Interpreting NFI Timber Volume Forecasts

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Summary

The Forestry Commission has produced a forecast of coniferous potential* timber production or availability approximately every five years since 1964, the purpose of which has been to inform policy development and investment in the timber growing and timber processing sectors. In producing the 2011 forecasts, considerable advances have been made in methodology, with improved field survey techniques, greater understanding of tree growth in new models and the capacity to model the impact of different harvesting regimes. These advances have allowed the Forestry Commission to produce a range of forecasts that will provide information on future potential timber production, carbon and biomass and also track the impact of management on the nature and structure of the forest resource.

The paper starts by describing how the Forestry Commission approached the derivation of the Great Britain (GB) production forecast for the private sector estate in the past, and goes on to explore how the Commission has built upon and improved this approach for the 2011 production forecast. There have been two factors key to this improvement. Firstly, the new forecast is using accurate and up to date inventory data as a basis for the private sector forecast. Secondly, it has developed an approach that aids understanding of the impact of future harvesting and thinning rates on the standing forest and, in so doing, has mitigated the problems involved in predicting these rates in the private sector estate. These directly influence the timing and level of potential production. Future harvesting rates also directly influence the difference between what could potentially be produced from GB forests in a given period of time and what will actually be produced. These differences arise from a number of factors, which are quantified in this paper and form part of the forecast results. The purpose of this paper is to explain how the forecasted future rates of harvesting were derived for the private sector and to explore and explain the assumptions and risks surrounding this approach.

In the 2011 forecast the Forestry Commission has distilled the historical 'single answer' approach to forecasting into several separate forecasts and products to give a fuller picture of what may happen in terms of future level of harvest and the resulting impact on forest composition. Previous forecasts only predicted timber volume production, which was founded on one view of how timber would be harvested over a 20-year period into the future. In reality, however, there is always a range of potential future levels of harvest. This range is a result of many interdependent and unpredictable factors such as the economy, the markets, wind, pests and industry practice, all of which change over time. These factors combine to give a range of potential production volume outcomes, though there can only be one actual future outcome.

* Terms such as production potential, availability, and production forecast are defined in Appendix A

To help assess the impact of such factors the 2011 forecasts distinguish what we can measure with a high degree of confidence, such as woodland area, standing volume, tree size and forecasts of timber growth and yield, from what we can predict or forecast with only a moderate to low degree of confidence, such as levels of industry activity and random events such as windblow or disease. Such distinctions enable a reliable picture of the current growing stock to be provided, onto which transparent representative scenarios can be built exploring how this stock may or may not be harvested, depending on future circumstances.

The validity of this approach has now been demonstrated by the NFI. The evidence now exists to show that even what may seem like modest changes in the assumptions used concerning the extent and timing of harvesting can have material impacts upon the total volume forecast to be produced and significant impacts on the timing of that volume. These findings are reported in the following sections and tables which illustrate the impacts of different harvesting scenarios. The analysis of the NFI data and forecast outputs has also shown that factors such as distance to road and ease of timber extraction will have relatively little impact on the overall volume of potential production in comparison to forest owner's choices in harvesting.

The use of the improved inventory data arising from the NFI has shown that there could be around 43% more potential timber production in the private sector than previously forecast. The reasons for this increase are that NFI found an increased coniferous woodland area, higher yield classes and higher stocking than was used in the 2005 forecast. These factors are explored in more depth in the NFI Statistical Report: *UK 25 year forecast of softwood availability.*

The evidence arising from the study of the different scenarios was used to help decide which scenario to use to produce the headline figures in the 2011 production forecast. Even though many future scenarios for potential production can now be run, only two have been chosen to produce these 'headline' forecasts. For the Forestry Commission estate (FC estate) currently approved felling and thinning plans were chosen, as this gave a relatively firm prediction of production, while for the private sector estate (where there is no single consistent source of felling and thinning plans) a biological potential forecast was chosen, as this set a 'ceiling' for potential production. This approach was refined by adding in restocking of areas felled within the forecast period and not thinning areas with a DAMS* score of 16 or above.

The alternative harvesting scenarios can increase or decrease cumulative production by 6% to 9% over the 25 year period. They can also cause significant differences in the

* DAMS (detailed aspect methodology score) gives a measure of an area of forest's exposure to wind.

timing of that production, with average or total production within individual 5 year intervals within the forecast period fluctuating by up to 50% between scenarios.

These factors combined have resulted in a new forecast that is radically different for the private sector compared to the last forecasts, both in terms of the absolute levels of forecast production volumes, and the complexity of the picture presented. To help with the interpretation of these results, the paper explores the reasons for choosing the harvesting scenarios used and the impact of choosing these over others. The paper also briefly covers how the Forestry Commission estate forecast was prepared for comparison purposes. This is brief since the base data for the Forestry Commission has not changed significantly since 2005 and the FC have full management plans that define harvesting practice within the forecast and thus do not require the use of scenarios and their interpretation.

The new National Forest Inventory (NFI) forecast outputs include:

- Current standing volume and forecast standing volume for the next 25 years.
- Forecast standing volume increments (gross and net).
- Harvested production arising from a range of harvesting scenarios including zero intervention, biological potential, FC estate felling and thinning plans, and a forecast based upon industry harvesting prescriptions, equivalent to those used for the 2005 production forecast.
- Biomass, carbon and straightness assessments.

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Introduction

A new approach to production forecasts

Traditionally, the Forestry Commission has supplied a forecast of availability of conifer timber volume that was predicted to be harvested over a 20-year period. This forecast of potential volume was broken down into top diameter size classes of 7–14, 14–18, 18+ centimetres, public sector and private sector and by Country. Since the establishment of the forecast in 1964, there have been a series of fluctuations in the predicted levels of 'available' timber arising from successive private sector forecasts. This has raised some concerns about the production forecast's accuracy and reliability. This concern led the Forestry Commission to review the production forecasting process to determine what could be done to prevent such fluctuations and increase confidence in the outputs. Through the review the following broad observations were made:

- In the past, the private sector forecast was not based on an accurate assessment of the growing stock.
- Assumptions made about the timing of future felling in the private sector estate were built in consultation with the sector, but often struggled to reflect actual practice or keep pace with changing practice.*
- When looking at previously forecast volumes retrospectively it could be observed that these volumes were relatively close to actual production in the private sector. It was observed that possible alternative reasons for this were:
    - that the forecasts were very accurate;
    - that the sector adjusts its future production capacity to match the forecast; or
    - that the forecast outputs were adjusted to match known future production capacity.

The review also noted that there were additional emergent requirements that the forecast should look to meet. These were:

- to take account of biomass, full-tree assortments and carbon sequestration potential;
- to forecast not only removals from the forest but also to estimate and track standing volume and increment within the forest while taking account of the impact of removals over the forecast period in order to generate a more holistic view of the sustainability of different management options.

* The approach used industry expertise of market behaviour to set generic felling prescriptions for particular species and yield classes within a region. These were then applied to the 20-year forecast period. A broader account of the approach can be found in the section: Evaluating alternative approaches to assessing future production.

Additionally, the review noted that the historical approach to forecasting would become less fit for purpose over time as:

- The Forestry Commission estate (FC estate) which had dominated production from 1970 to 2000, had since begun to be overtaken in production by the private sector estate.
- With the private sector estate becoming the principal supplier of timber, the new forecast needed to mitigate the increasing influence of the constraints on the private sector forecast caused by:
  - the weak growing stock assessment in the private sector;
  - the assumptions used for determining future felling and thinning practice in the private sector.
- The historical planting profile of Great Britain (GB), where most planting happened in the 1960s, 1970s and 1980s, led to an expected peak of conifer timber production around 2022 as these plantings matured, and it was considered to be important to test that expectation as 2022 approached.
- Initial work by the sector between 2000 and 2009 had pointed to demand for conifer timber potentially exceeding supply.
- New consumers, such as bioenergy suppliers, were entering the market and this necessitated a forecast that covered additional outputs, such as full-tree assortments and biomass.
- New consumers brought the need for a more accurate assessment of availability to allow for the improved evaluation of the impacts of additional demand.

To address these findings the Forestry Commission has implemented a new approach to production forecasting and forest monitoring overall. This approach has entailed:

- Establishing the new National Forest Inventory (NFI) of GB, which has involved the production of a map of all British forests and a programme of ground surveying of woodland areas within that map to assess the composition of forests. The survey has been conducted using a statistically designed sample and this has enabled estimates and forecasts to be produced to a known level of statistical accuracy.
- Distinguishing information on current standing timber volume and other characteristics of the forest resource (which can now be estimated with a measurable degree of precision) from future levels and patterns of harvesting (which are largely unpredictable).
- Creating a realistically estimated range of what could be produced from the GB timber resource under specified sets of assumptions about future harvesting practice. This provides a well-defined window or ‘broad path’ of opportunity within which to make

decisions, with the aim of avoiding the pitfalls in the historical approach of making one prediction of the future and ignoring the wide range of alternative scenarios.
- Expanding the outputs of the forecast to include carbon weights, biomass oven-dried weights, stem straightness scores, standing volume and increment.

This paper covers how and why this new approach was taken and explores how the results arising from this should be interpreted.

Objectives for the new forecast

In formulating a strategy for monitoring woodlands in the NFI programme, it was necessary to consider what questions needed to be answered by the NFI. Consultations between the NFI team and Forestry Commission policy teams within the countries were undertaken to determine GB forest monitoring requirements and how these would best be met. The following were identified as the high level questions that needed to be addressed in terms of timber:

- What standing volume is currently held in GB forests?
- How and why will that change?
- How fast is it growing?
- What are we currently harvesting?
- What is left?
- Is this sustainable?
- What will we harvest in future?
- Is this sustainable?

Most of these questions centre on the aspects of sustainable forest management that concern timber production.

While the forest industry has various views on the questions above, to date it has been based on little hard fact. The NFI and the new production forecast aim to support interpretation and decision-making in this area through the provision of such information. To answer these issues, basic information on metrics such as standing volume, gross increment and net increment are required.

Additionally, most of the above questions need to be viewed both retrospectively, using direct measurement to see how forests have been historically managed, and forward-looking through forecasting to see how they may be managed. Through this information, harvesting options can be evaluated in terms of how they have affected the growing stock as it now stands and how they will affect the growing stock in the future, in this way the impacts of different levels and types of harvesting activity can be evaluated.

To meet these requirements a solution was proposed that was evaluated from first principles. At its heart, this concerned the questions of what information needed to be gathered to meet the above questions, and how best this could be done. It was concluded that direct measurement of woodlands would be required, achieved through a statistical sample survey of forests. This should gather appropriate information to monitor all current forest reporting requirements and should enable measured assessments of forest parameters to be made both at a point in time and over time, the latter so that change detection could be achieved. This would additionally provide a sound body of information for forecasting.

To validate this approach a study of the approach of other countries to the task of forecasting was undertaken. The principal observation was that nearly all developed countries obtain their timber-related facts and figures through a national forest inventory, and most of these were composed of permanent forest monitoring plots. This approach enables the measurement over time of standing volume, increment and actual removals from the forest. It was also seen that in many countries the emphasis in timber reporting was on assessing the current levels of timber stock and on measuring removals from the forest. In common with the UK, these countries estimate future production in a forecast, but they do not view this in isolation from what is left within the forest after accounting for harvesting, as has been practised previously in the UK.

In the light of these findings the NFI was developed and adopted to strengthen forest monitoring. This is being achieved with the establishment of 10,000 permanent sample plots and 5,000 temporary plots across GB (see NFI Forecasts Methodology Overview) to be surveyed over a 5 year period. Having this base of information has allowed the current set of forecasts to move their emphasis from solely looking at future production, and to also accommodate measurement and reporting of estimated standing volume, increment and removals over time. This data has been the basis of providing the estimates of current standing volumes and will also, over time, produce directly observed data relating to the dynamics of increment and removals in the second round of the NFI between 2016 and 2020. In effect this series of forecasts will allow us to look forward, and in time through the establishment of a continuous NFI it will become possible to look at the same issues retrospectively.

Method and method development

A production forecast is derived through assessing what the forests are composed of today, how quickly they are growing and when this growth will be harvested. This is achieved firstly by estimating three key elements of the forests as they stand: the area of woodland, the type of woodland and its rate of growth. Forestry Commission growth and yield models are then applied to this data to predict how fast that forest will grow. This forecast of growth is then used in conjunction with assumptions about which stands of trees will be cut and when.

The UK coniferous timber production forecast is built from four separate forecasts, comprising of one for each of the Forestry Commission estate (FC estate) in Great Britain (GB); the private sector estate in GB; the FS managed estate in Northern Ireland and the private sector estate in Northern Ireland. All remaining non FC and non FS forests are referred to as 'private sector estate', but will include land owned by charities and local authorities, for example. All previous forecasts followed the same overall approach but each component forecast was derived in different ways, dependent upon ownership (FC, FS or private).

The Forestry Commission and Forest Service Forecasts

In both 2011 and 2005, the FC estate forecast was derived from the Commission's sub-compartment database (SCDB), an inventory with full coverage of the FC estate, giving woodland area, woodland type and growth rates (held on a stand-by–stand basis). This was used in combination with Forestry Commission felling and thinning plans (held as individual felling and thinning coupes across the entire estate) and these were processed through the Forestry Commission's Production Forecast system, which uses Forestry Commission growth and yield models. This process generates a prediction based on approved plans which are used to inform a commitment of production over the first five years of the forecast, and a broad prediction for the following 20 years. The Northern Ireland public forest forecast produced by the Forest Service was derived by following a similar approach and used the same growth and yield models. The main difference between the approaches used between 2005 and 2011 was the use of an updated and more highly developed version of the production forecast system, which included improved Sitka Spruce models and a wider range of thinning prescription options. A full account of the FC estate methodology for the 2005 and 2011 forecasts can be found in the *NFI Forecasts Methodology Overview* paper and the *Felling and Removals Forecasts* document.

Forestry Commission Marketing Plans

The volumes and assortments published in this removals forecast reflect the cumulative impact of managing the FC estate (as of 31 March 2011) in accordance with approved forest design and thinning plans as of 31 March 2011. These plans evolve over time to reflect emergent policies and events. For the first period of the forecast (2012-2016) the individual countries make a series of commitments to producing a proportion of what is forecast through their marketing strategies. For the Forestry Commission, beyond 2016 the forecast is a signal of intent only, but is based upon existing plans, which will as noted evolve over time. These plans however do form a sound basis for a forecast and are the harvesting scenario that was chosen for the Forestry Commission Estate.

Private Sector Forecast 2005

The 2005 GB private sector estate forecast was based upon a woodland area derived from the National Inventory of Woodland and Trees (NIWT) (which had a base year of 1995), woodland type taken from the 1995-99 NIWT field survey and growth data estimated with inputs from industry expertise. It also used generic assumptions provided by industry experts about trends in felling and thinning, rather than actual plans. In 2005 the private sector estate forecast in Northern Ireland was based upon inventory records of woodland and forests and management prescriptions established in line with the requirements of the UK Forestry Standard.

The statistical approach to predicting production potential from the GB private sector estate

Gathering inventory data in the private sector

A driver behind establishing the National Forest Inventory (NFI) in 2009 was the lack of data on GB forests. One of the NFI's main aims is to provide an accurate picture of the forest growing stock by assessing extent and type of woodland through mapping and direct measurement. The NFI also captures data on the biodiversity and social aspects of forests to provide a more holistic picture of GB forests. More detail on the approaches used in the NFI can be found in the papers *NFI Forecasts Methodology Overview* and *NFI Survey Manual.*

For the inventory of the private sector estate, the NFI produced a new GB 2011 woodland map (available on the NFI website), covering all woodland over 0.5 hectare and 20% canopy cover, including new planting, clearfell sites and restocked sites. The NFI map was based upon 25-cm resolution colour aerial photography for England and Scotland and 40-cm resolution aerial photography for Wales. The map was also validated and updated using satellite imagery, which gave an independent cross-check of woodland areas. Satellite imagery was also used to identify areas of woodland recently felled. This mapping work ensured that any clearfelling and woodland loss due to the establishment of wind farms or habitat restoration was included in the map. This map-

based estimate was refined and updated by the field survey work, which generally includes clearfelling through to 2011. This mapping represents the best estimate of woodland area in GB to date. It was found that there were 2.95 million hectares of woodland in GB, 8% more than previously estimated. This accounted for a 5.6% increase in stocked coniferous woodland area. The stocked area of coniferous species by age class can be found in the NFI Report; *Standing timber volume for coniferous trees in Britain*.

To define the areas of private sector woodland on the NFI map for the purposes of the private sector production forecast, the FC legal boundary as at 31 March 2011 was used to separate Forestry Commission forest from private sector forest. A full account of the NFI mapping exercise can be found in the *NFI Forecasts Methodology Overview* paper. The mapped woodland area results can be found in the *NFI Woodland Area Statistics* for Great Britain, England, Scotland and Wales, which are available on the NFI website - http://www.forestry.gov.uk/forestry/inventory.

Field surveys of 4,036 one-hectare sample squares were located at random within these mapped areas of private sector forests and were used to compile these forecasts. These squares represent a sub-sample of 15,000 statistically representative sample squares covering all GB woodland that are planned to be surveyed during the first cycle of the NFI survey (due for completion in 2015). At each sample square, the forest was stratified into different woodland types or stands, where information on species, management, ages and a range of other parameters were measured. An average of around two stands was found per square, resulting in data from 8,052 stands being used for the private sector estate production forecast. Within each stand, field-based computer systems were used to locate two or three 100 square metre (0.01 ha) circular plots, within which all trees over 4 centimetres dbh were mapped, species identified and diameters measured. This resulted in 228,311 trees being measured for exact location, species, diameter, age and stocking, and nearly 30,000 for stem straightness. For 59,334 of these trees, additional measures were taken of tree height and crown dimensions. All squares and plot locations were marked on the ground with metal pegs and their GPS data were recorded. At least 8 % of squares were remeasured by an independent quality assurance team in the field for the purposes of checking surveyor accuracy and consistency and all squares went through a series of quality assurance processes by office based teams. The *NFI Forecasts Methodology Overview* and *NFI Survey Methodology* papers cover this methodology in detail. This is the largest mensurational exercise ever undertaken on private sector woodland in GB.

Predicting future levels of harvesting in the private sector

A new approach to assessing the effects of future harvesting strategies upon potential production in the private sector estate was established for the 2011 forecast. This was done by evaluating a range of scenarios representing alternative harvesting strategies for their impact upon potential timber production over the 25-years.

The rationale behind this approach is that forecasts are derived by applying timings and extents of felling and thinning to an assessment of the growing stock. As levels of harvesting activity may vary under different market and policy conditions over time, it is very difficult to predict this over a 25-year time frame. In light of this the Forestry Commission has sought to find an approach to forecasting that, while not being too prescriptive about an uncertain future, can illuminate a 'broad path' down which events are likely to evolve. This broad path is set by the scale, nature and composition of the growing stock, paying particular attention to the age and growth rate of trees.

Evaluating alternative approaches to assessing future private sector harvesting rates

The 2005 private sector estate forecast was based upon a single prediction of levels of harvesting for a 20-year period. This involved Forestry Commission working with industry to build an industry view of how all the various elements that impact on levels of harvesting would combine into a specific level of harvesting activity over a 20-year period for each 2005 forecast region. While this approach had the benefit of giving a single firm result, it over-simplified a complex picture by effectively distilling a range of harvesting possibilities that could potentially happen into a single scenario with a single outcome. The approach used industry expertise of market and owner behaviour to set generic felling prescriptions for particular species and yield classes within a region. These were then applied to the 20-year forecast period. This was a difficult task for many reasons, including a poor evidence base on woodland ownership and intent from which management approaches can begin to be built. This resulted in applying a range of about 20 prescriptions of harvesting practice against hundreds of thousands of stands across GB and this very broad-brush approach over-generalised the picture of harvesting behaviour on a stand-by-stand basis.

Even if this approach was successful at describing harvesting approaches at one point in time, applying this single set of prescriptions constantly over two decades was problematic when taking into account the fluidity of markets and changing approaches to harvesting. This over-simplification of the future level of harvest was done to the point where it was improbable that the forecast would meet any prediction it made, because as time went by and if events other than those used to build the original assumptions transpired, actual harvesting levels were always bound to move away from the harvesting levels originally predicted. Therefore it was concluded that solely relying on

this approach was increasingly unreliable and a new approach needed to be established that enabled a range of potential future outcomes to be assessed. Advances in technology made available since the 2005 forecast enabled the FC to build the capacity to test a potential range of outcomes through running multiple harvesting scenarios.

Despite the difficulties involved in making a prediction of future private sector estate harvesting, there is still the need to provide a realistic view of potential or likely levels of timber production so that appropriate planning and investment can be made by the sector. An approach taken in other sectors to manage predictions with such uncertainty is to provide a range of scenarios for the future. These scenarios set out to encapsulate the 'worst case' and 'best case' scenarios for a given factor, often augmented by a 'probable case' falling between the two extremes. It was decided that a similar approach would be applied to timber production forecasting. If constructed correctly such scenarios for forestry should be relatively realistic as they are largely formed or bounded by the physical constraints of the biology of the growing stock, based upon the species, age and growth rates of the woodland resource. Within this range of scenarios, assessments can be made of the most likely outcomes under current or future circumstances and plans can be made accordingly. This has involved building a range of potential harvesting scenarios to help gauge the range of potential harvesting outcomes that may transpire over the 25-year period. The 2011 production forecast has used this approach to build a series of harvesting scenarios which centre on building an objective view of potential biological availability. The 2005 harvesting assumptions have been retained as the basis of one scenario, but this is now one of several scenarios analysed and is primarily used for the purposes of comparison with the 2005 forecast results.

The Forestry Commission has therefore, through the NFI, collected a body of data reflecting the composition of the forests and the associated physical constraints, such as growth rates, ages, and current and past harvesting levels. Alternative future harvesting assumptions have then been applied to this data to build a picture of how the growing stock may develop under these different scenarios.

Using this approach, the Forestry Commission has calculated a range of likely levels of timber that could come to market. Also the Forestry Commission has supplied estimates of the volumes involved with certain possible events, so that the potential impact of some factors such as pest outbreaks (e.g. the volume of timber susceptible to Phytopthora) can be assessed. It is then possible to evaluate the opportunities, risks and constraints associated with such events, which was not possible with a single interpretation or prediction of the future, as was supplied in previous forecasts.

This approach has been developed with input from the Confederation of Forest Industries (Confor), the Expert Group on Timber Trade Statistics (EGTTS) and the Private Sector Production Forecast Working Group.

Building scenarios of potential production

The 'broad path' of production set by the growing stock

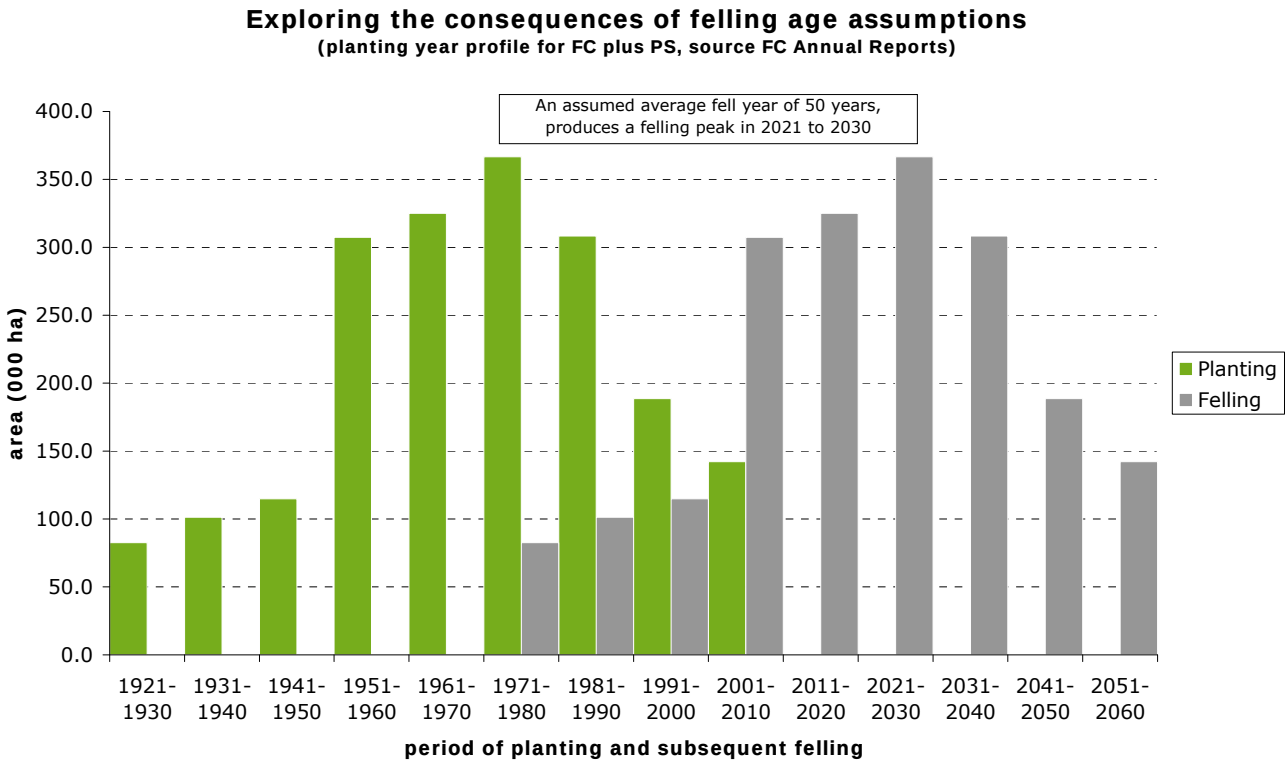
Once a coniferous crop is planted there is, in general, a sequence of predetermined, time-bound events set in motion. For most conifer crops, the year the crop is planted determines a future window of time within which it is likely to be felled. This life expectancy is often a product of the biological growth pattern of the tree, however, other factors combine with this to determine the timing of fellings. These are often economic in nature, but there are a wide variety of other owner objectives that may affect this timing. One particular factor is that many tree crops, especially those in the uplands, are felled because of the increasing likelihood that they will be blown over. This is a significant factor at present because of the dominance of upland Sitka spruce planting between 1960 and 1990 that will affect harvesting in the coming decades.

The time when a large proportion of forest owners choose to fell a planted crop will generally therefore fall between two physical bounds: after the trees have reached a size to harvest 'economically' (in the sense of realising assets sooner rather than later) and, for many stands, before the trees get so tall that they blow over (in practice between about 25 and 80 years after planting, dependent on species and site conditions) or slow down in growth. However, most conifers are unlikely to be felled much before 30 years or after 60 years of age, so there is a narrower probable window for the felling event. Thus, looking at when coniferous crops were planted can indicate a broad picture of when many are likely to be felled, and this can form the basis of a forecast. However, some owners will have other objectives to that of felling for purely economic purposes and may retain woodland, for example, for recreational, biodiversity or economic strategies other than realising assets in the shorter term. A proportion of woods will fall into this category and may therefore be felled later than would be expected by the 'economic' scenario.

Considering these factors, the best indicator of what may happen in the future in terms of harvesting is what happened in the past in terms of year of planting. On that basis, assuming a rotation of 30–55 years for conifers gives a broad but not unfeasible range of likely timings of fellings for a significant proportion of owners. It is therefore crucial to look at the timings and history of planting of conifers in the UK to estimate when harvested volumes will arise. In the UK there was a large post-war surge of planting, between 1960 and the late 1980s. This can be seen in green in Figure 1. Using the rule of thumb that most trees will be felled between the ages of 30 and 55 years we can begin to predict that this planting would be expected to produce a surge of felling during the period 1990 to 2040. In the 1980s the peak of this felling was predicted to fall around 2020 and is represented in grey in Figure 1. Since this prediction was built upon felling practices and felling ages that have since altered, the period when timber volumes are now likely to peak may well fall at a different point in time. It has been a core aim of

this study to pinpoint, as well as possible, the timing and scale of this peak, and the factors that will influence it.

Figure 1. Historical GB planting programme and consequent potential felling



Source: Forestry Commission Statistics

Within this biological bound of age, size and height of the trees broadly determining felling age, there are other factors to consider. Some of these can be measured easily, such as the growth rates of the trees themselves (which can determine, for example, age and year of maximum mean annual increment) and others which are more difficult to ascertain, such as policy, macro-economic factors and market demand, which present a wide range of possibilities. The study has worked to encapsulate the extremes of this range of possibilities and within those extremes to describe a range of possible outcomes, largely based upon less subjective determinants of felling age such as maximum MAI.

These outcomes describe the potential levels of timber that may be harvested and the potential standing volume remaining in the forest over time. They also attempt to illustrate the effects of factors that may prevent timber being harvested. The amount of standing volume removed also impacts upon certain measures of sustainable practice

and other important factors such as the levels of carbon sequestration in forests. Therefore, understanding the impact of these factors (growth rates, policy, markets, pests etc) upon harvesting levels is clearly important in terms of managing forests sustainability for both the environment and industry.

The impact of recent harvesting on potential production

Another large determinant of what is likely to happen in terms of future felling levels is what has already been felled. Clearly if the stands have already been harvested before the start of the forecast period they cannot contribute to future production. For example a large proportion of crops were planted in the 1960s to 1980s, if some owners are harvesting at 30 years of age, then many of such stands will have already been harvested and will not contribute to short term production. (Though in the longer term, further production can arise from restocked sites.) This assertion is supported by the rates of clearfell found in the satellite detection work used in producing the NFI map and by the NFI field survey, which has found that relatively few of the older conifer stands planted before 1970, and those of larger mean tree diameter, remain. How much of that asset is still standing will determine what is left for future cutting in the coming years. Therefore it is important to ascertain what has been harvested to date to ensure that the estimated growing stock and basis for the forecast is up to date.

Advances in satellite imagery and computer processing have enabled the Forestry Commission to pinpoint actual clearfell rates on a site-by-site basis much more accurately than in the past. However, such satellite imagery cannot identify areas of thinning and that therefore is discovered through the NFI field work. Having an up-to-date rolling field survey programme will further strengthen the evidence base for monitoring clearfell rates. This has currently given a much clearer picture of what has already occurred in terms of felling, and from this a better picture of what can still be felled can be built.

The 2011 production forecast was run on the basis of an up-to-date inventory which takes account of recent felling and thinning. Having this facility in place is particularly important in a period where felling rates are peaking and where the levels of harvest can fluctuate.

By monitoring levels of harvesting in the private sector, improvements are being made to current growing stock assessments and this information also narrows down the range of potential future production levels, which will make predictions of what may happen more closely representative of actual future out-turns.

The presence of permanent monitoring plots within the NFI will, over time, provide a picture of how different types of crops, under different ownership types, are thinned and felled, and this can be used to inform future production forecasts.

Measuring increment and actual cut over time

As noted earlier, the NFI's fieldwork and NFI forecasting emphasis will move GB from solely looking at estimates of future production, to one where this is seen in the context of measured standing volume and measured removals over time. Such actual observations will, over time, give a better indication of probable future cut. More importantly, they can be used to assess whether harvesting levels are sustainable over the medium term. However, there are currently several different interpretations of what constitutes a sustainable harvest, at a National or Regional level and a framework for measuring this within the UK is not in place.

Harvesting factors relevant to the 'broad path' of potential production

In the past the limitations of data and technology meant that only one forecast outcome was produced in each five-year forecasting exercise. This single forecast was often viewed as 'fact', not as it should have been as one future option of many that were possible. This was often forgotten and implicitly meant that the alternative options were not widely considered.

There is now the capability to look at several options and forecasts. The starting point chosen for reviewing these options is the 'base' biological potential of the woodland resource. This is the unrestricted biological capacity of the forest assuming no losses in productivity due to wind, pests etc. To this biological potential a series of constraining factors can be applied that will limit production from this theoretical maximum to a more realistic or practical level.

Essentially the range of potential scenarios and potential production falls between felling nothing at all (zero intervention) and felling everything. When building an overall picture of future harvesting regimes, actual outcomes will fall between the two extremes and the scenarios published fall more in the middle ground. But by defining these 'extreme' volumes, which can be confirmed with some certainty, the limit of the risks involved in assessing a level of harvest can be bounded. Such risks involve factors such as wind risk, pest and economic swings. By quantifying these risks, users of the forecasts can plan accordingly.

Factors that constrain and reduce production

To understand the difference between potential production and actual production the main factors that constrain volume production other than the crop's inherent biology can be considered, such as physical constraints (wind, roads), biological constraints (pests), legal constraints, management choices and national policy constraints. Figure 2 shows how 'netting off' these constraints reduces actual production.

Figure 2. Factors limiting actual production

1. The growing stock and its yield	----------
2. Less effects of physical factors	----------
3. Less effects of biological factors	----------
4. Less legal constraints	----------
5. Less policy constraints	----------
6. Less economic constraints	----------
7. Available timber	----------
8. Actual levels of harvesting	----------

These factors are determined by a variety of sub-factors, of which the main ones are listed below:

- Growing stock and increment levels:
  - the resource (area, species, age, yield)
  - silviculture
  - historical removal strategy's impact on current growing stock
- Physical factors:
  - wind
  - fire
  - roads
  - terrain
- Biological factors:
  - pests
  - disease
- Legal obligations:
  - UK law
  - European law
- Policy drivers:
  - Forestry Commission
  - UKFS (UK Forest Standard)
  - National Strategies (England, Great Britain and Wales) and Forest Service Northern Ireland's strategy
  - Funding levels within the public sector and incentives within the private sector.
  - International policies

The first level (level 1, see Figure 2) starts with the growing stock and its increment, which is the volume of all the trees that are growing. At its most basic level the growing stock (or standing volume) is a measurable fact and its projected increment involves minimal assumptions. These combine to provide a firm basis for projections of potential production. However, when looking at production over time, larger assumptions need to

be made about removals (level 8) and their impact on standing volume and increment over time.

At level 2 the volume that cannot be brought to market due to inescapable physical constraints is excluded, such as trees predicted to be lost to wind damage or that are inaccessible because of the terrain. Constraints on thinning and felling through exposure to wind or the risk of wind damage also need to be considered.

At level 3 the impact of attack by pests and disease is taken into account, whether this is actual volume lost or volume rescheduled as part of sanitation procedures.

At level 4, in principle, the potential is reduced by excluding areas for cutting that are protected by legal constraints. However, the UK does not have any outright bans on felling, but there are areas where there are restrictions on felling, such as tree preservation orders (TPOs), which can cover several trees in a single area. Such legal restrictions are modest in GB.

At level 5, availability can be further reduced through the policies that are set for the sector as a whole (e.g. the UK Forestry Standard) and those that individual organisations choose for themselves. Many woodland owners follow the principles of Sustainable forest management, which involves ensuring that the production of all forest and woodland benefits is maintained over the long term. This is achieved when the environmental, economic and social functions of forests and woodlands are interacting in support of each other. The precise point of balance will vary in individual forests and woodlands in response to management objectives and local circumstances. Volume production and increment is only one measure of this.

At level 6, availability is reduced by volume that is not considered to be economic to harvest.

That leaves, at step 7, the 'true' available or potential timber volume, which sets the envelope within which an attainable level of harvest can be determined. In practice steps 6 and 7 blur, with areas moving from 6 to 7 if timber prices are high etc.

Out of this potential volume decisions can be made on how much to cut, represented by step 8, the actual level of harvest.

Figure 3 summarises the factors that affect the level of timber harvesting in GB.

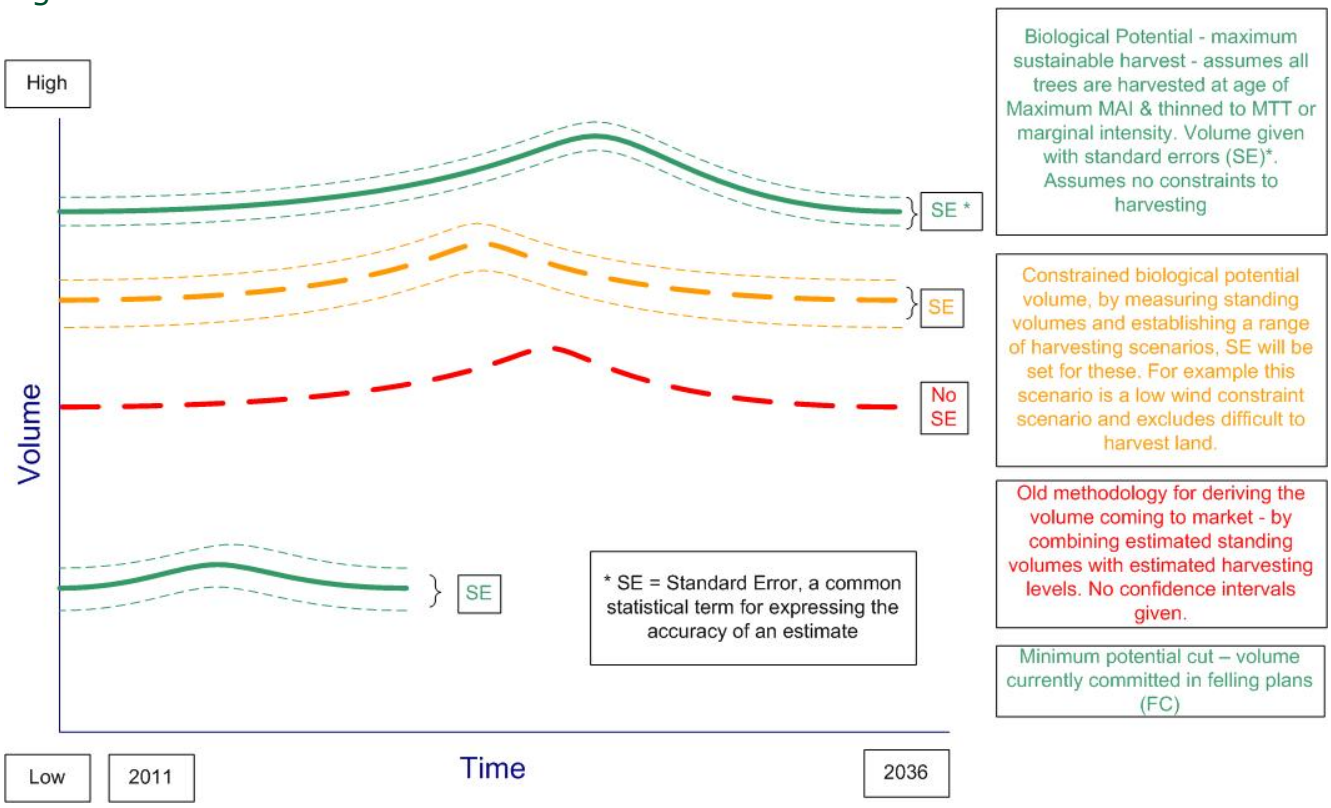
Figure 3. Factors that affect the level of timber harvesting in GB

Harvesting activity levels are set by factors such as:

- biology
- physical factors
- market/demand
- economic viability (thresholds/scale)
- harvestability
- custom and practice
- entry costs
- regulation and incentives

Forecasting potential harvesting levels is key to looking forwards and the NFI forecast provides a 'maxima' and 'minima' of potential harvesting levels, supplemented by assessing the factors that will affect these. Within this range of maxima and minima the Forestry Commission is providing credible alternative scenarios on potential levels of production, dependent upon possible market and policy scenarios, including cut under committed plans. Figure 4 outlines this approach and is the original figure used in consultation with the sector while developing the approaches.

Figure 4. Production forecast scenarios



Forecast Scenarios

To gauge a potential range of possible harvesting outcomes a series of standardised harvesting scenarios were developed for the production forecast. These were:

- **Clearfelling to biological potential**. This assumes choosing a felling age which maximises long term productivity by harvesting at first year of maximum mean annual increment (maximum MAI)*. Within this overall approach to felling, several variants were defined:
    - **Biological potential felling and thinning all**. A scenario which maximises productivity by felling at age of maximum MAI in all stands irrespective of wind risk and to thin all stands to management table thinning (MTT), throughout the forecast period (from 2011 onwards).
    - **Modified biological potential, thinning and felling assuming moderate wind risk measures**. This scenario takes account of wind risk, but assumes a relatively risk-tolerant approach in applying wind-risk constraints to harvesting practice. This assumes felling to year of maximum MAI and thinning of all stands to management table (MTT) in all crops less than DAMS 16, and felling at an assumed terminal height of 25m (if this is attained before year of maximum MAI) and no thinning for stands at or above DAMS 16.
    - **Modified biological potential, thinning and felling assuming strong wind risk measures**. This scenario also takes account of wind risk, but applies a less risk-tolerant constraint to harvesting practice. This assumes felling to year of maximum MAI and thinning of all stands to management table (MTT) in all crops less than DAMS 16, and felling at an assumed terminal height of 21m (if this is attained before year of maximum MAI) and no thinning for stands at or above DAMS 16.
    - **Modified biological potential, assuming thinning based upon observed activity**. This scenario sets year of clearfell at first year of maximum MAI for all mature stands and thinning to MTT is only applied in those stands which were observed within the NFI field survey as having been thinned already. No special wind-risk measures are assumed for mature stands. However, for stands that are too young to have yet been thinned according to management table prescription (taken to be younger than three years after prescribed age of first thin) the scenario assumes management according to the modified biological potential scenario with moderate wind risk measures, described above.
    - **Biological potential felling with no thinning.** Felling to maximise productivity by harvesting at first year of maximum MAI and undertaking no thinning.
- **Felling and thinning to the 2005 industry 'view'.** This scenario uses region-specific sets of harvesting prescriptions based upon what the sector thought would be

future harvesting practice with regard to age of felling and amount and type of thinning. These were derived in consultation with private sector growers and processors and were the basis of the 2000 and 2005 forecasts.

- **Management felling and thinning plans.** A forecast based upon detailed, stand by stand plans prescribing age of felling and type and intensity of thinning. **This applies to the Forestry Commission only.**
- **No harvesting.** Known as zero intervention**, this** scenario assumes no felling or thinning of any stand.

Forecasts were run for each of these scenarios, the outputs of which are presented in the results section.

*Age of first year of maximum mean annual increment has been a standard often used for setting a target for maximising timber productivity within stands over the long term and it is used on this basis within the biological potential scenarios within these forecasts. However, there is evidence to show that there are possible alternatives to achieving higher levels of productivity other than felling at first year of maximum MAI. This evidence points to there being a wide range of years where most of maximum productivity could be achieved. This range might be as wide as 20-30 years where maximum MAI to +/- 5% could be achieved. Such alternatives are currently being researched by the Forestry Commission.

Measuring the outcomes of different harvesting scenarios

Assessing the impact of scenarios in terms of average annual production within a 5 year period is the industry 'norm' for assessing potential production and these are the headline figures produced by the forecast:

Average annual production

This is the standard metric for assessing production and is the average annual amount of thinning and felling volume, produced over a 5 year period. This has formed the basis of the main tables or outputs of previous production forecasts.

This is now to be augmented by assessing other forest metrics that are intrinsically linked to average annual production, such as the amount of:

- overdue timber
- cumulative production over the forecast period
- the opening and closing standing volume within the 25 year period
- considering these metrics and average annual production over longer time scales.

Overdue timber

Overdue timber is that situated within stands that are over the age prescribed for felling by the management scenario used for a forecast. Application of the rules of the scenario dictates that such stands be immediately felled on day one of the forecast. With this being the case, this prescription is followed in the implementation of the forecast, but the volumes immediately felled by reason of being overdue are reported separately from other harvested volumes in recognition that this is an artificial and unlikely occurrence. The fact that, in the private sector especially, volume of overdue timber is non-zero and represents a significant amount of total standing volume at the start of the forecast indicates that a portion of the estate is not currently being managed according to the assumed scenario. For 'biological potential' type scenarios, this in turn 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. Since such stands are currently being managed in a way contrary to the assumed prescription, these, and some other stands that are currently below the age of maximum MAI, are also not likely to be managed in the assumed way in the future.

Reasons for such observed delayed felling leading to the existence of overdue timber at the start of the forecast is not known. For a particular stand, it could be for economic reasons (to obtain a larger log size, or the site is in a location that makes harvesting uneconomic, for example), or it may be that the stand is not being managed for production purposes, and there are no plans to fell the stand.

This is a different approach to that taken in 2005, when a panel of industry experts worked through a series of prescriptions to reflect industry behaviour in felling practice, and the prescription resulted in 27 million cubic metres of timber in the overdue category. This showed that not all owners operated to the 'norm' and that at least two tiers of harvesting practice were in operation at that time. In the 2005 forecast 18 million cubic metres of this overdue timber was allocated to be felled over a 20-year period and the remainder was left out of production.

Additionally, as a result of applying scenarios consistently, all areas felled as overdue will be restocked on a like for like basis, as per any other felled stand in the forecast period. In most scenarios, this approach will not materially impact on the forecast timber removals as the replacement crops will not mature within the forecast period.

It is the case, however, that restocked crops will contribute to the future standing volume of the growing stock, and this contribution increases through the forecast period. It should be noted, when interpreting the results of the forecasts, that these contributions derived from restocking of overdue crops are included in the forecasts of future standing volume.

Cumulative production

Cumulative production is the total amount of timber that would be harvested throughout the 25 year period if the scenario were to be applied. It is the sum of each year's production and it also has the total volume of the overdue timber added to the sum of production, to give an overall figure for all timber volumes that have arisen from the forest resource. It is a useful measure because comparisons between cumulative production arising from alternative scenarios remove the 'noise' around forecast volumes moving between 5 year periods within the 25 years under the different scenarios.

Standing Volume

Estimates of standing coniferous volume measure the total amount of standing coniferous volume within a forest area at a given point in time. Standing coniferous volume is defined as live coniferous stem wood to 7 centimetres top diameter and excludes roots, stumps, branches, foliage and deadwood. It also excludes standing volume in trees in woodlands of less than 0.5 hectare. Forecasts of how these volumes change over time could be used as a basis for measuring sustainable forest management. A representative snapshot of current standing coniferous volume and how it changes over time (within a 25-year window) is available in the NFI report *GB 25-yr forecast of standing volume and increment.*

Opening and Closing Standing Volume

Over any period of years, closing standing volumes are calculated by the formula: Closing standing volume = opening standing volume + total net annual increment – total annual removals. The totals for net increment and removals are obtained by summing these over the years of the period in question. This measures the net material effect upon the standing volume in the forest through harvesting to that scenario. It is an 'opening and closing account' of forest timber stocks, between the start of the period (opening standing volume) and what is remaining at the end (closing standing volume).

Longer term forecasts

A large determinant in the levels of total standing volume, potential production, overdue and cumulative production in GB is age class structure. GB's history of creating a man-made forest resource has created an uneven age class structure, which determines the evolution of standing volumes. This is in contrast with forests of a more evenly distributed age, which results in a more stable evolution of standing volume and increment. It should therefore be noted that any forecast is a snapshot of forest metrics, in this case for example taken over 25 years, looking at a fraction of the life cycles of the forests. If a 50 or 100-year window were to be used, a different perspective would be given. In the GB context therefore it is important that the age profile of the forest resource is taken into account when drawing meaningful conclusions on sustainable forest management of the GB forest estate.

Results

The factors that will impact on unrestricted biological potential include physical, biological, legal and policy constraints. The following tables and figures quantify the impact of each of these constraint factors in terms of either the volume lost to a factor through applying a scenario or the % area of forest involved or 'lost' from potential production to a factor .

Table 1. Scenarios for factors affecting levels of private sector production in 000m^3 obs

Scenario	Standing volume 2012–16	Standing volume 2032–36	Overdue	2012–16	2017–21	2022–26	2027–31	2032–36	Cumulative production
No harvesting	242,807	452,549	-	-	-	-	-	-	-
Biological potential constrained by physical factors									
Biological potential felling with no thinning	174,713	149,487	52,069	5,318	8,382	8,778	12,335	11,765	284,961
Modified biological potential, thinning and felling assuming moderate wind risk measures	175,227	139,305	41,810	7,591	9,569	11,255	12,648	11,641	305,325
Modified biological potential, thinning and felling assuming strong wind risk measures	167,979	131,012	48,644	7,584	10,465	11,202	11,494	10,487	304,812
Biological potential, assuming thinning based on observed activity	164,315	122,132	54,268	7,025	9,217	10,800	12,786	11,077	308,785
Biological potential felling and thining all	176,917	142,286	38,999	7,908	10,147	11,268	12,661	12,307	310,458
Market behaviour									
Felling and thinning to the 2005 industry 'view'	149,214	125,010	66,158	7,818	9,324	9,216	8,654	9,355	287,993

Notes:

- DAMS – detailed aspect methodology score

Standing volumes for the period 2012-16 differ between scenarios as the volumes for each period are derived by applying the different rates of felling and thinning assumed for each scenario in the first 5 year period. The amount of felling and thinning alters between scenarios, including the amount of overdue timber arising in the first year. More thinning and felling in the first five years and more overdue timber that is felled in the first year therefore result in less average annual standing volume in the first period.

It can be seen that opening and closing standing volumes vary significantly between scenarios, as does the amount of overdue. Average annual production varies between scenarios within 5 year periods, but cumulative production does not vary by more than

10% between scenarios. For assessing the impact of biological factors such as pests and diseases see tables 5 to 14, where this is dealt with separately.

Table 2. Factors that can restrict private sector harvesting

Constraint		% of Private sector woodland area
Harvesting constraints - terrain	% of stands where mechanised harvesting possible	94
	% of stands that require skyline harvesting	1
	% of stands that could not be harvested by tracked or wheeled vehicles	4
	% of stands where mechanised harvesting impossible	1
	Total	100
Harvesting constraints - roading	% of stands within 200 metres of a harvesting road	53
	% of stands within 200 to 400 metres of a harvesting road	19
	% of stands within 400 to 600 metres of a harvesting road	10
	% of stands within 600 to 800 metres of a harvesting road	6
	% of stands within 800 to 1000 metres of a harvesting road	4
	% of stands greater than 1000 metres to a harvesting road	9
	Total	100
	Current windblown area	3
Less legal constraints	No legal constraints	0
Less private sector policy constraints	TPOs limit the most, SSSIs to some extent, but the UK, unlike many other countries, has no area where felling is illegal	

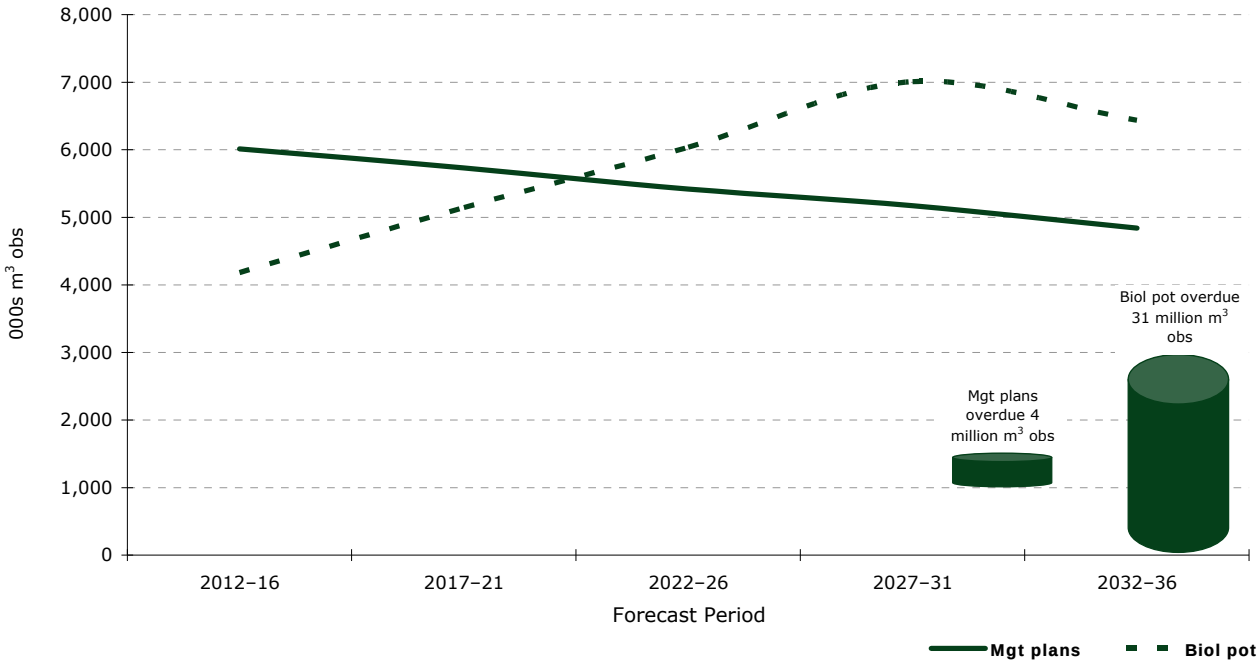
Notes:
- TPO – Tree Preservation Order
- SSSI – Site of Special Scientific Interest
- Harvesting roads could either be inside or outside of the forest and no assessment is made of whether the stand could practically be linked to the road

Table 3. Scenarios for the Forestry Commission estate

Scenario	Standing volume 2012–16	Standing volume 2032–36	Overdue	2012–16	2017–21	2022–26	2027–31	2032–36	Cumulative production
Biological potential constrained by physical factors									
Modified biological potential, thinning and felling assuming moderate wind risk measures	98,699	82,647	30,624	4,180	5,143	6,035	7,009	6,437	174,645
Market behaviour									
FC Estate management plans	114,821	95,408	3,900	6,013	5,730	5,420	5,172	4,841	139,781

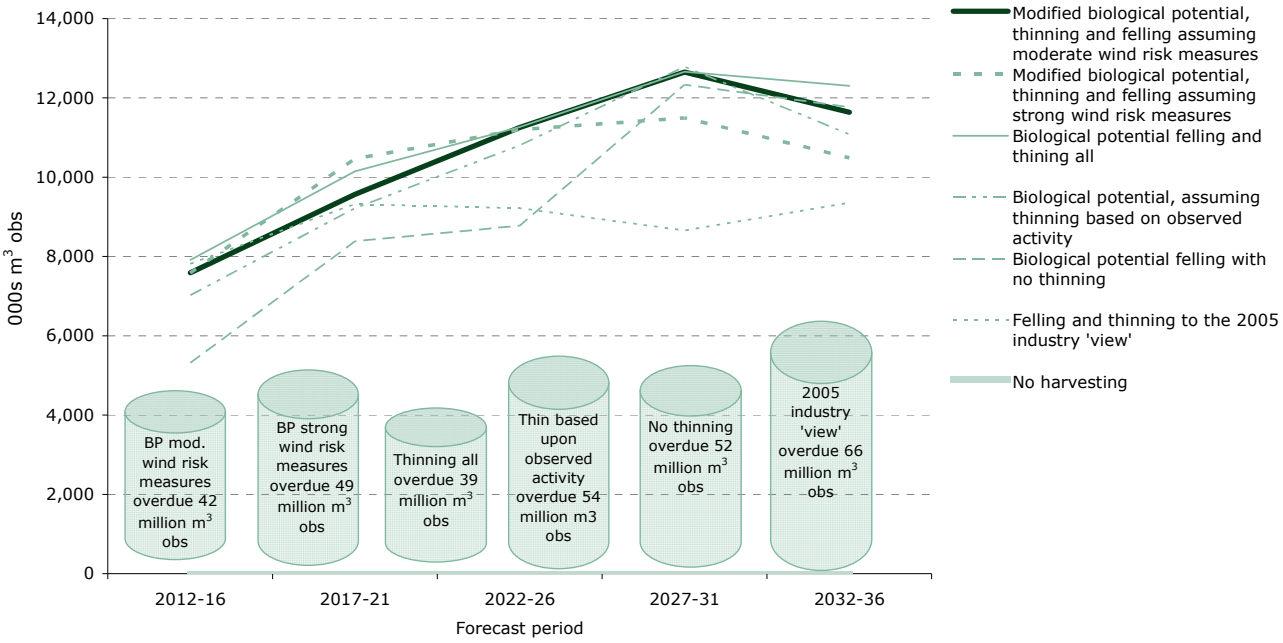
Notes:
- DAMS – detailed aspect methodology score
- Volumes in 000 m3 over bark standing

Figure 5. Comparison of production under management plans and biological potential scenarios on the Forestry Commission estate



Notes:
- The barrels account for the volume of timber that is overdue and felled within the first year of the forecast for each harvesting scenario presented

Figure 6. All private sector felling and thinning scenarios – thin and fell volume



Notes:

- The barrels account for the volume of timber that is overdue and felled within the first year of the forecast for each harvesting scenario presented
- Most scenarios assume felling at year of maximum MAI (or at an assumed terminal height), except for the 2005 industry harvesting prescriptions and zero intervention.

Figure 7. Private sector biological potential and 2005 assumptions, with two thinning scenarios

Figure 8. Private sector standing volume under all scenarios over the forecast period

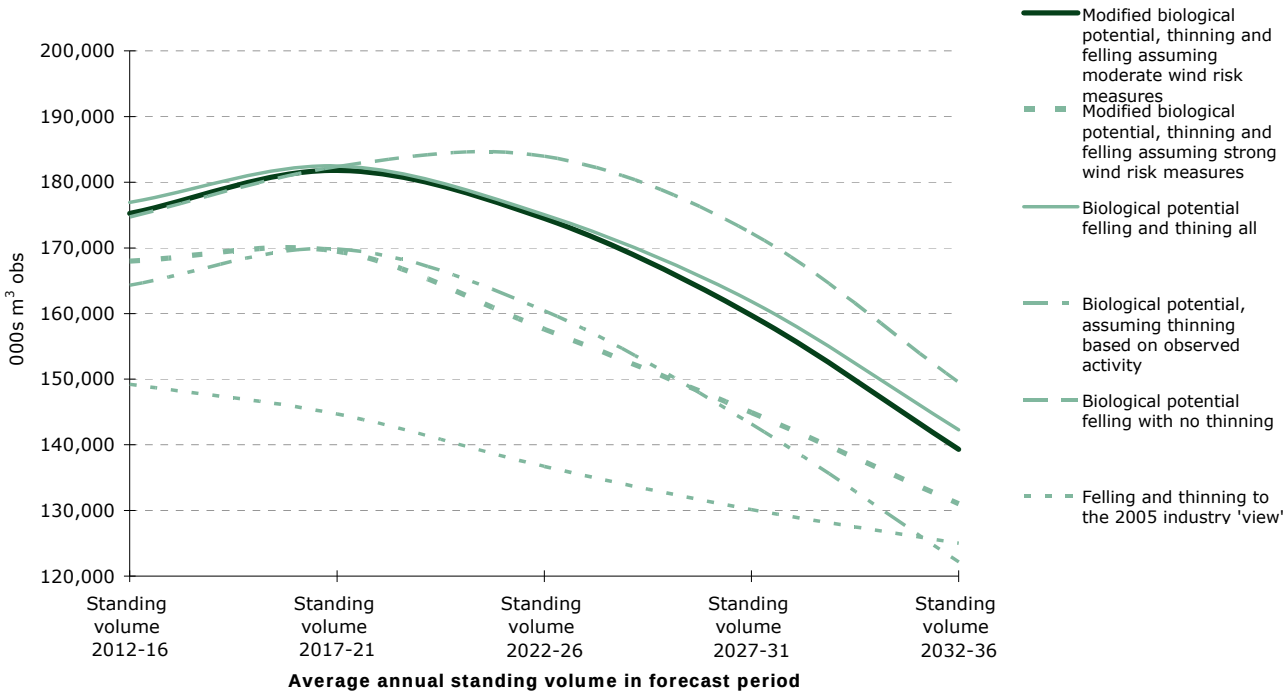
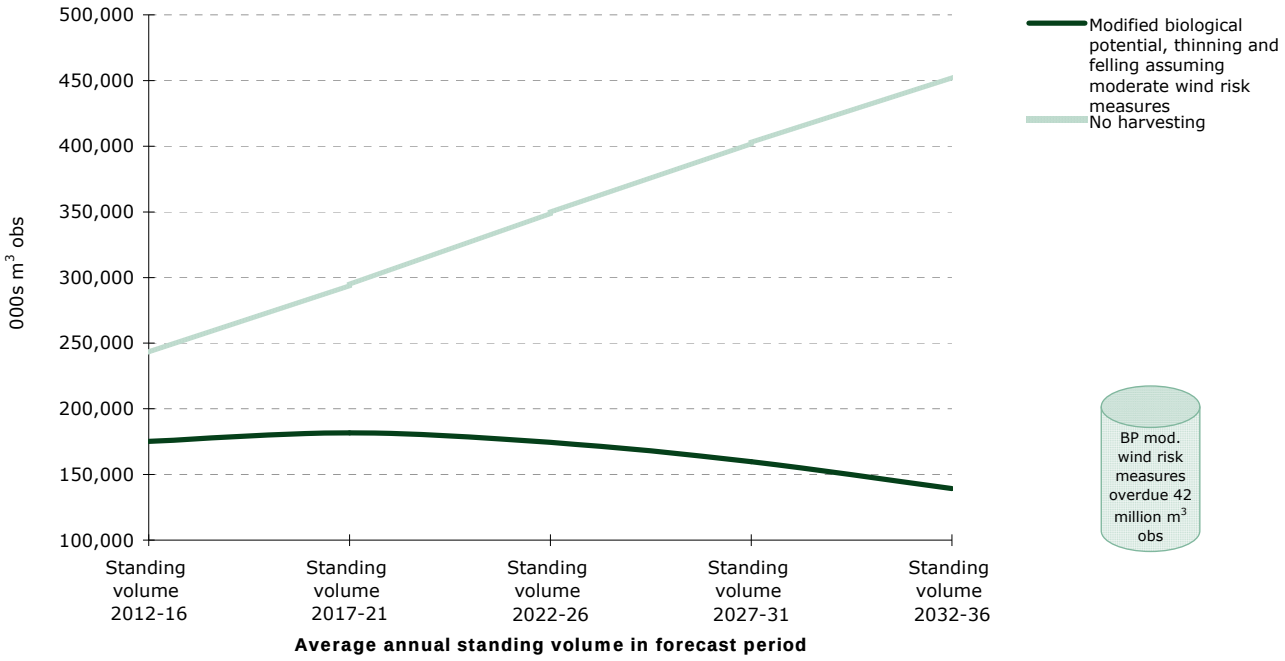


Figure 9. Private sector standing volume over the forecast period: biological potential and zero intervention



Notes:

- The barrel accounts for the volume of timber that is overdue and felled within the first year of the forecast for each harvesting scenario presented

Average annual potential production

The timing and amount of average annual production within a forecast is highly contingent upon the assumptions used concerning harvesting. Table 1 and Figure 6 show considerable changes in the profiles of forecast potential production through applying several different felling and thinning scenarios. Most scenarios do show a general trend of an increase in average annual forecast volumes, which rise to a peak. However, between scenarios the total amount of volume alters significantly within a period, in some instances by as much as a 50 % increase.

This underlying trend of a rise in potential production to a peak reflects the underlying age structure of coniferous forests in GB and the application of assumptions of all stands eventually being felled. The main exception to this trend is when applying the harvesting assumptions used in the 2005 forecast, and in this scenario the peak in production comes much sooner, followed by a dip and subsequent recovery. This is a consequence of applying shorter rotations on average than those resulting from felling at maximum MAI.

It is not only total volume that is impacted by applying alternative harvesting scenarios, the composition of that volume will alter also. Scenarios with longer rotations and higher levels of thinning will produce volume assortments with a higher proportion of larger diameter classes.

Cumulative production

Cumulative production is the total amount of timber that would be harvested throughout the 25 year period if the scenario were to be applied. It is the sum of each year's production and the volume of overdue timber. It is a useful measure in that it allows for comparison between single figures as opposed to ranges and removes the 'noise' around forecast volumes moving between 5 year periods within the 25 years of the forecast under the different scenarios. Forecast cumulative production ranges between 284 and 310 million cubic metres (a range of 6-8%), but this range includes 'extreme' harvesting scenarios, including the assumption of thinning all stands. Table 1 contains the cumulative volume for each scenario.

Overdue timber

Under the range of harvesting scenarios chosen for the private sector, whether biological potential and its variants or the 2005 industry harvesting prescriptions, there is a considerable amount of overdue timber evident in GB private sector coniferous forecasts. This ranges from around 35 to 65 million cubic metres of timber, dependent on which harvesting assumptions are used. If other harvesting assumptions were to be used which involved much longer rotations, overdue volumes would be lower. Figure 10 illustrates the high proportion of overdue timber that is over 60 years of age, and if, for example, an assumption of felling at 80 to 120 years of age were applied, the amount of

overdue would reduce significantly. Thus the amount of overdue volume under the scenarios run to date implies that there is a significant proportion of coniferous forests that are managed to longer rotation ages than may be considered as the 'norm' in terms of commercial timber activity, as defined by the assumptions of either felling at age of maximum MAI (around 50-60 years) or industry perceived practice (above 30 years).

Figure 10. Private sector overdue timber volume by age class

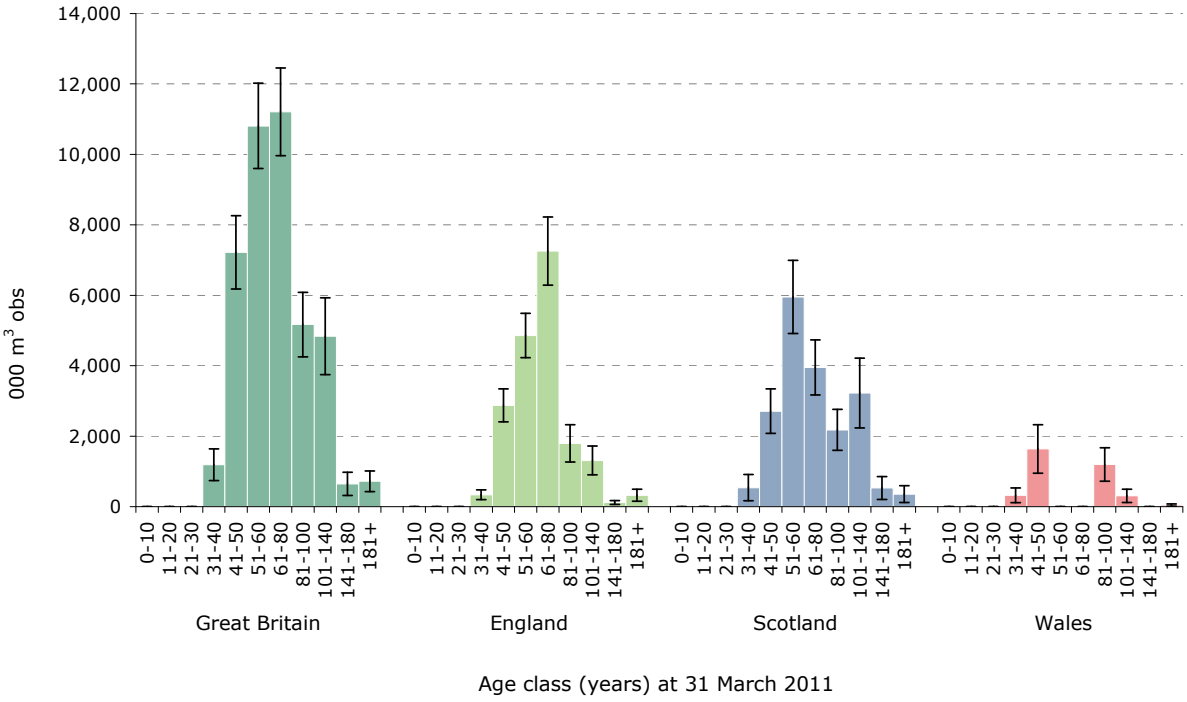
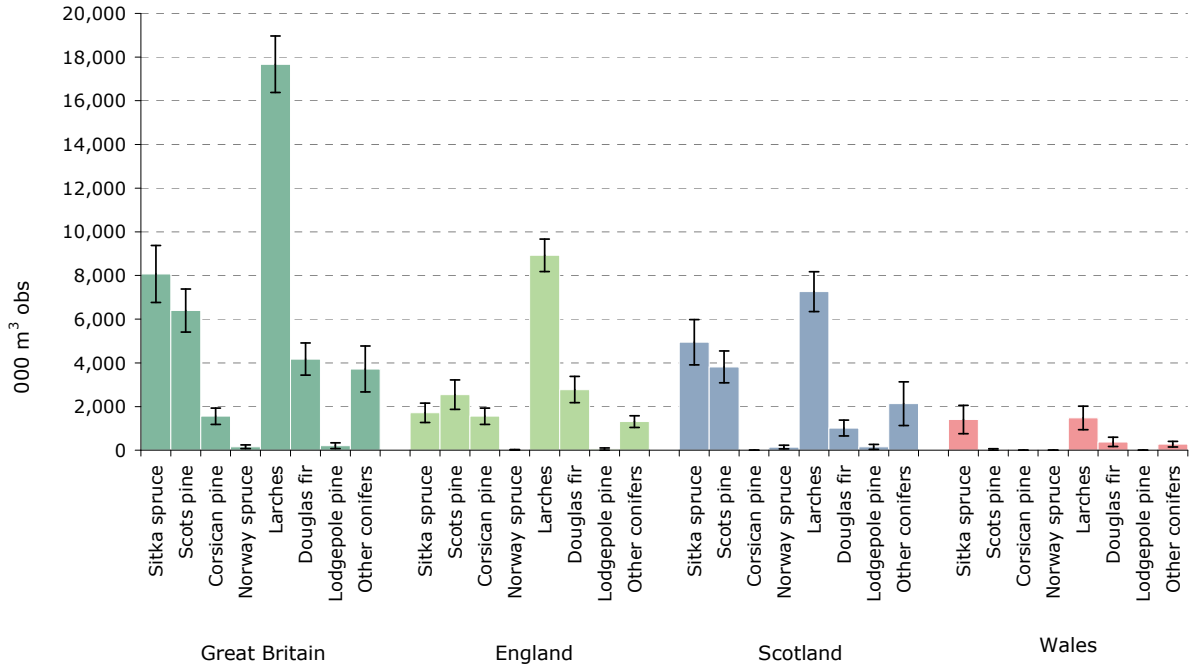


Figure 11. Private sector overdue timber volume by principal species



The NFI has found that the majority of this overdue timber is potentially harvestable and its harvesting is not restricted by physical factors (see Table 2 and Figures 13-16). It is therefore concluded that a significant proportion of this timber has not been harvested to date by reason of owner choice. Forest owners have a wide range of objectives in management and through the findings of the NFI it should be recognised that many owners practice significantly longer rotations than that determined by age of maximum MAI. Whether this timber will ever be harvested, or when, is a matter for further study. NFI will monitor such stands through its permanent sample plots and through this begin to build a picture of their long-term management.

Opening and Closing Standing Volume

In all scenarios standing volume declines over the forecast period. This is a result of the age profile of the forests and the assumption to fell, with a significant proportion of stands maturing within the forecast period. The assumption that these stands are felled is then applied according to the harvesting scenario. Treatment of overdue and differences in the felling assumptions applied refine this overall picture. This decline is seen because crops before harvesting have higher standing volumes than the younger

crops they are replaced with. However, there are observed differences between scenarios due to those scenarios with higher levels of removals reducing standing volume more than those with lower levels of removals. The range of reduction in standing volume over the period runs from 14 % for no thinning and the 2005 harvesting assumptions to 22 % for biological potential with an assumed terminal height set to 21m.

The 2005 harvesting assumptions scenario is the only harvesting scenario that results in a 'double peak' in production within the 25 year period. All other scenarios produce a single peak. It is thought that the double peak occurs because the much shorter rotations associated with this scenario, cause the next series of rotations to be brought forward into the currently forecast period from beyond the 25 time horizon of the forecast. This factor needs to be accounted for when making comparisons of standing volume with other scenarios. Longer term forecasts than those presented here would need to be performed and analysed in terms of future long-term production and standing volume in order to properly assess the full effects of this scenario over whole life-cycles of the resource.

Longer term forecasts

A large determinant in the levels of total standing volume, potential production, overdue and cumulative pruduction in GB is age class structure. GB's history of creating a man-made forest resource has created an uneven age class structure, which in combination with harvesting decisions determines the evolution of standing volumes. This is in contrast with forests of a more evenly distributed age, which result in a more stable evolution of standing volume and increment. It should therefore be noted that any forecast is a snapshot of forest metrics, in this case for example taken over 25 years, looking at a fraction of the life cycle of the forests. If a 50 or 100-year window were to be used, a different perspective may be evident. However, in longer term forecasts additional uncertainty is introduced as the assumptions made about future restocking will have more impact on longer-term results. In the GB context therefore it is important that the age profile of the forest resource is taken into account when drawing meaningful conclusions on sustainable forest management of the GB forest estate. Longer term forecasts for 50 years and over will be produced by the NFI in 2014.

Discussion of harvesting scenarios and constraints

Zero intervention

Although a highly theoretical scenario if it is applied to all forests, zero intervention will give a 'clean view' of the underlying dynamic of standing volume and increment within GB in the absence of assumed removals. It may be a management option for a proportion of woodlands. An interesting point to note is that under zero intervention standing volume increases from an average annual volume of 242 million cubic metres in

2012-16 to 453 million cubic metres in 2032-36. This shows how the volume in the tree stock would be expected to evolve in the absence of removals and is in itself a benchmark against which to judge relative levels of the proportion of increment cut. This reflects the fact that no removals of volume are undertaken and that existing trees are expected to grow at a rate that exceeds losses to natural mortality. The fact that the average age of coniferous trees in GB is relatively young and is currently below the age of maximum MAI for most species (see *NFI Report Standing timber volume for coniferous trees in Britain*), reflects the relatively recent establishment of most of Britain's productive forest. It should be noted that current Forestry Commission growth models do not reflect the full long term picture of tree senescence in very old stands and the consequent natural regeneration associated with this is not reflected in the scenario. Also, in a number of cases, these models are calibrated on sparse data covering the volume growth of older crops that are beyond the modelled age of maximum MAI, so they may be less reliable at predicting future growth rates of such stands.

Biological potential

The fell years under this scenario are taken from the first age of maximum mean annual increment (maximum MAI). Thinning prescriptions are to management table thinning (MTT) and are chosen to maximise potential (see section on thinning). To this unrestricted biological potential, a restriction of wind risk has been applied, in terms of restricting MTT thinning practice to areas of low or moderate exposure according to the DAMS classification. Terminal height restrictions can also be applied to this scenario in relation to wind risk. For the principal forecast results, a biological potential constrained by a strategy of no thinning above DAMS 16 and felling these areas at a terminal height of 25 metres has been applied (see the section on thinning). Results for non-thinning of all woods are also presented for comparison.

Again, although a theoretical scenario, this forms a benchmark for evaluation assuming that active management and productivity maximisation are pursued as objectives. This forecast sets a benchmark or 'high ceiling' of potential and as felling at maximum MAI is fully prescriptive and formulaic[*] in nature it is the least subjective scenario. The biological potential forecast gives a well-defined and widely understood indicator of potential cut in the private sector but market conditions and individual management objectives mean it is unlikely to be followed in practice across the whole estate.

Under this scenario standing volume will decrease over the period of the forecast. This is driven by the underlying age profile of the forests resulting in removals which average 10.5 million cubic metres per annum, peaking at 12.7 million cubic metres in 2027-31.

[*] Formulaic is used in the sense that the prescription of felling at maximum MAI and MTT is applied in a fixed, mechanical manner, on a stand-by-stand basis over time, and is not open to subjective influence or bias, such as using opinions of future economic activity or market behaviour.

In comparison to the industry-prescribed 2005 harvesting options, following a biological potential strategy leaves a higher standing volume of some 17 million cubic metres cubic metres at the end of the forest period and increases production overall. Compared to zero intervention, it interestingly decreases standing volume at the end of the forecast period by around 313 million cubic metres.

Physical constraints

Wind is the largest constraining factor faced by GB coniferous forests. Wind can directly damage a stand through events such as catastrophic windblow, where the whole crop is lost to wind. Catastrophic windblow is relatively rare, but endemic windblow, the progressive damage to trees on exposed and wet sites is more common. The risk of catastrophic and endemic windblow has a large effect on potential production by influencing the management of tree crops on sites susceptible to wind damage. In an attempt to avoid wind damage such crops are likely to be felled earlier to avoid significant wind damage, for example before they reach their terminal height, and they are also less likely to be thinned. This can significantly alter the profile of production at both the local and national level.

The forecast accounts for such factors in two ways:

- Reducing the likelihood of future wind damage
- Removing the volumes of timber associated with any current wind damage

Future damage

For most of the scenarios run in this series of forecasts an anticipatory approach to wind risk has been taken. This approach seeks to avoid windthrow before it happens and mirrors to some extent that which is practiced by the sector in the field. This is achieved within the forecast scenarios by the application of a 'wind risk' function in the forecast software and models. This function fells crops earlier in higher risk DAMS areas where there is thought to be a significant risk of windthrow before they reach an assumed terminal height. Different combinations of DAMS score and terminal heights have been applied and studied in different scenarios to test these assumptions and these are explored further in the section on thinning. This anticipatory approach is built into all the biological potential scenarios, apart from the non-thinning, zero intervention and thin all scenarios.

The current forecast does not take account of the damage that may arise from future wind events. Future forecasts may include a scenario of modelled damage due to wind using tools such as Forest GALES.

Current Damage

Trees that have already been blown over or damaged are taken into account in the private sector estate forecast by separating them from the main live standing stem volumes and identifying them as either windblown or wind damaged. This is done within the NFI field assessment at the stand, plot and tree level. This can be achieved since the NFI field survey assessments identify standing live trees separately from those that are windblown or wind snapped. The survey also identifies whether such trees are live or dead and if they cover large areas or are represented as a few single trees within a mostly undamaged stand. Whether the windblow is extensive or is represented by a few single trees in a standing crop, the volume and potential volume associated with such wind-damaged trees is accounted for by removing them from the main live standing volumes and thus any forecast volumes.

If the windblown trees identified are in crops where the live trees are to be felled or thinned in the first five years of the forecast, the windblow volume is added to the production volume. To this volume a degradation factor is applied to reduce the volume arising (the limit of five years of age is applied as it is assumed that after this the timber will be totally degraded). For the remaining windblow the volume is not included in future production figures and is reported separately:

- The current amount of windblow in the FC estate is 0.7%.
- The current amount of windblow on the private sector estate is 1%.

The total area of windblow over 0.05 hectares in area accounts for only 1 % of private sector forests. Dead trees represent 8% of the total of live non windblown stands and within these dead trees, windblow trees account for only 1% of dead trees while wind snapped trees account for 3%. From this it can be stated that actual windblow in the stands as they are today will not significantly reduce harvest potential overall and that this is not a significant contributing factor to determining actual production. However, the influence of wind on thinning and rotation lengths and the volumes arising from this within GB is more significant. This is accounted for in the section below on thinning.

The current forecast does not take account of the damage that may arise from future wind events, as may be modelled by applications such as Forest GALES. For most of the scenarios run in this series of forecasts a preventative approach to wind risk has been taken. This is achieved by a function in the forecast software and models that’s fells crops in higher risk DAMS areas where there is a significant risk of windthrow before they reach an assumed terminal height. Different combinations of DAMS scores and terminal heights can and have been applied and studied in different scenarios and this is explore further in the section on thinning approach and scenarios.

Thinning

For the FC estate thinning plans are held and these are used to determine the amount and timing of thinning within the forecast. These plans determine the extent, intensity, cycle and start date of thinning for the entire FC estate. For the private sector estate thinning (levels to which it is practised and over what geographic extent) is difficult to predict over a 25-year period as there is no single source of thinning plans. Over the past 25 years there have been wide swings in how often and where thinning is practised in both the FC and private sector estates. Looking forward 25 years there are likely to be similar movements. In light of this the NFI can approximate how thinning may occur in the private sector estate at a broad strategic level, but not at a specific site-based level. It has therefore aimed to achieve a strategic view through the application of four basic scenarios in thinning or combinations of them:

1. No thinning.
2. Thinning all crops.
3. Thinning crops only in areas of wind stability as defined DAMS (two variants of this).
4. Thinning older crops based on historical practice, ascertained from field survey evidence of previous thinning of the stand.

When applying thinning scenarios 2, 3 and 4, Forestry Commission MTT best practice is applied to forecasts in line with the age of the stand at the time of survey. MTT is the frequency and intensity of stand thinning as prescribed by Forestry Commission Booklet 48: Yield Models for Forest Management. Here stands are thinned at the marginal thinning intensity and on a five-year cycle. Scenario 4 has the advantage of being the least theoretical for older stands, as it is based on actual field observations, Table 4 and Figure 12 show the volumes of timber arising from thinning scenarios 1 to 4.

Table 4. Private sector potential production and standing volumes arising from different thinning scenarios

Scenario	Standing volume 2012–16	Standing volume 2032–36	Overdue	2012–16	2017–21	2022–26	2027–31	2032–36	Cumulative production
Biological potential felling with no thinning	174,713	149,487	52,069	5,318	8,382	8,778	12,335	11,765	284,961
Modified biological potential, thinning and felling assuming moderate wind risk measures	175,227	139,305	41,810	7,591	9,569	11,255	12,648	11,641	305,325
Modified biological potential, thinning and felling assuming strong wind risk measures	167,979	131,012	48,644	7,584	10,465	11,202	11,494	10,487	304,812
Biological potential, assuming thinning based on observed activity	164,315	122,132	54,268	7,025	9,217	10,800	12,786	11,077	308,785
Biological potential felling and thining all	176,917	142,286	38,999	7,908	10,147	11,268	12,661	12,307	310,458

Source: National Forestry Inventory

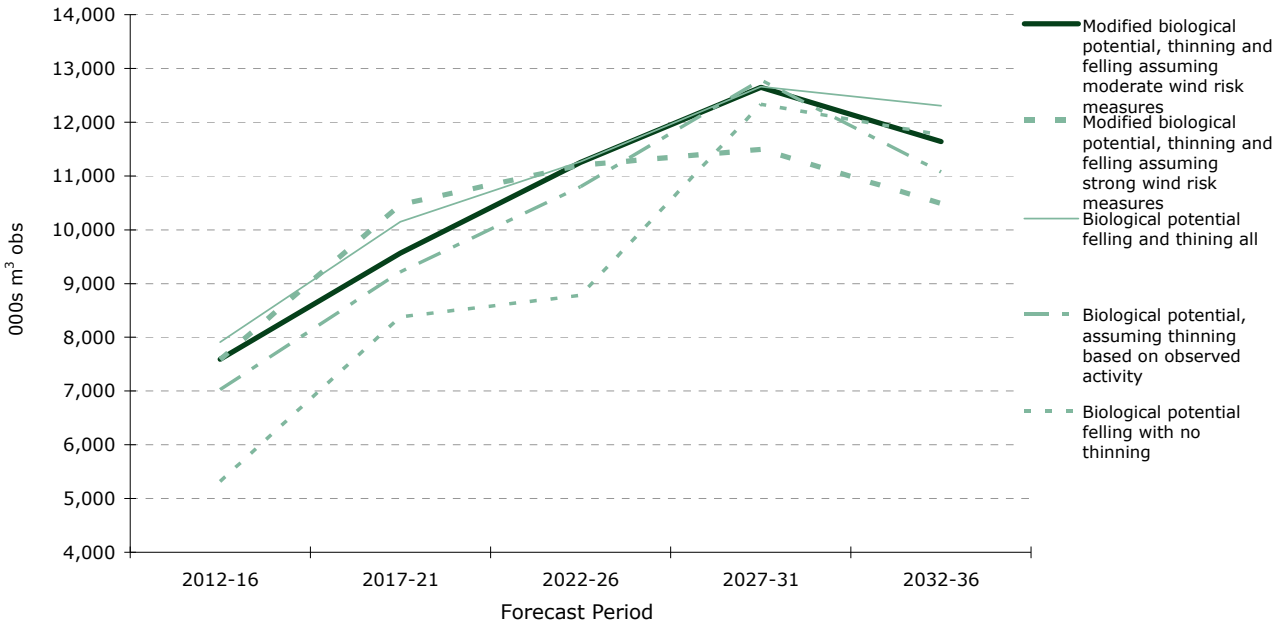
The impact upon standing volume shows that different thinning approaches can significantly alter standing volume as well as the profile of removals over time. Scenarios with higher thinning rates initially depress standing volume as timber is removed from stands during their growth. This ultimately leads to lower standing volumes during the stands lifespan and at time of clearfell. As non-thin stands tend to have reduced ages of maximum MAI compared to thinned stands, as a consequence the average age of non-thin stands will tend to be lower if managed to maximise productivity. The shorter rotation lengths associated with non thinning regimes will also affect the profile of production and bring volume forward in time if stands are managed to maximise productivity.

If stands are set to non thin as a consequence of high wind risk, they will also tend to have shorter rotations, this will depress both cumulative production and standing volume at time of clearfell.

Bringing more areas into thinning serves to bring volume forward and 'even out' production over time, lowering peaks and filling troughs in production. In the early periods of the forecast average annual production is higher in thinning scenarios compared to non thinning scenarios by up to 49%. This is not a case of simply taking volume from future periods and realising it earlier. Total forecast production in non-thin scenarios never exceeds that of thinning scenarios in any 5 year period and cumulative production is therefore always higher in scenarios with thinning. Thinning therefore

increases overall productivity compared to non-thinning. A contributory factor of this result is that non-thin growth and yield models have lower cumulative production than thin models at least partly because the latter (through thinning) anticipate tree mortality and recover this production in thinning volumes, whereas without thinning operations this volume will be lost.

Figure 12. Felling at maximum MAI with alternative thinning scenarios for the private sector



Harvesting constraints

The NFI can differentiate stands that are possible to access and harvest from those that are not, according to certain basic observable criteria. These criteria include presence or distance to roads, if the stands could be mechanically harvested or not, and the current volume and assortment of stands (as a proxy of value). Figures 13, 14, 15 and 16 present the NFI field survey findings on these factors. The survey however does not take account of issues that cannot be readily assessed in the field such as legal restrictions on access, seasonal variances in the ease of harvesting, timber haulage restrictions and economic viability. By measuring the observable factors that influence harvesting, a view on the overall capacity to harvest GB forests can be drawn. The findings show that only 0.25 % of stands are inaccessible by foot. Approximately 15 % of stands assessed have roads or harvesting tracks within them, more than 70% are within 400m of a road that

can take a commercial timber wagon and over 50% are within 200 metres of such a road (see Figure 13). Over 94% of stands assessed should be able to be harvested by mechanical techniques. This means either a wheeled or tracked vehicle could be used to harvest the stand if a road were within distance. The results show that compared to many temperate countries UK woods are relatively accessible, are relatively well roaded, and are within relatively close distances to the road network. As noted though, the road network is not always suitable for repeated forest traffic or has restricted usage to forest traffic. Taking all these factors into account, constraints upon the capacity to harvest are not principally determined by lack of access or physical ability to harvest. This leads to the conclusion that if stands are not harvested it is more likely to be through owner choice or economic viability, as opposed to physical constraints. If stands are not harvested because of physical factors it will mostly be on the basis of affordability. This may have the effect that sites that are easier to access and harvested will be harvested when timber prices are low and the sites that are more difficult to harvest will become more economic to harvest when prices are high. Thus the timing of harvesting of particular sites may be dependent upon future price developments, with some sites being more sensitive to this than others.

Figure 13. Distance to road in private sector surveyed squares

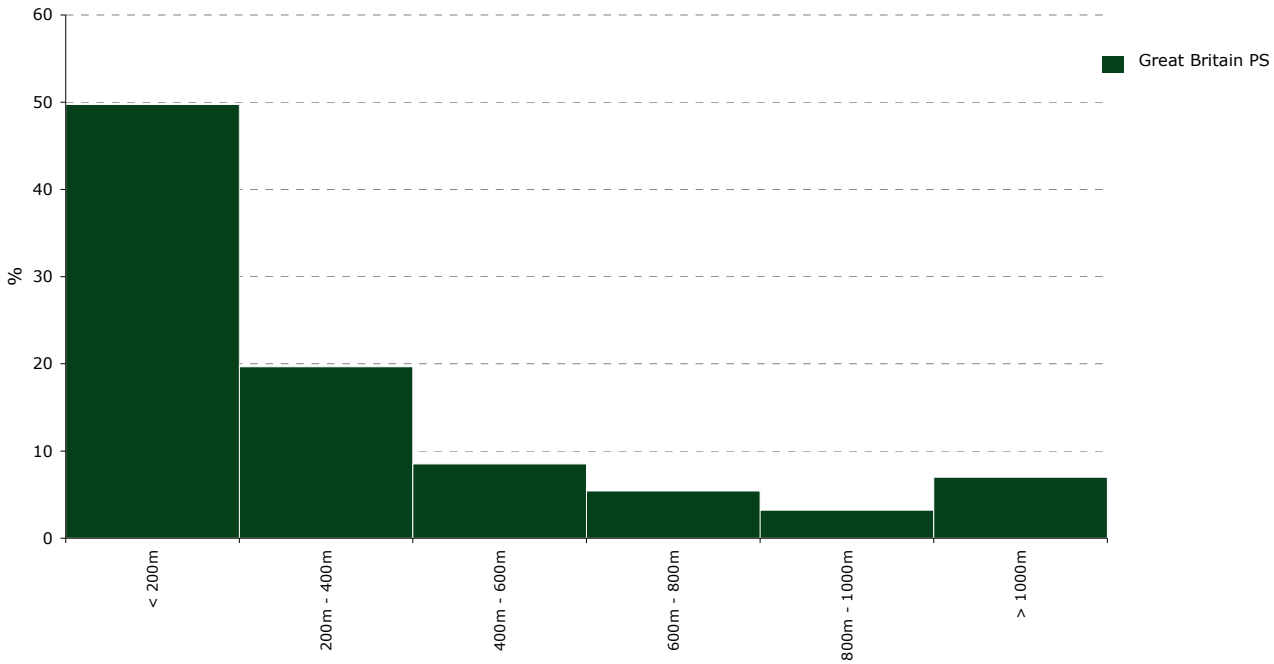


Figure 14. Proportion of survey squares which include a road or ride

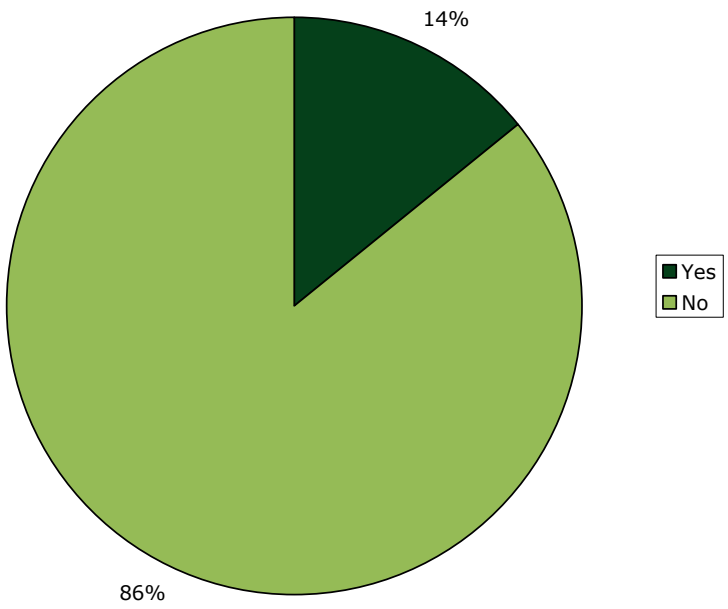
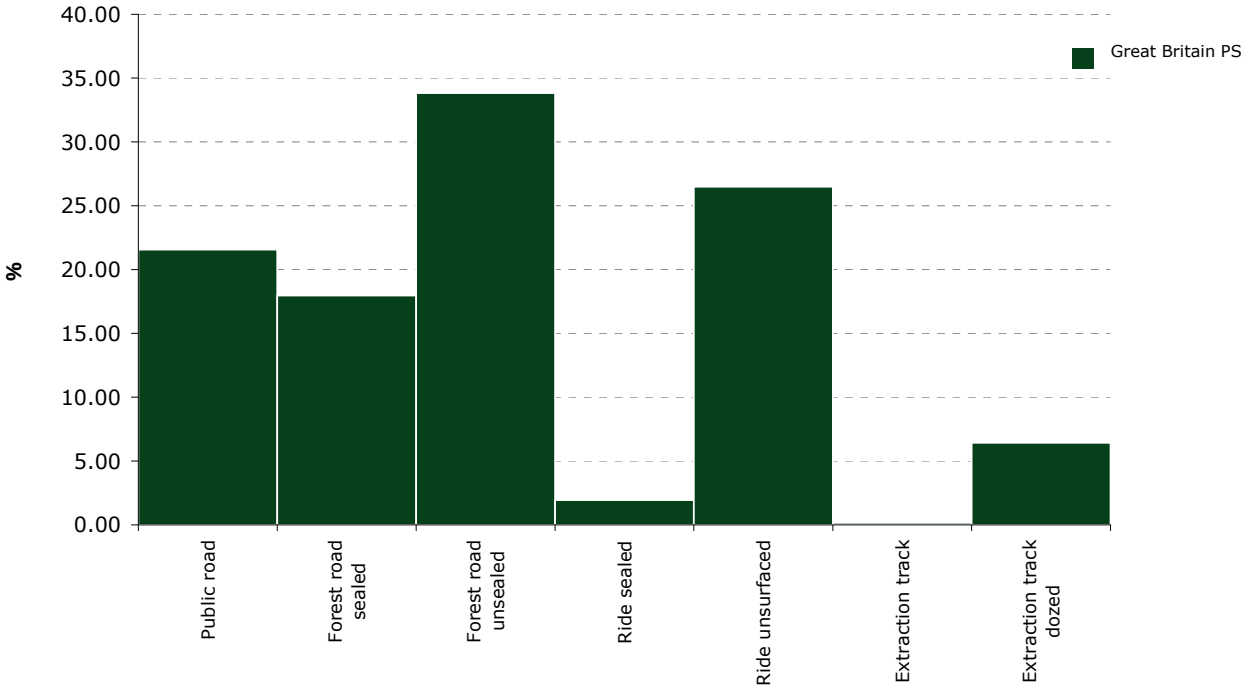


Figure 15. Type of access infrastructure within surveyed squares



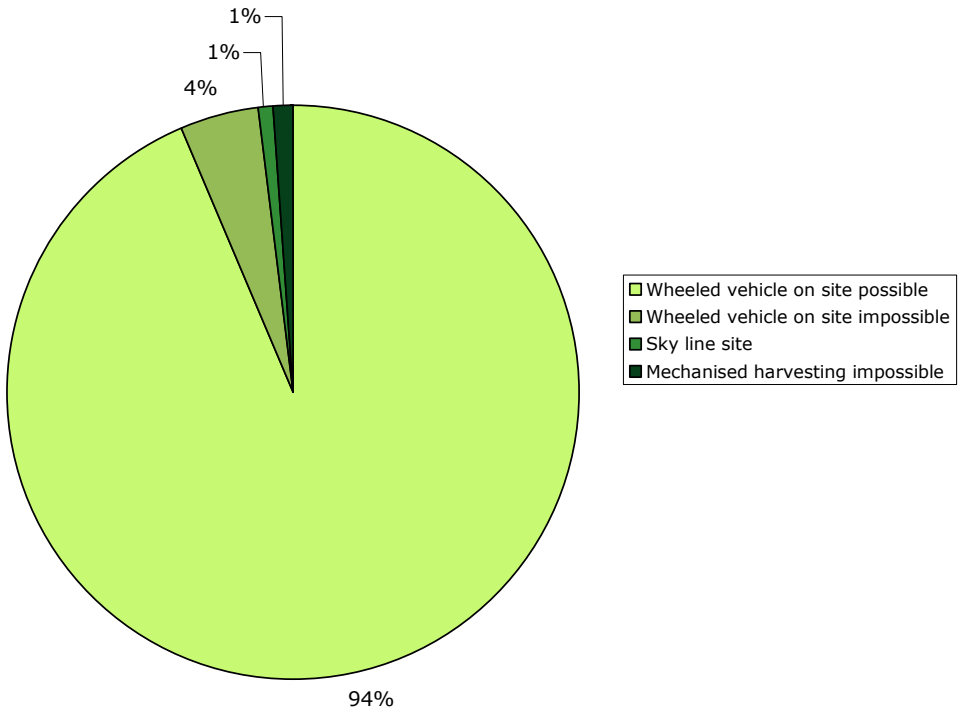
Types of access

A transport route is assessed and mapped as a linear feature regardless of its length and size within the sample square. The open space associated with the feature will *also* be mapped and assessed as a separate area as long as it meets the area criteria of ≥0.05ha within the square.

- Public Road - A road over which the public has the right of access. Also includes private roads.
- Forest Road sealed surface - A road through the forest for use by the owner and workers – tarmacked
- Forest Road unsealed surface - As above but metalled not tarmacked.
- Ride sealed surface - Rides are often vegetated, un-metalled or un-surfaced corridors often giving access to or through a forest. They also include de-classified CAT 1A roads that are no longer maintained but still surfaced.

- Ride unsurfaced - Rides are vegetated, un-metalled or un-surfaced corridors often giving access to or through a forest.
- Extraction rack: Dozed - A dozed path/corridor through the forest that is used to extract timber (Linear Feature assigned to the main Rack only).
- Extraction rack - A path/corridor through the forest that is used to extract timber (assign Linear Feature to the main Rack only).

Figure 16. Extraction options



The assessment criteria set for surveyors when gathering this information is 'can a harvesting vehicle get on site?' If not 'can a skyline be used or is it not possible to get any sort of mechanised harvesting on site?.' This is assessment considers *site* conditions regardless of the tree cover. Sites are categorised as:

- Wheeled vehicle on site possible – this category includes *any* mechanical harvesting: wheeled harvesting vehicles, tracked harvesting vehicles and skylines
- Wheeled vehicle on site impossible - tracked vehicles or skylines only can be used
- Sky line site – the site is such that only skylines can be used to harvest the site (e.g. for steep slopes where it would be dangerous or impossible for tracked or wheeled vehicles to operate)
- Mech. Harvesting Impossible
- Not Possible to Assess (this option is allowed when a surveyor cannot access the site)

Size of stand

Size of woodland may also be a factor determining whether timber is harvested or not and this is not directly assessed within these figures. The NFI does take account of this to some extent in so far as the NFI woodland area map only includes areas of forest over 0.5 hectares. As the map is used to derive total woodland area, and the forecast is based upon this area, this 0.5 hectare threshold automatically excludes very small isolated areas of conifers from the forecast. However, some owners may consider areas larger than 0.5 hectares as uneconomic to harvest. Also, any individual conifer trees and small clumps of conifers of less than 0.5 hectares standing within larger broadleaved woodlands will have been included in this assessment. These are less likely to be harvested as a result of their location and will cause a slight overestimate in production potential. However, they do not account for a significant proportion of total standing volume.

Biological constraints

Dothistroma needle blight and Phytopthora are currently influencing the scheduling of production within the UK.

Dothistroma needle blight

Generally, FC estate policy on Dothistroma on Corsican pine is one of active management and substitution where necessary. Sanitation felling is rarely necessary and early and heavy thinning to minimise the level of infection is the usual FC estate prescription. Even with this action, growth will taper off dramatically from point of infection in heavily infected stands and volume production will be reduced as a result. This drop in yield has not been accounted for either in the GB FC estate forecast or the private sector forecast. Where possible volumes 'lost' to the market due to infection will be substituted for by reallocating production in the short term, maintaining production overall. However, if infection is widespread it is likely that overall productivity will be reduced in the medium to long term. No similar industry-wide approach to managing Dothistroma appears to have emerged for the private sector estate so far, but its impact and management is likely to be similar to that of the FC estate, with the caveat that the private sector has a limited capacity for substitution compared to the FC.

There is a different outlook for lodgepole pine, where rapid mortality and timber degradation mean that early clearfelling is often the only solution to management of the disease, and this is currently the widespread prescription. How the disease spreads and how approaches to managing it will evolve over time are not yet known. This rapidly changing picture reinforces the need to interpret forecasts in the light of current knowledge about factors affecting future growth and management practice and to review the assumptions used. For example, all previous Forestry Commission forecasts of production did not take account of Dothistroma yet its introduction will affect production profiles in some regions. One way of assessing the potential range of outcomes surrounding such an outbreak is to examine the total amount of standing volume and potential production of susceptible species.

To gauge the overall potential impact of Dothistroma, the total standing volume (Table 5) and production volume associated with the susceptible species can be considered (see Tables 6 and 7). To gauge the total potential impact on potential future production volumes these can be subtracted from total production for all species. This is a very rough proxy of the potential impact of the disease, but gives an order of magnitude. Some of the susceptible species are very important within particular regions in GB. NFI reports on standing volumes of individual species within NFI regions (see NFI report: *Standing timber volume for coniferous trees in Britain*) can be used to assess the potential magnitude of such localised impacts. More sophisticated analyses would need

to model actual proportions of infection, consequent reductions in yield class and the impacts on the timing of harvesting of other species by substitution approaches.

Table 5. GB current standing volume of species as of 31 March 2011, with those susceptible to Dothistroma needle blight highlighted

	FC estate	Private sector	
	Volume (000 m^3 obs)	Volume (000 m^3 obs)	SE %
All conifers	124,575	211,167	2
Sitka spruce	70,766	99,247	3
Scots pine	**12,930**	**37,732**	**4**
Corsican pine	**6,309**	**5,648**	**12**
Norway spruce	6,678	13,067	8
Larches	9,235	26,887	8
Douglas fir	5,232	9,823	13
Lodgepole pine	**9,798**	**8,486**	**9**
Other conifers	3,627	10,547	12

At present the private sector biological potential forecast assumes that Lodgepole pine will be felled at time of maximum MAI unless it is on a site of DAMS above 16, when it will be felled at terminal height. If these sites become heavily infected and other management options are taken, the following profiles of production shown in Table 7 will be affected.

Table 6. FC GB and country coniferous timber potential volumes susceptible to Dothistroma needle blight

Average annual total volume top diameter overbark					
	2012-16	2017-21	2022-26	2027-31	2032-36
	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)
England					
Scots pine	141	127	126	109	92
Corsican pine	273	285	276	253	253
Lodgepole pine	43	41	34	21	16
Scotland					
Scots pine	216	215	226	220	202
Corsican pine	12	7	10	5	11
Lodgepole pine	423	280	284	276	214
Wales					
Scots pine	15	23	15	10	13
Corsican pine	18	24	29	22	12
Lodgepole pine	29	28	20	19	9
Great Britain					
Scots pine	372	366	367	339	307
Corsican pine	303	316	316	280	276
Lodgepole pine	496	348	338	316	239

Table 7. Private Sector GB and country coniferous timber potential volumes susceptible to Dothistroma needle blight

Average annual total volume top diameter overbark (thinning & felling)										
	2012-16		2017-21		2022-26		2027-31		2032-36	
	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %
England										
Scots pine	495	12	534	10	654	11	933	12	826	12
Corsican pine	224	18	288	18	232	26	151	28	112	42
Lodgepole pine	39	44	26	51	38	51	31	59	60	56
Scotland										
Scots pine	656	11	805	10	858	12	982	11	1,235	11
Corsican pine	5	145	5	138	4	149	39	23	58	67
Lodgepole pine	199	10	181	18	174	21	417	14	627	12
Wales										
Scots pine	20	49	17	53	18	61	21	54	9	55
Corsican pine	9	41	24	66	39	51	1	60	4	98
Lodgepole pine	10	34	11	33	10	34	11	35	53	52
Great Britain										
Scots pine	1,171	8	1,356	7	1,530	8	1,936	8	2,070	8
Corsican pine	237	18	317	18	276	23	191	23	174	35
Lodgepole pine	249	11	218	16	222	18	460	14	739	12

Dothistroma needle blight will not affect all of this volume, with some species and some areas much less susceptible to heavy infection. The potentially vulnerable volumes as a

proportion of standing volume are 24% and as a proportion of total production are 20%, 19%, 18%, 20% and 23% over the 5 periods of the 25-year forecast and need to be considered when predicting future levels of cut. This accounts for 29 % of net stocked coniferous woodland area. Standing volumes for the individual pine species can be found in the *NFI Report Standing timber volume for coniferous trees in Britain* and *GB 25- year forecast of standing volume and increment.*

Table 8. FC average annual standing coniferous timber volumes susceptible to Dothistroma needle blight

Average annual standing volume to 7cm top diameter					
	2012-16	2017-21	2022-26	2027-31	2032-36
	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)
England					
Scots pine	3,427	3,338	3,189	3,016	2,907
Corsican pine	4,947	4,995	4,829	4,605	4,327
Lodgepole pine	711	548	401	305	276
Scotland					
Scots pine	8,344	8,492	8,529	8,493	8,387
Corsican pine	331	343	338	346	334
Lodgepole pine	7,038	6,185	5,641	4,982	4,266
Wales					
Scots pine	480	447	400	404	397
Corsican pine	580	562	489	434	425
Lodgepole pine	546	450	368	318	303
Great Britain					
Scots pine	12,252	12,277	12,118	11,913	11,690
Corsican pine	5,857	5,900	5,655	5,385	5,087
Lodgepole pine	8,294	7,182	6,410	5,605	4,846

Table 9. Private sector average annual standing coniferous timber volumes susceptible to Dothistroma needle blight

	Average annual standing volume to 7cm top diameter									
	2012-16		2017-21		2022-26		2027-31		2032-36	
	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %
England										
Scots pine	12,669	6	13,110	7	12,290	7	10,378	8	8,121	9
Corsican pine	3,369	13	2,706	15	1,986	18	1,753	20	1,759	17
Lodgepole pine	1,046	26	1,016	28	1,038	28	971	30	809	32
Scotland										
Scots pine	19,456	6	21,014	6	22,393	6	23,678	6	23,151	7
Corsican pine	380	50	384	54	435	53	410	51	157	65
Lodgepole pine	7,361	10	8,525	9	9,839	9	10,248	8	9,534	9
Wales										
Scots pine	283	52	305	53	322	54	320	57	306	64
Corsican pine	262	43	255	43	118	59	18	89	9	54
Lodgepole pine	436	36	466	35	488	35	502	36	345	40
Great Britain										
Scots pine	32,407	4	34,429	4	35,005	5	34,377	5	31,577	5
Corsican pine	4,011	12	3,345	14	2,539	17	2,182	19	1,924	16
Lodgepole pine	8,843	9	10,007	8	11,366	8	11,721	8	10,688	8

Phytophthora

Phytophthora ramorum is currently restricted in the main to the south and west of Great Britain, where its impact is significant. Sanitation felling is the usual prescription and has brought a great deal of larch forward to harvesting in recent years. This trend is set to continue. FC estate policy is to substitute this volume for other volume that was to be harvested, so that overall production remains the same. No similar consistent policy in terms of substitution has been articulated by the private sector, but it is probable that the sector is taking a similar approach. For both sectors the picture of what the final level of impact will be and how this will be managed is unknown. Options for predicting or modelling this within the forecast were assessed, but with many unknowns it was decided not to speculate upon these. As a result the total standing volumes and potential production associated with susceptible species are shown in Tables 10-14, which provides the range of potential volume affected.

Table 10. GB standing volume of conifer species as of 31 March 2011 with those susceptible to Phytophthora highlighted,

	FC estate	Private sector	
	Volume ($000\ m^3$ obs)	Volume ($000\ m^3$ obs)	SE %
All conifers	124,575	211,167	2
Sitka spruce	70,766	99,247	3
Scots pine	12,930	37,732	4
Corsican pine	6,309	5,648	12
Norway spruce	6,678	13,067	8
Larches	**9,235**	**26,887**	**8**
Douglas fir	5,232	9,823	13
Lodgepole pine	9,798	8,486	9
Other conifers	3,627	10,547	12

Table 11. Potential Forestry Commission production volumes susceptible to Phytophthora

Average annual total volume top diameter overbark					
	2012-16	2017-21	2022-26	2027-31	2032-36
	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)
England					
Japanese larch	42	41	44	33	29
European larch	8	9	7	7	8
Hybrid larch	14	15	18	15	19
Other larches	0	0	0	0	0
Larches	**64**	**65**	**69**	**54**	**57**
Scotland					
Japanese larch	129	138	104	97	78
European larch	18	14	13	12	14
Hybrid larch	36	39	38	53	46
Other larches	0	0	0	0	0
Larches	**182**	**191**	**154**	**162**	**138**
Wales					
Japanese larch	68	77	69	50	55
European larch	2	1	2	1	1
Hybrid larch	12	12	13	16	23
Other larches	0	0	0	0	0
Larches	**82**	**90**	**84**	**67**	**79**
Great Britain					
Japanese larch	239	255	217	180	162
European larch	28	24	22	20	23
Hybrid larch	61	66	69	84	89
Other larches	0	0	0	0	0
Larches	**328**	**346**	**307**	**284**	**274**

Table 12. Potential private sector production volumes susceptible to Phytophthora

Average annual total volume top diameter overbark (thinning & felling)										
	2012-16		2017-21		2022-26		2027-31		2032-36	
	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %
England										
Japanese larch	56	29	49	25	25	35	51	16	72	15
European larch	56	24	72	30	32	32	18	25	52	33
Hybrid larch	140	21	68	29	60	30	114	14	116	10
Other larches	0	110	0	110	0	110	0	110	0	110
Larches	**251**	**14**	**190**	**17**	**117**	**19**	**182**	**10**	**241**	**10**
Scotland										
Japanese larch	49	55	14	32	27	39	50	48	49	50
European larch	213	29	115	39	175	36	55	41	83	30
Hybrid larch	243	25	200	25	131	25	209	21	212	14
Other larches	0	0	0	0	0	0	0	0	0	0
Larches	**506**	**16**	**329**	**29**	**334**	**21**	**315**	**17**	**344**	**12**
Wales										
Japanese larch	62	62	45	62	8	60	25	50	12	47
European larch	20	44	13	43	30	84	66	71	25	59
Hybrid larch	108	46	24	62	6	63	18	49	29	44
Other larches	0	0	0	0	0	0	0	0	2	111
Larches	**191**	**33**	**83**	**39**	**44**	**59**	**109**	**45**	**68**	**30**
Great Britain										
Japanese larch	188	27	116	27	81	21	166	22	176	21
European larch	263	23	254	25	218	28	98	48	132	22
Hybrid larch	518	17	303	17	246	18	387	14	400	9
Other larches	0	110	0	110	0	110	0	110	2	105
Larches	**948**	**12**	**603**	**18**	**495**	**16**	**606**	**12**	**653**	**8**

Note: Due to the statistical properties of these estimates, the sum of volumes of individual larches may not correspond to the estimates for all larches

Again Phytophthora will not impact on all of the volume, with some species and some areas much less susceptible to heavy infection, but the total volumes involved as a whole and as a proportion of production represent around 7% of production over the 25-year period. This accounts for around 10% of stocked woodland area.

Table 13. Potential Forestry Commission standing volumes susceptible to Phytophthora

Average annual standing volume to 7cm top diameter					
	2012-16	2017-21	2022-26	2027-31	2032-36
	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)	volume ($000m^3$obs)
England					
Japanese larch	966	951	887	859	878
European larch	290	283	272	268	256
Hybrid larch	359	420	467	507	539
Other larches	0	0	0	0	0
Larches	**1,615**	**1,655**	**1,627**	**1,634**	**1,673**
Scotland					
Japanese larch	2,849	2,545	2,305	2,171	2,115
European larch	540	520	507	503	502
Hybrid larch	1,043	1,101	1,172	1,199	1,178
Other larches	0	0	0	0	0
Larches	**4,432**	**4,166**	**3,984**	**3,873**	**3,794**
Wales					
Japanese larch	2,323	2,332	2,309	2,407	2,500
European larch	54	53	51	48	47
Hybrid larch	392	459	530	588	607
Other larches	0	0	0	0	0
Larches	**2,769**	**2,844**	**2,890**	**3,044**	**3,154**
Great Britain					
Japanese larch	6,138	5,829	5,502	5,438	5,493
European larch	884	856	831	819	805
Hybrid larch	1,794	1,980	2,169	2,294	2,323
Other larches	0	0	0	0	0
Larches	**8,816**	**8,665**	**8,502**	**8,551**	**8,621**

Table 14. Potential private sector standing volumes susceptible to Phytophthora

Average annual standing volume to 7cm top diameter										
	2012-16		2017-21		2022-26		2027-31		2032-36	
	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %	volume ($000m^3$ obs)	SE %
England										
Japanese larch	409	18	269	20	363	14	595	12	800	12
European larch	651	19	479	21	422	22	513	21	557	19
Hybrid larch	814	16	607	19	787	13	1,144	11	1,591	10
Other larches	0	110	0	110	0	110	0	110	0	110
Larches	**1,874**	**10**	**1,356**	**12**	**1,573**	**9**	**2,253**	**8**	**2,949**	**7**
Scotland										
Japanese larch	496	32	430	32	465	32	387	32	336	22
European larch	1,801	21	1,543	23	910	20	680	21	663	20
Hybrid larch	2,240	15	1,691	16	1,788	14	2,056	10	2,367	10
Other larches	0	0	0	0	0	0	0	0	0	0
Larches	**4,543**	**11**	**3,667**	**13**	**3,166**	**11**	**3,127**	**9**	**3,371**	**8**
Wales										
Japanese larch	341	44	199	47	130	45	135	40	182	41
European larch	512	46	525	47	497	47	247	36	181	36
Hybrid larch	533	35	206	39	232	38	307	35	361	33
Other larches	3	111	4	111	5	111	7	111	4	111
Larches	**1,398**	**23**	**940**	**29**	**868**	**29**	**697**	**21**	**732**	**21**
Great Britain										
Japanese larch	1,245	18	899	19	957	17	1,117	14	1,318	11
European larch	2,964	15	2,547	17	1,829	17	1,439	14	1,402	13
Hybrid larch	3,587	11	2,504	12	2,807	10	3,507	8	4,319	7
Other larches	3	102	5	103	6	104	7	105	5	105
Larches	**7,815**	**8**	**5,963**	**9**	**5,608**	**8**	**6,078**	**6**	**7,052**	**5**

Note: Due to the statistical properties of these estimates, the sum of volumes of individual larches may not correspond to the estimates for all larches

Legal constraints

In many temperate countries there are extensive areas of forests where harvesting is prohibited and where woodland is legally protected from harvesting. In the UK this is not the case. However it is a legal requirement to seek approval for felling via the felling licence system. Such approval will be given if appropriate account is taken of forestry policy. Attaining approval may involve the rescheduling of harvesting (or taking a different silvicultural approach to harvesting) for purposes such as age class restructuring, taking account of nature designations, landscape or amenity. However, it is rare for a felling licence not to be approved at all. As a consequence of legal constraints within the UK the forecasts have not removed any areas of woodland or timber volumes from the forecast on the basis of legal restrictions.

Policy constraints

Policy constraints play a role in determining harvesting levels and timing in the UK. Policy is represented by legislation like the Habitats Directive and the UK Forestry Standard (UKFS). Another example would be statutory designations for nature conservation or landscape amenity. Where such policies impact upon harvesting, this will generally involve the phasing, delaying or modification of the extent of harvesting, but rarely its prohibition. An example would be that felling coupes over a certain size may not be granted a felling licence and that smaller coupe sizes and phasing of harvesting would be required for a felling licence to be approved.

The full impact of such multiple policy factors on forestry in terms of volume production is difficult to assess as there are so many interdependent factors involved. As a consequence the forecast does not take account of such factors for the private sector forecast and the impact of policy upon potential production is not assessed. However, since policy rarely prohibits felling, it is thought that this will not reduce potential production significantly in the long term, but it may impact upon the timing of production to some extent.

For the Forestry Commission, the forecast is based upon design plan felling and thinning and with such will take account of policy. For the purposes of comparison a forecast has also been run as if the FC estate were managed to biological potential and this may give some measure of the impact of policy on biological potential, but it is an imperfect measure as design plans will also have to take account of harvesting and marketing constraints and the legacy of previous management regimes etc. Such a comparison can be found in Table 3 where the current FC estate management plans forecast is compared to a forecast where the same forest is managed to biological potential. The overall difference in cumulative production between the management plans and biological potential scenarios is marked with the latter producing around 20 % more volume. Part of this reduction could be ascribed to the effects of policy on production and is discussed in the following section.

Biological Potential of the Forestry Commission estate

This paper focuses on the application of different harvesting scenarios within the private sector. This is necessary because the main 2011 forecast is based upon an assumed biological potential scenario for the private sector and the impact of such an assumption on the forecast needs to be assessed.

The Forestry Commission estate forecast on the other hand is based upon existing plans for the FC estate. With such an extensive evidence base for harvesting practice, there is no great need for the application of scenarios or their evaluation. Indeed for the FC estate scenarios are only required for policy evaluation or for the purposes of comparison with the private sector. This section addresses the latter.

Presenting and combining scenarios based on different assumptions for the FC estate and the private sector estate has the disadvantage of not taking a consistent approach between the two sectors. This makes direct comparisons between factors such as the amount of overdue timber, average annual production and standing volumes problematic. To allow for a consistent comparison between the sectors on such factors the same biological potential harvesting assumptions that were applied to the private sector main forecast have been applied to the FC estate, the results of which are presented in Table 3 and Figure 5.

Application of this scenario to the FC estate produces results with features that are more similar to the results for the private sector estate with:

- A large increase in the amount of overdue timber
- More similarity with the results for the private sector estate with regard to the profile of production over time, with production increasing from 2011 to a peak in 2027-31, before a decline in the last 5-year period.

Profile of production

To some extent it should be expected that the same approach to harvesting would produce a similar result between the sectors. However, the National Inventory of Woodland and Trees (NIWT) had shown that Forestry Commission stands tended to be older on average than private sector stands and that this would lead to the expectation that Forestry Commission volume would be harvested earlier than that of the private sector. This finding from NIWT is true to some extent; NFI has found that 84% of FC stands are under 60 years of age compared to 87% in the private sector. This small difference between the two may seem a surprising result since FC started planting at higher levels earlier than the private sector, but it most likely reflects the fact that most of the early FC planting has been harvested and replaced with younger stands, reducing average age. The private sector on the other hand is still to a greater extent dominated by stands in their first rotation, which as a consequence have a similar average age.

This small difference in average age would lead to FC production coming a little earlier than that of the private sector, but it would seem that other factors that drive the age of

harvesting within biological potential such as yield class, wind exposure and species type are countervailing the impact of having slightly older crops.

Cumulative production

There is a marked difference in cumulative production in the application of the two scenarios within the Forestry Commission estate. There is around 20% less cumulative production for management plans than for biological potential.

Initial analysis has shown that this difference in cumulative production is primarily due to the proportion of total woodland area being set to 'non–forecastable' within the SCDB. Setting to 'non–forecastable' is used by Forestry Commission managers to exclude stands from the production forecast for operational or management purposes and this proportion currently is around 14% at a GB level. Examples of reasons for this would include:

- Lack of roading to stands
- Stands being uneconomic to harvest due to physical constraints (sited on islands etc)
- Stands of low quality that would be uneconomic to harvest
- Natural reserves
- Non intervention retentions for conservation or recreation

The difference will also include the impact of applying a range of alternative management choices on all the remaining forecastable stands that contribute to the forecast. This will include the impact of implementing sustainable forest management policy in line with the UKFS across all stands and woodlands managed by the Forestry Commission. This will involve applying different objectives to those assumed by the biological potential scenario, and will involve applying many different management approaches to that of aiming for biological potential. This will include, for example, extending and reducing rotation lengths to increase age class diversity, which is a core aspect of forest design and this factor alone will have an impact upon cumulative potential production. Forest management plans will also take account of operational constraints such as roading, pests and diseases, terrain and wind, each of which will constrain potential production.

There is clearly a difference in forecast production outcomes between biological potential and management plans, but attributing how this difference has arisen to a single cause is problematic. Many factors in combination will be driving this difference, as they drive management choices. It is likely that the application of current objectives is not the only cause of this difference. For example, how the forests were managed in the past before the UKFS may have had an impact, and past and present economic constraints may also have had an impact. All such factors could play a role and further work is required to fully understand the causes of this difference.

It should also be remembered that cumulative production is only one metric of measuring outcomes. This does not take account of the impact upon other forest metrics, such as opening and closing standing volume, diversity in age class, species

diversity and habitat structure. These are used to evaluate the wider objectives of increasing the environmental and social value of forests, as opposed to solely quantifying total timber production over a defined period of time. For example, management plans maintain a higher level of standing volume, carbon and biomass over the forecast period. They also produce yield at a more even rate and diversify age class structure. This reflects the policy of the Forestry Commission to restructure the FC forest estate by means of long term retention of stands and increasing use of low impact silvicultural systems, all of which will suppress production but increase the environmental and social value of forests. All such factors must be taken into account when appraising the impact of applying management plans on the FC estate.

Possible implications of FC estate forecasts on private sector harvesting rates

There are similarities in the drivers underlying the management of the FC estate and the private sector estate in GB, in particular that they both apply the UK Forest Standard to woodlands and both face similar operational and economic constraints. If it were assumed that these similarities resulted in closely matching management objectives and policies for the two sectors, then the difference observed on the FC estate between biological potential and management plans forecasts may be viewed as a guide to the most likely pattern of future harvesting on the private sector estate in comparison to that which is assumed by the biological potential forecast for that sector.

However, in spite of these similarities in the drivers, there are substantial differences to be found in the character of the two sectors, especially in regard to commercial motives and the choice and application of policy across the whole sectors. These will result in differences in the objectives of underlying management of the resource in the two sectors, which in turn impact upon the design and implementation of management of the respective estates. Factors which may vary between the two sectors are the extent to which the UKFS is applied, different economic drivers, different physical constraints and the level of active management. Without further study of these differences, the degree to which the difference between the management plans and biological potential forecasts for the FC estate can be translated to a likely future harvesting scenario for the private sector estate can not be easily ascertained.

Planned harvest

The Forestry Commission has maintained a commitment to bring the levels of timber in the forecast to market since 1970. This is continued in the current forecast and for the first 5 years of this forecast FC will produce a high proportion of the forecast volume, but this is set within tolerances quoted in the main forecast reports and country marketing strategies. For example Forestry Commission Scotland has adopted a policy of capping its harvest to 3,200,000 cubic metres per annum and is in the process of implementing this policy. However, a buoyant or depressed market will have minimal impact on the majority of volumes forecast to arise from the FC estate, and this provides a relatively secure base for future supply. Beyond this first 5-year period the forecast is a signal of intent only, but it is based upon existing and well designed management plans that are

likely not to radically alter. However, these plans will evolve over the next 25 years in response to operational factors, policy change and events, as they always have, yet despite such influences the Forestry Commission has a long precedent of producing at or near the forecast. This means that it can be postulated that a significant proportion of the Forestry Commission timber forecast will come to market over the 25-year period, which will account for between 40 % and 50 % of total potential production over the forecast period, with this proportion varying between five-year periods.

The private sector estate has produced a long term supply of timber to the market, and this is likely to continue. It is however difficult to predict the timing and absolute amount of this volume. Part of this difficulty arises from the absence of a single inventory for private sector forests, as would be expected when many thousands of individual owners are involved. This is one of the main reasons that the National Forest Inventory is required and with the NFI in place much of this is mitigated in terms of assessing standing volume. However, the other difficulty is predicting when harvest will occur is that there is no 'collective plan' for how that standing volume will be harvested. This is because there are many owners within the private sector, who have many different objectives in managing their woodlands and they do not function as a single entity. Some owners do hold plans for harvesting, but these are not brought together into a 'collective plan' that can be applied to the forecasts. Also even when plans exist, there is generally flexibility in their application and timing of harvesting may not happen as was originally planned. One factor that influences owner choices in harvesting practice is timber prices and owner objectives on profitability or return. Domestic timber prices are subject to economic cycles and influences and this in turn affects demand, price and activity over time. There is some evidence arising from the NFI in terms of annual rates of harvest that point towards such movements in the rates of harvesting activity in relation to these economic cycles.

Outside the actual physical nature and extent of the growing stock and owner objectives, such movements in price and demand are likely to be the largest determinate in the future level of harvesting in the private sector estate and with such in terms of the forecast the private sector does not have a 'planned harvest'.

Other events

Conversion of forests to other land uses such as wind farms and heathland restoration are currently discussed as factors that may have an impact upon future harvesting levels. Any wind farms or heathland restoration undertaken to date are reflected in all forecasts and volumes through the NFI ground survey and the remote sensing monitoring of clearfelling. However, the forecasts do not take account of possible future events.

The FC estate has a general policy of timber substitution in relation to wind farms. When timber comes to market as the result of wind farm development, an equivalent amount of timber that was due for harvest is withdrawn from the harvesting schedule elsewhere, so that overall production remains the same. Some of the devolved administrations also have compensatory planting policy in place to help mitigate such woodland loss, with an aim to maintain current levels through new planting. At present it is not a practical option for the private sector to collectively manage the cumulative affect of clearfelling and woodland loss for wind farms in terms of yield regulation.

Land use change and sales and purchase of land

Although there is a general presumption in the UKFS that forested land stays forested, land use can and does change from forest to non forest and this will impact on timber production potential. Additionally at any point in time there are active sales and purchases of land and such transactions often involve a change in approach to harvesting and occasionally they may involve a change in land use. The following situations are considered to be those that impact most on potential volume:

1. Forested land transferring from one ownership to another, whilst remaining as forest
2. Forested land transferring from one ownership to another and undergoing conversion to another land use
3. Forest land being converted to another land use
4. Open land being purchased to afforest
5. Existing open land being afforested

For situations 2, 3, 4 and 5 the NFI field work will take account of any land use changes that have happened up until 31 March 2011. For potential future changes the assumption in NFI forecasts is that land use does not change. This assumption could either overestimate or underestimate the amount of available growing stock in the future. However, since there is no quantifiable evidence base to take account of such changes, they have not been accounted for in current NFI forecasts. There is evidence for factor 1 however and this is accounted for thus:

Forested land transferring out of Forestry Commission ownership

The Forestry Commission has previously sold or disposed of significant amounts of forest land. This has been a key factor in the reduction of volume predicted to arise from the Forestry Commission estate. Disposals policy is the responsibility of the respective Ministers of each country and as policy evolves over time disposals may or may not occur over the forecast period. However, the forecast must make assumptions about how forest will be managed over the forecast period and thus has to make assumptions about past, current and potential disposals. This is done in three main ways:

1. Removing any areas already sold from the FC sub compartment database and transferring this area to the private sector forecast.
2. Accounting for planned disposals. Forestry Commission flag the year of any planned disposals within the sub compartment database and these areas will continue to contribute to the Forestry Commission forecast until the date of disposal. After that point these areas and volumes are reported upon separately.
3. The assumption of this forecast is that ownership in the future will remain constant (excluding those areas covered in point 2)

As of 31 March 2011, the Forestry Commission sub compartment database had around 30,000 hectares flagged for disposal. This disposal programme is an indication of intent and may change over time. These areas and the volume forecast to arise from them are accounted for separately to the main forecast tables and are shown in Table 15.

Table 15 Forecast volumes associated with land flagged for sale on the Forestry Commission estate

Country	2012-16 volume (000 m^3 obs)	2017-21 volume (000 m^3 obs)	2022-26 volume (000 m^3 obs)	2027-31 volume (000 m^3 obs)	2032-36 volume (000 m^3 obs)
England	57	51	47	42	41
Scotland	144	223	273	279	286
Wales	-	-	-	-	-
Great Britain	**201**	**273**	**320**	**321**	**328**

The harvesting scenario used for these is one of biological potential constrained by wind risk. Whether this land is sold in future is uncertain and whether this harvesting scenario is subsequently applied is unknown.

Restocking

During the consultation with the forestry sector on the approaches to scenarios there were mixed views on how and if restocking should be included in forecast scenarios. In the 2011 forecast any crops already planted or restocked on the ground are included in the production forecast ahead. However, the forecast also includes crops being clearfelled within the 25-year period and this section discusses how such crops are treated. Clearly if a forecast includes felled crops that are not replanted, then stocked areas will be reduced, and standing volume will also be reduced. The impact of not including restocking in production forecasts is not great in a 20 to 25-year forecast of production volumes as most crops do not produce significant volumes of timber below the age of 18–23 years, the age that the oldest restocked crops would have attained by the end of the forecast period. However, the impact on growing stock, biomass and carbon is likely to be significant, particularly after the first 15 years. For longer forecast

periods of over 50 years, restocking is important in all cases as eventually with a 50-year felling cycle all trees would have been felled by the end of the forecast period. Consequently there would be no volume left in the forecast if restocking was ignored.

To manage this, the forecast currently has a 'like-for-like' restock option. With selection of this option, the crops felled within the forecast period are replaced with a replanted crop with the same characteristics as that which had been felled. This approximates what may happen but, as with harvesting scenarios, it is not expected to represent all situations. Similar capacities are therefore required in scenario testing for restocking, as there are many restocking options possible in a 25-year cycle. The NFI will have the capacity to run a wider range of restocking scenarios from 2013 onwards. The impact of applying 'like-for-like' restocking on the main forecast outputs are shown in Tables 16 and 17, and Figure 17.

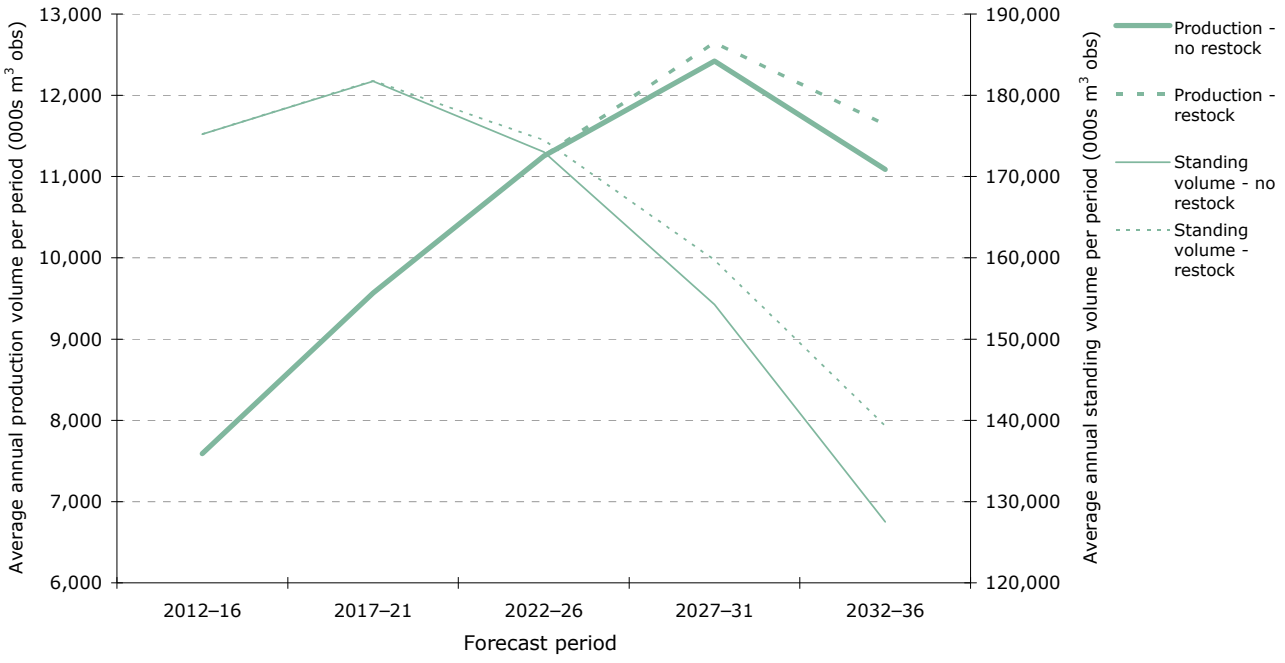
Table 16. Impact on private sector production volumes of adding restocking to the forecast

Average annual total volume top diameter overbark					
	2012-16 volume ($000m^3$obs)	2017-21 volume ($000m^3$obs)	2022-26 volume ($000m^3$obs)	2027-31 volume ($000m^3$obs)	2032-36 volume ($000m^3$obs)
England					
No restock	2,184	2,626	2,450	2,686	2,389
Restock	2,184	2,626	2,450	2,804	2,637
Scotland					
No restock	4,614	5,917	7,796	9,043	7,965
Restock	4,614	5,917	7,796	9,131	8,213
Wales					
No restock	793	1,025	1,008	694	736
Restock	793	1,025	1,008	713	791
Great Britain					
No restock	7,591	9,569	11,255	12,422	11,090
Restock	7,591	9,569	11,255	12,648	11,641

Table 17. Impact on private sector standing volumes of adding restocking to the forecast

Average annual total volume top diameter overbark					
	2012-16	2017-21	2022-26	2027-31	2032-36
	volume ($000m^3obs$)	volume ($000m^3obs$)	volume ($000m^3obs$)	volume ($000m^3obs$)	volume ($000m^3obs$)
England					
No restock	41,626	40,073	35,715	29,855	23,606
Restock	41,626	40,094	36,386	32,183	28,276
Scotland					
No restock	119,210	128,847	126,477	116,042	97,428
Restock	119,210	128,866	127,120	118,654	103,304
Wales					
No restock	14,391	12,829	10,837	8,374	6,478
Restock	14,391	12,834	10,962	8,885	7,725
Great Britain					
No restock	175,227	181,749	173,029	154,271	127,513
Restock	175,227	181,794	174,468	159,722	139,305

Figure 17. The impact on GB private sector production volumes of adding restocking to the forecast



It can be seen that the impact of adding restocking to the standing volume forecast is significant and this will equally apply to related metrics such as biomass and carbon. This impact is the principle driver behind adding restock to the forecasts. This contribution of

like-for-like restock on these forecasts is made greater by the felling and restocking of overdue timber and future forecast scenarios could be run to measure the full impact of this. The impact of adding restocking to a forecast of potential production is less marked but can be seen in the latter periods of the forecast: the impact in the first three periods is zero to negligible, but appears in the final two periods. If longer term forecasts were run, the potential production arising from like-for-like restock would eventually represent all production.

This like-for-like assumption is a simplification of what is likely to be a more complicated situation, where planting strategies in future may be different to the strategies that were in place when the previous crop was planted, 30 or more years in the past.

Planting practice at any point in time will depend upon private sector practice and government policy, as both influence the rate and type of replanting in forests. The result of this will be that future replanting will not entirely follow the assumptions used to derive this forecast.

An example of such differences would be the widely held opinion within the forest sector that many stands will exhibit a future increase in the proportion of open space and broadleaves in many situations. Consideration should also be given to current forest area losses associated with renewable energy projects, open habitat restoration and the low proportion of coniferous species (see Forestry Statistics) that are being replanted in some areas. However, although restocking does impact on standing volumes, differences between the type and level of restocking is not likely to impact greatly on a 25 year forecast of standing volume and increment. The impact will, however, become more apparent in longer-term forecasts with a substantially longer forecast horizon.

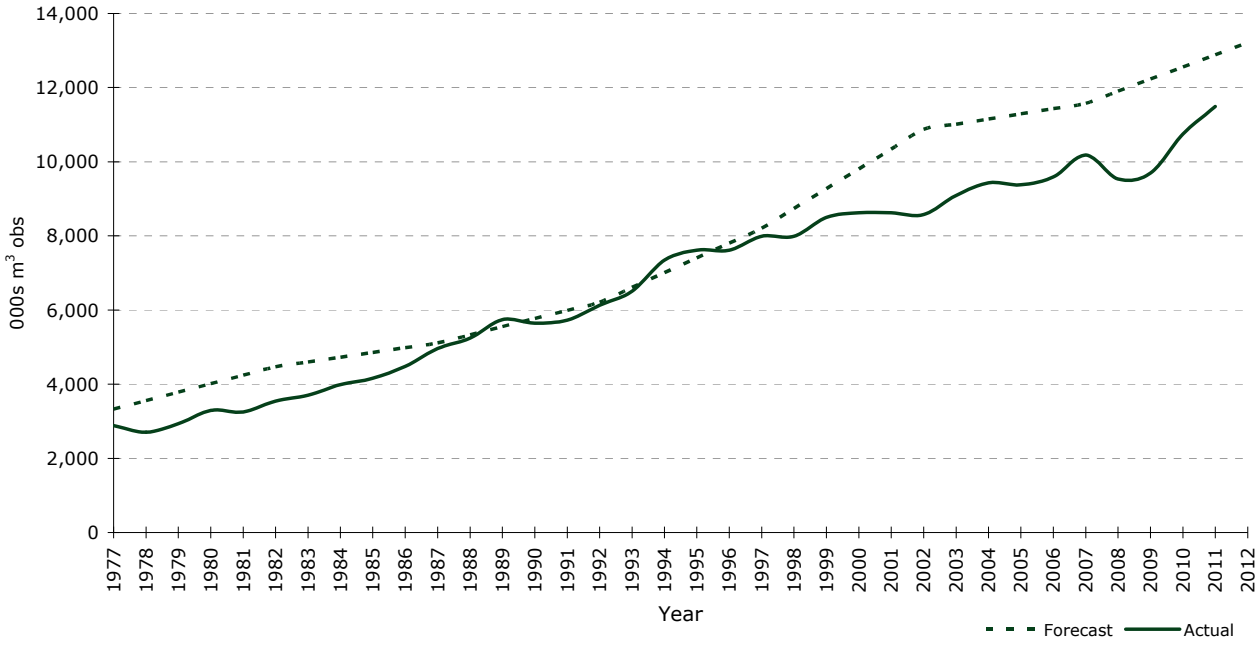
It is for this reason that FC is currently developing the capacity to run restocking scenarios, so that the impact of different restocking approaches can be assessed.

Actual harvest – owner choices

The actual level of harvest will be the result of what is collectively chosen by all owners to be harvested from the timber that is available. The amount of timber that is available is set by the biological and physical factors as discussed above. What is chosen is the important consideration and this is often different from what is available, as previous forecasts have shown (see Figure 18). Actual level of harvest has been below that forecast in the vast majority of years, over all the forecasts published since 1970 and based upon this it is probable that this trend will continue. This approach to harvesting is a likely cause of the accumulation of overdue timber that currently exists. Owner choice is the most likely cause of this difference as forests may be managed for a variety of objectives, not all of which include maximisation of timber productivity and felling at maximum MAI. For example, some coniferous forests, such as Scots pine forests are

managed for conservation where much longer rotations or permanent retentions are chosen. Many forests are managed for recreational and aesthetic purposes, where longer rotations are also often chosen. When and if timber is harvested is thus a matter of owner preference and choice, which are difficult to forecast.

Figure 18. Actual combined FC and PS production compared to previous forecasts



The forecast level of production potential shown in Figure 18 was established by combining historical forecasts produced by Forestry Commission prior to the 2011 forecast. This involved taking the volumes forecast from the first period from each of the historical forecasts and then these were compiled to produce an overall line. Actual timber produced is taken from Forestry Commission timber trade statistics.

NFI guide to estimating private sector production

Although this report has highlighted the pitfalls of making a single estimate of future production, there is some value in setting down an expert view of how events may transpire. However, this view must be taken with the caveats that have been outlined in this paper.

Looking at the volumes in Table 1 and the areas in Table 2 it can be seen that at present physical, biological, legal and harvesting constraints have relatively little impact on the total volume that could be produced. Therefore biological potential is perhaps not as theoretical as may first be thought and is a reasonable benchmark for the private sector, against which to predict actual production. The only significant and emergent exception to this is the potential impact of pests and diseases, the impact of which could exceed what can be ameliorated by substitution, particularly in regions with a high proportion of susceptible species. Extensive suppression of yield class due to disease could however alter this picture. Beyond the possible worst outcomes of pests and diseases it can be assumed that age and composition of the growing stock are the main drivers behind levels of harvesting and there are now quantifiable estimates of these to base forecasts upon. However, the other significant driver is 'practice', meaning the choices that owners make in terms of what they harvest and when, which is much less quantifiable. If what happens in the future can be based upon what has happened to date, then these drivers will continue to dominate and the increase in mature available growing stock will drive production upwards and owners will continue to choose to harvest a significant proportion of the available timber; the exact proportion will depend upon several factors, including owner choice and market demand.

Study of the data arising from the NFI and the scenarios from the production forecast leads to the conclusion that the majority of FC estate fell ages tend to be relatively close to year of maximum MAI. A proportion of the estate is harvested at ages beyond maximum MAI and this feature is also observed on the private sector estate. However, the level and extent of thinning on both the FC and the private sector estate is below that prescribed by MTT.

However, for a significant proportion of the private sector estate, age of felling is below year of maximum MAI for many stands, especially so for stands of Sitka spruce. As a result of this practice, relatively few stands of over 40 years of age or of mean dbh greater than 20–24 centimetres are evident in the current private sector growing stock. Non-spruce species tend to be retained for longer and consequently have a higher mean dbh, but they still fall mostly in the 20–30 centimetre dbh band and again are usually being felled earlier than maximum MAI. This practice if continued will depress potential production levels.

By considering the history of planting, many high DBH crops within the GB growing stock might be expected to be found. As they do not exist in any significant number is must be assumed that they have been felled. Indeed, forecasts in the 1970s noted that at that time average dbh measurements were in the range of 20–30 centimetres, but it was also noted that by the 2012 period there would be many 40–60 centimetre crops in GB forests as the existing forests of 1970 matured and grew. However, the NFI has not found these, so the conclusion is that such stands must have been felled. For spruces in

particular, the low mean dbh found in the survey strongly indicates felling below maximum MAI. This would indicate a general historical trend of felling planted conifers at young ages, before they attain higher dbh sizes.

Private sector estate thinning practice to date has been measured in the forest and it shows that 15% of crops have been thinned once and a further 17% more than once. This is well below what can be physically thinned and indicates that most private sector crops being non-thinned, thereby reducing rotation length, increasing standing volume at felling and reducing log content. If this trend of felling and thinning continues, the peak of felling could occur between 2017 and 2021. However, this would require a very substantial increase in the level of harvesting over a short period of time which, if not achieved, would move the peak of felling to a later date. Conversely, if the private sector fells at maximum MAI in future, then the peak will occur 20 years into the future, in the 2027 to 2031 period. The likelihood is that the timing of the peak of production will fall between those two extremes. Assuming the current trend that a significant proportion of the private sector will fell at 30 to 35 years or before crops attain 25 centimetres or more in dbh, corresponding to the range of ages and dbh's found in the NFI, and considering the fact that large areas of stands are currently at or are approaching that stage, the average age of fell in the private sector estate will probably rise, with some crops felled at 30 to 35 years but others being retained, increasing the average age of fell. That combined with the above factors will probably result in peak production occurring in the period 2022 to 2027.

Taking into account the volume contained in the increased growing stock, its age and the current levels and forms of activity, it is highly likely that harvested volumes will increase. Even with the impacts of Phytophthora and Dothistroma, it is likely that production will continue to rise significantly from the current 11 million cubic metres per annum of combined Forestry Commission and private sector production. Total production (FC/FS and private sector) is likely to rise until its peaks between around 16.5 million cubic metres and 17.5 million cubic metres during the period 2020 to 2030. This level of production allows for a 'markdown' in production for constraining factors such as diseases, ease of harvesting and owner choices and is conservative. After this peak, production will probably decline slightly by the end of the period. If a large proportion of overdue timber is harvested though, or rotation lengths increase on average this would increase production further. However, as noted this is only one opinion, based upon interpreting many circumstantial factors including current practice, all of which is highly subjective and highly likely to change over the next 25 years.

The outputs from the scenarios and the site factors measured within the National Forest Inventory field work, such as roading and extractability, are provided to aid understanding of a particular theme or impact. These factors will need different interpretation for different purposes, at different points in time. Through this it is hoped

that analysis of the information can quantify which timber it is more or less likely to be brought to market dependent upon contingent circumstances as they develop. Factoring all of these parameters into a single forecast for a 25 year period is problematic and has been avoided, except for the one heavily qualified example above. For example, the Forestry Commission can determine what volume of timber is susceptible to pests, but cannot predict what proportion of the resource will be infected and how much this will impact upon production.

Another example would be that it is relatively easy to assess which stands can be accessed and harvested and those which cannot, but translating that into a prediction of which stands will be harvested and when is problematic. NFI may determine which will be expensive to harvest and which will be cheaper. However, cost rarely precludes timber from being harvested. It will delay it in times of weak prices as the cost of harvesting mostly determines harvesting viability at times when prices are low. As timber prices fluctuate, so will a crop's likelihood of harvest over a period of 25 years. For example, in 2007 when prices were low, cost would have been a determining factor, but in 2011, with prices 30% higher, it was not such a strong determinant as in 2007. Predicting how this will evolve over 25 years is problematic. It is probably best to understand that ease of access and harvesting (and thus cost) is a factor to be considered and that a certain volume falls into each defined category, as opposed to generating a blanket prescription that defines exactly what will come to market based on this factor.

Through quantifying and exploring the time-boundedness and interdependent nature of these factors that drive future levels of harvesting, it becomes apparent why the current forecast has moved away from making a single forecast of private sector production.

Conclusions

Compared to the 2005 and earlier production forecasts, the 2011 production forecast is a more transparent picture of potential production, especially so for the private sector. This picture centres on providing an objective assessment of the upper bounds of biological potential, but also provides information on factors that may constrain this biological potential. The forecast also provides a harvesting scenario based upon the industry view of future practice derived in 2005 for comparison to this biological potential. With many outputs and scenarios the 2011 forecast presents a more complex picture than previous forecasts did, one that reflects the broad range of potential future outcomes and choices the sector has in terms of the level of harvesting and production within GB forests. As a consequence, the results from this forecast will require more time to fully interpret and derive its full implications. The important thing is that the 2011 forecast separates the measurement of the growing stock in terms of standing volume as a statistically quantified fact, from the much less quantifiable prediction of future harvesting behaviour that is a significant determinant in levels of production. This is a vital and key step if the sector is to monitor the impact of its actions on the growing stock.

The National Forest Inventory has found significantly more potential production than was previously estimated, around 30% more overall, with slightly less within the Forestry Commission estate but around 43% more in the private sector estate. The majority of this volume is not constrained by known factors and may be available at some point. The impact of the amount of roads, accessibility and the capacity to use mechanised harvesting has not been found to be a significant restriction on potential production. Legal restrictions and policy issues are also not expected to have large impacts on the availability of this potential production. Neither will pests and diseases given current levels of infection, but that may change in the future. Whether and when this volume is harvested will, in the main, be dependent upon owner choices with regard to the timing of fellings, the extent of thinning operations or if they even fell at all.

Under a wide range of harvesting scenarios production increases to a peak in the private sector, then decreases. This peak reflects the underlying age structure of the stands, created by the post war (1950's to 1980's) planting boom. Different harvesting scenarios affect the timing and scale of the peak, with differences of up to 10 years, ranging between 2017-21 and 2027-31. There are also differences in cumulative production of between -1% to 9% over the 25 year period between scenarios, and differences of up to 50% in average annual production within single 5 year periods. The conclusion is that the timing and scale of the peak in production is highly contingent upon harvesting practice.

The current low incidence and frequency of thinning, if it continues, will reduce overall production, increase the peak of production and reduce the sizes of assortments into smaller categories. The current practice (for a proportion of the private sector estate) of felling before maximum MAI, if continued, will suppress long-term productivity, bring forward the peak of production and will deepen the 'trough' in production after the expected peak.

Thinning a higher proportion of crops would increase productivity, bring volume forward, increase production in the early periods, extend rotations, defer and flatten the peak of production and reduce the depth of the trough. Cumulative volume production is higher overall if a higher proportion of stands are thinned. These are significant findings.

There are many such observations to be made upon the results and the depth of information generated by the current forecast may facilitate long-term debate and analysis of the UK forest resource and its management and harvesting strategies. The sector now has the information necessary to interpret the growing stock and how the cumulative effects of future events and in particular harvesting choices may impact upon that growing stock. It is possible that this knowledge could be used to formulate actions to attain future targets, such as actual levels of cut to maintain higher production overall, or a target standing volume, or a percentage cut of increment, or an annual production volume. It is hoped that through this process new options, practices and policies may come to light to help in managing the growing stock in such a way as to strengthen the sector in the long term.

The NFI has established a solid evidence base, capitalising upon advances in technology in the fields of computing, modelling, survey and remote sensing that now give the forest industry in GB access to a much wider and deeper field of information and knowledge than has existed before. It has provided a measure of the standing volume, increment, biomass stocks, carbon stocks and condition of GB woodlands. Through this step-change in available information the forestry sector will be better placed to meet the challenges and rigours of what is now a less opaque present and uncertain future.

Further information

This report explores the assumptions used in the preparation of forecasts of forest metrics published by the Forestry Commission. The following forecasts are currently available:

- NFI Report: 25-Year forecast of softwood availability
- NFI Statistical Analysis Reports:
    - UK 25-Year Forecast of Softwood Availability
    - GB 25-Year Forecast of Standing Coniferous Volume and Increment

The following forecasts are due to be published in 2012:

- GB 25-Year Forecast of Coniferous Carbon Stocks
- GB 25-Year Forecast of Coniferous Biomass Stocks

The NFI has produced a suite of documents upon which these reports are based. Further details on how the NFI has derived forecasts can be found in the NFI Methodology Paper *NFI Forecasts Methodology Overview* and the NFI Technical Documentation listed below. The data used for the compilation of the tables and charts of this report are also available for use in NFI Statistical Data.

NFI Technical Documentation for all forest volume themes:

- *Specification of NFI Growing Stock Calculations*
- *Forecast Types*
- *Bulking Up Samples in the NFI*
- *Restocking in the Forecast*
- *NFI Survey Manual*
- *NFI Mensuration Protocol*
- *NFI Map Protocol*
- *Technical Glossary*
- *Growing Stock Volume Forecasts*
- *Volume Increment Forecasts*

Other related NFI reports:

- NFI Report: Standing timber volume for coniferous trees in Britain

All documents and data can be found on the NFI website (www.forestry.gov.uk/inventory).

Appendix A: Definitions of 'forecast'

There has been some ambiguity in understanding what is meant in terms of 'actual production', 'availability', 'potential production' and 'production forecasts'. These are clarified here.

Actual production

Actual production relates to what timber volume was actually felled and removed from the forest. After a period of time actual production can be compared to past forecasts, to test the accuracy of the forecast.

In Great Britain actual production is assessed in two ways. The Forestry Commission keeps records of its own production for the FC estate, based upon sales records and uses these to monitor its actual production. For the private sector the Forestry Commission statistics branch works in conjunction with private sector processors to monitor private sector production by what is reported to have been delivered to the mills. These two approaches are subtly different in that for the private sector this involves converting delivered amounts to a standing volume cut, which necessitates assuming levels of conversion loss etc. Similar approaches are required for the Forest Commission Estate, but not to the same extent.

In the past forecasts of production for both the Forestry Commission and the private sector have often been reasonably close to actual production, though over the last 15 years actual production for the private sector has generally been below forecast (see Figure 18.

As well as monitoring actual production via sales or receipts as above, some elements of actual production can be directly measured in the forest and this is generally thought to be the most reliable method as it is less open to errors arising from conversion loss and unreported sales or receipts. At present this information is not available within GB. However, in future the NFI survey exercise will allow the Forestry Commission to measure this more accurately by measuring the volume of dead trees and felled whole trees left in the forest. NFI will not directly measure the volume of non-merchantable stem sections (sawdust, tops, butts) left in the forest, transport and storage losses, or bark. A separate exercise would need to be undertaken to achieve this. Through the establishment of permanent sample plots, in future the NFI will be able to provide direct estimates of growing stock changes over time as a result of tree growth, removals and other changes.

Production forecasts

The term 'production forecast' can take different meanings in different contexts. In industrial manufacturing, for example, this term will normally refer to a projection of production based upon a firm plan of operation that is highly likely to transpire. In biological contexts, such as UK forestry, a production forecast cannot have the same degree of likelihood of outcome due to the nature of the resource. In the forecasts presented in these reports, the FC estate forecast is the closest in nature to a production forecast in the industrial context, where there is a plan of production, based on felling and thinning plans. However, these plans are fluid and production will vary from them to some extent, even though they will, in the main, be followed. In the short term Forestry Commission make a commitment to produce a proportion of the forecast volume within the first five-year period, but after the first 5 years the FC forecast is a signal of intent only. This is because the FC forecast is based upon plans and such plans will alter over a 25-year period in response to significant events such as wind and pests and changes to country policies. Therefore over longer time horizons the Forestry Commission forecast changes in nature to be more a forecast of potential production.

Potential production

Potential production is defined as any forecast of production that is not based upon a fixed plan of production. Viewed another way, it may not necessarily happen and therefore should be viewed as one of potential. In the private sector for example there is no single plan of production and any forecast for this sector must make assumptions about future levels of harvest. It is likely that these assumptions will not transpire and therefore the private sector forecast should be regarded as one of potential production. It is conditional upon an assumed rate of harvesting, occurrence of wind damage, pests and diseases, and future management of the resource according to the assumed and formally expressed management scenario.

Availability

The term availability was historically used in two ways; firstly as an umbrella term to cover both production forecasts and potential production and secondly as shorthand for potential production. The actual definition used for availability in the 2005 production forecast was: 'Forecast results for the Private Sector represent estimates of volume potentially available, rather than a forecast of production. These estimates are based on the fully productive potential of the growing stock when managed according to the prescriptions provided by the industry working group'. The title of the 2005 forecast was 'United Kingdom: New Forecast of Softwood Availability'.

This definition used in the 2011 production forecast is as a short hand for potential production. An element of the Forestry Commission estate forecast is in the nature of a production forecast in the industrial sense, since part of it is based upon a marketing plan.

Glossary

actual production	Timber actually 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 receipts reported by timber processors. These figures are available from Forestry Commission Statistics.
age class	A grouping of trees into specific age ranges, for classification purposes.
annual allowable cut	A conceptual tool to assist in delivering sustainable forest management in harvesting practice, wherein a predefined ceiling is set on the levels of harvesting a forest resource can sustain without detriment to its long term productivity.
Area (forest/woodland)	Forest and woodland area is divided into net forest area – the land actually covered by trees (in the National Forest Inventory defined to the drip line of the canopy); and gross forest area which includes both the area covered by trees and the open spaces (of less than 0.5 hectares) within the forest boundary (e.g. rides, glades, ponds).
Availability	A term to describe what timber could potentially be available for harvesting within a forest area.
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 Management table thinning. It may not take account of factors that constrain thinning and felling (e.g. wind risk or pest attack). The forecast results set out in this report involve constraints on thinning and times of felling to take account of wind risk.
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'.
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 methodology score)	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.
dbh (diameter at breast height)	The diameter of a tree (overbark) at breast height, which is usually defined as 1.3 m along the axis of the stem from the ground.
design plan	A holistic spatial and temporal plan covering the main aspects of long-term woodland management such as felling and restocking.
FC estate (Forestry Commission estate)	Forests, woodlands, open land and other property managed by the Forestry Commission.
felling plan	A spatial and temporal plan of harvesting activity within a woodland.

forest	Land predominately covered in trees (defined as land under stands 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 the regulation of forestry, implementing forestry policy and management of state forests in GB. 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.
FS (Forest Service of Northern Ireland)	An agency within the Department of Agriculture and Rural Development in Northern Ireland responsible for the regulation of forestry and the management of state forests in Northern Ireland.
Great Britain (GB)	England, Scotland and Wales.
Growing stock	A term broadly referring to the standing resource of living trees at a point in time.
high forest	Woodland which is not managed as coppice or pollards and which may or may not be managed for timber.
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).
like-for-like	Replacement of felled trees by species with similar productivity. Usually taken to mean, after a period of two years, replacement of felled trees with trees of the same species and yield class.
maximising productivity	The management of woodland to maximise volume production by thinning at the MTI and felling to age of maximum MAI.
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.
Maximum MAI (MMAI)	The maximum value of mean annual increment for a forest stand as observed directly or estimated from Forestry Commission yield tables. Under UK conditions, maximum MAI is usually achieved after a number of decades. See *mean annual increment.*
Management Table thinning (MTT)	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 whilst also maintaining maximum cumulative volume production. See *thinning intensity*.
Mean annual increment (MAI)	The average rate of volume production up to a given year, expressed in m3 per hectare per year. In even-aged stands it is calculated by dividing cumulative volume production by age
MTI (marginal thinning intensity)	The maximum sustainable intensity of thinning defined as 70% of yield class per hectare per year (m3/ha/year).
NATIONAL FOREST INVENTORY (National Forest Inventory)	An inventory run by the Forestry Commission, set up in 2009, to provide a record of key information about GB forests and woodlands.
Net increment	Net increment is defined as volume growth, inclusive of any harvested volumes, less loss due to natural mortality, including endemic windthrow.
overbark	Used as a definition when the 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.
planned production	The volumes and assortments published in the removals forecast, reflecting the cumulative impact of managing the FC estate (as of 31 March 2011) in accordance with approved forest design and thinning plans.
potential production	A forecast which will not necessarily transpire. As the private sector estate forecast makes assumptions about future levels of harvest, and the assumptions may not transpire, this forecast is one of potential production.
private sector estate	Forests and woodlands in the UK not owned or managed by the Forestry Commission or FS. 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.
Dothistroma needle blight	An important disease of conifers (especially pines) which causes premature needle defoliation, resulting in loss of yield and, in severe cases, tree death. Also known as Red Band needle blight.
restocking plan	A spatial and temporal plan covering replacement planting in harvested areas.
softwood	The wood of coniferous trees or the conifers themselves.
stand	A relatively uniform collection of trees (from either artificial or natural regeneration), composed, for example, of a single species or a single age class.
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 useable 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 standing volume in trees in woodlands of less than 0.5 hectares. Usually expressed as m3 overbark standing (m3 obs).
stem wood	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 removal of a proportion of trees in a forest after canopy closure, usually to promote growth and greater value in the remaining trees.
Thinning intensity	A measure of the 'lightness' or 'heaviness' of a thinning, generally expressed in terms of the amount of timber volume per hectare removed relative to the growth rate of a forest stand.

timber	The woody product from felled trees, which is destined for construction material, pulp or paper industries.
top diameter	The diameter of the smaller (top) end of a 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 plus Northern Ireland.
volume per hectare	The woody volume of trees (measured in m3/ha).
windthrow/windblow	Uprooting of trees by the wind. There are two types: • Endemic windthrow: damage caused by frequently recurring peak winds. Forest management practices worsen endemic damage when windward-facing boundaries are created or stands are excessively thinned. • Catastrophic windthrow: an infrequent occurrence associated with exceptionally strong winds where large areas/numbers of trees are thrown over.
yield class (YC)	An index used in the UK of the potential productivity of even-aged stands of trees based on maximum MAI. It reflects the potential productivity of the site for the tree species growing on it.