8	8.0	
Larches	13	10.9	0.5	
Douglas fir	10	8.2	17.0	
Lodgepole pine	4	3.2	0.5	
Other conifer species	5	4.1	8.0	
Total	119	100.0	100.0	-20
Areas	Area	% of total woodland area		
Total conifer stocked area	119	41.0		
Total broadleaved stocked area	164	56.5		
Total conifer and broadleaved stocked area	284	97.5		
Total unstocked area	7	2.5		
Woodland area at 2021	291			
Projected change after one rotation				
Resultant total conifer stocked area	96	32.8		
Resultant total broadleaved stocked area	176	60.6		
Resultant total conifer and broadleaved stocked area	272	93.4	Figures assume 50% of the conifer reduction goes to blvd trees and 50% to open	

In long-term forecasts, these restock assumptions are applied only to the restocking of current stands and current clearfell areas. Should any of these restocked areas be felled during the forecast period, they are replaced by exactly the same crop in any subsequent rotations.

Appendix C Managing the restock

The management assumptions applied to current stands are also applied to the restocking (whether first or subsequent restocking) during the forecast period.

Appendix D Overdue assumptions

These are unchanged from the assumptions used in the *25-year forecast of softwood availability* (2016) and is best interpreted in conjunction with the decision tree in **Appendix A**.

Table 16. Overdue assumptions for GB

	Prescription by years beyond maximum MAI (as of base year). Derived from Yield Models prior to their revision.		
Species	0-10 yrs beyond	10-30 yrs beyond	30 + yrs beyond
Sitka spruce	Fell 50% 1- 25 yrs	Fell 50% 1- 25 yrs	Fell 75% 1-25 yrs
	Fell 50% 26-50	Fell 40% 26-50 yrs	
		10% zero intervention	25% zero intervention
Norway spruce	Fell 50% 1- 25 yrs	Fell 50% 1- 25 yrs	Fell 75% 1-25 yrs
	Fell 50% 26-50	Fell 40% 26-50 yrs	
		10% zero intervention	25% zero intervention
Douglas fir	Fell 50 % 1- 25 yrs,	Fell 75 % 1- 25 yrs,	Fell 75% over 10 yrs
	Fell 25% 26- 50 yrs	25% zero intervention	25% zero intervention
	25% zero intervention		
Scots pine	Fell 0% 1-25 yrs	Fell 50 % 1- 25 yrs,	Fell 50% 1- 25 yrs
	Fell 75% 26-50 yrs	Fell 25 % 26-50 yrs	50% zero intervention
	25% zero intervention	25% zero intervention	

	Prescription by years beyond maximum MAI (as of base year). Derived from Yield Models prior to their revision.		
Species	0-10 yrs beyond	10-30 yrs beyond	30 + yrs beyond
Larches	Fell 50% 1- 10 yrs,	Fell 50 % 1- 25 yrs	Fell 75% 1- 10 yrs
	Fell 40% 11-25 yrs,	Fell 40 % 26-50 yrs	25% zero intervention
	10% zero intervention	10% zero intervention	
Corsican pine	Fell 50% 1- 10 yrs,	Fell 50 % 1- 25 yrs	Fell 75% 1- 10 yrs
	Fell 40% 11-25 yrs,	Fell 25 % 26- 50 yrs	25% zero intervention
	10% zero intervention	25% zero intervention	
Lodgepole pine	Fell 50% 1- 10 yrs,	Fell 50 % 1-25 yrs	Fell 75% 1- 10 yrs
	Fell 40% 11- 25 yrs,	Fell 25 % 26- 50 yrs	25% zero intervention
	10% zero intervention	25% zero intervention	
Other species	Fell 50 % 1-25 yrs,	Fell 75 % 1- 25 yrs,	Fell 75% 1- 10 yrs
	Fell 25% 26- 50 yrs	25% zero intervention	25% zero intervention
	25% zero intervention		

Appendix E Long term forecast and impacts of change for the private sector in GB

Eight scenarios were investigated during the preparation of this report. These comprised:

- NFI field data collection cycles. Cycle 1 was collected between 2010 and 2015. Cycle 2 was collected between 2015 and 2020.
- M1 and M1v2 yield models
- Management based on modified biological potential and target diameter assumptions

Each of these scenarios was run for 100 years through to 2126.

The forecast results in the main body of this report are taken from a scenario which was built from:

- NFI Cycle 2 data collection
- M1v2 yield models
- Management based on target diameter assumptions

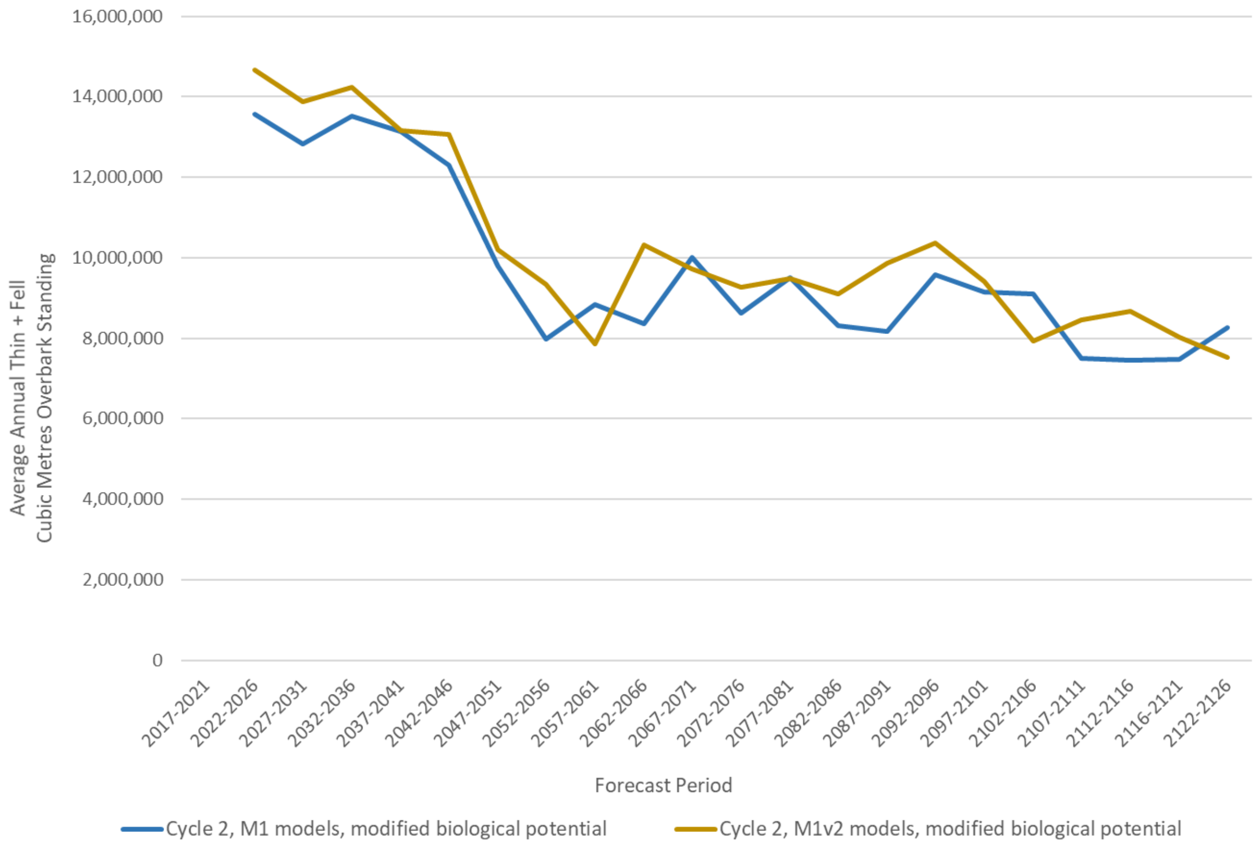
With the first 25 years of the forecast being presented.

In this appendix, we show the 100-year forecasts for key scenarios and how the changes between the cycles, the models and management assumptions impact the longer-term forecast.

Figure 13. Cycle 1 data, M1 model and cycle 2 data, M1 model, modified biological potential forecasts – GB private sector

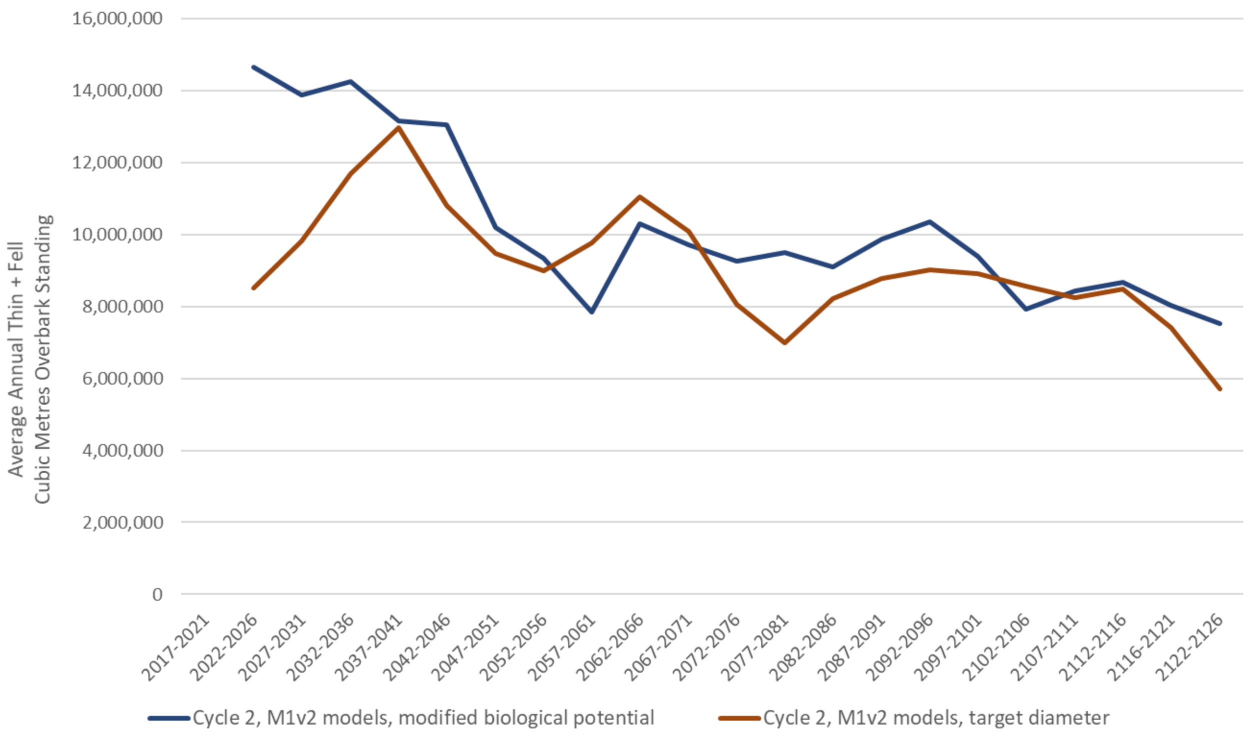
The results show good consistency of field work across the two cycles despite different surveyors being involved. The increase in volumes under the forecast from cycle 2 assessments indicates that the trees are growing faster than the models projected from the cycle 1 assessments. It might also indicate that less area was felled than assumed under the modified biological potential assumptions.

Figure 14. Cycle 2 data, M1 model and cycle 2 data, M1v2 model, modified biological potential forecasts – GB private sector



The general trend is that the M1v2 models increase the availability of softwood timber volume. This is particularly driven by the proportion of spruce in the forecast with production from Sitka spruce no longer constrained to a maximum yield class of 24.

Figure 15. Cycle 2 M1v2 models, modified biological potential and target diameter forecasts – GB private sector

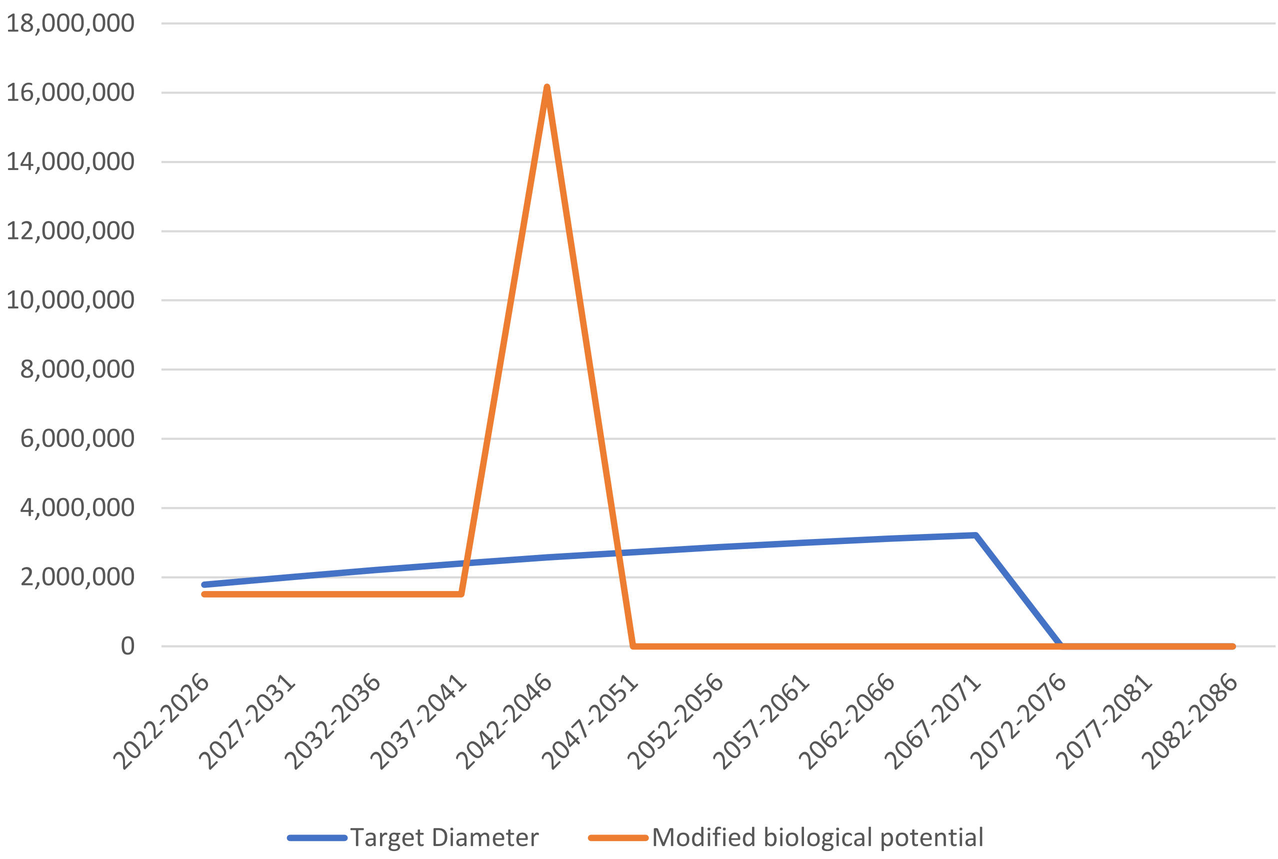


The changes in the forecast are significant in the opening periods of the forecast. This is due to the larger volume of overdue timber under the target diameter assumptions (98 million m^3 obs) than under the modified biological potential assumptions (73 million m^3 obs). Following the overdue assumptions, a reduced proportion of the stands are felled.

Here we illustrate the difference in outcomes between the Target diameter and modified biological potential management scenarios as they influence volumes forecast. In our example we take an average stand of Sitka spruce at yield class 16. This stand is 44 years old at the start of our forecast. With a mean stand diameter of 37 cm, the stand is already in the overdue category for the target diameter management assumptions. The age of maximum MAI for the stand is 58 years, which is 14 years into our forecast. As such, the stand is not classed as overdue under the modified biological potential assumptions.

The chart shows the average annual thin plus fell volume arising from this stand under the two scenarios. For simplicity we have assumed that the stand will not be restocked. The actual volume of production assumes that this single stand is 'bulked up' to represent an entire region and therefore the actual volume estimates are meaningless. The purpose is to illustrate the differences in profiles between the forecasts under the different management assumptions.

Figure 16. Thin plus fell volume to 7 cm for an 'average' Sitka spruce stand

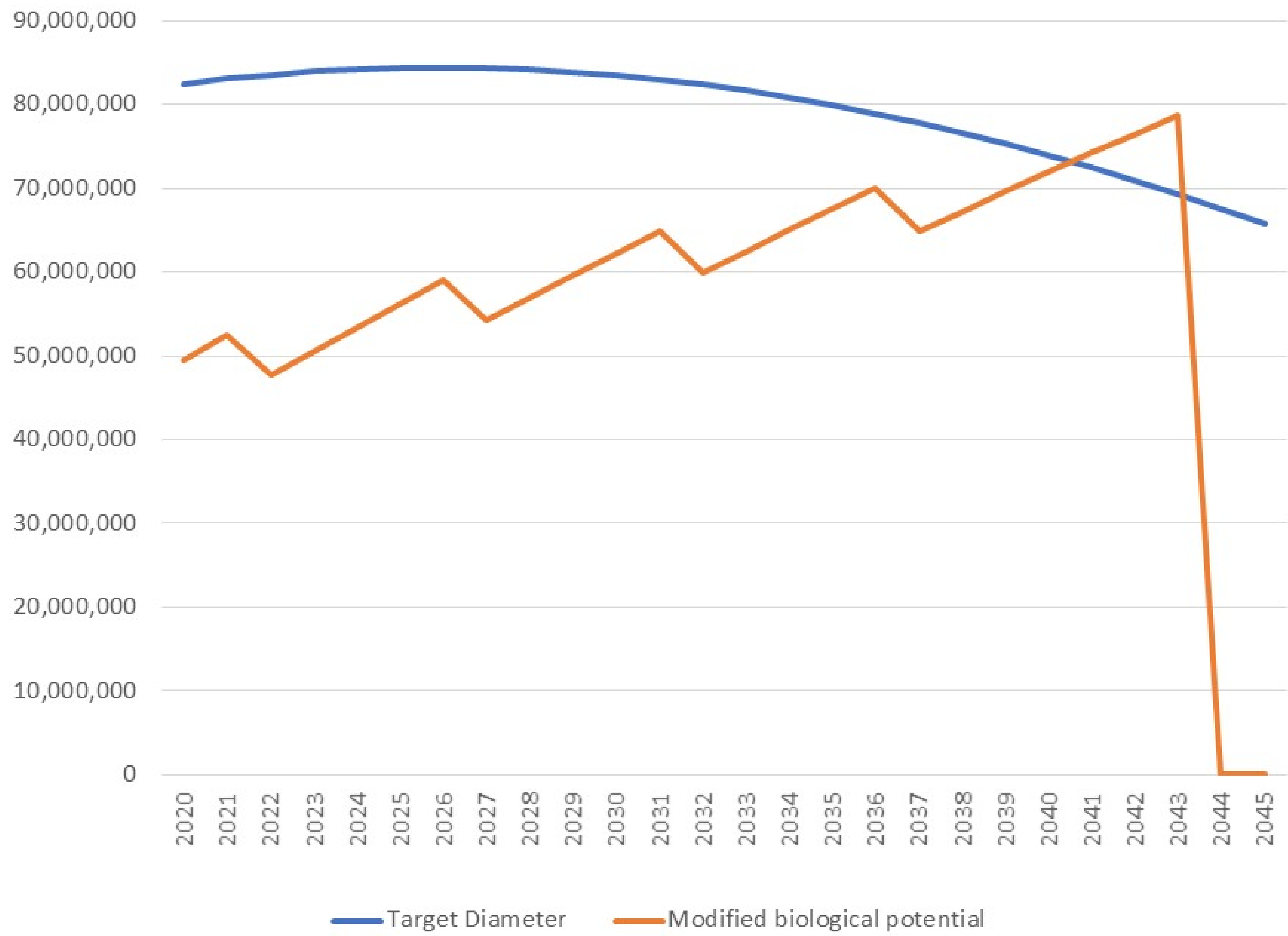


As we can see, under the modified biological potential assumptions, the harvesting prescription fells the stand when it reaches the age of maximum MAI, resulting in a spike when felling occurs. Whereas for the target diameter harvesting prescription the stand is passed to overdue handling, and felling occurs gradually over a longer period.

Conversely, if we look at the yearly standing volume under each of these management assumptions, we see very different patterns. Under the target diameter assumptions we see the standing volume of the overdue stand has a very gradual decrease for the target diameter forecast as the overdue handling is taking a small amount of volume out year on year. By contrast the modified biological potential forecast has a few steps where thinning occurs and volume is lost and a large decrease of volume at the end when the stand is felled.

Given the mix of species, ages and yield classes across a region, there are a multiplicity of stands that fall into the category of being classed as overdue under the target diameter assumptions and not overdue under the modified biological potential assumptions. The combined outcome is to ‘average’ out the larger felling volume from these stands whereas the overdue handling under the target diameter assumptions assumes some 2% of volume felled annually with no further thinning. Thereby resulting in the lower thin plus fell volume in the early periods of the forecast under the target diameter forecast than under the modified biological potential forecast.

Figure 17. Yearly standing volume for an ‘average’ Sitka spruce stand



Appendix F International definitions of gross and net increment

Increment can be calculated on a **gross** or **net** basis.

Gross increment: defined as the volume growth ignoring losses (see the Forecast Technical Document *Volume Forecast and Standing volume* (2011)). Gross increment therefore includes both losses due to natural processes and any cut volume resulting from forest harvesting operations. To calculate the gross increment for successive years, this would be:

((standing volume at the end of a year + natural losses, e.g., due to mortality and windthrow + harvested volume) – (standing volume at the beginning of a year))

Gross increment is always positive.

Net increment: defined as the volume growth less loss due to mortality, including windthrow, but not subtracting any harvested volume. To calculate the net increment for successive years, this would be:

(gross increment) – (losses, not including harvested volume, in the year).

Net increment may be negative for a stand.

This is discussed fully with worked examples in the Forecast Technical Document *Volume Increment Forecasts* (2011).

Appendix G Cumulative volume

Table 17. Cumulative volume production for the first five periods of each forecast; average annual volume within period

	2011	2016	2020 (BPDAMS)	2020 (Trgt diameter)
	volume (000m³ obs)	volume (000m³ obs)	volume (000m³ obs)	volume (000m³ obs)
England				
Unallocated overdue	18,866			
Allocated overdue		19,738	23,965	36,403
2012-16	2,184			
2017-21	2,626	3,284		
2022-26	2,450	3,001	3,302	2,570
2027-31	2,804	3,130	3,249	2,616
2032-36	2,637	2,943	3,006	2,319
2037-41		2,323	2,486	2,495
2042-46			2,821	2,057
Cumulative production	82,375	73,406	74,318	60,278
Scotland				
Unallocated overdue	19,443			
Allocated overdue		25,484	40,910	52,800
2012-16	4,614			
2017-21	5,917	7,291		
2022-26	7,796	8,096	10,202	5,092
2027-31	9,131	9,212	9,541	6,529
2032-36	8,213	9,045	10,472	8,608
2037-41		8,422	9,821	9,609
2042-46			9,430	7,965
Cumulative production	197,798	210,366	247,327	189,017
Wales				
Unallocated overdue	3,501			
Allocated overdue		4,419	8,181	9,349
2012-16	793			
2017-21	1,025	1,002		
2022-26	1,008	1,064	1,156	843
2027-31	713	790	1,093	683
2032-36	791	752	764	773
2037-41		700	856	870
2042-46			803	790
Cumulative production	25,153	21,536	23,356	19,799

Great Britain	2011	2016	2020 (BPDAMS)	2020 (Trgt diameter)
	volume (000m^3 obs)	volume (000m^3 obs)	volume (000m^3 obs)	volume (000m^3 obs)
Unallocated overdue	41,810			
Allocated overdue		49,641	73,055	98,552
2012-16	7,591			
2017-21	9,569	11,577		
2022-26	11,255	12,162	14,659	8,505
2027-31	12,648	13,131	13,883	9,828
2032-36	11,641	12,740	14,242	11,700
2037-41		11,446	13,163	12,974
2042-46			13,053	10,812
Cumulative production	305,325	305,278	345,001	269,094

Appendix H Growth and Yield models

Growth and yield models applied in this forecast

A new growth model, known as M1v2, has been developed and applied in producing this forecast. The model is an extension of an earlier model (M1), which has been applied in previous production forecasts. The key aim of developing M1v2 was to address and remove major inaccuracies identified in some of the earlier models of growth and yield.

Historical development of M1 model

The yield tables published in Forestry Commission Booklet 48 (Edwards & Christie, 1981) and subsequently in the Forest Yield software (Matthews *et al.*, 2016a) provide predictions of forest growth and yield for a range of tree species and growth rates relevant to UK conditions. However, only a finite range of management prescriptions are covered, usually representing relatively narrow tree planting spacings and 'standard' thinning, with tables representing no thinning included for some tree species. The static yield tables of Forest Yield are also difficult to apply for predicting the growth of stands with growing stock densities that are substantially different from the values given in the yield tables (e.g. relatively understocked or overstocked stands). The M1 growth model was first developed by Forest Research in 2005 to address the limitations associated with using yield tables, and the model was first applied for production forecasting in 2011 and subsequently in 2015.

The objective of developing the M1 growth model was to provide a flexible model for predicting forest growth and yield, in terms of the types of management prescriptions that could be applied and the growing stock that could be represented. A key aim was to enable dynamic predictions of growth and yield to be made across the full range of tree species and yield classes already represented in Forest Yield, rather than focusing on improving one or two species at a time. A further aim was to deliver these improvements as rapidly as possible, to address pressing requirements for more flexible and widely applicable growth models. These aims influenced the approach to designing and developing the M1 model.

Specifically, M1 is a dynamic representation of the yield tables originally published as FC Booklet 48:

- It gives results very similar to those in the yield tables of FC Booklet 48 when predicting the growth and yield of stands based on ‘standard’ assumptions about management represented in the original yield tables (e.g. planting spacings around 1.2 to 2.5 m and ‘standard’ thinning treatments)
- For non-standard management prescriptions, and for variations in growing stock, M1 uses algorithms to interpolate between, and extrapolate beyond, the results available in the Booklet 48 yield tables. Examples of the kinds of management prescriptions simulated in this way are thinning on extended cycles (e.g. 7 years) or removing a large proportion of the standing volume (e.g. as part of transforming stands to continuous cover management).

The algorithms in the M1 model use many of the growth relationships underlying the old yield tables as the basis for estimating growing stock and for calculating increment and making projections of future growth and yield. Hence the majority of assumptions about growth patterns exhibited by stands of different tree species have not been updated from those characterized in the 1960s for the construction of the original yield tables. Certain models in M1 were newly developed as part of the design of the algorithms for dynamically projecting forest growing stock:

- New models representing thinning interventions were developed that allowed more flexible and consistent representation of thinning in terms of variable thinning type (e.g. intermediate, crown, neutral), intensity of volume removed and length of thinning cycle. These models were calibrated for a range of tree species using data available on different thinning treatments in

FR permanent mensuration sample plots, including formal thinning experiments.

- Models for estimating tree survival and mortality in unthinned stands were also revised. The most important change was a new model for for Sitka spruce stands, with higher levels of tree survival predicted at narrow spacings. The Sitka spruce model was calibrated using the data on tree survival available from permanent and temporary mensuration sample plots.

When making dynamic projections of stand growth M1 also relies on several key assumptions made in developing the underlying Booklet 48 yield tables, specifically:

- The development of cumulative volume production (including losses to mortality) over time in a given forest stand is assumed to follow a model trajectory that does not change in response to thinning, provided that the removal of volume in thinnings does not exceed a threshold annual quantity (known as the 'marginal thinning intensity', see Matthews et al., 2016b), resulting in 'understocking' of the growing stock for long periods.
- A similar assumption is made regarding cumulative basal area production.
- If thinning above the marginal thinning intensity reduces the growing stock below target levels for a sustained period, then cumulative volume and basal increment are diminished compared with the rates represented in the standard yield tables.
- Thinning generally aims to remove suppressed and sub-dominant trees in stands, whilst retaining the more vigorously growing trees. Other patterns of thinning may also result in cumulative volume and basal area increment being diminished.

- The model trajectories for cumulative volume and basal area production vary slightly with planting spacing.
- The marginal thinning intensity can be expressed as a constant percentage of the yield class of a stand of trees, multiplied by the number of years for the planned thinning cycle. This percentage of the yield class assumed is 70%.

As already noted, the M1 model has already been applied in preparing the *25-year forecast of softwood timber availability* (2012) and *25-year forecast of softwood timber availability* (2016).

Development of the M1v2 model

Around the time of the development of the M1 model, the government's Macpherson Report[3] placed a responsibility on all government departments to undertake quality assurance (QA) assessments of any models routinely applied on developing and implementing government policy. Where models were accepted as being 'high impact' for policy and related practice there is a duty on the owner(s) of the models to communicate the key assumptions and limitations of the models. A duty is also placed on the user(s) of the models to understand these assumptions and limitations and any implications arising from them. In response, a QA exercise was carried out, reviewing a number of models developed and maintained by Forest Research with high-impact applications related to estimating and forecasting forest timber, biomass and carbon. This included the growth and yield models used for predicting the growth and potential production of forests and applied within the FC and private sector Forecast Systems.

The assessment highlighted some critical issues with the models for some applications and contexts. In particular, there was substantial evidence that the fundamental growth relationships referred to in the growth and yield models display

[3] https://www.gov.uk/government/publications/review-of-quality-assurance-of-government-models

significant biases. One consequence is that estimates of yield class ascribed to forest stands based on the yield models in Forest Yield are likely to be inaccurate. The conclusions of the QA assessment highlighted some important implications for evidence and information requirements for forest inventory and forecasting, including the risks of:

- Sub-optimal management of stands for volume production alongside wider objectives
- Revenue foregone
- Lost investment opportunities

Misleading evidence and guidance on certain policy issues, including the potential contribution of UK forests to climate change mitigation and the optimal management strategies for achieving this.

The outcome of the QA assessment recommended that, as a minimum response, the growth relationships referred to in the existing growth models should be updated to take account of the data currently available from FR permanent mensuration sample plots. This would make it possible to address apparent issues of bias in the growth patterns represented in the models.

The M1v2 growth model was developed to meet the above aims, and also to allow the 2020 Forecast to be based on models with improved growth relationships. M1v2 retains nearly all of the methodology of the original M1 model described earlier, but the growth relationships and yield tables it refers to are completely changed. Keeping the M1 methodology and updating the underlying yield tables offered the most effective way to develop and deliver more accurate yield models in a relatively short timescale with limited resources.

Development of YT2020 model

Revised basic yield tables were needed to provide the essential growth relationships used by M1v2 for projections. A completely new model, known as YT2020, was developed to generate a revised suite of yield tables representing standard management prescriptions (consisting of ‘standard thinning’ and no thinning).

YT2020 was constructed using sets of ‘elemental models’, describing the fundamental relationships between growth and yield variables for a range of tree species, including newly developed and calibrated models for:

- Top height development with age (Manso *et.al*, 2020)
- Cumulative volume development with top height (varying with planting spacing)
- Cumulative basal area development with top height (varying with planting spacing)
- Main crop volume and basal area development with top height under a ‘standard thinning’ treatment (also varying with planting spacing).

All of these relationships have been developed and calibrated using the latest available data from permanent mensuration sample plots maintained by Forest Research.

YT2020 also uses elemental models for predicting tree survival/mortality and the growing stock remaining (numbers of trees, basal area and volume) after different types and intensities of thinning (including after losses from mortality); these were developed for the original M1 model.

The YT2020 model can be used to produce standard yield tables for all of the tree species originally represented in FC Booklet 48, including some additional tree species and refined species groups, e.g. new models for “sequoias”, and separate models for alder, “ash and birch” and “sycamore and other maples”, replacing a combined “sycamore, alder, ash and birch” model. Yield tables can be produced for a range of planting spacings from very narrow (e.g. 0.9 m) to very wide (e.g. 8 m) and for yield classes between 1 and 40 m^3 per hectare per year. This is a much wider range than available previously and in particular allows extremes of slow growth rates in broadleaves and fast growth rates in conifers (notably Sitka spruce) to be better represented than before. Yield classes are also defined at a finer scale of intervals of 1 instead of 2 m^3 per hectare per year.

For Sitka spruce, the revision of fundamental growth relationships also considered the growth and yield of genetically improved Sitka spruce (Matthews *et al*., 2020). Data from permanent sample plots on unimproved Sitka spruce stands were supplemented with available data on the growing stock and growth of improved Sitka spruce. These data were compiled from several sources including genetics experiments managed by Forest Research, surveys in improved Sitka spruce stands on the public forest estate carried out by Forest Research and operational survey data provided by a private forest management company.

Based on an analysis of these data sources, it was concluded that the relationships describing the development of key growth variables, used in the construction of the new yield models for unimproved Sitka spruce, could also be applied for representing stands of improved Sitka spruce. The main distinguishing feature of improved Sitka spruce (the fast growth rate) could be represented by the high yield classes already represented in the new models. Future research based on improved data may permit the refinement of this approach.

Impacts of applying new yield models

The impacts on forecasts of applying the new YT2020 and M1v2 yield models are variable, depending on the tree species and yield class being considered. These impacts are illustrated below for the example of Sitka spruce stands, given the importance of this tree species for softwood forecasts. A summary is then given for the differing impacts on predictions for a range of tree species.

Comparison of models for Sitka spruce

Yield models represent complex non-linear systems, so it is not possible to make simple or general statements about differences in their predictions. Instead, comparisons need to be made for specific situations, defined by certain assumptions. Below, a comparison is made of the old and new yield models for Sitka spruce by defining the following specific question:

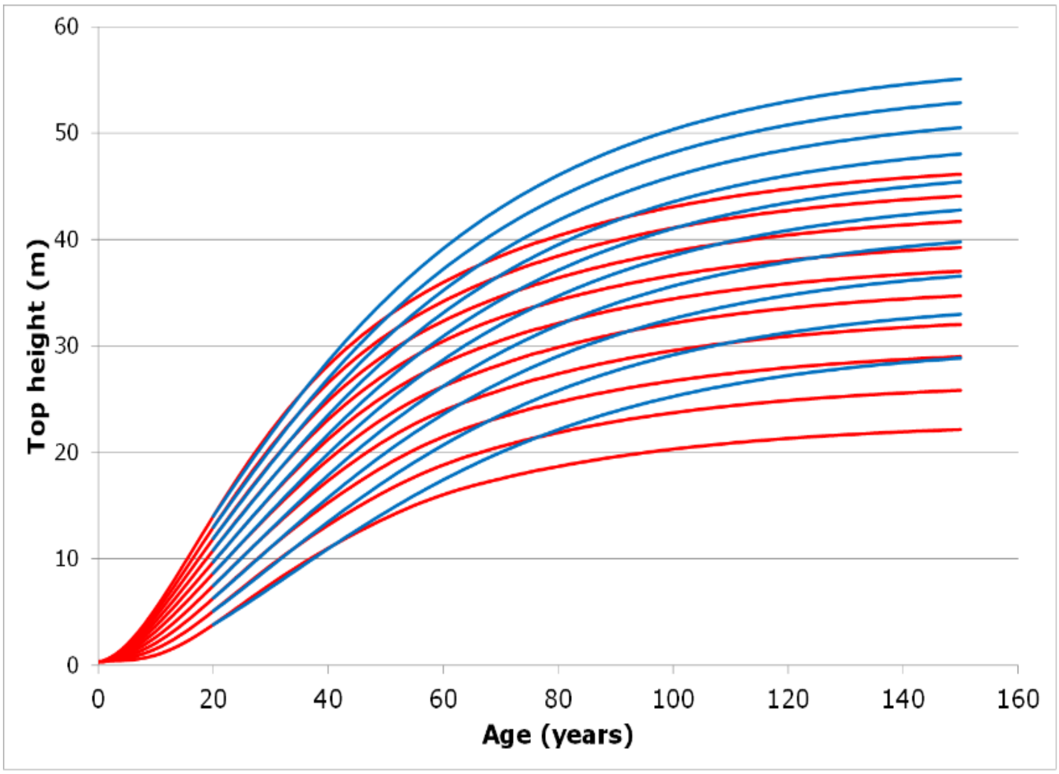
Suppose a surveyor has visited a 20 year old stand of Sitka spruce trees and measured the top height. How would the stand be predicted to develop according to the old and new yield models?

Further assumptions are needed before a comparison can be made. For this example, it was also assumed that:

- The trees were planted at the “standard” planting spacing specified in the old yield models (1.7 m spacing in the case of Sitka spruce)
- The stand is left unthinned.

Figure 18 shows the development of top height with age, as projected from age 20 using the old and new yield models.

Figure 18. Development of top height with age in Sitka spruce stands for different yield classes, as predicted by the old yield models (red curves) and the new yield models (blue curves). The red curves describe the development of top height versus age for yield classes of 6 to 24 in steps of 2.

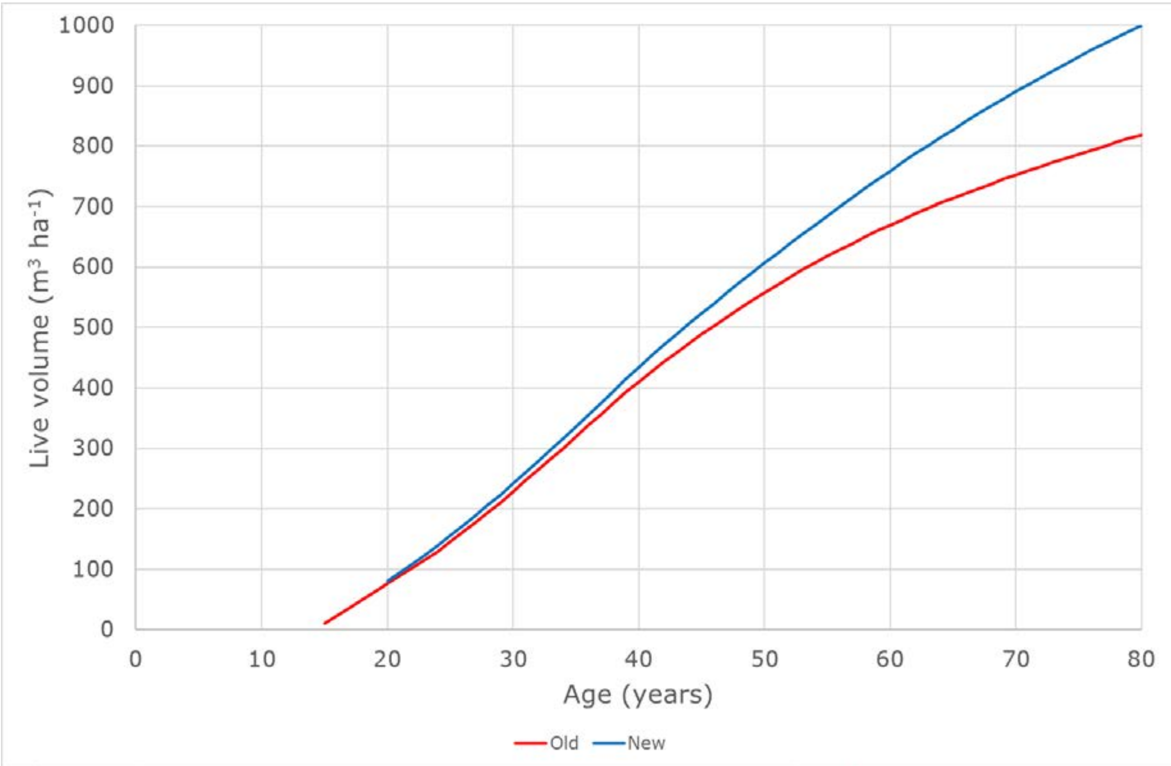


The starting point for each projection made using the new yield models in **Figure 18** (blue curves) is the top height predicted by the old yield model at age 20 (red curves), for each of the yield classes for Sitka spruce represented in the old models (6 to 24, in steps of 2).

It is apparent that predictions of top height made by the new model follow those of the old model quite closely up to a stand age of about 40 years. However, beyond this age, the new yield models predict that top height growth in Sitka spruce stands continues more vigorously than suggested by the old models. This is particularly important because cumulative volume production in both the old and new yield models is related to top height growth (see earlier in this discussion). However, note that the new predictions of top height will reach the recommended terminal heights referred to in managing windthrow risk at younger stand ages than suggested by the old yield models.

Figure 19 shows the development of live volume in an example stand of Sitka spruce trees, as predicted by the old and new yield models. These results are based on predictions for an unthinned stand planted at 1.7 m spacing, with a yield class of 12 according to the old yield model.

Figure 19. Development of live volume with age in an example stand of unthinned Sitka spruce as predicted by the old yield model (red curve) and the new yield model (blue curve). The stand has a yield class of 12 according to the old yield model.



It can be seen from **Figure 19** that:

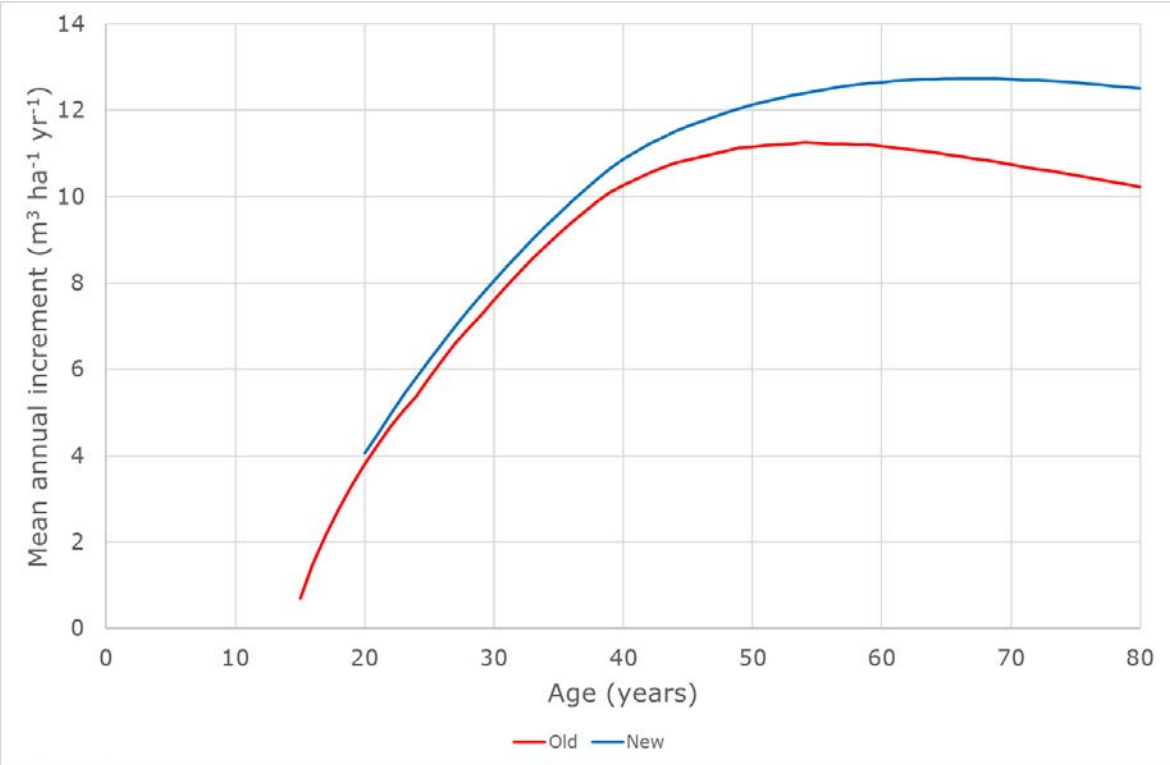
- The predictions made by the two models at age 20 are almost coincident. It is stressed that these are independent predictions made by the two models and no adjustments have been made to model inputs to get this agreement

- Projections of volume made by the two models beyond age 20 are in reasonably close agreement up to age 40. Beyond this age the predictions diverge, with the new model predicting more live volume than the old model. The new model predicts an ‘extra’ 6% of volume at age 40, 9% more at age 50 and 17% at the time of maximum mean annual increment (MAI) in the new yield model (67 years for MAI of live volume in an unthinned stand).

It follows that differences in predictions of live volume made by the two models depend on the assumed rotation age. The age at which top height is assessed to obtain a value for yield class is also a factor.

Figure 20 shows the development of mean annual increment (MAI) of live volume made by the old and new models in the example stand of Sitka spruce. Note that the projection for the old yield model does not peak at 12 m^3 per hectare per year, because volume lost as a result of stand mortality is excluded from the projected volume and the calculated MAI. (A projection of cumulative volume including losses from mortality does peak at the value equal to the yield class.)

Figure 20. Development of mean annual increment of live volume with age in an example stand of unthinned Sitka spruce as predicted by the old yield model (red curve) and the new yield model (blue curve). The stand has a yield class of 12 according to the old yield model.

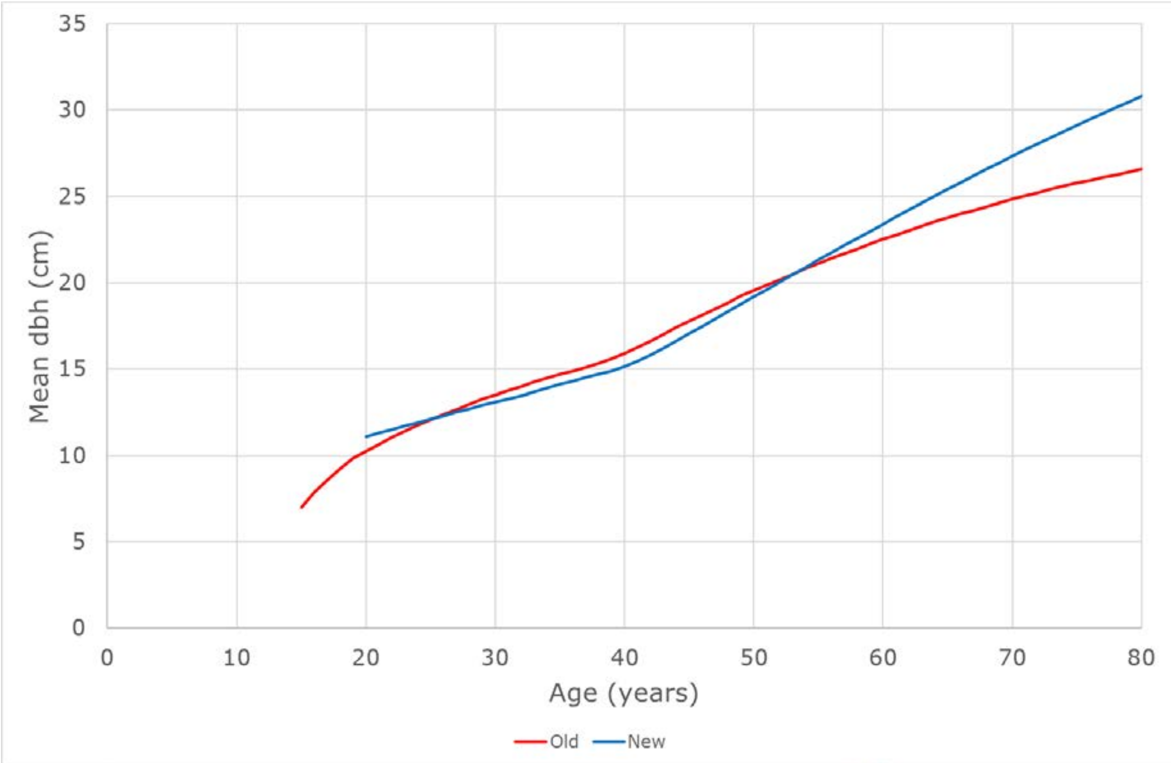


It is apparent from **Figure 20** that MAI of live volume maximises at a higher value in the new yield model (12.7 m^3 per hectare per year, compared with 11.3 m^3 per hectare per year in the old yield model). However, the predicted peak value of MAI occurs later in the new yield model (age 67 instead of age 54). The projected development of MAI in the new model is also relatively flat near the maximum value, with values close to the maximum predicted for an interval of about 30 years centred on the maximum. This interval overlaps with the time of maximum MAI predicted by the old model.

Figure **21** shows the development of stand quadratic mean dbh of live trees made by the old and new yield models for the example stand of Sitka spruce.

The predicted values of mean dbh made by the two models are quite close to one another over a stand age range of 20 to 60 years. Beyond age 60, the projections made by the two models diverge, with the new model predicting a sustained increment of mean dbh up to age 80, whilst the old model indicates a tapering off of mean dbh increment.

Figure 21. Development of mean dbh of live trees with age in an example stand of unthinned Sitka spruce as predicted by the old yield model (red curve) and the new yield model (blue curve). The stand has a yield class of 12 according to the old yield model.



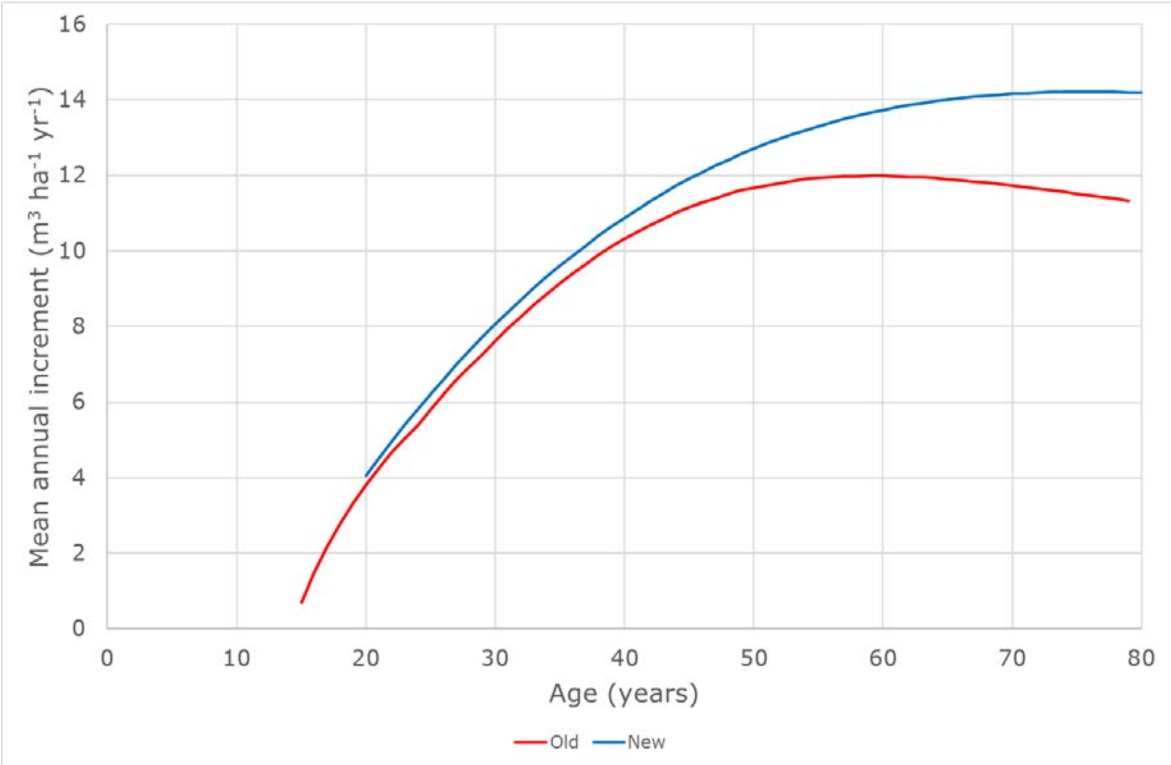
It must be recalled that **Figure 21** shows a comparison of predictions made by the old M1 model and the new M1v2/YT2020 models. This is not the same as comparing to the original yield tables published in FC Booklet 48 and Forest Yield. As explained earlier, new elemental models for predicting tree mortality/survival were already included in the M1 model developed for the softwood production forecast published in 2011. The original Sitka spruce models predict higher rates of tree mortality in unthinned stands, hence lower numbers of surviving trees, whilst predictions of mean dbh are higher than those of M1 and M1v2/YT2020, with the difference increasing with stand age.

Figure 22 shows the development of mean annual increment (MAI) of cumulative live volume made by the old and new models for an example stand of Sitka spruce similar to the one considered above, but in which thinning is carried out according to the standard ("management table") prescription. For these results, cumulative live volume at a given stand age is the sum of the standing volume plus the volume of thinnings harvested from the stand up to that point. Note that the projection for the old yield model peaks at 12 m^3 per hectare per year, as would be expected for a stand with a yield class of 12.

It is apparent from **Figure 22** that MAI of cumulative volume maximises at a higher value in the new yield model (14.2 m^3 per hectare per year, compared with 12.0 m^3 per hectare per year in the old yield model). The predicted peak value of MAI occurs over 20 years later in the new yield model (age 76 instead of age 54).

The difference in MAI depends on the age at which the comparison is made. At age 40 the difference in MAI is 5%; at the time of maximum MAI in the old yield model, the difference is 11%. Hence, the choice of felling age influences the magnitude of the predicted difference in cumulative volume.

Figure 22. Development of mean annual increment of cumulative volume with age in an example stand of thinned Sitka spruce as predicted by the old yield model (red curve) and the new yield model (blue curve). The stand has a yield class of 12 according to the old yield model.



General comparison of old and new models

The changes in predictions of top height, volume and mean dbh for Sitka spruce as a result of applying the new yield models as described above are important, given the relevance of Sitka spruce in UK forestry. However, the changes for other tree species do not follow a consistent pattern. This is illustrated by the results in **Table 18**, which shows estimates of yield class based on the old and new yield models for a selection of coniferous tree species.

As highlighted earlier, simple comparisons of yield models are not possible; the results in Table 1 have been calculated by posing the following question:

Suppose a surveyor has visited a 25 year old stand of trees (of a certain species) and assessed the yield class using the old yield models, based on an assessment of *top height. What would be the yield class if the new yield models were to be applied instead?*

An initial tree planting spacing of 2 m has also been assumed in producing the yield class estimates in **Table 18**.

Yield class estimates are rounded to the nearest whole number. Yield class estimates that are higher according to new model are highlighted in **Table 18** with green shading, whilst those that are lower are highlighted in amber.

As can be seen in **Table 18**, whilst yield class is invariably predicted to be higher for Sitka spruce when using the new yield models, this pattern is not exhibited generally for all tree species. Yield class is consistently lower for Scots pine when estimated using the new yield models, whilst for other species the new yield class may be the same, lower or higher, depending on the old yield class being compared with. It is important to note that the maximum MAI (the basis of the yield class) occurs at different times in the new yield models, compared to the old models. Predictions of MAI would change if comparisons were made for a different stand age, e.g. if age of maximum MAI in the old yield models was used for estimating MAI from the new yield models. The age of maximum MAI predicted for Sitka spruce stands is generally older when applying the new yield model, compared to the old yield model, but this pattern is not universally observed, e.g. age of maximum MAI is about the same in both models for Scots pine.

Table 18. Comparison of yield classes estimated according to the old and new yield models

Old YC	New YC						
	SS	NS	SP	DF	GF	WRC	WH
4			2				5
6	8	5	5				7
8	10	7	7	6			9
10	12	9	9	9			10
12	14	12	11	12	13	11	12
14	16	15		14	15	14	13
16	18	17		17	17	17	
18	20	20		19	18	20	
20	22	23		22	20	22	
22	24	26		24	22	25	
24	26			26	24	29	
26					26		
28					28		
30					29		

Note: SS = Sitka spruce; NS = Norway spruce; SP = Scots pine; DF = Douglas fir; GF = grand fir; WRC = Western red cedar; WH = Western hemlock.

Certain other changes have been introduced in the new yield models. The recommended time of first thinning as part of a ‘standard’ management prescription has generally been adjusted by a few years; the details depend on the tree species and yield class considered. Notably, the percentage of yield class referred to in calculating marginal thinning intensity has been changed for most tree species. Although the familiar intensity of 70% of yield class still applies in the new Sitka spruce yield models, a value of 65% has been characterised as the marginal intensity for many tree species, with values of 60% or 75% being applied for some tree species. Additionally, some early thinnings for models representing high yield classes are constrained not to exceed 40% of standing volume.

Overall impact of new yield models on forecasts

Given the many changes in the predictions made by the new M1v2 and YT2020 yield models for different tree species, it would be difficult to work out exactly how and why forecasts for the UK and regions would change by applying these models in place of the old M1 model. It is possible that the differing changes in predicted volume and mean dbh for a large set of forest components of different tree species and yield classes might cancel one another out, to give net results that are quite similar to forecasts based on the old yield model. Predicted volumes might be expected to change for regions where Sitka spruce stands form a major part of the forest area, but this depends on the assumptions made about future management prescriptions including felling ages. As illustrated above, if relatively young felling ages are assumed, the volume production in Sitka spruce stands predicted by the new yield models is similar to predictions based on the old yield models. The new yield models predict more volume production than given by the old yield models when longer rotations are considered. However, there are likely to be significant operational constraints on managing Sitka spruce stands on long rotations.

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Appendix I Modified biological potential management assumptions

A set of management assumptions intended to maximise productivity whilst factoring in thinning and wind constraints was first developed for the *50-year forecast of softwood timber availability* (2014) and also used in the *25-year forecast of softwood timber availability* (2016). These assumptions, referred to as modified biological potential, was used as the headline scenario applied to the forecasts generated for private sector forests in GB. The regime is designed:

- to maximise productivity (biological potential), within which it is assumed that timber will be harvested in the year of maximum Mean Annual Increment (MAI) as identified by the M1 models.
- to take account of thinning and wind constraints with stands being thinned unless they are assessed with a DAMS (Detailed Aspect Methodology Score) score of 16 or greater in which case they are treated as no thin and a top height at clearfell of 25 m is applied.
- to harvest a proportion of overdue stands (i.e. stands that have exceeded the prescribed age for felling according to the scenario), where overdue stands are handled according **Table 16**.
- to restock stands which are currently felled and to restock any stands felled within the forecast period according to the country-level restocking options described in **Table 13** (England), **Table 14** (Scotland) and **Table 15** (Wales).

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