Forest Research

Estimating the wood fuel potential of Woolhope Dome: Final Report – *Draft*

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Contents

Executive Summary

Introduction

Woolhope Dome is a rural area covering 5582 hectares with high biodiversity value in Herefordshire, in the West Midlands of England. The Woolhope Dome Project is a pioneering nature conservation concept, and one of the pilot projects in the UK, seeking to bring about large-scale biodiversity gains at the landscape level in combination with socio-economic interests.

This report describes a study carried out by Forest Research as part of the Woolhope Dome Project to:

- Estimate the extent of the wood fuel resource available in Woolhope Dome woodlands.
- Identify physical and environmental constraints on wood fuel production and to quantify their potential influence.
- Develop a wood fuel inventory and forecast for Woolhope Dome woodlands.
- Estimate potential greenhouse gas reductions that might be achieved through local production and utilization of wood fuel and other timber products.
- Support local woodland landowners and managers in making decisions about whether to produce woodfuel from their woodlands.

Methods

The three major tasks involved in the study consisted of:

1. A strategic survey and forecast of the potential wood fuel resource in the woodlands forming Woolhope Dome.
2. An analysis of constraints on potential woodfuel production as part of the strategic survey and forecast.
3. The development of operational tools which could be used to manage woodfuel production from individual woodlands or parcels of woodlands.

The successful completion of these tasks required the specification, documentation and testing of three new methodologies for woodland assessment and estimation of productive potential:

- A rapid survey protocol for the strategic assessment of the composition and productive potential of a significant woodland area, possibly formed of a diverse mix of individual stands.
- A measurement protocol for the operational assessment of the growing stock and woodfuel potential of individual woodlands.

- A calculation protocol for estimating the potential of woodlands to produce woodfuel through thinning, subject to local operational constraints.

In addition, it was necessary to develop and explore the use of a novel approach to production forecasting, suitable for application to a relative small region or locality involving complex management decisions.

Rapid survey approach

The rapid survey methodology developed for Woolhope Dome was based on a 'cut-down' version of the mensurational assessment protocol recently proposed used as part of the Southwest Woodlands resource survey (FR and RDI, 2009). The full rapid survey methodology is given in Appendix 1 of this report.

Operational survey approach

The methodology for operational assessment of woodlands was developed as an extension to existing procedures for the measurement of woodlands for the purposes of sale of timber as thinnings or fellings (Matthews and Mackie, 2006; Mackie and Matthews, 2008). The full assessment methodology, including supporting data collection forms, is given in Appendix 2 of this report.

Thinning control calculations

Existing published systems for thinning control in British woodlands (Rollinson, 1988) were considered unsuitable for determining levels of harvesting as thinnings in woodlands that were either believed to be undermanaged or might be subject to significant environmental constraints. Therefore, a novel method for calculation of thinning cut was developed which aims to maintain a characteristic level of stock in stands as they develop over time. The full calculation methodology is given in Appendix 4 of this report.

Long-term forecast of maximum potential production

The first stage in estimating the potential for production of wood fuel from the Woolhope Dome region involved making a forecast of the theoretical long-term maximum quantity of wood fuel that the woodlands in the region might supply. An implicit assumption in the calculation of such an estimate was that all of the woodlands in the region can be actively managed in order to maximise production from every stand. However, some allowance is made for the likelihood that not all harvested wood would be utilised for wood fuel. The resultant estimate was 3450 oven dry tonnes of woody biomass per year.

Medium-term forecast of realistic potential production

In reality woodlands are rarely managed for maximum production due to a range of practical, environmental and social constraints. For the Woolhope Dome project, it was essential to derive realistic estimates of the quantity of wood fuel that might be produced. An estimate was made of the actual availability of wood fuel from woodlands in Woolhope Dome over the next 20 years. This involved combining the results of a trial of the rapid survey with the estimates of theoretical maximum long-term potential production. The resultant estimate was 1380 oven dry tonnes of woody biomass per year.

Long-term forecast of realistic potential production

The estimation of the realistic potential for wood fuel production *in the long term* is the most problematic task to be attempted in this project. An upper limit on realistic long-term was estimated at about 2400 oven dry tonnes of woody biomass per year.

Conclusions

Modelling and survey approaches can be applied to estimate the potential for wood fuel production from a region of woodlands such as Woolhope Dome:

- Operational assessment protocols (Appendices 1 and 4) can be used to make 'yes/no' decisions about thinning to produce wood fuel in particular stands.
- Rapid survey protocols (Appendix 2) can be used to assess the overall near term potential for wood fuel production across a significant area of woodland made up of many stands.

A modelling approach can be used to estimate the theoretical long-term maximum potential for wood fuel production from a significant area of woodland made up of many stands:

- A combination if model-derived and rapid survey results can be used to estimate the realistic potential for wood fuel production from a significant area of woodland over the short and medium terms.
- The derivation of a realistic estimate of long-term potential for wood fuel production is more speculative, depending on local knowledge and clear decisions on how woodlands are to be managed in the future.

For Woolhope Dome woodlands, the estimated theoretical long-term maximum potential for production of wood fuel is 3450 oven dry tonnes per year. The estimated long-term realistic potential for production of wood fuel is estimated to be at most 2400 oven dry tonnes per year. The estimated realistic potential to produce wood fuel over the next 20 years is 1380 oven dry tonnes per year. This is roughly enough wood fuel to supply heat to 700 domestic dwellings and, if used in place of fossil fuels, would represent a reduction in greenhouse gas emissions of between 345-900 tC-eq per year (1250-3300 tCO_2-eq per year). The medium-term realistic estimate is smaller than the long-term estimate apparently due to the general age class structure of stands forming the Woolhope Dome woodlands as well as 'understocking' in some stands.

Recommendations

The assessment and modelling methods developed in this project should have the potential for wider application and options for their dissemination should be considered. Forest Research Technical Development is already carrying out trials of some of the assessment protocols in training courses for wood fuel project developers.

The assessment and modelling protocols developed in this project lend themselves readily for implementation within easy-to-use computer software which could include checks on procedure and data integrity as well as automating most, possibly all, of the intermediate calculations. Options for development of such software packages should be considered.

If there is continued and growing interest in promoting the management of woodlands in the Woolhope Dome region then options for further, more extensive survey work should be considered, for example carrying out a rapid survey across the entire woodland area. This latter option might also present an opportunity to check the precision of the rapid survey approach proposed in this project.

1. Introduction

Woolhope Dome is a rural area covering 5582 hectares with high biodiversity value in Herefordshire the West Midlands of England (see Figure 1.1). The Woolhope Dome Project is a pioneering nature conservation concept, and one of the pilot projects in the UK, seeking to bring about large-scale biodiversity gains at the landscape level in combination with socio-economic interests. The project is intended to be an example of best practice for other areas with similar high biodiversity value.

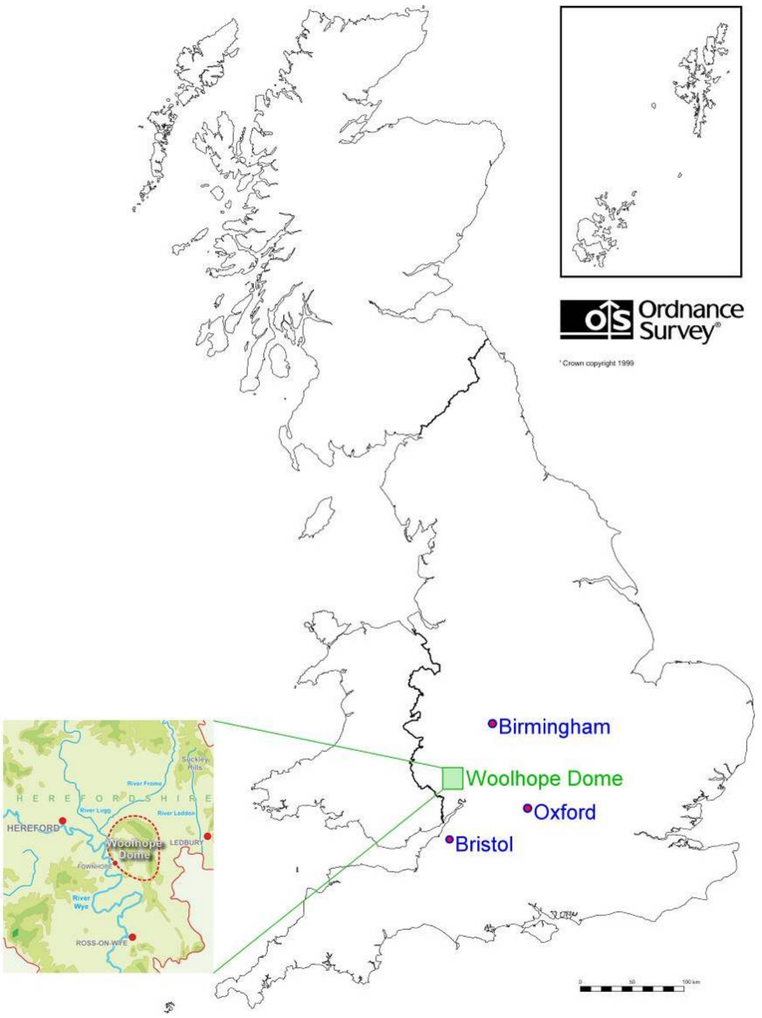

Figure 1.1 Map of Great Britain showing the location of Woolhope Dome.

The project is based on a collaboration between Natural England, Wye Valley AONB, Forestry Commission England and Herefordshire Wildlife Trust. The project's partnership approach involves the local community and achieves benefits for the local economy and ecology by focusing on restoring strong links between the various habitats (grassland, commons, woods and orchards) within environmental schemes, providing high biodiversity gains while encouraging local produce and producers. With 30% of the Woolhope Dome area formed of woodland, a key element of this approach involves improving the management and quality of woodlands by developing local markets for wood fuel.

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In addition, it was necessary to develop and explore the use of a novel approach to production forecasting, suitable for application to a relative small region or locality involving complex management decisions.

The main body of this report begins by describing the development and testing of the new methodologies (Sections 2 and 3 respectively). The strategic resource assessment of woodlands forming Woolhope Dome is discussed in Section 4, where key results are also presented. Section 5 includes a discussion of the results and offers some conclusions, lessons learned and recommendations for managing a possible increase in wood fuel production from the Woolhope Dome region.

2. Development of methodologies

Protocol for rapid survey of woodlands

In the context of monitoring and reporting forest carbon stocks and stock changes, Matthews and Mackie (2008) have identified several different types of woodland assessment which may be appropriate for different reporting objectives and scales in terms of woodland area. These cover:

- Model-based assessments
- Full enumeration (census) of trees
- Plot-based assessments
- Operational survey assessments
- Sample-based inventory assessments

An operational survey assessment methodology would seem most suitable for the rapid survey of woodlands comprising several thousand hectares such as in Woolhope Dome. Such methods are novel and almost untried in British forestry, therefore the application of such an approach in this study is exploratory.

The survey methodology developed for Woolhope Dome was based on a 'cut-down' version of the mensurational assessment protocol recently proposed for use as part of the Forestry Commission's National Forest Inventory (Mackie and Matthews, 2009). Essentially, the Woolhope Dome rapid survey protocol involves the following steps:

Visiting all (or as many as possible) of the stands forming the woodlands in the survey area.
Walking to each 'centroid' of the stand (in loose terms the point at the middle of the stand).
At the centroid, carrying out assessments of basal area per hectare, numbers of trees per hectare and mean diameter of trees. A rough assessment of stand top height is also made.

The full rapid survey methodology is given in Appendix 1 of this report.

Protocol for operational assessment of woodlands

The methodology for operational assessment of woodlands was developed as an extension to existing procedures for the measurement of woodlands for the purposes of sale of timber as thinnings or fellings (Matthews and Mackie, 2006; Mackie and Matthews, 2008). The two-step abbreviated tariffing procedures, specifically those known as "Step I Method A, Step II Method 4-5" and "Step I Method B, Step II Method 6" were used as the basis for the methodology.

In broad principles, Step I involves making an assessment of the number of trees in the area of woodland of interest, while Step II involves making an assessment of the stem volume per tree. The estimates from the two steps are then combined to establish the total stem volume. According to normal forestry conventions, stem volume is measured in cubic metres as straight timber in the stem and any major forks of a tree with a minimum diameter of 7 cm over bark and a minimum length of 3 metres. Clearly, for the purposes of wood fuel production, it is possible to consider material of smaller diameter and shorter lengths, which may not be particularly straight, including branchwood. It is also preferable to express quantities of material in units of mass rather than volume, for example as fresh tonnes or oven dry tonnes of biomass. The major tasks involved in extending the abbreviated tariffing procedures thus involved specifying how to estimate quantities of wood other than in the stem, and describing how to derive estimates expressed in tonnes. The approach adopted for the BSORT methodology and associated computer model (Matthews and Duckworth, 2005; Brewer *et al*., 2008) were applied extensively for these purposes.

In addition to the fundamental extensions to existing procedures described above, the aim was to present the new methodology as a practical field guide rather than a technical treatise, so that practitioners should find it reasonably straightforward to apply in real situations. This included designing forms that might be used for field data collection and a worked example of how to process measurements into the essential results for a woodland.

The full assessment methodology, including supporting data collection forms, is given in Appendix 2 of this report.

Protocol for calculation of 'allowable cut' and target thinning in woodlands

Existing published systems for thinning control in British woodlands (Rollinson, 1988) were considered unsuitable for determining levels of harvesting as thinnings in woodlands that were either believed to be undermanaged or might be subject to significant environmental constraints (e.g. a requirement to minimise the visual effect of thinning on stands and the surrounding landscape). Therefore, a novel method for calculation of thinning cut was developed which aims to maintain a characteristic level of stock in stands as they develop over time.

It is evident that the approach to thinning control proposed here was understood by the developers of the original thinning control system (see Bradley, Christie and Johnston, 1966), but, at that time, it was considered overcomplicated for the management of young, fast-growing conifer plantations. As a consequence, the existing system placed emphasis on identifying a constant thinning yield that was the sustainable maximum stem volume that could be produced over a typical commercial, even-aged rotation, assuming clearfelling at the economically optimum time. However, in the context of bringing existing woodlands into management for woodfuel production, many of which will not be managed for maximum productivity, a system such as proposed here seems more appropriate. Some aspects of existing thinning control systems remain relevant, in particular the definition of thinning 'types' and of 'marginal thinning intensity' (also sometimes referred to 'Management Table Intensity' or 'MTI', see Appendix 3).

An understanding of such existing principles behind thinning practice and control is needed in order to follow the description of the new thinning control methodology, and Appendix 3 of this report provides an introductory discussion of the relevant concepts and terminology, including definitions for the quantities 'top height', 'yield class' and 'MTI'. Further definitions of relevant terms such as 'biomass', 'branch wood' and 'oven dry tonnes' are given in the Glossary.

The proposed new thinning control system relies on the following assumptions:

1. For any tree species, it is possible to identify a characteristic minimum level of stem volume per hectare that should be left behind after thinning.
2. Any thinning operation should not reduce the standing volume to a level below this characteristic minimum.
3. The characteristic minimum level of standing volume increases as a stand of trees grows.
4. For any tree species, it is possible to construct a relationship describing the characteristic minimum level of standing volume as a single-valued function of top height, usually independent of yield class.
5. Any individual thinning intervention should not remove more than a certain characteristic maximum level of stem volume per hectare.
6. The characteristic maximum level of thinning volume per hectare shows a simple dependence on yield class.

Figure 2.1 illustrates the physical realisation of these assumptions, taking Scots pine stands as an example. Essentially, for each tree species, a 'standard curve' was constructed describing the development of the assumed characteristic minimum level of stem volume per hectare with top height. In order to estimate the thinning cut in an area of woodland, an operational assessment as described in Appendix 2 is made in each of the stands forming the area of woodland of interest. From these assessments, estimates are obtained for the top height and standing volume in each stand. The potential thinning volume can be estimated separately for each stand by:

- Plotting the estimate of standing volume against the estimate of top height as a point on a graph.
- Comparing the point estimate with the standard curve, to see whether the standing volume is greater or smaller than the characteristic minimum level.

If the standing volume estimate is below the curve, this suggests that the stand is currently unsuitable for thinning, as illustrated by case (a) in Figure 2.1. If the standing volume estimate is above the curve, then this suggests a thinning is possible. An unadjusted thinning volume is calculated as the difference between the standing volume estimate and the value given by the curve for the same top height, as illustrated by cases (b) and (c) in Figure 2.1. However, as illustrated in case (c) of Figure 2.1, it is also assumed that the volume removed in a single thinning should not exceed a certain amount. This is to avoid overthinning of the growing stock and to reduce possible impacts on stand stability. The developers of the original thinning control system used in British woodlands estimated that, to allow for these constraints, the maximum thinning intensity should not exceed 1.4 MTI. Sometimes, local management constraints may result in managers electing to adopt a smaller value for the maximum thinning intensity, say 1.0 MTI or even 0.8 MTI. For example, these sorts of values might be considered appropriate in situations where there was an intention to minimise the visual effect of thinning on stands and the surrounding landscape.

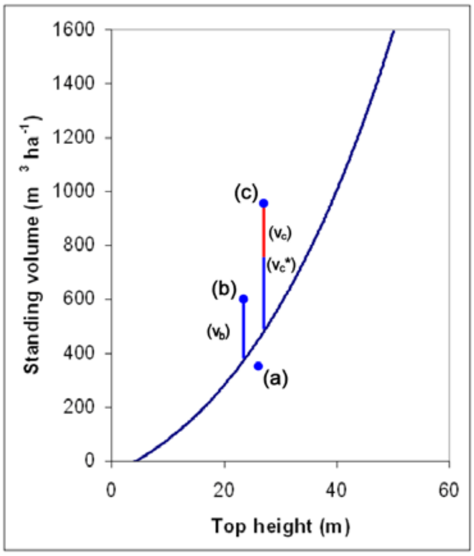


Figure 2.1 The characteristic minimum level of stem volume per hectare that should be left behind after thinning in Scots pine stands, plotted against stand top height. Examples of how this relationship can be used to make decisions about thinning are illustrated in cases (a)-(c). In each case, it is assumed that an operational assessment has been made of the top height and standing volume in the stand and the result is plotted on the graph and compared with the standard curve.

(a): the standing volume is below the curve – thinning not recommended. (b): The standing volume is above the curve – the recommended thinning volume is the difference between the volume assessment and the value suggested by the curve for the same top height (v_b). (c): The standing volume is significantly above the curve. A thinning volume can be calculated as the difference between the volume assessment and the value suggested by the curve for the same top height (v_c), however this is 'capped' at the characteristic maximum thinning volume v_c*, to prevent 'overthinning'.

Having decided whether a thinning is feasible and having calculated a target thinning volume. A thinning calculator software tool developed by Forest Research (Arcangeli *et al.* 2006) can be used to estimate the associated target numbers of trees per hectare, basal area per hectare and mean diameter of trees to be removed as thinnings. (Marking thinnings in terms of numbers of trees and target diameters is generally easier for field practitioners than working with a target volume.)

The full calculation methodology is given in Appendix 4 of this report. As with the operational assessment methodology, this is intended to serve as a practical field guide rather than a technical treatise, and includes supporting calculation forms.

3. Testing of methodologies

Operational assessment of woodlands and calculation of 'allowable cut'

The operational assessment protocol was trialled in four woodlands with contrasting area, species composition, age and stocking densities as summarised in Table 3.1. The locations of the four trial woodlands are shown in Figure 3.1.

Table 3.1 Woodlands used for trials of operational assessment procedure.

Woodland name	Species	Area (ha)	Age* (years)	Yield class**	Stocking** (trees per ha)
Mains wood	Douglas fir/ Norway spruce	11	20	16	1310
Park coppice	Douglas fir/ Norway spruce	19	45	16	385
Canwood Knoll	Douglas fir	4	20	16	1825
Fownhope (Cherry Hill)	Oak/larch	29	100	6	196

*Approximate estimates; ** Based on results from assessment procedure.

Figure 3.1 Locations of woodlands assessed as part of trial of operational assessment procedure (sites shown in green).

The plot-based approach to assessments described in the protocol was identified as being appropriate for application in all four woodlands. Details of the data collected and subsequent calculations are given in Appendix 5. From application of the calculation protocol (also described in Appendix 5), three out of the four trial woodlands were found to have potential for production from thinnings, as described in Table 3.2.

Table 3.2 Estimated potential stem volume for thinning in trial woodlands.

Woodland name	Standing volume (m^3 ha^{-1})	Thinning volume (m^3 ha^{-1})	
		Potential	Constrained
Mains wood	242	32	32
Park coppice	497	120	56
Canwood Knoll	86	0	0
Fownhope (Cherry Hill)	274	17	17

The constrained estimates of thinning volume in Table 3.2 were based on the assumption that the thinning volume yield should not exceed 100% of MTI (the 'maximum thinning intensity referred to in the protocol in Appendix 4, see also Appendix

3) on a 5 year thinning cycle, so as to avoid significant loss of stand increment or risk stand instability with high susceptibility to windthrow.

If other considerations were to be taken into account, for example a requirement not to make large gaps in the woodland canopy, this might require the adoption of a lower thinning intensity than 100% MTI (e.g. 50% MTI), with consequent reductions in the constrained estimates of thinning volume. This is a matter that any plan for wood fuel production from Woolhope Dome woodlands would need to address carefully.

The estimates of thinning yield per hectare in Table 3.1 are applicable for a period of 5 years (equivalent to the assumed 5 year thinning cycle), thus the annualised potential production from the four trial woodlands over a 5 year period could be found by dividing the constrained estimates by 5 (Table 3.3). Also shown in Table 3.3 are estimates of the total thinning volume yield for each woodland, obtained by multiplying the annualised thinning volume by the net area for each woodland. Net area is estimated for each stand by the surveyor while taking operational assessments and represents an adjustment of gross area to allow for unproductive ground such as roads, rides, lakes, boulders etc.

Table 3.3 Estimated potential stem volume for thinning in trial woodlands.

Woodland name	Estimated thinning volume (m^3)			
	For period (per ha)	Annualised (per ha)	Net area* (ha)	Annualised (for woodland)
Mains wood	32	6.5	10.5	68
Park coppice	56	11.2	17.8	199
Canwood Knoll	0	0	3.7	0
Fownhope (Cherry Hill)	17	3.5	29.4	103

*Based on gross area in Table 3.1 and gross:net area factor as assessed in woodlands, see Appendix 5.

Table 3.4 gives the estimated tree biomass (in oven dry tonnes) available for harvesting as thinnings in the four trial woodlands, as calculated using the thinning calculator and FieldBSORT software tool referred to in the calculation protocol (Appendix 4).

Table 3.4 Estimated potential tree biomass for thinning in trial woodlands.

Woodland name	Thinning biomass (oven dry tonnes for woodland)			
	Stem wood*	Stem tips	Branch wood	Total
For 5 year thinning cycle				
Mains wood	140	6	25	171
Park coppice	409	2	54	465
Canwood Knoll	0	0	0	0
Fownhope (Cherry Hill)	288	1	94	383
Annualised (i.e. oven dry tonnes per year)				
Mains wood	28	1	5	34
Park coppice	82	0	11	93
Canwood Knoll	0	0	0	0
Fownhope (Cherry Hill)	58	0	19	77

*Sum of sawlog, roundwood, bark and offcut biomass as estimated using BSORT model.

The "bottom line" results in Table 3.4 indicate that the four trial woodlands could provide a total of just over 1000 oven dry tonnes of wood fuel over a period of 5 years, or just over 200 oven dry tonnes per year. Roughly speaking, this would be sufficient wood fuel to provide heating for around 50 domestic dwellings for a 5 year period (BEC, 2009a).

The experience of applying the operational assessment and calculation protocols presented in Appendices 2 and 4, and the results derived as summarised in tables 3.1-3.4, have demonstrated that the approach proposed to evaluation and control of thinning in woodlands could be used as a practical approach to managing the production of wood fuel.

However, three critical issues would need to be addressed in any attempt to actually use this approach:

1. The methodology requires the "informed" selection of the "maximum thinning intensity" referred to in the calculation protocol (Appendix 4). A standard, slightly conservative value of 1.0 was used in the calculations here but a smaller value (e.g. 0.5) may be appropriate to use in areas where conservation a very high priority.
2. The total estimates assume that all of the harvested wood – consisting of all branches and the complete stem – is available for utilisation as wood fuel. In practice, some parts of harvested trees, notably large diameter stem wood of good quality is much more appropriate for utilisation as sawn timber. Allowances therefore need to be made for the quantities of wood not used for fuel, for example by excluding sawlog material from estimates. However, the position is complicated because offcuts produced in sawmills may be fed back into the wood fuel supply chain. In the case of branch wood, in practice not all of the material produced in felling of trees will be

removed from site due to environmental constraints (see point 3). These issues are considered further in Section 4 of this report.

3. Further allowances need to be made for practical and environmental constraints on potential for wood fuel production (e.g. access issues, availability of suitable contractors, risks to soil nutrient status arising from removal of biomass, presence of nesting birds).

Rapid survey of woodlands

The rapid survey protocol was trialled in as many of the woodlands across Woolhope Dome as possible within a survey period of 5 working days by a lone surveyor. The woodland areas covered by the trial survey are shown in Figure 3.2. The Figure also indicates woodlands managed by the Forestry Commission (for which subcompartment data were already available) and woodland areas where access by surveyors was denied by the owners or could not be agreed in time for the survey.

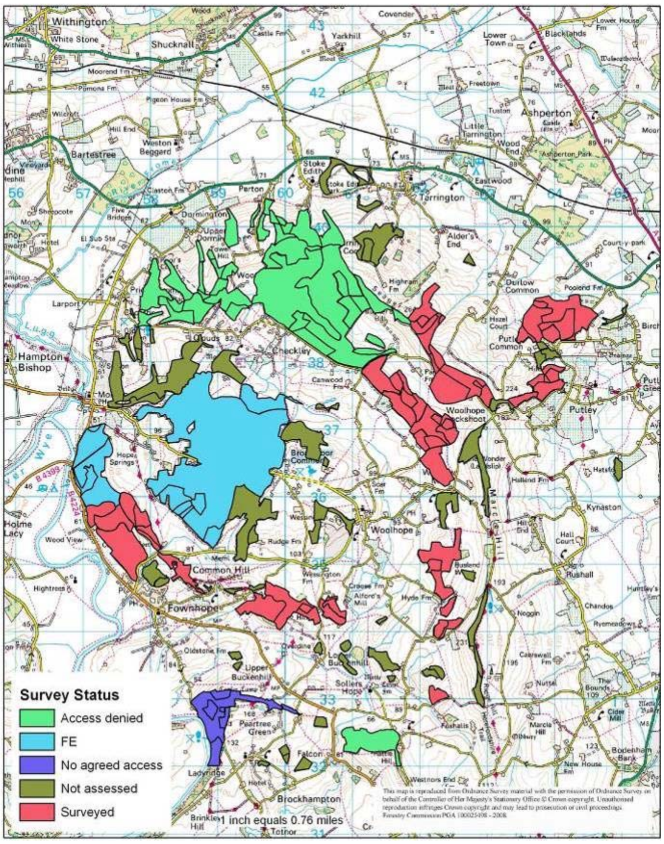


Figure 3.2 Locations of woodlands assessed in trial of rapid survey procedure.

A total of 331 hectares of woodland was surveyed over the 5-day period, a 'work rate' of 66 hectares per day. This would suggest that, subject to the resolution of access issues in some woodlands, a complete survey of Woolhope Dome woodlands could be completed in 22 days (i.e. person-days).

The rapid assessment approach permits a number of variables to be assessed in individual stands forming a group of woodlands. The most important for the purposes of assessing potential for thinning (for wood fuel production or other purposes) are:

- Species composition of the stand
- Top height of the stand
- Basal area per hectare of the stand.

Assessments of these variables form a central element of the rapid survey protocol, and the results for the 331 hectares of woodland surveyed in the trial are given in Table 3.5. The Forestry Commission has published standard methods for estimating the standing stem volume in stands based on assessments of basal area and top height (Matthews and Mackie, 2006). The most relevant method involves obtaining an estimate of 'form height' based on the top height of each stand by reference to standard tables for the main tree species in Britain. Form height is a conversion factor representing the quantity of stem volume per unit of basal area that might be expected in a stand of trees, thus stem volume can be calculated simply as,

Stem volume per hectare = form height x basal area per hectare.

The standard relationships in Matthews and Mackie (2006) were used to estimate the standing volume per hectare in each of the stands assessed as part of the rapid survey and the results are given in Table 3.5.

In a further calculation step, the top height and approximate age of each surveyed stand could be used to estimate yield class (Edwards and Christie, 1981; see also Appendices 3 and 4). Estimates of yield class for each surveyed stand are also reported in Table 3.5.

Given estimates of standing volume, top height and yield class for each stand, it was possible to apply the 'thinning cut' component of the operational assessment protocol (Appendix 4) to each stand in order to estimate the potential thinning volume. The relevant calculation steps and final results for the 331 hectares of woodland covered in the survey are all shown in Table 3.5. Relevant results from the operational assessment trials have also been included in the table, bringing the total area assessed to 391 hectares.

It should be noted that, by the nature of the rapid survey approach, results for an individual stand are likely to be very imprecise but precision should improve when results for a collection of stands are considered. For the 391 hectares of woodland forming the survey area, from Table 3.5 it was estimated that a total of 7569 m^3 of stem volume was potentially available for harvesting as thinnings over a 5-year period. Taking a conservative estimate for the mean basic density of the timber in these woodlands of 0.4 oven dry tonnes per cubic metre, and assuming a further 20% of woody material potentially available in branch wood (see results for stem wood and branch wood Table 3.4), this suggests the potential availability of 3633 oven dry tonnes of wood fuel for the 5 year period, or just over 725 odt per year. Roughly speaking, this would be sufficient wood fuel to provide heating for around 180 domestic dwellings for a 5 year period (BEC, 2009a).

The trial of the rapid survey procedure seems to have been successful, having provided useful estimates of potential for wood fuel production across a significant area of woodlands based on quite quickly obtained data. However, the three qualifying comments made at the conclusion of the discussion of trials of the operational assessment protocol also apply to the estimates above and in Table 3.5.

In addition, experience of analysing the trial data suggests some improvements:

- The estimation of number of trees per hectare (based on the assessments of distances between three trees selected according to a specified statistical design – see Appendix 1) was found to give biased results. In practice, the estimates for numbers of trees are of most relevance as input data to the FieldBSORT software tool for the detailed estimation of biomass in tree components. Arguably this is a level of detail not needed in such a survey, suggesting that the assessment of number of trees does not need to be taken. This would mean that surveys could be made even more quickly than suggested by the trial carried out in this study.
- If there was considered to be a need for the survey to provide input data for the FieldBSORT tool, then numbers of trees per hectare could be assessed using an alternative approach to the one trialled here. This would involve assessment of the dbh of a 'mean tree' in each stand, selected subjectively by the surveyor. This assessment would be faster to make than the distance-based assessment in the current version of the protocol. However, some 'calibration' of the surveyors dbh assessments would be needed, requiring a fraction of the stands surveyed to receive plot-based assessments.
- Stem biomass production in oven dry tonnes per year could be estimated more robustly from the survey results for stem volume by applying a species-specific basic density to each of the stands assessed, allowing for tree species. This is explored further in Section 4 of this report.

It must also be noted that assessment of basal area using relascope sweeps, as described in the rapid survey protocol, requires skilled and experienced surveyors, otherwise there is likely to be significant bias in results.

Table 3.5 Summary results from rapid survey of woodlands in Woolhope Dome.

Species	Main species	Age	Basal area (m^2 ha^{-1})	Top height (m)	Form height (m)	Stand volume (m^3 ha^{-1})	GYC	Benchmark volume (m^3 ha^{-1})	Standing volume margin (m^3 ha^{-1})	Maximum volume cut (m^3 ha^{-1})	Potential thinning volume (m^3 ha^{-1})	Gross area (ha)	Net area (ha)	Thinning volume for woodland (m^3)
Ah coppice with standards	AH	40	26	18.7	8.1	212	6	172	40	21	21	4.6	3.9	82.1
Ok/Ah	OK	80	22	17.6	7.6	168	4	161	7	14	7	3.3	2.8	19.7
Ah/Yew	AH	90	16	25.4	10.8	173	8	344	-171		0	2.3	2.0	0.0
Ok/Ah	OK	90	38	21.8	9.5	360	4	216	144	14	14	24.0	20.4	285.6
Ok	OK	90	30	28	11.7	350	8	298	52	28	28	8.5	7.2	202.3
Ok/SC	OK	100	24	24.7	10.6	254	6	257	-3		0	15.0	12.8	0.0
DF	DF	25	50		3.8	188	8	71	117	28	28	4.6	3.9	109.5
NS	NS	45	37	22.3	9.6	357	18	376	-19		0	2.0	1.7	0.0
DF	DF	20	24	10.6	4.0	96	12	83	13	42	13	3.9	3.3	44.2
DF/NS	DF	45	52	22	8.9	462	12	257	205	42	42	4.7	4.0	167.8
DF/NS	DF	45	39	28.2	11.5	449	18	402	47	63	47	18.7	15.9	753.4
EL	EL	50	29	29.9	14.6	425	12	396	29	42	29	2.5	2.1	61.1
Ok overstorey	OK	120	4	23.7	10.2	41	6	243	-202		0	7.5	6.4	0.0
SC coppice	SC	20	40	13.3	4.5	181	10	99	82	35	35	2.0	1.7	59.5
SC coppice	SC	20	63	17.2	6.7	419	10	154	265	35	35	2.3	2.0	68.4
Ah	AH	15	19	14.5	6.1	116	12	87	29	42	29	3.6	3.1	88.8
Df/NS	DF	45					16				56	18.7	17.8	996.8
SS/JL	SS	50	50	33.7	14.7	734	24	535	199	84	84	1.3	1.1	92.8
DF	DF	30	28	20.3	8.2	228	16	228	0		0	8.3	7.1	0.0
NS	NS	30	36	17.4	7.4	265	20	251	14	70	14	2.7	2.3	31.8
DF/NS/WH	DF	50	40	25.8	10.5	420	14	341	79	49	49	4.7	4.0	195.8
JL/SP	JL	50	25	26.7	12.9	323	14	327	-4		0	6.5	5.5	0.0
WH	WH	50	53	26.4	11.8	625	18	477	148	63	63	1.5	1.3	80.3
SS	SS	45	42	30.3	13.2	553	24	535	18	84	18	6.4	5.4	97.1
DF/NS	DF	30					16				32	11.0	10.5	336
Ok	OK	120	28	20.9	9.1	255	4	202	53	14	14	3.2	2.7	38.1
Ok/Ah/WCh overstorey	OK	80	14	17.1	7.4	104	4	154	-50		0	3.5	3.0	0.0
Syc/Ah/Bi lowerstorey	SY	40	13	12.5	5.0	65	2	57	8	7	7	3.5	3.0	20.8
Ok/Ah	OK	120	32	23.3	10.1	322	4	236	86	14	14	29.4	25.0	349.9
SC coppice	SC	20	59	15.6	5.8	343	10	134	209	35	35	14.2	12.1	422.5
Ok/Ah/SC	OK	100	26	23.8	10.2	266	6	243	23	21	21	9.9	8.4	176.7
NM/Ok understorey	NM	30	8	13.7	5.7	45	2	37	8	7	7	1.0	0.9	6.0
Ok overstorey	OK	90	24	21.3	9.3	222	4	209	13	14	13	3.1	2.6	35.3
Ah	AH	80	17	27.5	11.5	196	10	411	-215		0	11.0	9.4	0.0
SC	SC	80	32	26.2	10.7	344	8	277	67	28	28	3.7	3.1	88.1
DF	DF	45	24	25.1	10.2	245	14	330	-85		0	3.7	3.1	0.0
SC/Ah coppice (85/15)	SC	20	49	14.4	5.2	252	10	113	139	35	35	4.3	3.7	127.9
DF	DF	45	24	18.5	7.4	177	8	193	-16		0	1.8	1.5	0.0
Ok/Ah	OK	120	16	25.9	11.0	176	6	270	-94		0	15.7	13.3	0.0
Ok	OK	80	34	24.8	10.6	361	6	257	104	21	21	16.6	14.1	296.3
JL/Ah/Syc/Asp/Bi	JL	35	31	18.2	8.3	259	10	191	68	35	35	2.5	2.1	74.4
JL/Syc/Be/Ah	JL	35	30	17.8	8.1	244	10	184	60	35	35	0.7	0.6	20.8
Ah/Ok/Asp/Be/NM/Bi	AH	35	16	10.8	4.1	65	0	37	28	0	0	1.3	1.1	0.0
Ok/Be/Bi	OK	35	6	14.2	6.0	36	6	113	-77		0	1.0	0.9	0.0
Ok/Be/Bi/Asp/NM/Ah/JL	OK	35	13	12.5	5.0	65	4	86	-21		0	1.2	1.0	0.0
CP	CP	35	54	15.5	7.1	383	12	221	162	42	42	16.0	13.6	571.2
DF/NS	DF	35	50	27.2	11.1	555	22	377	178	77	77	15.7	13.3	1027.6
HL/SP	HL	35	18	23.9	11.4	205	14	278	-73		0	4.0	3.4	0.0
NS/Bi	NS	35	22	19.5	8.3	183	20	300	-117		0	8.2	7.0	0.0
DF/CP	DF	40	22	29.3	12.0	264	22	427	-163		0	7.2	6.1	0.0
Ok	OK	80	30	20.3	8.8	265	4	195	70	14	14	3.4	2.9	40.5
Ah	AH	60	19	21.9	9.5	181	6	243	-62		0	4.7	4.0	0.0
Ok/Ah	OK	100					6				17	29.4	29.4	499.8
														7568.8

Notes to Table 3.5

Species: derived from local knowledge.
Main species: based on species column, subjective selection. Essentially the assumption was that the first listed species was the dominant species in each stand.

Age: subjective estimate, informed by local knowledge wherever possible.

Basal area: derived from rapid survey assessments.

Top height: derived from rapid survey assessments.

Form height: derived from top height using Equation 6 and Table A8.5 in Appendix 8 of Matthews and Mackie (2006), with additional reference where needed to Appendix 7 of Matthews and Mackie (2006).

Stand volume: obtained by multiplying basal area by form height.

GYC (General Yield Class): derived from age and top height using Forest Yield software (Matthews *et al*., in preparation.)

Benchmark volume: derived using steps in calculation protocol in Appendix 4 of this report.

Standing volume margin: derived using steps in calculation protocol in Appendix 4 of this report. (Calculated as the standing volume minus the benchmark volume. Results indicating no volume available for thinning are highlighted in red.)

Maximum volume cut: derived using steps in calculation protocol in Appendix 4 of this report. (Calculated as 1.0 x 0.7 x GYC x 5.)

Potential thinning volume: derived using steps in calculation protocol in Appendix 4 of this report. (Calculated as the smallest of the standing volume margin and the maximum volume cut.)

Gross area: from GIS map of Woolhope Dome Woodlands (supplied by Natural England).

Net area: default assumption that gross:net area conversion factor is 0.85.

Thinning volume for woodland: obtained by multiplying the potential thinning volume by the net area.

4. Strategic resource assessment

In Section 3 of this report, the survey and assessment procedures discussed in Section 2 were evaluated by means of trials and estimates of potential wood fuel production were given for the surveyed areas of woodland. In these sections, the emphasis was on *operational* evaluation, e.g. to determine potential for wood fuel production in specific woodlands, or areas of woodlands, in the immediate term, e.g. this year or over the next 5 years. This section reports an element of the Woolhope Dome project which is related but with a different, more strategic objective. The aim in this section is to describe how modelling approaches can be used to evaluate the potential of the complete woodland area falling within the Woolhope Dome region for producing wood fuel in the long term and medium (20 year) terms.

Assessment of theoretical long term potential woodfuel supply

The first stage in estimating the potential for production of wood fuel from the Woolhope Dome region involved making a forecast of the theoretical long-term maximum quantity of wood fuel that the woodlands in the region might supply. This involves assuming that all of the woodlands in the region can be actively managed in order to maximise production from every stand. However, some allowance is made for the likelihood that not all harvested wood would be utilised for wood fuel.

Estimation of wood fuel productivity of individual stands. Production from commercial forestry systems is usually more complex than for annual or perennial energy crops or for short rotation forestry in that production takes place as a series of episodes over the life cycle of a forest stand (i.e. thinnings and fellings) and a mix of biomass components is obtained (i.e. sawlogs, roundwood, branches and conceivably roots and stumps), To complicate matters further, it is unlikely that sawlogs would be accessible for utilisation as woodfuel due to their high value as a source of structural material. This also applies to some extent to roundwood production, particularly from coniferous forests. There will, however, be an opportunity to supply woodfuel from secondary production arising from sawmills notably in the form of wood chunks and sawdust. At the same time, the harvesting of branch and root material from some forest stands is likely to be constrained by the need to avoid ground damage and soil acidification while conserving soil fertility and carbon stocks.

To estimate the available biomass for a range of common tree species by yield class, a representative range of conifer and broadleaf species was selected. The Forestry Commission yield models for these species (Edwards and Christie, 1981) were then referred to and estimates of yield used as inputs to the BSORT biomass model (Matthews and Duckworth, 2005) to produce estimates of potential biomass production in oven dry tonnes. Yield models for both thinned and unthinned stands were considered.

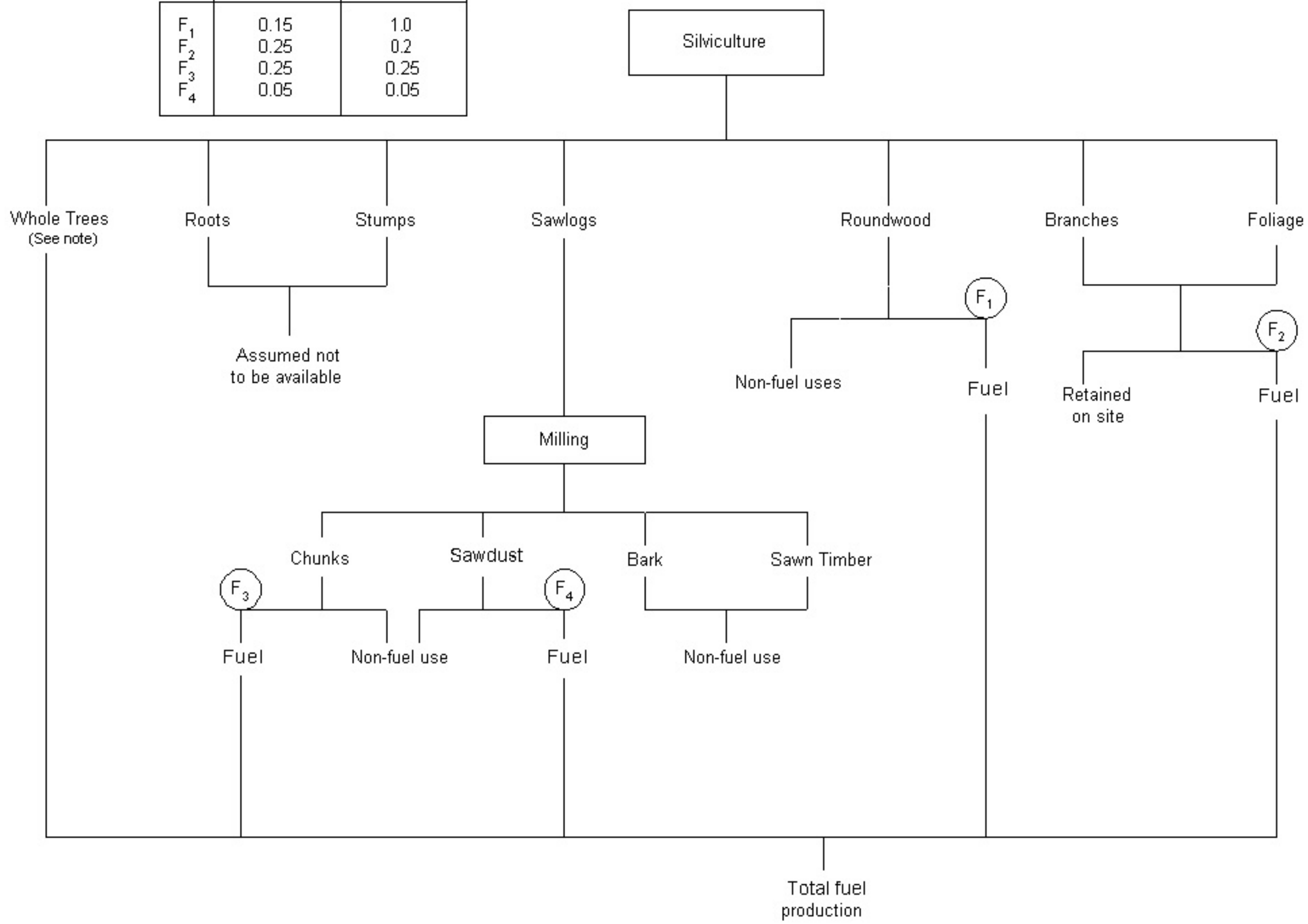
Outputs were produced for full rotations of the selected forest stands, broken down into relevant tree components, specifically:

- Roots
- Stumps
- Sawlogs
- Roundwood
- Stem tips
- Branches
- Foliage.

An example of output for a thinned stand of yield class 8 Scots pine is shown in Table 4.1. The total production of each component over a rotation was annualised assuming a two year fallow period, as illustrated in the table. The fraction of total biomass production available as wood fuel was estimated by applying the generalised biomass flow chart to the results for total biomass. These calculations are illustrated in Figure 4.1, based on the results from Table 4.1.

Figure 4.1 Generalised biomass flow chart for conventional forestry systems.

Note: For thinned conifer stands, production from the first two thinnings was assumed to consist of removal of whole trees for use as fuel (not including stumps and roots). A similar assumption was made for broadleaf stands but involving the first three thinnings, with the exception of beech and oak (first five thinnings).



Values assumed for partition coefficients F_1-F_4

	Conifer	Broadleaf
F_1	0.15	1.0
F_2	0.25	0.2
F_3	0.25	0.25
F_4	0.05	0.05

Table 4.1 Example output from BSORT model for Scots pine, yield class 8 Biomasses are given at each thinning age and for the final felling in odt ha^{-1}.

Age	Roots	Stump	Sawlog	Roundwood	Stem Tips	Branches	Foliage
31	6.3852	0.5154	0.0000	9.1282	3.6049	4.7694	2.1983
36	5.5088	0.4355	0.0054	10.0862	2.1452	3.8596	1.7730
41	4.3187	0.3262	1.0310	9.79.5	1.0806	2.9167	1.3328
46	3.7945	0.2828	2.5961	8.2181	0.9293	2.5327	1.1491
51	3.5199	0.2575	4.3343	6.5380	0.7891	2.3620	1.0621
56	3.3441	0.2394	6.1860	4.9315	0.5159	2.2799	1.0141
61	35.8851	2.4970	83.1315	26.3761	3.2240	25.9701	11.1475
Total	62.7563	4.5538	97.2843	75.0686	12.289	44.6904	19.6769
[1]Annualised	0.9961	0.0723	1.5442	1.1916	0.1951	0.7094	0.3123

[1] Calculated from total biomass by dividing by 63 years (61 year rotation plus 2 fallow years).

The estimated wood fuel production for different species, yield classes and management regimes was then plotted against yield class to investigate whether a simple relationship could be established. Inspection of the results revealed that:

- Wood fuel production was strongly linearly correlated with yield class.
- The linear relationship was very similar for many species, although distinct species groups could be identified.
- The relationship shifted depending on whether stands were thinned or not.

An example of the observed correlation between potential biomass production and yield class is illustrated in Figure 4.2.

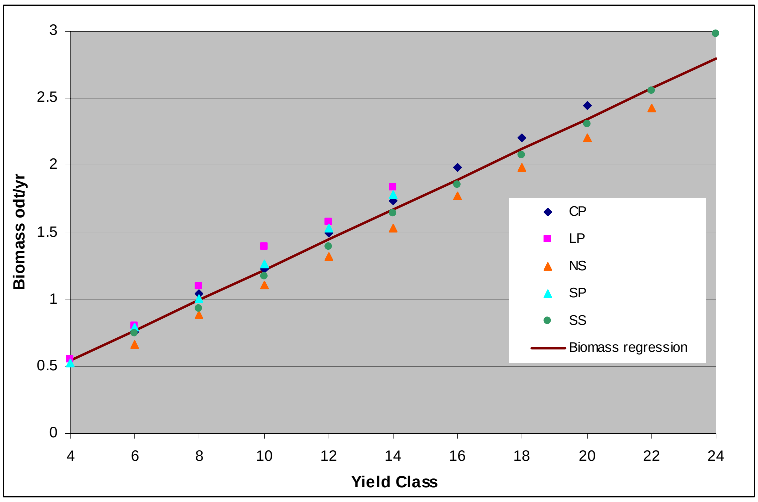


Figure 4.2 Relationship between estimated biomass production and yield class. An example based on results for spruces and pines is shown.

For the example species group pines and spruces (thinned stands). It was decided to discount results for unthinned stands on an assumption that an objective of encouraging wood fuel production in existing woodlands may be achieved through more active silvicultural management involving thinning. Three characteristic equations describing the relationship between potential biomass production and yield class were derived for the major species groups of:

- Broadleaf stands
- Larches and Douglas fir stands
- Other conifer stands

The equations are of the simple linear form,

$$\text{Biomass} = a + b \text{ Yield Class}$$

The parameters for these equations are listed in Table 4.2.

Table 4.2 Parameters of equations relating biomass to yield class.

	a	*b*
Broadleaf Stands	1.151	0.2874
Larches & Douglas Fir	0.3227	0.12397
Other Conifers	0.0952	0.1255

Mapping of wood fuel potential for woodlands in Woolhope Dome. Predictions were made of wood fuel potentially available from the woodlands forming Woolhope Dome made using a combination of:

- A woodland map provided by Natural England (Figure 4.3).
- Records of the species composition and yield class of Forestry Commission woodlands obtained from the Forestry Commission's subcompartment database.
- Information about the species composition of the woodlands obtained from N. Smith (personal communication).
- Estimates of the yield class (GYC) of privately owned woodlands obtained from the rapid survey trial described in Section 3 of this report.
- The biomass equations described in Table 4.2.

The calculation steps and final estimate for each stand making up the Woolhope Dome woodlands are shown in Table 4.3 (pages 27-29).

Table 4.3 Estimation of theoretical long-term maximum potential availability of wood fuel from Woodlands forming Woolhope Dome.

Plot ID	Hectares	Species	Age	YC	Net area	odt/ha/y	odt/y
0	1.57	OK/AH	80	5.4	1.33	2.70	3.60
1	0.94	OK/AH	80	5.4	0.80	2.70	2.16
2	0.73	OK	120	5.4	0.62	2.70	1.67
3	1.80	AH/OK	80	5.8	1.53	2.82	4.30
4	1.39	OK	120	5.4	1.18	2.70	3.20
5	0.75	OK/AH	100	5.4	0.63	2.70	1.71
6	4.17	OK/AH	20	5.4	3.54	2.70	9.57
7	0.83	OK/AH	120	5.4	0.70	2.70	1.90
8	1.50	OK/AH	90	5.4	1.28	2.70	3.45
9	0.90	OK/AH	100	5.4	0.77	2.70	2.07
10	1.65	NS/AH/BI	250	20.3	1.41	2.64	3.72
11	0.37	AH/OK	90	5.8	0.32	2.82	0.89
12	1.41	AH/BI/NM	20	5.8	1.20	2.82	3.38
13	2.97	AH/OK/SC	30	5.8	2.53	2.82	7.12
14	1.32	JL	40	6.6	1.12	1.14	1.28
15	2.94	DF	20	14.8	2.49	2.16	5.38
16	2.90	OK/AH	100	5.4	2.47	2.70	6.67
17	26.44	OK/AH	90	5.4	22.47	2.70	60.75
18	2.39	DF	400	14.8	2.03	2.16	4.38
19	0.49		0	0	0.41	0.00	0.00
20	3.56	JL	50	6.6	3.03	1.14	3.45
21	1.37	AH	0	5.8	1.16	2.82	3.28
22	3.30	NS	50	20.3	2.80	2.64	7.41
23	4.60	Ah coppice with standards	40	6	3.91	2.88	11.24
24	3.93	DF/NS/MB	40	14.8	3.34	2.16	7.20
25	2.03	DF/NS/MB	40	14.8	1.73	2.16	3.73
26	2.11	OK/AH	80	5.4	1.79	2.70	4.85
27	2.75	SC coppice	30	5	2.33	2.59	6.04
28	7.07	DF	50	14.8	6.01	2.16	12.97
29	3.28	OK/AH	80	4	2.79	2.30	6.41
30	8.71	OK/AH	80	5.4	7.40	2.70	20.00
31	2.10	MC/MB	5	8	1.79	1.10	1.96
32	3.13	NS	15	20.3	2.66	2.64	7.03
33	2.43	AH	90	8	2.07	3.45	7.13
34	23.97	OK/AH/BI	90	4	20.38	2.30	46.88
35	2.68	OK	120	4.1	2.28	2.33	5.31
36	5.80	OK	120	4.6	4.93	2.47	12.20
37	3.60	AH/OK	60	5.8	3.06	2.82	8.63
38	3.63	AH/OK	60	5.8	3.09	2.82	8.70
39	1.25	MB	10	1.2	1.06	1.50	1.58
40	8.54	OK	120	8	7.26	3.45	25.03
41	2.93	EL	60	6.1	2.49	1.08	2.69
42	4.58		0	7.7	3.90	0.00	0.00
43	9.68	SC coppice	30	5	8.23	2.59	21.29
44	10.01	Be	60	6.3	8.51	2.96	25.19
45	32.37	Be/MC	70	6	27.51	2.88	79.11
46	5.89	AH/OK/SYC	80	7.1	5.00	3.19	15.97
47	3.06	AH/OK	100	5.8	2.60	2.82	7.32
48	15.00	OK/AH/SC	100	6	12.75	2.88	36.67
49	0.39	Open water	0	0	0.33	0.00	0.00
50	4.59	DF	25	8	3.90	1.31	5.13
51	1.02	SC	50	8	0.87	3.45	3.00
52	15.37	MC/MB	0	9.7	13.07	3.94	51.47
53	16.54	SC coppice/OK	40	5	14.06	2.59	36.39
54	19.12	OK/AH	100	5.4	16.25	2.70	43.93
55	1.97	NS	45	18	1.68	2.35	3.95
		SUB TOTAL			**254.8**		**670.4**

Table 4.3 Estimation of theoretical long-term maximum potential availability of wood fuel from Woodlands forming Woolhope Dome (continued).

Plot ID	Hectares	Species	Age	YC	Net area	odt/ha/y	odt/y
56	3.09	OK/AH	45	5.4	2.62	2.70	7.09
57	3.92	DF	20	12	3.33	1.81	6.03
58	4.70	DF/NS	45	12	4.00	1.81	7.23
59	16.97	OK/AH	110	7.3	14.43	3.25	46.87
60	7.54	OK/AH/BI	90	5.4	6.41	2.70	17.33
61	6.60	DF	45	14.8	5.61	2.16	12.11
62	3.57	DF	15	14.8	3.03	2.16	6.54
63	261.38	MC/MB	0	10.1	222.17	4.05	900.63
64	18.68	DF/NS	45	18	15.88	2.55	40.55
65	2.51	EL	50	12	2.13	1.81	3.86
66	2.99	OK/AH/MC	50	5.4	2.54	2.70	6.88
67	11.83	SC coppice	20	10	10.05	4.03	40.47
68	2.61	AH/OK	80	5.8	2.22	2.82	6.26
69	1.43	SC coppice	20	5	1.22	2.59	3.15
70	12.59	AH/OK	90	5.8	10.70	2.82	30.14
71	12.08	NS	40	13.4	10.27	1.78	18.25
72	3.43	CP	30	12	2.91	1.60	4.67
73	3.62	AH	15	12	3.07	4.60	14.14
74	1.30	AH/OK	80	5.8	1.11	2.82	3.12
75	9.05	DF	10	14.8	7.69	2.16	16.59
76	2.76	DF	40	14.8	2.35	2.16	5.06
77	2.67	AH/OK	80	5.8	2.27	2.82	6.40
78	1.03	MB	10	5	0.87	2.59	2.26
79	3.53	SC coppice	30	5	3.00	2.59	7.76
80	2.82	MB	15	5	2.40	2.59	6.21
81	4.65	OK/AH	80	5.4	3.95	2.70	10.68
82	4.94	DF	20	14.8	4.20	2.16	9.06
83	0.63	AH	60	5.8	0.53	2.82	1.50
84	1.93	SS/JL	50	24	1.64	3.11	5.10
85	3.84	OK/AH	100	5.4	3.27	2.70	8.83
86	10.99	DF/NS	30	17	9.34	2.43	22.70
87	2.79	DF/JL	45	14.8	2.37	2.16	5.12
88	1.85	OK	100	5.4	1.57	2.70	4.24
89	1.25	DF	15	14.8	1.06	2.16	2.29
90	10.05	CP/DF	5	12	8.54	1.60	13.67
91	12.70	DF/JL/WH/WRC/SP	50	14.5	10.80	2.12	22.89
92	6.40	SS	45	24	5.44	3.11	16.89
93	4.27	OK	80	5.4	3.63	2.70	9.82
94	7.99	OK/AH	80	5.4	6.79	2.70	18.35
95	4.06	SC coppice	20	5	3.45	2.59	8.93
96	8.61	MB	30	5	7.32	2.59	18.93
97	3.00	DF	15	14.8	2.55	2.16	5.49
98	10.30	OK/AH	80	5.4	8.76	2.70	23.67
99	1.11	DF	15	14.8	0.94	2.16	2.03
100	8.59	DF	30	14.8	7.30	2.16	15.75
101	4.94	DF	15	14.8	4.20	2.16	9.07
102	2.69	SS	40	16.5	2.28	2.17	4.95
103	9.17	MB	5	5	7.80	2.59	20.18
104	16.13	OK/AH	100	5.4	13.71	2.70	37.06
105	2.36	AH	10	5.8	2.00	2.82	5.64
106	1.06	AH	15	5.8	0.90	2.82	2.53
107	76.22	AH/OK/SC	100	5.8	64.79	2.82	182.56
108	1.93	DF/NS	15	14.8	1.64	2.16	3.54
109	4.25	OK/AH	80	5.4	3.62	2.70	9.77
110	19.00	DF/JL/CP	35	14.8	16.15	2.16	34.85
111	3.83	OK/AH	15	5.4	3.25	2.70	8.79
		SUB TOTAL			**556.1**		**1764.5**

Table 4.3
Estimation of theoretical long-term maximum potential availability of wood fuel from Woodlands forming Woolhope Dome (continued).

Plot ID	Hectares	Species	Age	YC	Net area	odt/ha/y	odt/y
112	7.84	DF	30	14.8	6.66	2.16	14.37
113	3.81	JL/AH	20	6.6	3.24	1.14	3.69
114	1.15	DF	40	14.8	0.98	2.16	2.11
115	13.31	DF/NS	20	14.8	11.31	2.16	24.40
116	2.10	OK/AH	80	5.4	1.79	2.70	4.83
117	10.55	MB/MC	30	5	8.97	2.59	23.22
118	0.83	DF	40	14.8	0.71	2.16	1.53
119	2.69	OK/AH	100	5.4	2.29	2.70	6.19
120	1.26	OK/AH	100	5.4	1.07	2.70	2.88
121	1.29	OK/AH	80	5.4	1.10	2.70	2.97
122	0.40	AH/OK	80	5.8	0.34	2.82	0.95
123	2.07	Bare land	0	0	1.76	0.00	0.00
124	10.17	OK/AH	80	3.3	8.64	2.10	18.14
125	1.17	OK/AH	80	5.4	0.99	2.70	2.69
126	6.67	OK/AH	120	5.4	5.67	2.70	15.33
127	29.40	OK/AH	120	4	24.99	2.30	57.48
128	23.56	OK/AH	100	5.4	20.03	2.70	54.14
129	1.70	DF	25	14.8	1.45	2.16	3.12
130	14.19	SC coppice	20	10	12.06	4.03	48.55
131	9.92	OK/AH	100	6	8.43	2.88	24.25
132	4.79	AH/OK/SC	80	5.8	4.07	2.82	11.47
133	4.03	OK/AH	90	3.5	3.43	2.16	7.39
134	4.11	DF/SC coppice	5	14.8	3.49	2.16	7.53
135	14.68	AH	80	9.5	12.48	3.88	48.42
136	6.05		0	0	5.14	0.00	0.00
137	3.72	DF	45	14	3.16	2.06	6.51
138	4.35	SC/AH coppice	20	10	3.70	4.03	14.88
139	1.77	DF	45	8	1.50	1.31	1.98
140	15.70	OK/AH	120	6	13.34	2.88	38.37
141	16.60	OK/AH/BI	80	6	14.11	2.88	40.56
142	3.19	AH/OK/Aspen/Be/NM/Bi	35	10	2.71	4.03	10.93
143	3.48	OK/Be/Bi/Aspen/NM/AH/JL	35	3.1	2.96	2.04	6.04
144	30.68	DF/CP/NS/AH	35	13.2	26.07	1.96	51.08
145	12.16	CP/NS/JL/SP/BI	35	18	10.33	2.35	24.33
146	7.25	DF/CP	40	22	6.16	3.05	18.79
147	5.16		0	0	4.39	0.00	0.00
148	3.41	OK/AH	80	4	2.90	2.30	6.66
149	4.70	AH/SC	60	6	3.99	2.88	11.48
150	2.62	JL/DF	35	6.6	2.23	1.14	2.54
151	27.52	OK/AH/BI	60	5.4	23.39	2.70	63.23
152	5.77	JL/DF	30	6.6	4.90	1.14	5.59
153	5.37	DF	45	14.8	4.56	2.16	9.85
154	33.37	OK/AH	100	4.5	28.36	2.44	69.32
155	12.25	DF	40	14.8	10.41	2.16	22.46
156	3.57	SC coppice	20	5	3.03	2.59	7.84
157	3.61	DF	40	14.8	3.07	2.16	6.62
158	1.40	Open water	0	0	1.19	0.00	0.00
159	3.78	JL/AH	40	6.6	3.21	1.14	3.66
160	80.80	DF/CP/NS/WRC	35	14.8	68.68	2.16	148.16
161	19.12	DF/NS/CP	30	14.8	16.25	2.16	35.06
162	9.21	OK/AH	60	5.4	7.83	2.70	21.16
		SUB TOTAL			**423.5**		**1012.78**
TOTAL	**1452.3**				**1234.4**		**3447.6**

Key to origin of YC:

nnn	= from sampled stands - ForestYield GYC curves
nnn	= weighted YC for species based on sampled stands
nnn	= weighted YC from SCDB - FE estate

Notes to Table 4.3

Plot ID: the identification number for each sub-division of forest area within Woolhope dome (see figure 4.3).

Gross area: the gross area of the stand(s) forming the woodland was found from the woodland map (Figure 4.3).

Species: the main species of tree forming each stand from Forestry Commission records or local information.

Yield class (GYC): the yield class of the stand was obtained either from Forestry Commission records or from the rapid survey of woodlands. If no estimate of yield class was available from these sources, the estimated mean yield class of woodlands in Woolhope Dome was used. (Mean yield estimated from the rapid survey of woodlands, separately for broadleaf and conifer species, and involved calculating a weighted mean by stand area.)

Net area: the net area of each stand was calculated assuming a gross:net area conversion factor of 0.85.

Per-hectare wood fuel: The theoretical long-term maximum potential wood fuel production, in units of oven dry tonnes per hectare per year, was calculated for each stand from yield class using the equations in Table 4.2, referring to the appropriate species group.

Total wood fuel: The theoretical long-term maximum potential wood fuel production, in units of total oven dry tonnes per year, was by multiplying the per-hectare estimates.

From the calculations in Table 4.3 it is estimated that:

- The total area of woodlands in Woolhope Dome is 1452 ha, with an estimated net area of 1234 ha (based on a gross:net area conversion factor of 0.85).
- The theoretical long-term maximum potential supply of wood fuel from woodlands in Woolhope Dome is 3448 (i.e. just under 3450) oven dry tonnes per year.

Roughly speaking, a long-term supply of this magnitude would be sufficient wood fuel to provide heating for around 820 domestic dwellings (BEC, 2009a).

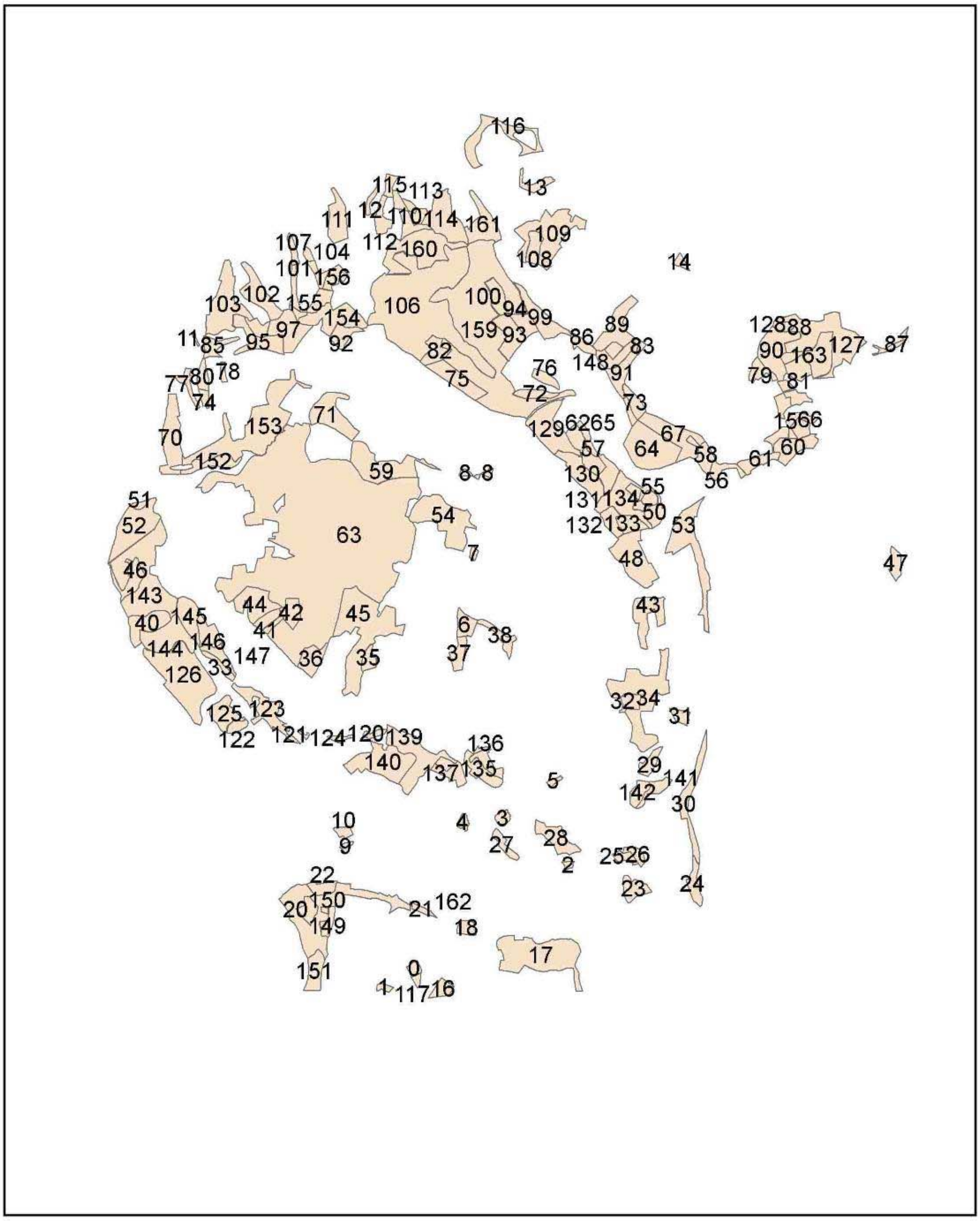


Figure 4.3 Map of sub-divisions of forest area within Woolhope dome showing ID numbers.

Figure 4.4 is a map of the woodlands in the Woolhope Dome region, showing the estimates of theoretical long-term potential wood fuel availability from each woodland. The map requires careful interpretation because the estimates of wood fuel availability involve a combination of the species, growth rate and physical area occupied by different woodlands. For example, the area shown as having the greatest potential for woo fuel production is also the largest single polygon on the map, so to some extent, this estimate simply reflects the area involved. However, this result could also be interpreted as having some relation to reality – the large woodland area represents the main block within Woolhope Dome managed by the Forestry Commission. Thus, this is genuinely a significant area of woodland under managed by a single entity with the consequent opportunity to organise long-term supplies of wood fuel from across the woodland area.

Perhaps the most notable feature in Figure 4.4 is the numerous examples of small fragments of woodland for which the estimated potential for wood fuel supply is small, say less than 5 oven dry tonnes per year. Coordinating potentially low levels of wood fuel production from these dispersed, small woodlands represents a significant challenge and in practice this would almost certainly constrain actual production.

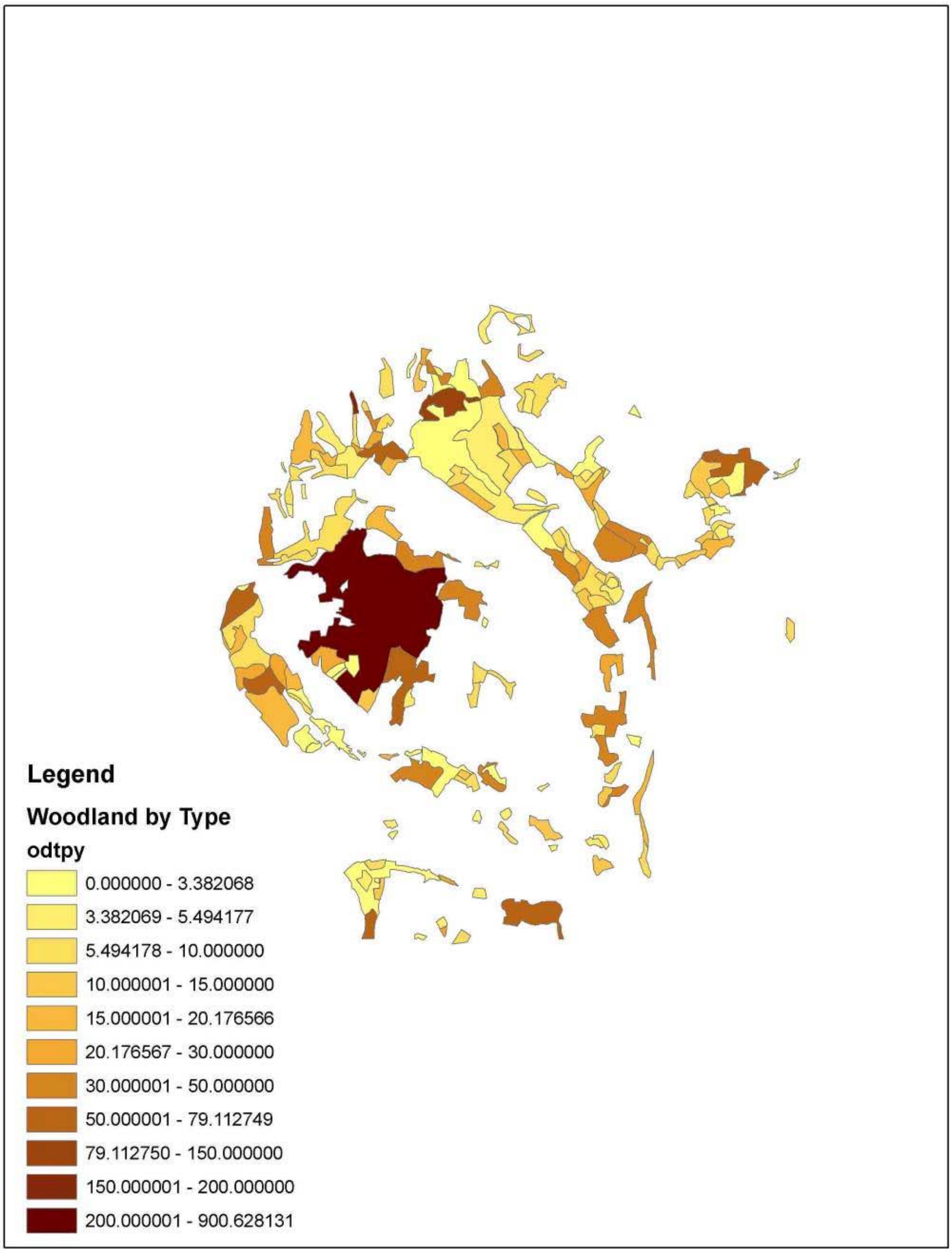


Figure 4.4 Map of woodlands in Woolhope Dome region showing spatial distribution of theoretical long-term maximum potential for production of wood fuel.

Assessment of realistic potential woodfuel supply in medium and long terms

In reality woodlands are rarely managed for maximum production due to a range of practical, environmental and social constraints. Therefore, in terms of the realistic long-term production of wood fuel from Woolhope Dome woodlands, it is evident that only a fraction of the estimated 3450 odt per year will ever actually be realised.

Moreover, woodlands can only achieve maximum production consistently and smoothly over time if they are managed over long periods for such an objective. For example, the woodlands would need to be structured so as to ensure that there are areas of woodland in all age classes from newly established up to intended time of clearfell, so that there are always areas of woodland 'coming on stream for production'. In real situations, such as encountered at Woolhope Dome, woodlands are not homogenous but, at any particular time, are composed of an uneven distribution of species, growth rates, age classes and levels of growing stock. This unevenness causes significant peaks and troughs in the potential availability of wood fuel. It is therefore important to know not only the realistic long-term potential for supply of wood fuel from a given area of woodlands, but also the realistic potential supply from the woodlands in the medium term (say the next 20 years), allowing for the current status of the woodlands.

For the Woolhope Dome project, it was essential to understand the constraints on wood fuel production in the medium term and to derive realistic estimates of the quantity of wood fuel in the medium and long terms.

Assessment of realistic medium term potential. An estimate was made of the actual availability of wood fuel from woodlands in Woolhope Dome over the next 20 years. This involved combining the results of the rapid survey trial described in Section 3 with the estimates of theoretical maximum long-term potential production described earlier in this section.

The calculations in Table 3.5 based on the rapid survey assessments were repeated for each woodland covered in the survey. However, in this case, the estimates of available wood fuel were not constrained by a 'maximum allowable cut' (which would only apply in the short term, i.e. for a 5 year period). Instead, wherever the results for a woodland indicated that stem wood was available for harvesting (i.e. the 'standing volume margin' in Table 3.5 was greater than zero), it was assumed that this volume would be harvested over the ensuing 20 year period, either as a single thinning or several staged thinnings. Based on this assumption it was possible to estimate the potential for stem volume production in each woodland over the next 20 years as expressed in cubic metres per hectare per year, as shown in Table 4.4. These results for potential stem volume production were then converted to estimates of realistic potential for wood fuel production expressed in oven dry tonnes per hectare per year, using a series of calculation steps explained in the notes to Table 4.4.

For each woodland assessed as part of the rapid survey, the assessments of species and yield class were used to derive an estimate of theoretical maximum long-term potential wood fuel production, based on the equations given in Table 4.2. These theoretical maximum estimates were then compared with the realistic estimates derived for the woodlands forming the rapid survey area, as shown in the final three columns of Table 4.4.

A ratio was calculated, expressing the realistic estimate of wood fuel availability as a fraction of the theoretical maximum estimate. As can be seen in Table 4.4, this ratio varied considerably for different woodlands, reflecting their variable stocking densities, as might be expected. In a few cases, the ratio was found to be greater than one (most obviously Busland Wood, at 1.59), suggesting overstocking. However, in the vast majority of woodlands, the ratio was less than one and for a large number of woodlands the ratio was actually zero, suggesting understocking or, at the very least, no potential for production of wood fuel for the next 20 years.

The mean ratio (weighted by woodland area) was calculated for all the woodlands forming the rapid survey area and this was found to be 0.41. The implication of this result is that, over the next 20 years, a realistic estimate of the actual potential for wood fuel production from woodlands in Woolhope Dome might be taken as about 40% of the theoretical maximum long-term estimate that was derived in Table 4.3. This suggests a potential wood fuel availability over the next 20 years of 1380 oven dry tonnes per year, as opposed to the theoretical maximum estimate in Table 4.3 of 3448 oven dry tonnes per year. Roughly speaking, this would be enough wood fuel to provide heating for around 325 domestic dwellings over this 20 year period (BEC, 2009a).

Certain caveats need to be attached to the results in Table 4.4 and the estimate of realistic medium-term wood fuel production described above, notably:

- The results for individual woodlands (e.g. standing volume margin, ratio of total wood fuel to equation wood fuel estimate) will be very imprecise for individual woodlands. However, precision should improve significantly when mean results for a large sample of woodlands are considered.
- The estimated mean value of 0.41 for the ratio total wood fuel: equation wood fuel estimate relies on the assumption that the woodlands sampled as part of the rapid survey trial are statistically representative of the entire population of woodlands in

Woolhope Dome. In practice, the selection of woodlands for rapid assessment did not conform to a strict statistical design. Instead, woodlands were surveyed as they were encountered during a tour of part of the Woolhope Dome region, and sampling was subject to access being permitted by woodland owners.

- The estimates of realistic potential take account of the current status of the growing stock in woodlands and some other factors that may constrain production (e.g. limits to the quantities of branch wood that can be removed from woodlands). However, other potential constraining factors, such as difficult site access or a requirement to prioritise landscape, amenity or wildlife management objectives, are not considered.
- Further growth of woodlands over the 20 year periods is not considered in the estimates. If this was allowed for, this would suggest that rather more wood fuel might be available, going some way to 'balance out' the impacts of the constraining factors noted above.

Assessment of realistic long term potential. As already described, it has been possible to estimate:

- Realistic potential production in the short term from specific selected woodlands (Tables 3.4 and 3.5).
- Realistic potential in the medium term production from all woodlands (Table 4.4).
- Theoretical potential maximum production from all woodlands in the medium term (Table 4.3).

The estimation of the realistic potential for wood fuel production *in the long term* is the most problematic task to be attempted in this project. Clearly, the realistic long term level of wood fuel production would be expected to be substantially below that suggested by the theoretical maximum estimate of Table 4.3. The medium term estimate has indicated that production over the next 20 years could realistically approach 40% of the theoretical maximum, although even this does not allow for certain constraining factors identified above. On the other hand, the 40% estimate might also reflect what appears to be the extent of understocking in woodlands in Woolhope Dome, so the longer term production may rise to somewhere between 40% and 100%. Beyond these observations, the setting of the 'mark down' on the theoretical maximum estimate begins to enter the realms of speculation. Ultimately, local knowledge and clear decisions about how forests are to be managed would be needed before an estimate of long-term potential could be improved beyond the rather wide range of 40%-100% of maximum potential. However, one slight refinement might be considered: in certain circumstances it is conceivable that the value used as the basis for Management Table Thinning Intensity (Appendix 3), i.e. 70% of maximum potential production, might be referred to as a first estimate of the upper limit on potential production, for example in situations where harvesting is limited to thinning and to the exclusion of clearfelling. (Such a regime might well be considered in the management of woodlands forming many areas of Woolhope Dome.) This concept would suggest estimating an upper limit on realistic production of wood fuel as 70% of the maximum estimate presented in Table 4.3, i.e. about 2400 oven dry tonnes per year or roughly enough wood fuel to provide heating for around 570 domestic dwellings (BEC, 2009a).

Potential greenhouse gas impacts of wood fuel production

One of the major motivations for increasing the production and utilisation of wood fuel is the potential impact on greenhouse gas emissions. Biomass, of which wood fuel is one type, is recognised as being a renewable source of energy with low greenhouse gas emissions (BEC, 2009b; IEA 2003). If wood fuel is utilised for energy as a substitute for fossil fuels (which have higher greenhouse gas emissions), then effectively greenhouse gas emissions can be reduced.

Broad estimates can be made of the potential greenhouse gas emissions reductions that might be achieved through the utilisation of wood fuel produced from Woolhope Dome woodlands. These estimates depend on a number of factors, most notably the type of energy conversion system assumed and the type of fossil fuel being replaced by wood fuel. If it is assumed that wood fuel produced in Woolhope Dome is used locally to supply small scale heating systems, then calculations based on the analysis of Szendrődi (2006) suggest that the greenhouse gas emissions reduction that might be achieved range from approximately 0.25 to 0.65 tonnes carbon equivalent per oven dry tonne of utilised wood fuel (tC-eq odt^{-1}), depending on whether the wood fuel is used in substitution for natural gas or electricity respectively. (These are worst and best case examples.) The factors can also be expressed as approximately 0.9 and 2.4 tonnes carbon dioxide equivalent per oven dry tonne (tCO_2-eq odt^{-1}).

Combining these factors with the estimated range for realistic long-term production of wood fuel from Woolhope Dome of 1380-2400 odt per year gives annual greenhouse gas reductions of between 345-1560 (tC-eq odt^{-1}) or 1240-5760 (tCO_2-eq odt^{-1}).

At present, total UK emissions of carbon dioxide amount to about 580 million tonnes per year ($MtCO_2\ yr^{-1}$), thus the emissions reductions potentially achievable through utilising wood fuel from the relatively small area of wood land in Woolhope Dome represent roughly between 0.0002% and 0.001% of current carbon dioxide emissions.

Table 4.4

Woodland	Species	Main spp.	Net area (ha)	Standing volume margin (m^3 ha^{-1})	Thinning vol. annualised for 20 years (m^3 ha^{-1} yr^{-1})	Stem biomass (odt ha^{-1} yr^{-1})	Branchwood biomass (odt ha^{-1} yr^{-1})	Woodfuel - stemwood (odt ha^{-1} yr^{-1})	Woodfuel - branchwood (odt ha^{-1} yr^{-1})	Total woodfuel (odt ha^{-1} yr^{-1})	Equation wood fuel estimate (odt ha^{-1} yr^{-1})	Ratio
Lyndalls Wood	Ah coppice with standards	AH	3.9	40	1.99	1.1	0.3	0.9	0.1	1.0	2.88	0.33
	Ok/Ah	OK	2.8	7	0.35	0.2	0.1	0.2	0.0	0.2	2.30	0.08
Nupend Wood	Ah/Yew	AH	2.0	0	0.00							0.00
Busland Wood	Ok/Ah	OK	20.4	144	7.19	4.0	1.2	3.4	0.2	3.7	2.30	1.59
Fownhope Park	Ok	OK	7.2	52	2.60	1.5	0.4	1.2	0.1	1.3	3.45	0.38
Nurdens Wood	Ok/SC	OK	12.8	0	0.00							0.00
Round Hill Wood	DF	DF	3.9	117	5.84	2.4	0.5	0.4	0.1	0.5	1.31	0.36
Round Hill Wood	NS	NS	1.7	0	0.00							0.00
Canwood Knoll	DF	DF	3.3	13	0.67	0.3	0.1	0.0	0.0	0.1	1.81	0.03
	DF/NS	DF	4.0	205	10.23	4.2	0.8	0.6	0.2	0.8	1.81	0.46
Park Coppice	DF/NS	DF	15.9	47	2.37	1.0	0.2	0.1	0.0	0.2	2.55	0.08
	EL	EL	2.1	29	1.44	0.6	0.1	0.1	0.0	0.1	1.81	0.07
	SC coppice	SC	10.0	82	4.12	1.8	0.5	1.5	0.1	1.6	4.03	0.41
	SC coppice	SC	0.0	265	13.26							0.00
	Ok overstorey	OK	0.0	0	0.00							0.00
	Ah	AH	3.1	29	1.45	0.8	0.2	0.7	0.0	0.7	4.60	0.15
Cossington Wood	SS/JL	SS	1.1	199	9.94	3.3	0.7	0.5	0.2	0.7	3.11	0.21
Mains Wood	NS	NS	0.0	14	0.69							0.00
Mains Wood	DF	DF	9.4	0	0.01							0.00
Mains Wood	WH	WH	10.8	148	7.41	2.7	0.5	0.4	0.1	0.5	2.35	0.23
Mains Wood	JL/SP	JL	0.0	0	0.00							0.00
Mains Wood	DF/NS/WH	DF	0.0	79	3.95							0.00
Seager Hill	SS	SS	5.4	18	0.89	0.3	0.1	0.0	0.0	0.1	3.11	0.02
Shears Hill	Ok	OK	2.7	53	2.64	1.5	0.4	1.3	0.1	1.3	2.30	0.59
Shears Hill	Ok/Ah/WCh overstorey	OK	3.0	0	0.00							0.00
	Syc/Ah/Bi lowerstorey	SY	3.0	8	0.42	0.2	0.1	0.2	0.0	0.2	1.73	0.11
	Ok/Ah	OK	25.0	86	4.29	2.4	0.7	2.0	0.1	2.2	2.30	0.95
Canwood Knoll	SC coppice	SC	12.1	209	10.43	4.6	1.4	3.9	0.3	4.2	4.03	1.04
	Ok/Ah/SC	OK	8.4	23	1.17	0.7	0.2	0.6	0.0	0.6	2.88	0.21
Deveraux Park	Ok overstorey	OK	2.6	13	0.67	0.4	0.1	0.3	0.0	0.3	2.30	0.15
Deveraux Park	NM/Ok understorey	Ok underst	0.9	8	0.42	0.2	0.1	0.2	0.0	0.2	1.73	0.13
Canwood Knoll	Ah	AH	9.4	0	0.00							0.00
Deveraux Park	SC	SC	3.1	67	3.34	1.5	0.4	1.2	0.1	1.3	3.45	0.39
Siege Wood	DF	DF	3.1	0	0.00							0.00
	SC/Ah coppice (85/15)	SC	3.7	139	6.97	3.1	0.9	2.6	0.2	2.8	4.03	0.69
Buckenhill Wood	DF	DF	1.5	0	0.00							0.00
Mabley Grove	Ok/Ah	OK	13.3	0	0.00							0.00
Lea Wood	Ok	OK	14.1	104	5.19	2.9	0.9	2.5	0.2	2.6	2.88	0.92
	JL/Ah/Syc/Asp/Bi	JL	2.1	68	3.38	1.4	0.3	0.2	0.1	0.3	1.56	0.18
	JL/Syc/Be/Ah	JL	0.6	60	2.99	1.2	0.2	0.2	0.1	0.2	1.56	0.16
Glowson Wood	Ah/Ok/Asp/Be/NM/Bi	AH	1.1	28	1.41							0.00
	Ok/Be/Bi/Asp/NM/Ah/JL	OK	1.0	0	0.00							0.00
	Ok/Be/Bi	OK	0.9	0	0.00							0.00
Fownhope Park	CP	CP	13.6	162	8.09	3.2	0.6	0.5	0.2	0.6	1.60	0.40
Fownhope Park	DF/NS	DF	13.3	178	8.89	3.6	0.7	0.5	0.2	0.7	3.05	0.24
	NS/Bi	NS	7.0	0	0.00							0.00
	HL/SP	HL	3.4	0	0.00							0.00
Nupend Wood	DF/CP	DF	6.1	0	0.00							0.00
Nupend Wood	Ok	OK	2.9	70	3.52	2.0	0.6	1.7	0.1	1.8	2.30	0.78
	Ah	AH	4.0	0	0							

Notes to Table 4.4

Species/main spp: the main species of tree forming each stand from Forestry Commission records or local information.

Net area: the net area of each stand was calculated from the gross area assuming a gross:net area conversion factor of 0.85. Gross area was obtained from the woodland map (e.g. Figure 4.3).

Standing volume margin: the stem volume potentially available for harvest at present, as estimated using the calculation protocol in Appendix 4. Based on assessments collected during the rapid survey trial.

Thinning vol. annualised for 20 years: the standing volume margin divided by 20 years. (Essentially this is assuming that the available volume will be harvested over the ensuing 20 year period.)

Stem biomass: obtained by multiplying the annualised thinning volume by the wood basic density for the tree species.

Branch wood biomass: obtained by multiplying the stem biomass by an assumed 'expansion factor'. The factors used were 0.3 for broadleaved species and 0.2 for conifers. (Compare with results for stem and branch biomass in Table 3.4)

Wood fuel stem wood: the quantity of stem wood ultimately available for utilisation as wood fuel (either directly or as a co-product, see for example Figure 4.1). Estimated by multiplying the stem biomass by 0.85 for broadleaved species and 0.15 for conifers.

Wood fuel branch wood: the quantity of branch wood available for harvesting for wood fuel. Estimated by multiplying the branch wood biomass by 0.2 for broadleaved species and 0.25 for conifers. (In other words, the assumption was made that, on average, 20-25% of branch wood could be recovered from woodlands.)

Total wood fuel: the sum of wood fuel stem wood and wood fuel branch wood. For each woodland, this is an estimate of the total wood fuel availability over the next 20 years, expressed in oven dry tonnes per hectare per year, allowing for the current growing stock.

Equation wood fuel estimate: for each woodland, this is the theoretical long-term maximum potential for wood fuel production expressed in oven dry tonnes per hectare per year. Calculated from the species and yield class of each woodland using the equations in Table 4.2.

Ratio: The value for 'total wood fuel' divided by the value for 'equation wood fuel estimate'. For each woodland, this represents the fraction of the theoretical maximum potential wood fuel production that might be realistically achieved over the next 20 years.

5. Main conclusions and recommendations

Modelling and survey approaches can be applied to estimate the potential for wood fuel production from a region of woodlands such as Woolhope Dome:

- Operational assessment protocols (Appendices 1 and 4) can be used to make 'yes/no' decisions about thinning to produce wood fuel in particular stands.
- Rapid survey protocols (Appendix 2, Table 3.5) can be used to assess the overall near term potential for wood fuel production across a significant area of woodland made up of many stands.
- A modelling approach can be used to estimate the theoretical long-term maximum potential for wood fuel production from a significant area of woodland made up of many stands.
- A combination if model-derived and rapid survey results can be used to estimate the realistic potential for wood fuel production from a significant area of woodland over the short and medium terms.
- The derivation of a realistic estimate of long-term potential for wood fuel production is more speculative, depending on local knowledge and clear decisions on how woodlands are to be managed in the future.

For Woolhope Dome woodlands, the estimated theoretical long-term maximum potential for production of wood fuel is 3450 oven dry tonnes per year. The estimated realistic potential to produce wood fuel over the next 20 years is 1380 oven dry tonnes per year. This is roughly enough wood fuel to supply heat to 325 domestic dwellings and, if used in place of fossil fuels, would represent a reduction in greenhouse gas emissions of between 345-900 tC-eq per year (1240-3300 tCO_2-eq per year).

The assessment and modelling methods developed in this project should have the potential for wider application and options for their dissemination should be considered. Forest Research Technical Development is already carrying out trials of some of the assessment protocols in training courses for wood fuel project developers.

The assessment and modelling protocols developed in this project lend themselves readily for implementation within easy-to-use computer software which could include checks on procedure and data integrity as well as automating most, possibly all, of the intermediate calculations. Options for development of such software packages should be considered.

If there is continued and growing interest in promoting the management of woodlands in the Woolhope Dome region then options for further, more extensive survey work should be considered, for example carrying out a rapid survey across the entire woodland area. This latter option might also present an opportunity to check the precision of the rapid survey approach proposed in this project.

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Glossary

Basal area	The cross-sectional area of the stem of an individual tree at its breast height point.
Basal area per hectare	The sum of the basal areas of trees in an area of woodland expressed on a per-hectare basis.
Biomass	All of the material making up a tree or one of its components such as stem or branches.
Branch	The woody material of trees excluding the stem, stump and roots.
Crown	The branches and foliage of a tree.
Cubic metre (m^3)	Unit of volume, usually used as the unit for tree stem volumes.
Diameter at breast height (dbh)	The diameter on the main stem of a tree at 'breast height', i.e. 1.3 metres from ground level. See Appendix 3 for more details.
General yield class (GYC)	An index used in Britain of the potential productivity of even-aged stands of trees. See Appendix 3 for more details.
Hectare (ha)	Unit of area equivalent to 100 metres x 100 metres = 10,000 square metres. 1 ha = 2.47 acres.
Mean dbh	The dbh relating to the mean basal area of the trees in an area of woodland.
Numbers of trees per hectare	The number of trees in an area of woodland expressed on a per-hectare basis.
Oven dry tonne (odt)	Unit of mass. When applied to wood, it represents the mass of wood in tonnes, not including the mass due to the moisture content of the wood (which may vary considerably).
Overstocked	A subjective term used to describe a stand composed of: *Either* trees whose continued growth is constrained by extensive competition between their crowns. *Or* Trees whose stocking density is greater than a specified target level, for example as obtained from a standard yield table. *Or* both of the above.
Stand	A distinct area of woodland, generally composed of a uniform group of trees in terms of species composition and the spatial distribution, age class distribution and size class distribution of the trees.
Stem	The woody material forming the above ground main growing shoot of a tree. By convention, the stem is taken to include all woody volume above ground with a diameter greater than 7 cm over bark. This may mean that significant 'straight' branches are included as part of the main stem.

Stocking/stocking density	Usually the number of trees in a given area. usually expressed on a per hectare basis. Sometimes used to refer to basal area or volume per hectare.
Thinning	The periodic harvesting of trees in a woodland, involving the removal of some trees for commercial utilisation and the retention of others for future production or long term retention. See Appendix 3 for full discussion.
Top height	The mean total height of the 100 largest trees in a hectare of woodland. Usually assessed on a sample of the largest trees in a series of circular plots of 0.01 ha in area.
Volume/volume per hectare	The stem volume, expressed in cubic metres, to 7 cm top diameter over bark of an individual tree, group of trees or all the trees in a woodland.
Woodland	An area covered by trees. The standard definition is that at least 20% of the area is covered by tree canopy/crown. A woodland may be composed of one or more stands.
Yield class	An index used in Britain of the potential productivity of even-aged stands of trees. See Appendix 3 for full discussion.
Understocked	A subjective term used to describe a stand composed of: *Either* trees with significant open (and by implication 'unproductive') open space between their crowns *Or* Trees whose stocking density is less than a specified target level, for example as obtained from a standard yield table *Or* both of the above.

Appendix 1 Rapid survey protocol.

Introduction

This protocol is intended for assessment of the woodfuel potential of a region of forest or estate composed of several hundred or perhaps thousands of stands. It is assumed that the relevant region has already been mapped (most likely on a GIS) and divided into distinct areas or stands of trees, sometimes known as "subcompartments", possibly based on interpretation of aerial images. In some instances this may be on the basis of information available from the GB National inventory of woodlands and trees (NIWT). The survey protocol involves visiting every stand mapped and carrying out the assessments detailed below.

Pre-assessment and ground-truthing

On site the surveyor should walk around the compartment to ground-truth the boundaries of the stand and ensure the shape of the area on the map is consistent. If there is a significant difference this should be drawn on a paper copy of the map for adjustment of the boundaries in the GIS later. The surveyor should also check that the species and age data for the stand seem plausible.

Having established the boundaries of the stand or subcompartment, the surveyor should then walk to the centre of the stand. During the walk in, if the stand is composed of a mix of species, the proportions of each component species should be noted down. Once the surveyor reaches the centre of the stand the following assessments should be made:

1. Basal area per hectare in the compartment/polygon

    a. If the stand or subcompartment is composed of thicket-stage conifers or contains a dense understorey where relascope assessments are not feasible, this assessment may be omitted in exceptional circumstances. However, you will have to record your justification and reasoning. (You may be asked to answer questions about it if the particular square is subsequently assessed for quality assurance purposes).

    b. Standing at the centroid of the stand or subcompartment , carry out a basal area (BA) sweep with a relascope. The relascope factor should be appropriate for the stocking density of the trees. Record the count. It may be easier to do separate sweeps for each species in the upper-most storey and combine these.

c. If the point at which the basal area sweep is taken is on a slope then measure the slope. This can be done using the angle function on a Vertex III/IV hypsometer or other suitable height measuring device.

2. Diameter and stocking assessment

a. Standing at the centroid of the stand or subcompartment find the nearest tree. Measure and record the horizontal distance from the centroid to the centre of the nearest measurable tree (> 1.3 m in height). If the tree identified in this step has a dbh of 4 cm or more measure and record the dbh.

b. Identify the tree nearest to the tree located in step a and measure and record the horizontal distance between the centres of each tree. If the tree identified in this step has a dbh of 4 cm or more measure and record the dbh.

c. Identify the tree which is nearest to the tree located in step b and measure and record the horizontal distance between the centre of this tree and the tree identified in step b. If the tree identified in this step has a dbh of 4 cm or more measure and record the dbh. Figure A1.1 give an example of the measurements to take in steps a-c.

d. If the horizontal distances in steps a, b and c cannot be measured because the section is on a slope then the slope should also be measured when measuring the distances. This can be done using the angle function on a Haglöf Vertex III/IV hypsometer or other suitable measuring device.

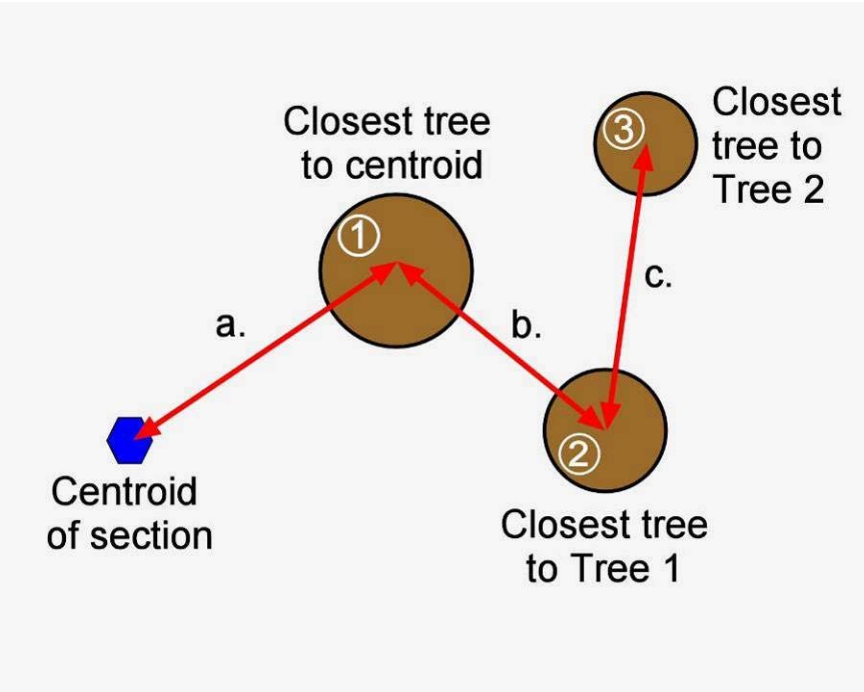

Figure A1.1 Diagram showing stocking assessments.

3. Dominant tree height in each compartment

a. Assessments are made on the heights of trees identified as dominant. These assessments are made while standing at the centroid of the stand or subcompartment facing the direction of one particular cardinal compass point (N, E, S or W). The direction faced in a given compartment is always the same, but a new direction is selected for each compartment in sequence, proceed around the points of the compass (see Figure A1.2). For example, in the first compartment the surveyor will look North and select a dominant tree within a 90° angle, 45° either side of North.

b. Looking 45° either side of the compass direction (Figure A1.2) select a tree which is in the upper half of the canopy of the upper-most storey in the stand. The selected tree should be at least as far away from the surveyor as they are tall, so that its position in the canopy can be judged clearly. If no suitable tree falls within the 45° arc, then the surveyor should turn to the next compass point.

c. Measure and record the total height of each selected tree using a Vertex III/IV hypsometer or other suitable measuring device. Place the Vertex III

Transponder on the tree(s) ensuring a good line of sight to the top of the tree when standing 1 to 1.5 times the height away from the tree. As you have temporarily marked the centroid this should allow you to move around the stand to find the best direction to measure from.

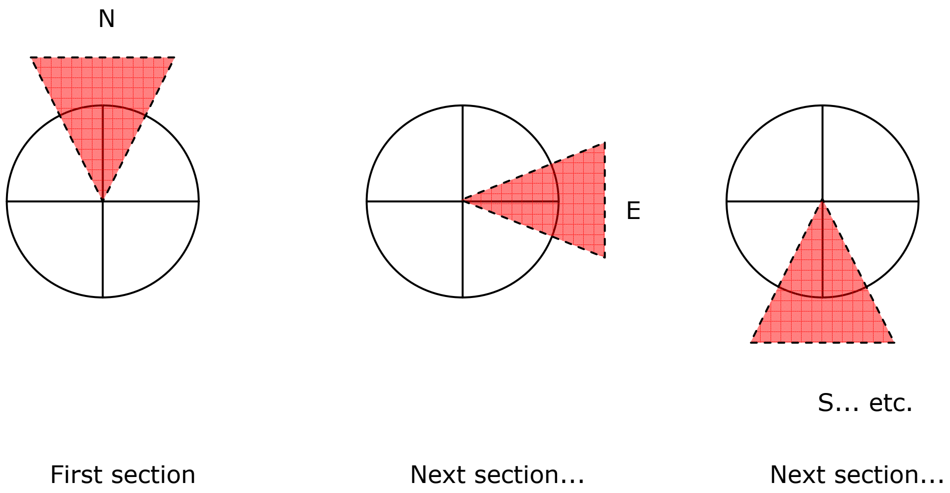

Figure A1.2 Diagram showing zones to select trees for height measurement from the centroid of each stand or subcompartment. (The area shaded red moves clockwise to the next cardinal point in each successive section.)

Appendix 2 operational assessment protocol.

The following procedures are to be used in the assessment of growing stock in a parcel of stands and for the estimation of the potential for production of woodfuel.

Stratification of stands forming parcel

It is essential that the stands to be measured are first *correctly stratified*, i.e. divided into parts (strata or components) each consisting of acceptable uniformity. This broadly entails separating species, storeys and areas of different height or age and measuring each of these strata independently.

When the stands have been stratified as far as practical, it is then necessary to decide on the level of *sampling intensity* which should be applied to each stratum.

The key in Figure 1 and the accompanying notes provide guidance on the various aspects to be considered in correctly stratifying and sampling stands.

Notes for Figure 1

1. Does the stand contain more than one species?
Normally each component species will be sampled and recorded separately except when it is known, from prior experience in that area, that the tariff numbers of different species of the same age and height are similar. Situations such as this will tend to occur in early pole stage stands of closely related species, e.g. Scots and Corsican pine. To group species together in this way also assumes that no species differentiation is required in the volume estimate, by the potential buyer for example.

2. Does the stand contain more than one storey?
In two-storied stands each component, if not of a different species, will usually be of markedly different age. Occasionally situations will arise where a 'two storied' situation has been achieved by thinning. Whenever two 'storeys' can be clearly discerned, then each one should be measured separately.

3. Does variation exceed 3 *years in age or* 4 *m in top height? If so, can area be subdivided conveniently so that variation within each part is within the specified limits?*
This is the final stage in separating out strata to be assessed individually, in sampling, recording and computation. Having separated out species and storeys, each component must be examined for variation in height or age. Where variation exceeds the specified limits, the area should if possible be subdivided into parts such that variation within each part is contained within the specified limits. If the variation occurs locally such that sub-division is not practical, then the problem must be tackled by raising the level of sampling intensity. It is advisable also to treat separately stands which have had markedly different thinning histories.

Technical terms referred to in the procedures are explained in a glossary at the end of this document.

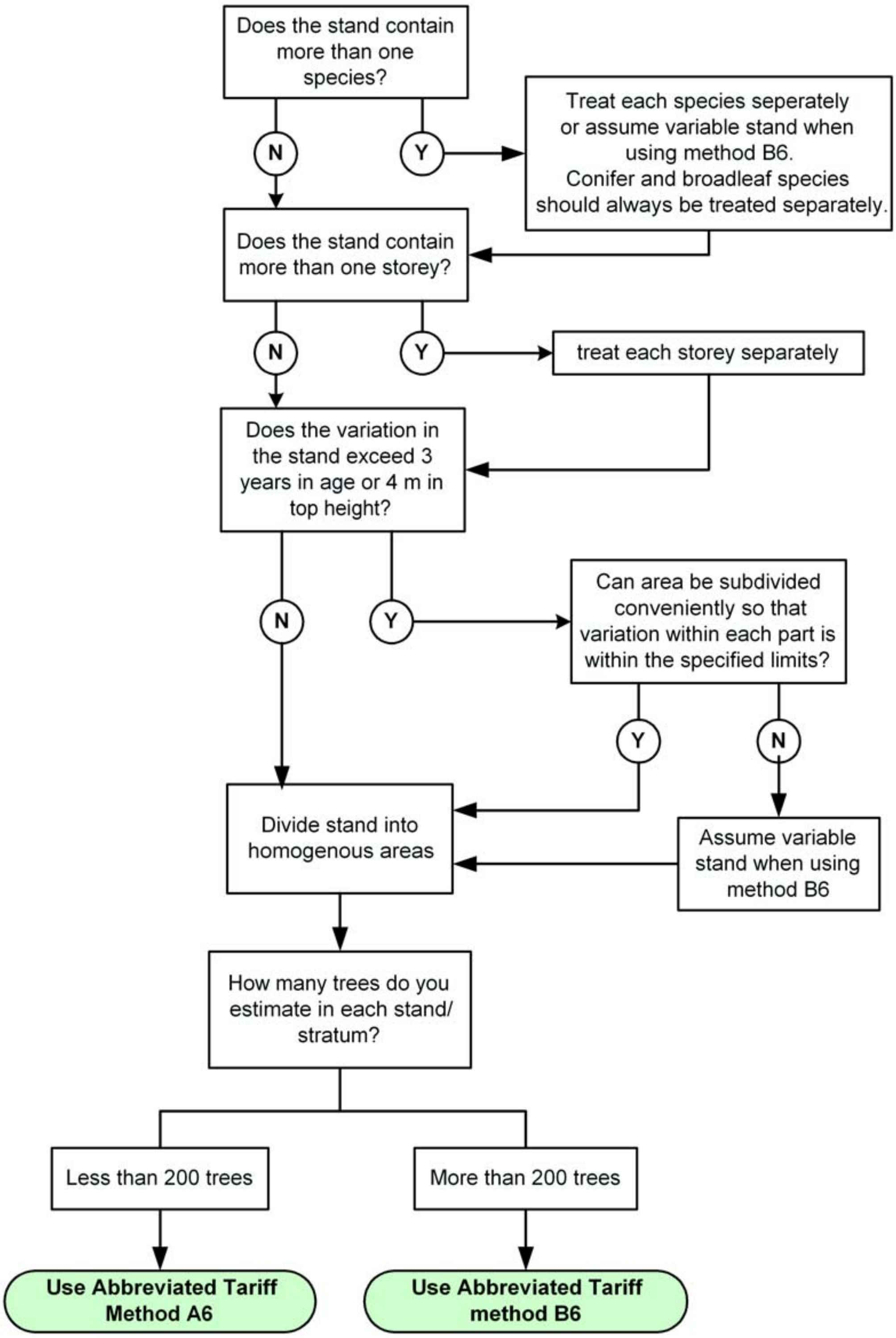

Figure 1 Decision tree for stratification and selecting sampling method.

Estimating total stem volume using an abbreviated tariffing procedure

The method used to determine the standing volume of each stand/stratum is based on several abbreviated tariff procedures developed by the Forestry Commission.

There are basically two steps required for estimating the volume of a stand using the abbreviated tariff system:

Pre-tariff checks and stocking assessment:
Carry out pre-tariff checks then estimate the total number of trees (either by counting them - known as method A - or by estimating their average stocking - known as method B -) and the proportion in each dbh class (either by measuring all the trees or by measuring a sample).

Tariff number estimation:
Identify a suitable Tariff Number assessment. In this procedure, tariff number is estimated from an assessment of top height (known as method 6).

The results of these two steps are combined to give an estimate of the mean volume of the trees in the stand and/or the total volume of the stand. There are two possible approaches known as "A6" and "B6". Figure 1 helps to choose the right approach. Method A6 is generally regarded as more accurate than method B6.

Abbreviated tariff method A6

Count all the trees and measure their dbh.

This method can only be used if the trees are being marked, and an estimate of volume is not required until the whole stand has been marked.

Pre-field work checks

Because method A6 involves actually counting all of the trees, it may not be necessary to make an accurate area assessment. However a reasonable estimate of area is needed in later calculations. If possible, measure the net area for the stand. Usually net area is found by measuring gross area and then assessing the gross:net area ratio. If an accurate assessment of gross:net area ratio is not possible, net area may be estimated by multiplying gross area by an assumed gross:net area ratio of 0.85.
If the gross area is being taken from a map, the precise boundaries of the stand should be checked.

Estimate the total number of trees with a dbh of 10 cm or more, and choose the appropriate volume sampling fraction from Table 1. This gives you the value of "n" used later in the field work.

Table 1 Sampling fractions.

No. of trees	Volume sampling fraction
10-20	1:1
21-30	1:2
31-40	1:3
41-50	1:4
51-60	1:5
61-70	1:6
71-80	1:7
81-90	1:8
91-100	1:9
101-200	1:10

Field work

a. Count the measurable trees as they are being marked and measure their dbh (a measurable tree is defined as having a dbh of 7 cm or more. Trees with a dbh less than 7 cm are assumed to have no volume and are conventionally classified as 'unmeasurable'.)

The form on page 6 can be used for data collection. When trees are counted and measured for dbh, the count can be recorded against the appropriate dbh using columns 1 and 2 of the from (see worked example on page 7).

b. Measure the total height of a sample of 'top height trees'.

Every n^{th} tree is a sample tree for top height where n is taken from Table 1 for the number of trees in the stand. Measure and record the total height of the tree of largest dbh within 5.6 m of each sample tree.

Office work

The form on page 6 can be used for carrying out office-based calculations.

a. Calculate the mean value of the total height measurements. This is an assessment of the top height for the stand/stratum. Record this value at the bottom of the form.
b. Find an estimate of tariff number for the stand/stratum using the top height and the table in Annex 2. Record this value in the space provided near the top of the form.
c. Construct a girthing sheet for the stand/stratum using the form on page 5. This involves working out the number of trees in each dbh class. These numbers can be recorded in columns 1 to 3 of the form.
(if the form has been used for data collection, the information needed for columns 1 and 2 will have been recorded already)
d. Add up the number of trees in each dbh class to find the total number of trees in the stand/stratum. The total can be recorded at the bottom of column 3.
e. Work out the basal area per tree for each dbh class using the table in Appendix 3. The values can be recorded in column 4 of the form.
f. Multiply the number of trees in each class by the associated basal area per tree to find the total basal area per dbh class and record these values in column 5 of the form.
g. Add up the basal areas in each dbh class to find the estimated total basal area for the stand/stratum and record the result at the bottom of column 5.

h. Estimate mean basal area by dividing the total basal area by the total number of trees (bottom of column 3) and record in the space provided near the top of the form
i. Find the mean dhb closest to the mean basal area using the table in Appendix 3. Record the mean dbh in the space provided near the top of the form.
j. Work out the stem volume per tree for each dbh class using the tariff tables in Annex 4 and record this in column 6 of the from.
k. Multiply the number of trees in each dbh class by the associated volume per tree to find the total stem volume per dbh class and record these values in column 7 of the from.
l. Add up the volumes in each dbh class to find the estimated total stem volume for the stand/stratum and record the result at the bottom of column 7.
m. Divide the total stand/stratum number of trees, basal area and volume by the area for the stand/stratum to obtain estimates expressed on a per-hectare basis. These results can be recorded in the boxes below columns 3, 5 and 7.

Abbreviated tariff method A6:
Data recording and processing form

Woodland name/identifier: ....
Area (indicate gross or net): ....
Species: .... Age: ....
Tariff number (based on top height): ....
Mean basal area (m2) Mean dbh:...................cm.

Dbh (cm)	Count (use gate style, i.e.)	No. of trees	Basal area per tree (m^2)	Basal area in class (m^2)	Volume per tree (m^3)	Volume in class (m^3)
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(3)x(6)
Totals for stand/stratum						
Totals per hectare						

Total heights (m)

1	2	3	4	5	6	7	8	9	10

11	12	13	14	15	16	17	18	19	20

Top height (mean of total heights) ....m

Abbreviated tariff method A6:
Data recording and processing form - worked example

Appendix 1. Abbreviated tariff method A6: Data recording and processing form

Woodland name/identifier: BENTLEY FOREST, SUB-COMPARTMENT 4

Stand/Stratum: 1

Area (indicate gross or net): 0.9 ha

Species: MIXED BROADLEAVES, PREDOMINANTLY SYCAMORE Age: 64

Tariff number (based on top height): 29 Mean dbh: 41 cm.

Dbh (cm)	Count (use gate style, i.e. 卌)	No. of trees	Basal area per tree (m^2)	Basal area in class (m^2)	Volume per tree (m^3)	Volume in class (m^3)
33	II	2	0.086	0.172	0.75	1.5
4	卌 卌 卌 卌 II	22	0.091	2.002	0.80	17.6
5	卌 IIII	9	0.096	0.864	0.84	7.56
6	卌 卌 卌 III	18	0.102	1.836	0.90	16.2
7	卌 卌 卌 卌 IIII	24	0.108	2.592	0.95	22.8
8	卌 II	7	0.113	0.791	1.00	7.0
9	卌 卌 II	12	0.119	1.428	1.06	12.72
40	卌 卌 卌 卌 I	21	0.126	2.646	1.11	23.31
1	卌 卌 II	12	0.132	1.584	1.17	14.04
2	卌 卌	10	0.139	1.390	1.23	12.30
3	卌	5	0.145	0.725	1.29	6.45
4	I	1	0.152	0.152	1.35	1.35
5	卌 卌	10	0.159	1.590	1.42	14.20
6	卌 卌 II	12	0.166	1.992	1.48	17.76
7	卌 III	8	0.173	1.384	1.55	12.4
8	卌	5	0.181	0.905	1.62	8.1
9	卌	5	0.189	0.945	1.68	8.4
50	卌	5	0.196	0.980	1.76	8.8
1			–			
2	I	1	0.212	0.212	1.90	1.90
3			–			
4			–			
5	II	2	0.238	0.476	2.13	4.26
6	I	1	0.246	0.246	2.21	2.21
7			–			
8			–			
9			–			
60	I	1	0.283	0.283	2.54	2.54
1			–			
Totals for stand/stratum			-	25.195	-	223.4
Totals per hectare			-	27.99	-	248.22

Total heights (m)

1	2	3	4	5	6	7	8	9	10
24.2	24.5	27.4	27	26.3	27.1	28.4	28.1	23	23.5

11	12	13	14	15	16	17	18	19	20
24.2	24.9	26.2	26.8	26.7	23.5	27.9	27.4		

Top height (mean of total heights) 26.0 m.

7

Abbreviated tariff method B6

Lay out and measure sample plots.

Pre-field work

a. Choose a convenient sample plot size which contains a minimum of 7, and preferably not more than 20, trees. Table 2 gives plot sizes. All the plots must be circular and the same size.

Table 2 Circular plot dimensions for specified plot areas.

Plot area (ha)	Radius (m)
0.01	5.6
0.02	8.0
0.05	12.6

b. Measure the net area for the stand. Strictly, it is important that net area is measured accurately as this is a frequent source of error in final results. Usually, net area is found by measuring gross area and then assessing the gross:net area ratio. If an accurate assessment of gross:net area ratio is not possible, then, as a final resort, net area may be estimated by multiplying gross area by an assumed gross:net area ratio of 0.85.
If the gross area is being taken from a map, the precise boundaries of the stand should be checked.

Field work

a. Locate 'n' sample plots at random throughout the stand, where n is read from Table 3. The boundary of each plot should be at least 5 m from the edge of the stand. In addition plots boundaries should not contain any area that would be excluded in the assessment of net area, for example, open waters, significant path and tracks.

Table 3 Number of sample plots.

Area of stand/stratum (ha)	Uniform stand	Variable stand
0.5-2	6	8
2-10	8	12
Over 10	10	16

b. Measure and record the dbh of all the measurable trees in each plot. A measurable tree is defined as having a dbh of 7 cm or more. Trees with a dbh less than 7 cm are assumed to have no volume and are conventionally classified as 'unmeasurable'.

c. Measure and record the total height of the tree of largest diameter within 5.6 m of the centre point of each plot. If there are no trees within 5.6 m of the centre point then a new point should be selected at random for the assessment of top height.

Office work

The form on page 10 can be used for carrying out office-based calculations. The form can be used for data collection. In each plot, when trees are counted and measured for dbh, the count can be recorded against the appropriate dbh using columns 1 to 17 of the form (see worked example on page 11).

a. Record the total area assessed (the sum of the plots areas) in the space provided near the top of the form.
b. Calculate the mean value of the total height. This is an assessment of top height for the stand/stratum. Record this value at the bottom of the form.
c. Find an estimate of tariff number for the stand/stratum using the top height and the table in Annex 2. Record this value in the space provided near the top of the form.
d. Construct a girthing sheet for the stand/stratum. This involves counting the numbers of trees in each dbh class for each sample plot, then add together the counts for all plots to obtain a combined girthing sheet. The counts for individual plots can be recorded in columns 2 to 18 of the form.
e. These combined counts are then expressed on a per hectare basis by dividing the combined count for each class by the total area of the sample plots. The per hectare counts can be recorded in column 19 of the form.
f. Add up the resulting number of trees per hectare in each dbh class to find the total number of trees per hectare in the stand/stratum. Record the results at the bottom of column 19.
g. Work out the basal area per tree for each dbh class using the table in Annex 3. The values can be recorded in column 20 of the form.
h. Multiply the number of trees per hectare in each dbh class by the associated basal area per tree to find the total basal area per hectare in each dbh class and record these values in column 21 of the form.
i. Add up the per hectare basal areas in each dbh class to find the estimated total per hectare basal area for the stand/stratum and record the result at the bottom of column 21.

j. Estimate mean basal area by dividing the total basal area per hectare by the total number of trees per hectare. Record the mean dbh in the space provided near the top of the form.
k. Find the mean dbh closest to the mean basal area using the table in Annex 3 and record in the space provided near the top of the form.
l. Work out the stem volume per tree for each dbh class using the tariff tables in Annex 4 and record the results in column 22 of the form.
m. Multiply the number of trees per hectare in each dbh class by the associated volume per tree to find the total stem volume per hectare in each dbh class and record in column 23 of the form.
n. Add up the per hectare volumes in each dbh class to find the estimated total stem volume per hectare for the stand/stratum. Record this result at the bottom of column 23.
o. Multiply the total stand/stratum numbers of trees per hectare, basal area per hectare and volume per hectare by the net area of the stand/stratum to obtain estimates for the whole stand/stratum. These results can be recorded in the boxes below columns 19, 21, and 23 of the form.

Abbreviated tariff method B6:
Data recording and processing form

Woodland name/identifier: ....

Stand/Stratum:..

Species: .... Age:........

Tariff number (based on top height): ....

Gross Area: ....

Gross:net ratio: ....

Net area: ....

Total area of plots: ....(ha)

Mean basal area m^2

Mean dbh (estimated from mean basal area) .... cm

Dbh (cm)	Count of trees (use gate style, i.e. ~~IIII~~)																Total trees for plots	Total trees per ha	Basal area per tree (m^2)	Basal area per ha in class (m^2)	Volume per tree (m^3)	Volume per ha in class (m^3)
	Plot number																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)

Abbreviated tariff method B6:
Data recording and processing form (continued)

Dbh (cm)	Count of trees (use gate style, i.e. 𝍸)																Total trees for plots	Total trees per ha	Basal area per tree (m^2)	Basal area per ha in class (m^2)	Volume per tree (m^3)	Volume per ha in class (m^3)
	Plot number																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
Totals per hectare																						
Totals for stand/stratum																						

Total heights (m)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Top height (mean of total heights) .... m.

Abbreviated tariff method B6: Data recording and processing form - Worked example

Appendix 4. Abbreviated tariff method B6: Data recording and processing form

Woodland name/identifier: BENTLEY FOREST, SUB-COMP. 2

Gross Area: 6.8

Stand/Stratum: 1

Gross:net ratio: 0.8

Species: MIXED BROADLEAVES, PREDOMINANTLY OAK Age: 35

Net area: 5.2

Tariff number (based on top height): 19

Total area of plots: 0.08 (ha).

Dbh (cm)	Count of trees (use gate style, i.e. 卌) Plot number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total trees for plots	Total trees per ha	Basal area per tree (m^2)	Basal area per ha in class (m^2)	Volume per tree (m^3)	Volume per ha in class (m^3)
7	卌 卌 卌 I	卌 IIII	II	卌 卌 卌	I	III	II	IIII									52	650	0.0038	2.47	0.005	3.25
8	卌 卌 卌	卌 卌 卌	I	IIII	III	IIII	卌	卌 I									53	663	0.0050	3.315	0.012	7.956
9	卌 卌 II	卌 I	卌 卌 IIII	IIII	卌 卌	卌 卌	卌 卌 卌 II	卌 IIII									82	1025	0.0064	6.56	0.020	20.5
10	I	卌	I	卌 III	卌 卌 IIII	卌 卌 卌	卌 卌 I	卌									61	763	0.0079	6.028	0.029	22.127
11	II	I	II	II	II	卌 II	II	卌 I									24	300	0.0095	2.85	0.039	11.7
12	I	I	III	IIII		I	卌	卌									20	250	0.0113	2.825	0.049	12.25
13		II		I	II		I	II									8	100	0.0133	1.33	0.061	6.1
14			IIII	卌	I			IIII									14	175	0.0154	2.695	0.074	12.95
15			I					I									2	25	0.018	0.45	0.087	2.175
16			I				III										4	50	0.020	1.0	0.102	5.1
17							I										1	13	0.023	0.299	0.117	1.521

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Abbreviated tariff method B6: Data recording and processing form - Worked example (continued)

Appendix 4 (cont). Abbreviated tariff method B6: Data recording and processing form

Dbh (cm)	Count of trees (use gate style, i.e. IIII) Plot number																Total trees for plots	Total trees per ha	Basal area per tree (m²)	Basal area per ha in class (m²)	Volume per tree (m³)	Volume per ha in class (m³)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16						
																	Totals per hectare	4014	-	29.82	-	105.63
																	Totals for stand/stratum	20,873	-	155.06	-	549.28

Total heights (m)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9.7	11.7	10.9	11.2	11.3	11.1	10.9	10.4								

Top height (mean of total heights) ..10.9..... m.

Mean dbh (estimated from mean basal area) .....10...... cm.

2

Annex 1 Top height/tariff number table.

Top height (m)	Species													
	SP	CP	LP	SS	NS	EL	JL/HL	DF	WH	RC	GF	NF	OK	BI
3	12	9	8	10	11	7	9	9	11	8	7	8	11	8
3.5	12	9	9	10	11	8	9	10	11	9	8	8	11	9
4	13	10	9	11	12	9	10	11	12	9	9	9	12	10
4.5	13	11	10	12	12	9	11	11	12	10	9	10	12	10
5	14	11	11	12	13	10	11	12	13	10	10	10	13	11
5.5	14	12	12	13	13	11	12	12	14	11	11	11	13	11
6	15	13	12	13	14	11	13	13	14	11	12	12	14	12
6.5	15	14	13	14	15	12	13	13	15	12	12	12	15	12
7	16	14	14	15	15	13	14	14	16	13	13	13	15	13
7.5	16	15	14	15	16	13	15	15	16	13	14	14	16	13
8	17	16	15	16	16	14	16	15	17	14	14	14	16	14
8.5	17	16	16	16	17	15	16	16	17	14	15	15	17	14
9	18	17	16	17	18	15	17	16	18	15	16	16	17	15
9.5	18	18	17	18	18	16	18	17	19	15	16	16	18	15
10	19	18	18	18	19	17	18	17	19	16	17	17	18	16
10.5	19	19	19	19	19	18	19	18	20	16	18	18	19	16
11	20	20	19	19	20	18	20	18	20	17	18	18	19	17
11.5	20	20	20	20	20	19	20	19	21	17	19	19	20	17
12	21	21	21	21	21	20	21	20	22	18	20	20	20	18
12.5	21	22	21	21	22	20	22	20	22	18	20	21	21	18
13	22	23	22	22	22	21	22	21	23	19	21	21	21	18
13.5	22	23	23	23	23	22	23	21	24	19	22	22	22	19
14	23	24	24	23	23	22	24	22	24	20	23	23	22	19
14.5	24	25	24	24	24	23	24	22	25	21	23	23	23	20
15	24	25	25	24	24	24	25	23	25	21	24	24	23	20
15.5	25	26	26	25	25	25	26	24	26	22	25	25	24	21
16	25	27	26	26	26	25	26	24	27	22	25	25	24	21
16.5	26	27	27	26	26	26	27	25	27	23	26	26	25	22
17	26	28	28	27	27	27	28	25	28	23	27	27	25	22
17.5	27	29	28	27	27	27	29	26	28	24	27	27	25	22
18	27	30	29	28	28	28	29	26	29	24	28	28	26	23
18.5	28	30	30	29	29	29	30	27	30	25	29	29	26	23
19	28	31	31	29	29	29	31	28	30	25	29	29	27	24
19.5	29	32	31	30	30	30	31	28	31	26	30	30	27	24
20	29	32	32	30	30	31	32	29	31	26	31	31	28	25
20.5	30	33	33	31	31	31	33	29	32	27	31	31	28	25
21	30	34	33	32	31	32	33	30	33	27	32	32	28	25
21.5	31	34	34	32	32	33	34	30	33	28	33	33	29	26
22	31	35	35	33	33	34	35	31	34	29	33	33	29	26
22.5	32	36	36	33	33	34	35	31	35	29	34	34	30	27
23	32	37	36	34	34	35	36	32	35	30	35	35	30	27
23.5	33	37	37	35	34	36	37	33	36	30	36	35	30	27
24	33	38	38	35	35	36	37	33	36	31	36	36	31	28
24.5	34	39	38	36	35	37	38	34	37	31	37	37	31	28
25	34	39	39	36	36	38	39	34	38	32	38	37	31	28
25.5	35	40	40	37	37	38	40	35	38	32	38	38	32	29
26	35	41	40	38	37	39	40	35	39	33	39	39	32	29
26.5	36	41	41	38	38	40	41	36	39	33	40	39	32	29
27	36	42	42	39	38	40	42	37	40	34	40	40	33	30
27.5	37	43	43	39	39	41	42	37	41	34	41	41	33	30
28	37	43	43	40	40	42	43	38	41	35	42	41	34	30
28.5	38	44	44	41	40	43	44	38	42	36	42	42	34	31
29	38	45	45	41	41	43	44	39	43	36	43	43	34	31
29.5	39	46	45	42	41	44	45	39	43	37	44	43	35	31
30	39	46	46	42	42	45	46	40	44	37	44	44	35	32

For species not in the table refer to Appendix 2.
When applying to a mixture of species in one stratum, choose the table entry for the most common species.

Annex 2 Top height/tariff number for different/other species.

Common name	Abbreviation	Stand tariff from top height
Noble fir	NF	✓
Grand fir	GF	✓
European silver fir	-	NF
Siberian fir	-	NF
Nordmann fir	-	NF
Douglas fir	DF	✓
Western hemlock	WH	✓
Norway spruce	NS	✓
Sitka spruce	SS	✓
Omorika spruce	-	NS
Oriental spruce	-	NS
White spruce	-	NS
Englemann spruce	-	NS
Blue spruce	-	NS
Japanese larch	JL	✓
European larch	EL	✓
Hybrid larch	HL	✓
Scots pine	SP	✓
Corsican pine	CP	✓
Lodgepole pine	LP	✓
Maritime pine	-	LP
Monterey pine	-	CP
Ponderosa pine	-	SP
Weymouth pine/(Eastern) white pine	-	SP
Western red pine	-	CP
Bishop pine	-	LP
Coast redwood	-	GF
Wellingtonia/Giant sequoia	-	GF
Monterey cypress	-	RC
Lawson cypress	-	RC
Nootka cypress	-	RC
Western red cedar	RC	✓
Leyland cypress	-	RC

Common name	Abbreviation	Stand tariff from top height
Black-poplar	-	BI
Hybrid black poplar	-	BI
Silver birch	BI	✓
Downy birch	BI	✓
Common alder	-	OK
Grey alder	-	OK
Italian alder	-	OK
Hornbeam	-	OK
Beech	BE	OK
Roble	-	OK
Raoul	-	OK
Sweet chestnut/Spanish chestnut	-	OK
Red oak	-	OK
Sessile oak	OK	✓
Pedunculate oak	OK	✓
Wych elm	-	OK
English elm	-	OK
Wild cherry	-	BI
Bird cherry	-	BI
Norway maple	-	BI
Field maple	-	BI
Sycamore	-	BI
Horse chestnut	-	OK
Ash	-	OK
Hazel	-	BI
London plane	-	-

Annex 3 Dbh/basal area table.

dbh or diameter (cm)	Basal area or cross-sectional area (m^2)	dbh or diameter (cm)	Basal area or cross-sectional area (m^2)
7	0.0038	54	0.229
8	0.0050	55	0.238
9	0.0064	56	0.246
10	0.0079	57	0.255
11	0.0095	58	0.264
12	0.0113	59	0.273
13	0.0133	60	0.283
14	0.0154	61	0.292
15	0.018	62	0.302
16	0.020	63	0.312
17	0.023	64	0.322
18	0.025	65	0.332
19	0.028	66	0.342
20	0.031	67	0.353
21	0.035	68	0.363
22	0.038	69	0.374
23	0.042	70	0.385
24	0.045	71	0.396
25	0.049	72	0.407
26	0.053	73	0.419
27	0.057	74	0.430
28	0.062	75	0.442
29	0.066	76	0.454
30	0.071	77	0.466
31	0.075	78	0.478
32	0.080	79	0.490
33	0.086	80	0.503
34	0.091	81	0.515
35	0.096	82	0.528
36	0.102	83	0.541
37	0.108	84	0.554
38	0.113	85	0.567
39	0.119	86	0.581
40	0.126	87	0.594
41	0.132	88	0.608
42	0.139	89	0.622
43	0.145	90	0.636
44	0.152	91	0.650
45	0.159	92	0.665
46	0.166	93	0.679
47	0.173	94	0.694
48	0.181	95	0.709
49	0.189	96	0.724
50	0.196	97	0.739
51	0.204	98	0.754
52	0.212	99	0.770
53	0.221	100	0.785

Annex 4 Single tree volume dbh/tariff number - dbh 7 to 40 cm, tariff numbers 1 to 30.

	Tariff number																													
dbh (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
7	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
8	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.010	0.010	0.011	0.011	0.011	0.012	0.012	0.012	0.013	0.013	0.013	0.014	0.014	0.015	0.015	0.015	0.016	0.016
9	0.006	0.006	0.007	0.008	0.009	0.010	0.010	0.011	0.012	0.013	0.014	0.014	0.015	0.016	0.017	0.018	0.018	0.019	0.020	0.021	0.022	0.022	0.023	0.024	0.025	0.025	0.026	0.027	0.028	0.029
10	0.006	0.007	0.009	0.010	0.011	0.012	0.014	0.015	0.016	0.017	0.019	0.020	0.021	0.022	0.024	0.025	0.026	0.028	0.029	0.030	0.031	0.033	0.034	0.035	0.036	0.038	0.039	0.040	0.041	0.043
11	0.007	0.008	0.010	0.012	0.014	0.015	0.017	0.019	0.021	0.023	0.024	0.026	0.028	0.030	0.031	0.033	0.035	0.037	0.039	0.040	0.042	0.044	0.046	0.048	0.049	0.051	0.053	0.055	0.056	0.058
12	0.007	0.009	0.012	0.014	0.016	0.019	0.021	0.023	0.026	0.028	0.031	0.033	0.035	0.038	0.040	0.042	0.045	0.047	0.049	0.052	0.054	0.056	0.059	0.061	0.063	0.066	0.068	0.070	0.073	0.075
13	0.008	0.011	0.013	0.016	0.019	0.022	0.025	0.028	0.031	0.034	0.037	0.040	0.043	0.046	0.049	0.052	0.055	0.058	0.061	0.064	0.067	0.070	0.073	0.076	0.079	0.082	0.085	0.088	0.091	0.094
14	0.008	0.012	0.015	0.019	0.023	0.026	0.030	0.034	0.037	0.041	0.045	0.048	0.052	0.055	0.059	0.063	0.066	0.070	0.074	0.077	0.081	0.085	0.088	0.092	0.095	0.099	0.103	0.106	0.110	0.114
15	0.009	0.013	0.017	0.022	0.026	0.031	0.035	0.039	0.044	0.048	0.052	0.057	0.061	0.065	0.070	0.074	0.078	0.083	0.087	0.091	0.096	0.100	0.105	0.109	0.113	0.118	0.122	0.126	0.131	0.135
16	0.009	0.015	0.020	0.025	0.030	0.035	0.040	0.045	0.050	0.056	0.061	0.066	0.071	0.076	0.081	0.086	0.091	0.096	0.102	0.107	0.112	0.117	0.122	0.127	0.132	0.137	0.143	0.148	0.153	0.158
17	0.010	0.016	0.022	0.028	0.034	0.040	0.046	0.052	0.058	0.064	0.070	0.075	0.081	0.087	0.093	0.099	0.105	0.111	0.117	0.123	0.129	0.135	0.141	0.147	0.153	0.159	0.165	0.170	0.176	0.182
18	0.011	0.018	0.024	0.031	0.038	0.045	0.052	0.058	0.065	0.072	0.079	0.086	0.093	0.099	0.106	0.113	0.120	0.127	0.133	0.140	0.147	0.154	0.161	0.167	0.174	0.181	0.188	0.195	0.201	0.208
19	0.012	0.019	0.027	0.035	0.043	0.050	0.058	0.066	0.073	0.081	0.089	0.097	0.104	0.112	0.120	0.127	0.135	0.143	0.151	0.158	0.166	0.174	0.181	0.189	0.197	0.205	0.212	0.220	0.228	0.236
20	0.012	0.021	0.030	0.039	0.047	0.056	0.065	0.073	0.082	0.091	0.099	0.108	0.117	0.125	0.134	0.143	0.151	0.160	0.169	0.178	0.186	0.195	0.204	0.212	0.221	0.230	0.238	0.247	0.256	0.264
21	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.28	0.29
22	0.01	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.32	0.33
23	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.11	0.12	0.13	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.29	0.30	0.31	0.32	0.34	0.35	0.36
24	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.11	0.12	0.13	0.15	0.16	0.17	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.36	0.37	0.38	0.39
25	0.02	0.03	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.15	0.16	0.17	0.19	0.20	0.22	0.23	0.25	0.26	0.27	0.29	0.30	0.32	0.33	0.35	0.36	0.37	0.39	0.40	0.42	0.43
26	0.02	0.03	0.05	0.06	0.08	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.20	0.22	0.24	0.25	0.27	0.28	0.30	0.31	0.33	0.34	0.36	0.38	0.39	0.41	0.42	0.44	0.45	0.47
27	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.15	0.17	0.19	0.20	0.22	0.24	0.26	0.27	0.29	0.31	0.32	0.34	0.36	0.37	0.39	0.41	0.42	0.44	0.46	0.47	0.49	0.51
28	0.02	0.04	0.06	0.08	0.09	0.11	0.13	0.15	0.17	0.18	0.20	0.22	0.24	0.26	0.28	0.29	0.31	0.33	0.35	0.37	0.38	0.40	0.42	0.44	0.46	0.48	0.49	0.51	0.53	0.55
29	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.37	0.39	0.41	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.59
30	0.02	0.04	0.07	0.09	0.11	0.13	0.15	0.17	0.19	0.21	0.23	0.25	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.47	0.49	0.51	0.53	0.55	0.57	0.59	0.61	0.63
31	0.02	0.05	0.07	0.09	0.11	0.14	0.16	0.18	0.20	0.23	0.25	0.27	0.30	0.32	0.34	0.36	0.39	0.41	0.43	0.45	0.48	0.50	0.52	0.54	0.57	0.59	0.61	0.63	0.66	0.68
32	0.03	0.05	0.07	0.10	0.12	0.15	0.17	0.19	0.22	0.24	0.27	0.29	0.32	0.34	0.36	0.39	0.41	0.44	0.46	0.48	0.51	0.53	0.56	0.58	0.60	0.63	0.65	0.68	0.70	0.73
33	0.03	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.28	0.31	0.34	0.36	0.39	0.41	0.44	0.46	0.49	0.52	0.54	0.57	0.59	0.62	0.64	0.67	0.70	0.72	0.75	0.77
34	0.03	0.06	0.08	0.11	0.14	0.17	0.19	0.22	0.25	0.28	0.30	0.33	0.36	0.38	0.41	0.44	0.47	0.49	0.52	0.55	0.58	0.60	0.63	0.66	0.69	0.71	0.74	0.77	0.80	0.82
35	0.03	0.06	0.09	0.12	0.15	0.18	0.20	0.23	0.26	0.29	0.32	0.35	0.38	0.41	0.44	0.47	0.50	0.52	0.55	0.58	0.61	0.64	0.67	0.70	0.73	0.76	0.79	0.82	0.84	0.87
36	0.03	0.06	0.09	0.12	0.15	0.19	0.22	0.25	0.28	0.31	0.34	0.37	0.40	0.43	0.46	0.49	0.53	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.77	0.80	0.83	0.86	0.90	0.93
37	0.03	0.07	0.10	0.13	0.16	0.20	0.23	0.26	0.29	0.33	0.36	0.39	0.43	0.46	0.49	0.52	0.56	0.59	0.62	0.65	0.69	0.72	0.75	0.78	0.82	0.85	0.88	0.92	0.95	0.98
38	0.03	0.07	0.10	0.14	0.17	0.21	0.24	0.28	0.31	0.35	0.38	0.41	0.45	0.48	0.52	0.55	0.59	0.62	0.66	0.69	0.73	0.76	0.79	0.83	0.86	0.90	0.93	0.97	1.00	1.04
39	0.04	0.07	0.11	0.15	0.18	0.22	0.25	0.29	0.33	0.36	0.40	0.44	0.47	0.51	0.55	0.58	0.62	0.66	0.69	0.73	0.76	0.80	0.84	0.87	0.91	0.95	0.98	1.02	1.06	1.09
40	0.04	0.08	0.11	0.15	0.19	0.23	0.27	0.31	0.35	0.38	0.42	0.46	0.50	0.54	0.58	0.61	0.65	0.69	0.73	0.77	0.81	0.84	0.88	0.92	0.96	1.00	1.04	1.07	1.11	1.15

Annex 4 Single tree volume dbh/tariff number - dbh 41 to 80 cm, tariff numbers 1 to 30.

	Tariff number																													
dbh (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
41	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.61	0.65	0.69	0.73	0.77	0.81	0.85	0.89	0.93	0.97	1.01	1.05	1.09	1.13	1.17	1.21
42	0.04	0.08	0.13	0.17	0.21	0.25	0.30	0.34	0.38	0.42	0.47	0.51	0.55	0.59	0.64	0.68	0.72	0.76	0.81	0.85	0.89	0.93	0.98	1.02	1.06	1.10	1.14	1.19	1.23	1.27
43	0.04	0.09	0.13	0.18	0.22	0.27	0.31	0.36	0.40	0.44	0.49	0.53	0.58	0.62	0.67	0.71	0.76	0.80	0.85	0.89	0.93	0.98	1.02	1.07	1.11	1.16	1.20	1.25	1.29	1.33
44	0.05	0.09	0.14	0.19	0.23	0.28	0.33	0.37	0.42	0.47	0.51	0.56	0.61	0.65	0.70	0.75	0.79	0.84	0.89	0.93	0.98	1.03	1.07	1.12	1.17	1.21	1.26	1.31	1.35	1.40
45	0.05	0.10	0.14	0.19	0.24	0.29	0.34	0.39	0.44	0.49	0.54	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.93	0.98	1.02	1.07	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.47
46	0.05	0.10	0.15	0.20	0.25	0.30	0.36	0.41	0.46	0.51	0.56	0.61	0.66	0.71	0.77	0.82	0.87	0.92	0.97	1.02	1.07	1.12	1.17	1.23	1.28	1.33	1.38	1.43	1.48	1.53
47	0.05	0.10	0.16	0.21	0.26	0.32	0.37	0.43	0.48	0.53	0.59	0.64	0.69	0.75	0.80	0.85	0.91	0.96	1.01	1.07	1.12	1.17	1.23	1.28	1.33	1.39	1.44	1.49	1.55	1.60
48	0.05	0.11	0.16	0.22	0.28	0.33	0.39	0.44	0.50	0.56	0.61	0.67	0.72	0.78	0.83	0.89	0.95	1.00	1.06	1.11	1.17	1.22	1.28	1.34	1.39	1.45	1.50	1.56	1.62	1.67
49	0.06	0.11	0.17	0.23	0.29	0.35	0.40	0.46	0.52	0.58	0.64	0.70	0.75	0.81	0.87	0.93	0.99	1.04	1.10	1.16	1.22	1.28	1.34	1.39	1.45	1.51	1.57	1.63	1.68	1.74
50	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60	0.66	0.72	0.79	0.85	0.91	0.97	1.03	1.09	1.15	1.21	1.27	1.33	1.39	1.45	1.51	1.57	1.63	1.69	1.76	1.82
51	0.06	0.12	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.82	0.88	0.94	1.01	1.07	1.13	1.20	1.26	1.32	1.39	1.45	1.51	1.57	1.64	1.70	1.76	1.83	1.89
52	0.06	0.13	0.19	0.26	0.32	0.39	0.46	0.52	0.59	0.65	0.72	0.78	0.85	0.92	0.98	1.05	1.11	1.18	1.24	1.31	1.38	1.44	1.51	1.57	1.64	1.70	1.77	1.84	1.90	1.97
53	0.06	0.13	0.20	0.27	0.34	0.41	0.47	0.54	0.61	0.68	0.75	0.82	0.88	0.95	1.02	1.09	1.16	1.22	1.29	1.36	1.43	1.50	1.57	1.63	1.70	1.77	1.84	1.91	1.98	2.04
54	0.07	0.14	0.21	0.28	0.35	0.42	0.49	0.56	0.63	0.70	0.78	0.85	0.92	0.99	1.06	1.13	1.20	1.27	1.34	1.41	1.48	1.56	1.63	1.70	1.77	1.84	1.91	1.98	2.05	2.12
55	0.07	0.14	0.22	0.29	0.36	0.44	0.51	0.58	0.66	0.73	0.80	0.88	0.95	1.03	1.10	1.17	1.25	1.32	1.39	1.47	1.54	1.61	1.69	1.76	1.84	1.91	1.98	2.06	2.13	2.20
56	0.07	0.15	0.22	0.30	0.38	0.45	0.53	0.61	0.68	0.76	0.83	0.91	0.99	1.06	1.14	1.22	1.29	1.37	1.45	1.52	1.60	1.67	1.75	1.83	1.90	1.98	2.06	2.13	2.21	2.29
57	0.07	0.15	0.23	0.31	0.39	0.47	0.55	0.63	0.71	0.79	0.87	0.94	1.02	1.10	1.18	1.26	1.34	1.42	1.50	1.58	1.66	1.74	1.82	1.89	1.97	2.05	2.13	2.21	2.29	2.37
58	0.08	0.16	0.24	0.32	0.40	0.49	0.57	0.65	0.73	0.81	0.90	0.98	1.06	1.14	1.22	1.31	1.39	1.47	1.55	1.63	1.72	1.80	1.88	1.96	2.04	2.13	2.21	2.29	2.37	2.45
59	0.08	0.16	0.25	0.33	0.42	0.50	0.59	0.67	0.76	0.84	0.93	1.01	1.10	1.18	1.27	1.35	1.44	1.52	1.61	1.69	1.78	1.86	1.95	2.03	2.12	2.20	2.29	2.37	2.46	2.54
60	0.08	0.17	0.26	0.34	0.43	0.52	0.61	0.70	0.78	0.87	0.96	1.05	1.14	1.22	1.31	1.40	1.49	1.57	1.66	1.75	1.84	1.93	2.01	2.10	2.19	2.28	2.37	2.45	2.54	2.63
61	0.08	0.17	0.26	0.36	0.45	0.54	0.63	0.72	0.81	0.90	0.99	1.08	1.17	1.26	1.36	1.45	1.54	1.63	1.72	1.81	1.90	1.99	2.08	2.17	2.26	2.35	2.45	2.54	2.63	2.72
62	0.09	0.18	0.27	0.37	0.46	0.56	0.65	0.74	0.84	0.93	1.02	1.12	1.21	1.31	1.40	1.49	1.59	1.68	1.78	1.87	1.96	2.06	2.15	2.25	2.34	2.43	2.53	2.62	2.72	2.81
63	0.09	0.19	0.28	0.38	0.48	0.57	0.67	0.77	0.86	0.96	1.06	1.16	1.25	1.35	1.45	1.54	1.64	1.74	1.83	1.93	2.03	2.13	2.22	2.32	2.42	2.51	2.61	2.71	2.80	2.90
64	0.09	0.19	0.29	0.39	0.49	0.59	0.69	0.79	0.89	0.99	1.09	1.19	1.29	1.39	1.49	1.59	1.69	1.79	1.89	1.99	2.09	2.19	2.29	2.39	2.49	2.59	2.69	2.79	2.90	3.00
65	0.09	0.20	0.30	0.40	0.51	0.61	0.71	0.82	0.92	1.02	1.13	1.23	1.33	1.44	1.54	1.64	1.75	1.85	1.95	2.06	2.16	2.26	2.37	2.47	2.57	2.68	2.78	2.88	2.99	3.09
66	0.10	0.20	0.31	0.42	0.52	0.63	0.74	0.84	0.95	1.06	1.16	1.27	1.38	1.48	1.59	1.70	1.80	1.91	2.02	2.12	2.23	2.33	2.44	2.55	2.65	2.76	2.87	2.97	3.08	3.19
67	0.10	0.21	0.32	0.43	0.54	0.65	0.76	0.87	0.98	1.09	1.20	1.31	1.42	1.53	1.64	1.75	1.86	1.97	2.08	2.19	2.30	2.41	2.52	2.63	2.74	2.85	2.96	3.07	3.18	3.29
68	0.10	0.22	0.33	0.44	0.56	0.67	0.78	0.89	1.01	1.12	1.23	1.35	1.46	1.57	1.69	1.80	1.91	2.03	2.14	2.25	2.37	2.48	2.59	2.71	2.82	2.93	3.05	3.16	3.27	3.39
69	0.11	0.22	0.34	0.46	0.57	0.69	0.80	0.92	1.04	1.15	1.27	1.39	1.50	1.62	1.74	1.85	1.97	2.09	2.20	2.32	2.44	2.55	2.67	2.79	2.90	3.02	3.14	3.25	3.37	3.49
70	0.11	0.23	0.35	0.47	0.59	0.71	0.83	0.95	1.07	1.19	1.31	1.43	1.55	1.67	1.79	1.91	2.03	2.15	2.27	2.39	2.51	2.63	2.75	2.87	2.99	3.11	3.23	3.35	3.47	3.59
71	0.11	0.23	0.36	0.48	0.61	0.73	0.85	0.98	1.10	1.22	1.35	1.47	1.59	1.72	1.84	1.96	2.09	2.21	2.33	2.46	2.58	2.71	2.83	2.95	3.08	3.20	3.32	3.45	3.57	3.69
72	0.11	0.24	0.37	0.50	0.62	0.75	0.88	1.00	1.13	1.26	1.39	1.51	1.64	1.77	1.89	2.02	2.15	2.27	2.40	2.53	2.66	2.78	2.91	3.04	3.16	3.29	3.42	3.55	3.67	3.80
73	0.12	0.25	0.38	0.51	0.64	0.77	0.90	1.03	1.16	1.29	1.42	1.55	1.69	1.82	1.95	2.08	2.21	2.34	2.47	2.60	2.73	2.86	2.99	3.12	3.25	3.38	3.51	3.65	3.78	3.91
74	0.12	0.25	0.39	0.52	0.66	0.79	0.93	1.06	1.19	1.33	1.46	1.60	1.73	1.87	2.00	2.13	2.27	2.40	2.54	2.67	2.81	2.94	3.07	3.21	3.34	3.48	3.61	3.75	3.88	4.01
75	0.12	0.26	0.40	0.54	0.68	0.81	0.95	1.09	1.23	1.37	1.50	1.64	1.78	1.92	2.06	2.19	2.33	2.47	2.61	2.75	2.88	3.02	3.16	3.30	3.44	3.57	3.71	3.85	3.99	4.13
76	0.13	0.27	0.41	0.55	0.69	0.84	0.98	1.12	1.26	1.40	1.54	1.69	1.83	1.97	2.11	2.25	2.39	2.54	2.68	2.82	2.96	3.10	3.24	3.39	3.53	3.67	3.81	3.95	4.09	4.24
77	0.13	0.28	0.42	0.57	0.71	0.86	1.00	1.15	1.29	1.44	1.59	1.73	1.88	2.02	2.17	2.31	2.46	2.60	2.75	2.89	3.04	3.19	3.33	3.48	3.62	3.77	3.91	4.06	4.20	4.35
78	0.13	0.28	0.43	0.58	0.73	0.88	1.03	1.18	1.33	1.48	1.63	1.78	1.93	2.07	2.22	2.37	2.52	2.67	2.82	2.97	3.12	3.27	3.42	3.57	3.72	3.87	4.02	4.17	4.31	4.46
79	0.14	0.29	0.44	0.60	0.75	0.90	1.06	1.21	1.36	1.52	1.67	1.82	1.98	2.13	2.28	2.44	2.59	2.74	2.89	3.05	3.20	3.35	3.51	3.66	3.81	3.97	4.12	4.27	4.43	4.58
80	0.14	0.30	0.45	0.61	0.77	0.93	1.08	1.24	1.40	1.55	1.71	1.87	2.03	2.18	2.34	2.50	2.65	2.81	2.97	3.13	3.28	3.44	3.60	3.75	3.91	4.07	4.23	4.38	4.54	4.70

Annex 4 Single tree volume dbh/tariff number - dbh 81 to 120 cm, tariff numbers 1 to 30.

	Tariff number																													
dbh (cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
81	0.14	0.30	0.47	0.63	0.79	0.95	1.11	1.27	1.43	1.59	1.76	1.92	2.08	2.24	2.40	2.56	2.72	2.88	3.04	3.21	3.37	3.53	3.69	3.85	4.01	4.17	4.33	4.49	4.66	4.82
82	0.15	0.31	0.48	0.64	0.81	0.97	1.14	1.30	1.47	1.63	1.80	1.96	2.13	2.29	2.46	2.62	2.79	2.96	3.12	3.29	3.45	3.62	3.78	3.95	4.11	4.28	4.44	4.61	4.77	4.94
83	0.15	0.32	0.49	0.66	0.83	1.00	1.17	1.34	1.50	1.67	1.84	2.01	2.18	2.35	2.52	2.69	2.86	3.03	3.20	3.37	3.54	3.70	3.87	4.04	4.21	4.38	4.55	4.72	4.89	5.06
84	0.15	0.33	0.50	0.67	0.85	1.02	1.19	1.37	1.54	1.71	1.89	2.06	2.23	2.41	2.58	2.76	2.93	3.10	3.28	3.45	3.62	3.80	3.97	4.14	4.32	4.49	4.66	4.84	5.01	5.18
85	0.16	0.34	0.51	0.69	0.87	1.05	1.22	1.40	1.58	1.76	1.93	2.11	2.29	2.47	2.64	2.82	3.00	3.18	3.35	3.53	3.71	3.89	4.06	4.24	4.42	4.60	4.77	4.95	5.13	5.31
86	0.16	0.34	0.53	0.71	0.89	1.07	1.25	1.43	1.62	1.80	1.98	2.16	2.34	2.52	2.71	2.89	3.07	3.25	3.43	3.62	3.80	3.98	4.16	4.34	4.52	4.71	4.89	5.07	5.25	5.43
87	0.17	0.35	0.54	0.72	0.91	1.10	1.28	1.47	1.65	1.84	2.03	2.21	2.40	2.58	2.77	2.96	3.14	3.33	3.51	3.70	3.89	4.07	4.26	4.44	4.63	4.82	5.00	5.19	5.38	5.56
88	0.17	0.36	0.55	0.74	0.93	1.12	1.31	1.50	1.69	1.88	2.07	2.26	2.45	2.64	2.83	3.03	3.22	3.41	3.60	3.79	3.98	4.17	4.36	4.55	4.74	4.93	5.12	5.31	5.50	5.69
89	0.17	0.37	0.56	0.76	0.95	1.15	1.34	1.54	1.73	1.93	2.12	2.32	2.51	2.70	2.90	3.09	3.29	3.48	3.68	3.87	4.07	4.26	4.46	4.65	4.85	5.04	5.24	5.43	5.63	5.82
90	0.18	0.38	0.57	0.77	0.97	1.17	1.37	1.57	1.77	1.97	2.17	2.37	2.57	2.77	2.97	3.16	3.36	3.56	3.76	3.96	4.16	4.36	4.56	4.76	4.96	5.16	5.36	5.56	5.75	5.95
91	0.18	0.38	0.59	0.79	1.00	1.20	1.40	1.61	1.81	2.01	2.22	2.42	2.62	2.83	3.03	3.24	3.44	3.64	3.85	4.05	4.25	4.46	4.66	4.87	5.07	5.27	5.48	5.68	5.88	6.09
92	0.18	0.39	0.60	0.81	1.02	1.23	1.43	1.64	1.85	2.06	2.27	2.47	2.68	2.89	3.10	3.31	3.52	3.72	3.93	4.14	4.35	4.56	4.77	4.97	5.18	5.39	5.60	5.81	6.01	6.22
93	0.19	0.40	0.61	0.83	1.04	1.25	1.47	1.68	1.89	2.10	2.32	2.53	2.74	2.95	3.17	3.38	3.59	3.81	4.02	4.23	4.44	4.66	4.87	5.08	5.30	5.51	5.72	5.93	6.15	6.36
94	0.19	0.41	0.63	0.84	1.06	1.28	1.50	1.71	1.93	2.15	2.37	2.58	2.80	3.02	3.24	3.45	3.67	3.89	4.11	4.32	4.54	4.76	4.98	5.19	5.41	5.63	5.85	6.06	6.28	6.50
95	0.20	0.42	0.64	0.86	1.08	1.31	1.53	1.75	1.97	2.20	2.42	2.64	2.86	3.08	3.31	3.53	3.75	3.97	4.19	4.42	4.64	4.86	5.08	5.30	5.53	5.75	5.97	6.19	6.42	6.64
96	0.20	0.43	0.65	0.88	1.11	1.33	1.56	1.79	2.01	2.24	2.47	2.70	2.92	3.15	3.38	3.60	3.83	4.06	4.28	4.51	4.74	4.96	5.19	5.42	5.64	5.87	6.10	6.32	6.55	6.78
97	0.20	0.44	0.67	0.90	1.13	1.36	1.59	1.83	2.06	2.29	2.52	2.75	2.98	3.22	3.45	3.68	3.91	4.14	4.37	4.60	4.84	5.07	5.30	5.53	5.76	5.99	6.23	6.46	6.69	6.92
98	0.21	0.45	0.68	0.92	1.15	1.39	1.63	1.86	2.10	2.34	2.57	2.81	3.05	3.28	3.52	3.76	3.99	4.23	4.46	4.70	4.94	5.17	5.41	5.65	5.88	6.12	6.36	6.59	6.83	7.07
99	0.21	0.45	0.70	0.94	1.18	1.42	1.66	1.90	2.14	2.38	2.63	2.87	3.11	3.35	3.59	3.83	4.07	4.31	4.56	4.80	5.04	5.28	5.52	5.76	6.00	6.25	6.49	6.73	6.97	7.21
100	0.22	0.46	0.71	0.96	1.20	1.45	1.69	1.94	2.19	2.43	2.68	2.93	3.17	3.42	3.66	3.91	4.16	4.40	4.65	4.90	5.14	5.39	5.63	5.88	6.13	6.37	6.62	6.87	7.11	7.36
101	0.22	0.47	0.72	0.97	1.23	1.48	1.73	1.98	2.23	2.48	2.73	2.98	3.24	3.49	3.74	3.99	4.24	4.49	4.74	4.99	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25	7.51
102	0.23	0.48	0.74	0.99	1.25	1.51	1.76	2.02	2.28	2.53	2.79	3.04	3.30	3.56	3.81	4.07	4.33	4.58	4.84	5.09	5.35	5.61	5.86	6.12	6.38	6.63	6.89	7.14	7.40	7.66
103	0.23	0.49	0.75	1.01	1.28	1.54	1.80	2.06	2.32	2.58	2.84	3.10	3.37	3.63	3.89	4.15	4.41	4.67	4.93	5.19	5.46	5.72	5.98	6.24	6.50	6.76	7.02	7.29	7.55	7.81
104	0.23	0.50	0.77	1.03	1.30	1.57	1.83	2.10	2.37	2.63	2.90	3.17	3.43	3.70	3.96	4.23	4.50	4.76	5.03	5.30	5.56	5.83	6.10	6.36	6.63	6.89	7.16	7.43	7.69	7.96
105	0.24	0.51	0.78	1.05	1.33	1.60	1.87	2.14	2.41	2.68	2.95	3.23	3.50	3.77	4.04	4.31	4.58	4.86	5.13	5.40	5.67	5.94	6.21	6.49	6.76	7.03	7.30	7.57	7.84	8.11
106	0.24	0.52	0.80	1.07	1.35	1.63	1.90	2.18	2.46	2.73	3.01	3.29	3.57	3.84	4.12	4.40	4.67	4.95	5.23	5.50	5.78	6.06	6.33	6.61	6.89	7.16	7.44	7.72	7.99	8.27
107	0.25	0.53	0.81	1.09	1.38	1.66	1.94	2.22	2.50	2.79	3.07	3.35	3.63	3.91	4.20	4.48	4.76	5.04	5.33	5.61	5.89	6.17	6.45	6.74	7.02	7.30	7.58	7.86	8.15	8.43
108	0.25	0.54	0.83	1.11	1.40	1.69	1.98	2.26	2.55	2.84	3.13	3.41	3.70	3.99	4.28	4.56	4.85	5.14	5.43	5.71	6.00	6.29	6.58	6.86	7.15	7.44	7.72	8.01	8.30	8.59
109	0.26	0.55	0.84	1.14	1.43	1.72	2.01	2.31	2.60	2.89	3.18	3.48	3.77	4.06	4.36	4.65	4.94	5.23	5.53	5.82	6.11	6.41	6.70	6.99	7.28	7.58	7.87	8.16	8.45	8.75
110	0.26	0.56	0.86	1.16	1.45	1.75	2.05	2.35	2.65	2.95	3.24	3.54	3.84	4.14	4.44	4.73	5.03	5.33	5.63	5.93	6.23	6.52	6.82	7.12	7.42	7.72	8.01	8.31	8.61	8.91
111	0.27	0.57	0.87	1.18	1.48	1.78	2.09	2.39	2.70	3.00	3.30	3.61	3.91	4.21	4.52	4.82	5.13	5.43	5.73	6.04	6.34	6.64	6.95	7.25	7.55	7.86	8.16	8.47	8.77	9.07
112	0.27	0.58	0.89	1.20	1.51	1.82	2.13	2.44	2.74	3.05	3.36	3.67	3.98	4.29	4.60	4.91	5.22	5.53	5.84	6.15	6.45	6.76	7.07	7.38	7.69	8.00	8.31	8.62	8.93	9.24
113	0.28	0.59	0.91	1.22	1.54	1.85	2.16	2.48	2.79	3.11	3.42	3.74	4.05	4.37	4.68	5.00	5.31	5.63	5.94	6.26	6.57	6.89	7.20	7.52	7.83	8.14	8.46	8.77	9.09	9.40
114	0.28	0.60	0.92	1.24	1.56	1.88	2.20	2.52	2.84	3.16	3.48	3.80	4.13	4.45	4.77	5.09	5.41	5.73	6.05	6.37	6.69	7.01	7.33	7.65	7.97	8.29	8.61	8.93	9.25	9.57
115	0.29	0.61	0.94	1.26	1.59	1.92	2.24	2.57	2.89	3.22	3.55	3.87	4.20	4.52	4.85	5.18	5.50	5.83	6.15	6.48	6.81	7.13	7.46	7.78	8.11	8.44	8.76	9.09	9.41	9.74
116	0.29	0.62	0.95	1.29	1.62	1.95	2.28	2.61	2.94	3.28	3.61	3.94	4.27	4.60	4.94	5.27	5.60	5.93	6.26	6.59	6.93	7.26	7.59	7.92	8.25	8.58	8.92	9.25	9.58	9.91
117	0.30	0.63	0.97	1.31	1.65	1.98	2.32	2.66	3.00	3.33	3.67	4.01	4.35	4.68	5.02	5.36	5.70	6.03	6.37	6.71	7.05	7.38	7.72	8.06	8.40	8.73	9.07	9.41	9.75	10.08
118	0.30	0.64	0.99	1.33	1.67	2.02	2.36	2.70	3.05	3.39	3.73	4.08	4.42	4.76	5.11	5.45	5.79	6.14	6.48	6.82	7.17	7.51	7.85	8.20	8.54	8.88	9.23	9.57	9.91	10.26
119	0.31	0.65	1.00	1.35	1.70	2.05	2.40	2.75	3.10	3.45	3.80	4.15	4.50	4.85	5.19	5.54	5.89	6.24	6.59	6.94	7.29	7.64	7.99	8.34	8.69	9.04	9.38	9.73	10.08	10.43
120	0.31	0.67	1.02	1.38	1.73	2.09	2.44	2.80	3.15	3.51	3.86	4.22	4.57	4.93	5.28	5.64	5.99	6.35	6.70	7.06	7.41	7.77	8.12	8.48	8.83	9.19	9.54	9.90	10.25	10.61

Annex 4 Single tree volume dbh/tariff number - dbh 7 to 40 cm, tariff numbers 31 to 60.

	Tariff number																													
dbh (cm)	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
7	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
8	0.016	0.017	0.017	0.018	0.018	0.018	0.019	0.019	0.019	0.020	0.020	0.021	0.021	0.021	0.022	0.022	0.022	0.023	0.023	0.024	0.024	0.024	0.025	0.025	0.025	0.026	0.026	0.026	0.027	0.027
9	0.029	0.030	0.031	0.032	0.033	0.033	0.034	0.035	0.036	0.037	0.037	0.038	0.039	0.040	0.041	0.041	0.042	0.043	0.044	0.044	0.045	0.046	0.047	0.048	0.048	0.049	0.050	0.051	0.052	0.052
10	0.044	0.045	0.046	0.048	0.049	0.050	0.052	0.053	0.054	0.055	0.057	0.058	0.059	0.060	0.062	0.063	0.064	0.065	0.067	0.068	0.069	0.070	0.072	0.073	0.074	0.075	0.077	0.078	0.079	0.081
11	0.060	0.062	0.064	0.065	0.067	0.069	0.071	0.072	0.074	0.076	0.078	0.080	0.081	0.083	0.085	0.087	0.088	0.090	0.092	0.094	0.096	0.097	0.099	0.101	0.103	0.105	0.106	0.108	0.110	0.112
12	0.078	0.080	0.082	0.085	0.087	0.089	0.092	0.094	0.096	0.099	0.101	0.103	0.106	0.108	0.110	0.113	0.115	0.118	0.120	0.122	0.125	0.127	0.129	0.132	0.134	0.136	0.139	0.141	0.143	0.146
13	0.097	0.100	0.103	0.106	0.109	0.111	0.114	0.117	0.120	0.123	0.126	0.129	0.132	0.135	0.138	0.141	0.144	0.147	0.150	0.153	0.156	0.159	0.162	0.165	0.168	0.171	0.174	0.177	0.180	0.183
14	0.117	0.121	0.125	0.128	0.132	0.135	0.139	0.143	0.146	0.150	0.154	0.157	0.161	0.165	0.168	0.172	0.175	0.179	0.183	0.186	0.190	0.194	0.197	0.201	0.205	0.208	0.212	0.215	0.219	0.223
15	0.139	0.144	0.148	0.152	0.157	0.161	0.166	0.170	0.174	0.179	0.183	0.187	0.192	0.196	0.200	0.205	0.209	0.213	0.218	0.222	0.227	0.231	0.235	0.240	0.244	0.248	0.253	0.257	0.261	0.266
16	0.163	0.168	0.173	0.178	0.184	0.189	0.194	0.199	0.204	0.209	0.214	0.219	0.225	0.230	0.235	0.240	0.245	0.250	0.255	0.260	0.266	0.271	0.276	0.281	0.286	0.291	0.296	0.301	0.306	0.312
17	0.188	0.194	0.200	0.206	0.212	0.218	0.224	0.230	0.236	0.242	0.248	0.254	0.260	0.265	0.271	0.277	0.283	0.289	0.295	0.301	0.307	0.313	0.319	0.325	0.331	0.337	0.343	0.349	0.355	0.360
18	0.215	0.222	0.229	0.235	0.242	0.249	0.256	0.263	0.269	0.276	0.283	0.290	0.297	0.303	0.310	0.317	0.324	0.331	0.337	0.344	0.351	0.358	0.365	0.372	0.378	0.385	0.392	0.399	0.406	0.412
19	0.243	0.251	0.259	0.266	0.274	0.282	0.290	0.297	0.305	0.313	0.320	0.328	0.336	0.344	0.351	0.359	0.367	0.374	0.382	0.390	0.398	0.405	0.413	0.421	0.429	0.436	0.444	0.452	0.459	0.467
20	0.273	0.282	0.290	0.299	0.308	0.316	0.325	0.334	0.343	0.351	0.360	0.369	0.377	0.386	0.395	0.403	0.412	0.421	0.429	0.438	0.447	0.455	0.464	0.473	0.481	0.490	0.499	0.508	0.516	0.525
21	0.30	0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59
22	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.61	0.62	0.63	0.64	0.65
23	0.37	0.38	0.40	0.41	0.42	0.43	0.44	0.45	0.47	0.48	0.49	0.50	0.51	0.53	0.54	0.55	0.56	0.57	0.59	0.60	0.61	0.62	0.63	0.64	0.66	0.67	0.68	0.69	0.70	0.72
24	0.41	0.42	0.43	0.45	0.46	0.47	0.49	0.50	0.51	0.52	0.54	0.55	0.56	0.58	0.59	0.60	0.62	0.63	0.64	0.66	0.67	0.68	0.69	0.71	0.72	0.73	0.75	0.76	0.77	0.79
25	0.44	0.46	0.47	0.49	0.50	0.52	0.53	0.54	0.56	0.57	0.59	0.60	0.62	0.63	0.64	0.66	0.67	0.69	0.70	0.72	0.73	0.74	0.76	0.77	0.79	0.80	0.82	0.83	0.84	0.86
26	0.48	0.50	0.51	0.53	0.55	0.56	0.58	0.59	0.61	0.62	0.64	0.65	0.67	0.69	0.70	0.72	0.73	0.75	0.76	0.78	0.79	0.81	0.83	0.84	0.86	0.87	0.89	0.90	0.92	0.93
27	0.52	0.54	0.56	0.57	0.59	0.61	0.63	0.64	0.66	0.68	0.69	0.71	0.73	0.74	0.76	0.78	0.79	0.81	0.83	0.84	0.86	0.88	0.89	0.91	0.93	0.94	0.96	0.98	1.00	1.01
28	0.57	0.58	0.60	0.62	0.64	0.66	0.68	0.69	0.71	0.73	0.75	0.77	0.78	0.80	0.82	0.84	0.86	0.88	0.89	0.91	0.93	0.95	0.97	0.98	1.00	1.02	1.04	1.06	1.08	1.09
29	0.61	0.63	0.65	0.67	0.69	0.71	0.73	0.75	0.77	0.79	0.81	0.83	0.84	0.86	0.88	0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18
30	0.65	0.68	0.70	0.72	0.74	0.76	0.78	0.80	0.82	0.84	0.87	0.89	0.91	0.93	0.95	0.97	0.99	1.01	1.03	1.05	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22	1.24	1.27
31	0.70	0.72	0.75	0.77	0.79	0.81	0.84	0.86	0.88	0.90	0.93	0.95	0.97	0.99	1.02	1.04	1.06	1.09	1.11	1.13	1.15	1.18	1.20	1.22	1.24	1.27	1.29	1.31	1.33	1.36
32	0.75	0.77	0.80	0.82	0.85	0.87	0.89	0.92	0.94	0.97	0.99	1.01	1.04	1.06	1.09	1.11	1.14	1.16	1.18	1.21	1.23	1.26	1.28	1.30	1.33	1.35	1.38	1.40	1.43	1.45
33	0.80	0.82	0.85	0.88	0.90	0.93	0.95	0.98	1.01	1.03	1.06	1.08	1.11	1.13	1.16	1.19	1.21	1.24	1.26	1.29	1.31	1.34	1.37	1.39	1.42	1.44	1.47	1.49	1.52	1.55
34	0.85	0.88	0.91	0.93	0.96	0.99	1.01	1.04	1.07	1.10	1.12	1.15	1.18	1.21	1.23	1.26	1.29	1.32	1.34	1.37	1.40	1.43	1.45	1.48	1.51	1.54	1.56	1.59	1.62	1.64
35	0.90	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.16	1.19	1.22	1.25	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.49	1.51	1.54	1.57	1.60	1.63	1.66	1.69	1.72	1.75
36	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.33	1.36	1.39	1.42	1.45	1.48	1.51	1.54	1.57	1.61	1.64	1.67	1.70	1.73	1.76	1.79	1.82	1.85
37	1.01	1.05	1.08	1.11	1.14	1.18	1.21	1.24	1.27	1.31	1.34	1.37	1.40	1.44	1.47	1.50	1.54	1.57	1.60	1.63	1.67	1.70	1.73	1.76	1.80	1.83	1.86	1.89	1.93	1.96
38	1.07	1.10	1.14	1.17	1.21	1.24	1.28	1.31	1.35	1.38	1.42	1.45	1.48	1.52	1.55	1.59	1.62	1.66	1.69	1.73	1.76	1.80	1.83	1.86	1.90	1.93	1.97	2.00	2.04	2.07
39	1.13	1.17	1.20	1.24	1.27	1.31	1.35	1.38	1.42	1.46	1.49	1.53	1.57	1.60	1.64	1.68	1.71	1.75	1.78	1.82	1.86	1.89	1.93	1.97	2.00	2.04	2.08	2.11	2.15	2.19
40	1.19	1.23	1.27	1.30	1.34	1.38	1.42	1.46	1.50	1.53	1.57	1.61	1.65	1.69	1.73	1.77	1.80	1.84	1.88	1.92	1.96	2.00	2.03	2.07	2.11	2.15	2.19	2.23	2.26	2.30

Annex 4 Single tree volume dbh/tariff number - dbh 41 to 80 cm, tariff numbers 31 to 60.

	Tariff number																													
dbh (cm)	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
41	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.53	1.57	1.61	1.66	1.70	1.74	1.78	1.82	1.86	1.90	1.94	1.98	2.02	2.06	2.10	2.14	2.18	2.22	2.26	2.30	2.34	2.38	2.42
42	1.31	1.36	1.40	1.44	1.48	1.53	1.57	1.61	1.65	1.70	1.74	1.78	1.82	1.87	1.91	1.95	1.99	2.04	2.08	2.12	2.16	2.21	2.25	2.29	2.33	2.38	2.42	2.46	2.50	2.55
43	1.38	1.42	1.47	1.51	1.56	1.60	1.65	1.69	1.74	1.78	1.82	1.87	1.91	1.96	2.00	2.05	2.09	2.14	2.18	2.23	2.27	2.31	2.36	2.40	2.45	2.49	2.54	2.58	2.63	2.67
44	1.45	1.49	1.54	1.59	1.63	1.68	1.73	1.77	1.82	1.87	1.91	1.96	2.01	2.05	2.10	2.15	2.19	2.24	2.29	2.33	2.38	2.43	2.47	2.52	2.57	2.61	2.66	2.71	2.75	2.80
45	1.51	1.56	1.61	1.66	1.71	1.76	1.81	1.86	1.91	1.95	2.00	2.05	2.10	2.15	2.20	2.25	2.30	2.35	2.39	2.44	2.49	2.54	2.59	2.64	2.69	2.74	2.79	2.83	2.88	2.93
46	1.58	1.63	1.69	1.74	1.79	1.84	1.89	1.94	1.99	2.04	2.09	2.15	2.20	2.25	2.30	2.35	2.40	2.45	2.50	2.56	2.61	2.66	2.71	2.76	2.81	2.86	2.91	2.96	3.02	3.07
47	1.65	1.71	1.76	1.81	1.87	1.92	1.98	2.03	2.08	2.14	2.19	2.24	2.30	2.35	2.40	2.46	2.51	2.56	2.62	2.67	2.72	2.78	2.83	2.88	2.94	2.99	3.04	3.10	3.15	3.20
48	1.73	1.78	1.84	1.89	1.95	2.01	2.06	2.12	2.17	2.23	2.28	2.34	2.40	2.45	2.51	2.56	2.62	2.68	2.73	2.79	2.84	2.90	2.95	3.01	3.07	3.12	3.18	3.23	3.29	3.35
49	1.80	1.86	1.92	1.98	2.03	2.09	2.15	2.21	2.27	2.32	2.38	2.44	2.50	2.56	2.62	2.67	2.73	2.79	2.85	2.91	2.97	3.02	3.08	3.14	3.20	3.26	3.31	3.37	3.43	3.49
50	1.88	1.94	2.00	2.06	2.12	2.18	2.24	2.30	2.36	2.42	2.48	2.54	2.60	2.67	2.73	2.79	2.85	2.91	2.97	3.03	3.09	3.15	3.21	3.27	3.33	3.39	3.45	3.51	3.57	3.64
51	1.95	2.02	2.08	2.14	2.21	2.27	2.33	2.40	2.46	2.52	2.59	2.65	2.71	2.77	2.84	2.90	2.96	3.03	3.09	3.15	3.22	3.28	3.34	3.41	3.47	3.53	3.60	3.66	3.72	3.79
52	2.03	2.10	2.16	2.23	2.30	2.36	2.43	2.49	2.56	2.62	2.69	2.76	2.82	2.89	2.95	3.02	3.08	3.15	3.21	3.28	3.35	3.41	3.48	3.54	3.61	3.67	3.74	3.81	3.87	3.94
53	2.11	2.18	2.25	2.32	2.39	2.45	2.52	2.59	2.66	2.73	2.80	2.86	2.93	3.00	3.07	3.14	3.21	3.27	3.34	3.41	3.48	3.55	3.62	3.68	3.75	3.82	3.89	3.96	4.02	4.09
54	2.19	2.27	2.34	2.41	2.48	2.55	2.62	2.69	2.76	2.83	2.90	2.97	3.05	3.12	3.19	3.26	3.33	3.40	3.47	3.54	3.61	3.68	3.76	3.83	3.90	3.97	4.04	4.11	4.18	4.25
55	2.28	2.35	2.42	2.50	2.57	2.65	2.72	2.79	2.87	2.94	3.01	3.09	3.16	3.23	3.31	3.38	3.46	3.53	3.60	3.68	3.75	3.82	3.90	3.97	4.04	4.12	4.19	4.27	4.34	4.41
56	2.36	2.44	2.52	2.59	2.67	2.74	2.82	2.90	2.97	3.05	3.13	3.20	3.28	3.36	3.43	3.51	3.58	3.66	3.74	3.81	3.89	3.97	4.04	4.12	4.20	4.27	4.35	4.42	4.50	4.58
57	2.45	2.53	2.61	2.69	2.77	2.84	2.92	3.00	3.08	3.16	3.24	3.32	3.40	3.48	3.56	3.64	3.72	3.79	3.87	3.95	4.03	4.11	4.19	4.27	4.35	4.43	4.51	4.59	4.67	4.74
58	2.54	2.62	2.70	2.78	2.86	2.95	3.03	3.11	3.19	3.27	3.36	3.44	3.52	3.60	3.68	3.77	3.85	3.93	4.01	4.09	4.18	4.26	4.34	4.42	4.51	4.59	4.67	4.75	4.83	4.92
59	2.63	2.71	2.80	2.88	2.97	3.05	3.14	3.22	3.31	3.39	3.47	3.56	3.64	3.73	3.81	3.90	3.98	4.07	4.15	4.24	4.32	4.41	4.49	4.58	4.66	4.75	4.83	4.92	5.00	5.09
60	2.72	2.80	2.89	2.98	3.07	3.16	3.24	3.33	3.42	3.51	3.60	3.68	3.77	3.86	3.95	4.03	4.12	4.21	4.30	4.39	4.47	4.56	4.65	4.74	4.83	4.91	5.00	5.09	5.18	5.26
61	2.81	2.90	2.99	3.08	3.17	3.26	3.35	3.45	3.54	3.63	3.72	3.81	3.90	3.99	4.08	4.17	4.26	4.35	4.44	4.54	4.63	4.72	4.81	4.90	4.99	5.08	5.17	5.26	5.35	5.44
62	2.90	3.00	3.09	3.18	3.28	3.37	3.47	3.56	3.65	3.75	3.84	3.94	4.03	4.12	4.22	4.31	4.41	4.50	4.59	4.69	4.78	4.87	4.97	5.06	5.16	5.25	5.34	5.44	5.53	5.63
63	3.00	3.10	3.19	3.29	3.39	3.48	3.58	3.68	3.77	3.87	3.97	4.07	4.16	4.26	4.36	4.45	4.55	4.65	4.74	4.84	4.94	5.04	5.13	5.23	5.33	5.42	5.52	5.62	5.71	5.81
64	3.10	3.20	3.30	3.40	3.50	3.60	3.70	3.80	3.90	4.00	4.10	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00	5.10	5.20	5.30	5.40	5.50	5.60	5.70	5.80	5.90	6.00
65	3.19	3.30	3.40	3.50	3.61	3.71	3.81	3.92	4.02	4.12	4.23	4.33	4.43	4.54	4.64	4.74	4.85	4.95	5.05	5.16	5.26	5.36	5.47	5.57	5.67	5.78	5.88	5.98	6.09	6.19
66	3.29	3.40	3.51	3.61	3.72	3.83	3.93	4.04	4.15	4.25	4.36	4.47	4.57	4.68	4.79	4.89	5.00	5.11	5.21	5.32	5.43	5.53	5.64	5.75	5.85	5.96	6.06	6.17	6.28	6.38
67	3.40	3.51	3.62	3.73	3.83	3.94	4.05	4.16	4.27	4.38	4.49	4.60	4.71	4.82	4.93	5.04	5.15	5.26	5.37	5.48	5.59	5.70	5.81	5.92	6.03	6.14	6.25	6.36	6.47	6.58
68	3.50	3.61	3.73	3.84	3.95	4.06	4.18	4.29	4.40	4.52	4.63	4.74	4.86	4.97	5.08	5.20	5.31	5.42	5.54	5.65	5.76	5.88	5.99	6.10	6.22	6.33	6.44	6.56	6.67	6.78
69	3.60	3.72	3.84	3.95	4.07	4.19	4.30	4.42	4.54	4.65	4.77	4.89	5.00	5.12	5.24	5.35	5.47	5.59	5.70	5.82	5.94	6.05	6.17	6.28	6.40	6.52	6.63	6.75	6.87	6.98
70	3.71	3.83	3.95	4.07	4.19	4.31	4.43	4.55	4.67	4.79	4.91	5.03	5.15	5.27	5.39	5.51	5.63	5.75	5.87	5.99	6.11	6.23	6.35	6.47	6.59	6.71	6.83	6.95	7.07	7.19
71	3.82	3.94	4.06	4.19	4.31	4.43	4.56	4.68	4.81	4.93	5.05	5.18	5.30	5.42	5.55	5.67	5.79	5.92	6.04	6.16	6.29	6.41	6.53	6.66	6.78	6.91	7.03	7.15	7.28	7.40
72	3.93	4.05	4.18	4.31	4.43	4.56	4.69	4.82	4.94	5.07	5.20	5.32	5.45	5.58	5.71	5.83	5.96	6.09	6.21	6.34	6.47	6.59	6.72	6.85	6.98	7.10	7.23	7.36	7.48	7.61
73	4.04	4.17	4.30	4.43	4.56	4.69	4.82	4.95	5.08	5.21	5.34	5.47	5.60	5.74	5.87	6.00	6.13	6.26	6.39	6.52	6.65	6.78	6.91	7.04	7.17	7.30	7.43	7.56	7.70	7.83
74	4.15	4.28	4.42	4.55	4.69	4.82	4.95	5.09	5.22	5.36	5.49	5.63	5.76	5.89	6.03	6.16	6.30	6.43	6.57	6.70	6.83	6.97	7.10	7.24	7.37	7.51	7.64	7.77	7.91	8.04
75	4.26	4.40	4.54	4.68	4.81	4.95	5.09	5.23	5.37	5.50	5.64	5.78	5.92	6.06	6.19	6.33	6.47	6.61	6.75	6.88	7.02	7.16	7.30	7.44	7.57	7.71	7.85	7.99	8.13	8.26
76	4.38	4.52	4.66	4.80	4.95	5.09	5.23	5.37	5.51	5.65	5.80	5.94	6.08	6.22	6.36	6.50	6.65	6.79	6.93	7.07	7.21	7.35	7.50	7.64	7.78	7.92	8.06	8.20	8.35	8.49
77	4.50	4.64	4.79	4.93	5.08	5.22	5.37	5.51	5.66	5.80	5.95	6.10	6.24	6.39	6.53	6.68	6.82	6.97	7.11	7.26	7.41	7.55	7.70	7.84	7.99	8.13	8.28	8.42	8.57	8.71
78	4.61	4.76	4.91	5.06	5.21	5.36	5.51	5.66	5.81	5.96	6.11	6.26	6.41	6.55	6.70	6.85	7.00	7.15	7.30	7.45	7.60	7.75	7.90	8.05	8.20	8.35	8.50	8.65	8.79	8.94
79	4.73	4.89	5.04	5.19	5.35	5.50	5.65	5.81	5.96	6.11	6.27	6.42	6.57	6.73	6.88	7.03	7.18	7.34	7.49	7.64	7.80	7.95	8.10	8.26	8.41	8.56	8.72	8.87	9.02	9.18
80	4.85	5.01	5.17	5.33	5.48	5.64	5.80	5.95	6.11	6.27	6.43	6.58	6.74	6.90	7.05	7.21	7.37	7.53	7.68	7.84	8.00	8.15	8.31	8.47	8.63	8.78	8.94	9.10	9.25	9.41

Annex 4 Single tree volume dbh/tariff number - dbh 81 to 120 cm, tariff numbers 31 to 60.

	Tariff number																													
dbh (cm)	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
81	4.98	5.14	5.30	5.46	5.62	5.78	5.94	6.11	6.27	6.43	6.59	6.75	6.91	7.07	7.23	7.39	7.56	7.72	7.88	8.04	8.20	8.36	8.52	8.68	8.84	9.01	9.17	9.33	9.49	9.65
82	5.10	5.27	5.43	5.60	5.76	5.93	6.09	6.26	6.42	6.59	6.75	6.92	7.08	7.25	7.41	7.58	7.74	7.91	8.08	8.24	8.41	8.57	8.74	8.90	9.07	9.23	9.40	9.56	9.73	9.89
83	5.23	5.40	5.57	5.74	5.91	6.07	6.24	6.41	6.58	6.75	6.92	7.09	7.26	7.43	7.60	7.77	7.94	8.11	8.27	8.44	8.61	8.78	8.95	9.12	9.29	9.46	9.63	9.80	9.97	10.14
84	5.36	5.53	5.70	5.88	6.05	6.22	6.40	6.57	6.74	6.92	7.09	7.26	7.44	7.61	7.78	7.96	8.13	8.30	8.48	8.65	8.82	9.00	9.17	9.34	9.52	9.69	9.86	10.04	10.21	10.38
85	5.48	5.66	5.84	6.02	6.20	6.37	6.55	6.73	6.91	7.08	7.26	7.44	7.62	7.79	7.97	8.15	8.33	8.50	8.68	8.86	9.04	9.21	9.39	9.57	9.75	9.92	10.10	10.28	10.46	10.63
86	5.62	5.80	5.98	6.16	6.34	6.52	6.71	6.89	7.07	7.25	7.43	7.62	7.80	7.98	8.16	8.34	8.52	8.71	8.89	9.07	9.25	9.43	9.61	9.80	9.98	10.16	10.34	10.52	10.71	10.89
87	5.75	5.93	6.12	6.31	6.49	6.68	6.86	7.05	7.24	7.42	7.61	7.79	7.98	8.17	8.35	8.54	8.72	8.91	9.10	9.28	9.47	9.66	9.84	10.03	10.21	10.40	10.59	10.77	10.96	11.14
88	5.88	6.07	6.26	6.45	6.64	6.83	7.02	7.21	7.40	7.59	7.79	7.98	8.17	8.36	8.55	8.74	8.93	9.12	9.31	9.50	9.69	9.88	10.07	10.26	10.45	10.64	10.83	11.02	11.21	11.40
89	6.02	6.21	6.41	6.60	6.80	6.99	7.18	7.38	7.57	7.77	7.96	8.16	8.35	8.55	8.74	8.94	9.13	9.33	9.52	9.72	9.91	10.11	10.30	10.50	10.69	10.89	11.08	11.28	11.47	11.67
90	6.15	6.35	6.55	6.75	6.95	7.15	7.35	7.55	7.75	7.95	8.15	8.34	8.54	8.74	8.94	9.14	9.34	9.54	9.74	9.94	10.14	10.34	10.54	10.73	10.93	11.13	11.33	11.53	11.73	11.93
91	6.29	6.49	6.70	6.90	7.11	7.31	7.51	7.72	7.92	8.12	8.33	8.53	8.74	8.94	9.14	9.35	9.55	9.75	9.96	10.16	10.37	10.57	10.77	10.98	11.18	11.38	11.59	11.79	11.99	12.20
92	6.43	6.64	6.85	7.06	7.26	7.47	7.68	7.89	8.10	8.30	8.51	8.72	8.93	9.14	9.35	9.55	9.76	9.97	10.18	10.39	10.60	10.80	11.01	11.22	11.43	11.64	11.84	12.05	12.26	12.47
93	6.57	6.78	7.00	7.21	7.42	7.64	7.85	8.06	8.27	8.49	8.70	8.91	9.13	9.34	9.55	9.76	9.98	10.19	10.40	10.62	10.83	11.04	11.25	11.47	11.68	11.89	12.10	12.32	12.53	12.74
94	6.72	6.93	7.15	7.37	7.58	7.80	8.02	8.24	8.45	8.67	8.89	9.11	9.32	9.54	9.76	9.98	10.19	10.41	10.63	10.85	11.06	11.28	11.50	11.72	11.93	12.15	12.37	12.59	12.80	13.02
95	6.86	7.08	7.30	7.53	7.75	7.97	8.19	8.41	8.64	8.86	9.08	9.30	9.52	9.75	9.97	10.19	10.41	10.64	10.86	11.08	11.30	11.52	11.75	11.97	12.19	12.41	12.63	12.86	13.08	13.30
96	7.01	7.23	7.46	7.69	7.91	8.14	8.37	8.59	8.82	9.05	9.27	9.50	9.73	9.95	10.18	10.41	10.63	10.86	11.09	11.31	11.54	11.77	12.00	12.22	12.45	12.68	12.90	13.13	13.36	13.58
97	7.15	7.38	7.62	7.85	8.08	8.31	8.54	8.77	9.01	9.24	9.47	9.70	9.93	10.16	10.40	10.63	10.86	11.09	11.32	11.55	11.78	12.02	12.25	12.48	12.71	12.94	13.17	13.41	13.64	13.87
98	7.30	7.54	7.77	8.01	8.25	8.48	8.72	8.96	9.19	9.43	9.67	9.90	10.14	10.38	10.61	10.85	11.08	11.32	11.56	11.79	12.03	12.27	12.50	12.74	12.98	13.21	13.45	13.69	13.92	14.16
99	7.45	7.69	7.93	8.18	8.42	8.66	8.90	9.14	9.38	9.62	9.86	10.11	10.35	10.59	10.83	11.07	11.31	11.55	11.80	12.04	12.28	12.52	12.76	13.00	13.24	13.48	13.73	13.97	14.21	14.45
100	7.60	7.85	8.10	8.34	8.59	8.83	9.08	9.33	9.57	9.82	10.07	10.31	10.56	10.80	11.05	11.30	11.54	11.79	12.04	12.28	12.53	12.77	13.02	13.27	13.51	13.76	14.01	14.25	14.50	14.74
101	7.76	8.01	8.26	8.51	8.76	9.01	9.26	9.52	9.77	10.02	10.27	10.52	10.77	11.02	11.27	11.53	11.78	12.03	12.28	12.53	12.78	13.03	13.28	13.53	13.79	14.04	14.29	14.54	14.79	15.04
102	7.91	8.17	8.42	8.68	8.94	9.19	9.45	9.71	9.96	10.22	10.47	10.73	10.99	11.24	11.50	11.76	12.01	12.27	12.52	12.78	13.04	13.29	13.55	13.81	14.06	14.32	14.57	14.83	15.09	15.34
103	8.07	8.33	8.59	8.85	9.11	9.38	9.64	9.90	10.16	10.42	10.68	10.94	11.20	11.47	11.73	11.99	12.25	12.51	12.77	13.03	13.29	13.56	13.82	14.08	14.34	14.60	14.86	15.12	15.39	15.65
104	8.23	8.49	8.76	9.03	9.29	9.56	9.83	10.09	10.36	10.62	10.89	11.16	11.42	11.69	11.96	12.22	12.49	12.76	13.02	13.29	13.56	13.82	14.09	14.35	14.62	14.89	15.15	15.42	15.69	15.95
105	8.39	8.66	8.93	9.20	9.47	9.74	10.02	10.29	10.56	10.83	11.10	11.37	11.65	11.92	12.19	12.46	12.73	13.00	13.28	13.55	13.82	14.09	14.36	14.63	14.90	15.18	15.45	15.72	15.99	16.26
106	8.55	8.82	9.10	9.38	9.65	9.93	10.21	10.49	10.76	11.04	11.32	11.59	11.87	12.15	12.42	12.70	12.98	13.25	13.53	13.81	14.08	14.36	14.64	14.91	15.19	15.47	15.74	16.02	16.30	16.58
107	8.71	8.99	9.27	9.56	9.84	10.12	10.40	10.68	10.97	11.25	11.53	11.81	12.10	12.38	12.66	12.94	13.22	13.51	13.79	14.07	14.35	14.63	14.92	15.20	15.48	15.76	16.04	16.33	16.61	16.89
108	8.87	9.16	9.45	9.74	10.02	10.31	10.60	10.89	11.17	11.46	11.75	12.04	12.32	12.61	12.90	13.19	13.47	13.76	14.05	14.34	14.62	14.91	15.20	15.48	15.77	16.06	16.35	16.63	16.92	17.21
109	9.04	9.33	9.63	9.92	10.21	10.50	10.80	11.09	11.38	11.68	11.97	12.26	12.55	12.85	13.14	13.43	13.72	14.02	14.31	14.60	14.90	15.19	15.48	15.77	16.07	16.36	16.65	16.95	17.24	17.53
110	9.21	9.51	9.80	10.10	10.40	10.70	11.00	11.29	11.59	11.89	12.19	12.49	12.79	13.08	13.38	13.68	13.98	14.28	14.57	14.87	15.17	15.47	15.77	16.07	16.36	16.66	16.96	17.26	17.56	17.85
111	9.38	9.68	9.98	10.29	10.59	10.89	11.20	11.50	11.81	12.11	12.41	12.72	13.02	13.32	13.63	13.93	14.23	14.54	14.84	15.15	15.45	15.75	16.06	16.36	16.66	16.97	17.27	17.57	17.88	18.18
112	9.55	9.86	10.16	10.47	10.78	11.09	11.40	11.71	12.02	12.33	12.64	12.95	13.26	13.57	13.87	14.18	14.49	14.80	15.11	15.42	15.73	16.04	16.35	16.66	16.97	17.28	17.59	17.89	18.20	18.51
113	9.72	10.03	10.35	10.66	10.98	11.29	11.61	11.92	12.24	12.55	12.87	13.18	13.50	13.81	14.12	14.44	14.75	15.07	15.38	15.70	16.01	16.33	16.64	16.96	17.27	17.59	17.90	18.22	18.53	18.85
114	9.89	10.21	10.53	10.85	11.17	11.49	11.81	12.13	12.45	12.77	13.10	13.42	13.74	14.06	14.38	14.70	15.02	15.34	15.66	15.98	16.30	16.62	16.94	17.26	17.58	17.90	18.22	18.54	18.86	19.18
115	10.07	10.39	10.72	11.04	11.37	11.70	12.02	12.35	12.67	13.00	13.33	13.65	13.98	14.30	14.63	14.96	15.28	15.61	15.94	16.26	16.59	16.91	17.24	17.57	17.89	18.22	18.54	18.87	19.20	19.52
116	10.24	10.57	10.91	11.24	11.57	11.90	12.23	12.57	12.90	13.23	13.56	13.89	14.22	14.56	14.89	15.22	15.55	15.88	16.21	16.55	16.88	17.21	17.54	17.87	18.20	18.54	18.87	19.20	19.53	19.86
117	10.42	10.76	11.10	11.43	11.77	12.11	12.45	12.78	13.12	13.46	13.80	14.13	14.47	14.81	15.15	15.48	15.82	16.16	16.50	16.83	17.17	17.51	17.85	18.18	18.52	18.86	19.20	19.53	19.87	20.21
118	10.60	10.94	11.29	11.63	11.97	12.32	12.66	13.00	13.35	13.69	14.03	14.38	14.72	15.06	15.41	15.75	16.09	16.44	16.78	17.12	17.47	17.81	18.15	18.50	18.84	19.18	19.53	19.87	20.21	20.56
119	10.78	11.13	11.48	11.83	12.18	12.53	12.88	13.23	13.57	13.92	14.27	14.62	14.97	15.32	15.67	16.02	16.37	16.72	17.07	17.42	17.77	18.11	18.46	18.81	19.16	19.51	19.86	20.21	20.56	20.91
120	10.96	11.32	11.67	12.03	12.38	12.74	13.09	13.45	13.80	14.16	14.51	14.87	15.23	15.58	15.94	16.29	16.65	17.00	17.36	17.71	18.07	18.42	18.78	19.13	19.49	19.84	20.20	20.55	20.91	21.26

Appendix 3 Basic introduction to mensuration, growth, yield and thinning in woodlands.

Measuring diameter on a tree

The *dbh* is the diameter at the breast height point on a tree. Trees with a dbh of less than 7 cm are assumed to have no volume and are conventionally classified as 'unmeasurable'.

The *breast height point* is the point on the tree which is 1.3 m above ground level. On sloping ground, this is the ground level on the upper side of the tree, while on leaning trees on level ground, this is the ground level on the underside of the tree.

The *mean diameter* of a stand or of a group of trees is the diameter of the tree of mean basal area, which is the same as the quadratic mean of the dbhs of all the trees. Unmeasurable trees are normally excluded from this calculation, but if they are included this should be clearly stated. The mean diameter can be calculated using a calculator or computer:

- Square each dbh.
- Add all the squared values together.
- Divide by the number of trees, to give the mean squared dbh.
- Calculate the square root of this value, to give the mean dbh.

Measuring basal area

The basal area of an individual tree is the cross-sectional area of the tree at its breast height point:

$$ba = \frac{\pi \times dbh^2}{40000}$$

where ba = basal area in m^2
dbh = diameter at breast height in cm.

The *basal area of a stand* is the sum of the basal areas of all the trees in the stand. All basal areas should be recorded in square metres, or square metres per hectare.

The basal area of a stand can be estimated using one of two methods:

- Using a relascope (see Appendix 1)
- Measuring the basal areas of individual trees and adding them together.

Measuring length and height

Lengths and heights are measured in metres. They are conventionally rounded down to the nearest 0.1 m for lengths up to 10 m, and to the nearest whole metre for lengths greater than 10 m.

The *total height* of a standing tree is the vertical distance from the base of the tree to the uppermost point (tip). The total length of a felled tree is the straight line distance from the base to the tip. The total height of young standing trees can be measured with graduated poles. The total height of felled trees should be measured with a tape. The total height of other trees should be measured with a manual or electronic hypsometer or clinometer, and the instructions supplied with the instrument should be followed. Each tree should ideally be measured from both sides, and the two measurements averaged. The distance of the observation points from the tree should be in the region of 1 to 1.5 times the height of the tree. When measuring the heights of trees it is important to remember that accurate use of hypsometers or clinometers requires training, checking, and, most of all, practice.

The *timber height* of a tree (or the *timber length*) is the distance from the base of the tree to the lowest point on the main stem where the diameter is 7 cm overbark. In hardwoods and occasionally in conifers this point may alternatively be the 'spring of the crown', i.e. the lowest point at which no main stem is distinguishable. It should be measured in exactly the same way as total height.

The *top height* of a stand is the average total height of the 'top height trees' in the stand. The top height of a stand is the average total height of the 100 trees of largest dbh per hectare. A top height sample tree can be identified as the tree of largest dbh in a 0.01 ha sample plot. This is not necessarily the tallest tree.

Measuring volume

In general volumes are recorded in cubic metres to two or three significant figures as required.

The conventional top diameter limit for volume is 7 cm overbark, or the point at which no main stem is distinguishable, whichever comes first. As a consequence trees with a dbh of less than 7 cm are normally ignored when estimating volume.

Measuring volume productivity

An important measure of volume productivity in forestry is cumulative volume production. Cumulative timber volume production is the standing volume per hectare attained by a forest stand in a given year plus the sum of per-hectare volumes removed as thinnings up to that year. Cumulative volume production represents the total production of timber volume from a stand up to a given year in the stand's development.

An example of cumulative volume production as measured in a permanent sample plot of even-aged Sitka spruce is given in Table A3.1. As an illustration of how cumulative volume production is calculated, in Table A3.1 cumulative production up to age 44 years is

369 + 34 + 33 + 49 + 24 + 35 + 61 + 53 = 658 cubic metres per hectare.

Table A3.1 Standing volume and production over time in an even aged stand of Sitka spruce (permanent mensuration sample plot 1222, Brendon, Somerset, established 1948, felled 1986 at age 57).

Year	Stand age (years)	Volume per hectare (m^3 ha^{-1})			Mean annual increment (m^3 ha^{-1} yr^{-1})
		Standing after thinning	Removed as thinnings	Cumulative volume	
1948	19	103	34	137	7.2
1951	22	-	33	-	-
1953	24	121	49	237	9.9
1958	29	-	24	-	-
1963	34	262	35	437	12.9
1967	38	272	61	508	13.3
1973	44	369	53	658	15.0
1978	49	396	59	744	15.2
1986	57	531	-	879	15.4

Strictly speaking, cumulative volume production is not a meaningful physical or biological variable. The main applications of cumulative volume production are in economic analysis and in support of practical forest management. In essence cumulative volume production represents the out-turn of commercial stem volume from a stand up to a given year in the stand's development.

Mean annual increment (mai) is the average rate of cumulative volume production up to a given year. In even aged stands it is calculated by dividing cumulative volume production by age. For example, for the Sitka spruce stand in Table A3.1, the mean annual increment up to age 44 years is 658 / 44 = 15.0 cubic metres per hectare per year.

For an even-aged stand of trees, mai follows a characteristic pattern of development with respect to stand age. This pattern has been described in Forestry Commission Booklet 48 (Edwards and Christie, 1981) and is repeated in Figure A3.1. In the early years of stand development, mai rises steadily from zero to a maximum value. For typical even-aged conifer stands grown under UK conditions, this maximum value is usually reached after several decades. From this point on mai declines steadily, although the rate of decline may be slight in the years immediately following attainment of maximum mai. The existence of a stand age t_{max} for which mai takes a maximum value mai_{max} may be regarded as being of great commercial significance in the management of even-aged stands particularly if the aim is to maximise sustainable volume production. Specifically, if mai_{max} occurs at a predictable stand age t_{max} then a forest manager may choose to clearfell the stand at this age. The average rate of volume production over the rotation period t_{max} will then be mai_{max}. The forest manager can then replant or regenerate a new stand on the clearfelled site and, if this new stand is also grown over a rotation period t_{max} then average rate of volume production of the new stand will again be mai_{max} provided that the fertility of the site has not been depleted and environmental conditions have not changed. Clearly, managing a stand on this site using any rotation period other than t_{max} will result in a lower average rate of volume production, because the mai achieved by an even-aged stand on this site must be lower for a stand age other than t_{max}.

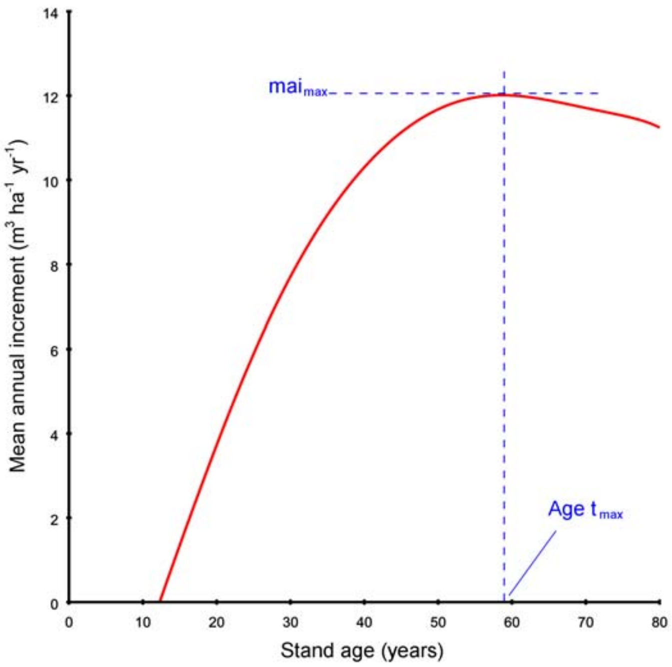


Figure A3.1 Time course of mean annual increment of cumulative volume production for an even-aged stand. The example curve is based on the Forestry Commission Booklet 48 yield model for Sitka spruce, yield class 12.

Forecasting future production – yield models and yield class

Future volume production can be forecast by referring to an appropriate yield model. Yield models are based on characteristic growth curves for a given species and management regime, including series for describing the development of mai and cumulative volume production. Examples of such curves are given in Figures A3.2 (mai) and A3.3 (cumulative volume).

It is possible to construct a curve for mai development (and an equivalent one for cumulative volume) with any selected value of maximum mai. However, for ease of use, the curves referred to in yield models are restricted to a particular set of maximum values. By convention in British forestry, mai curves usually have maxima equal to even numbers, e.g. 2, 4, 6 ... cubic metres per hectare per year. This maximum value can be used as an index to identify each of the different curves – this index is known as yield class. Yield class is thus an index measure of forest productivity based on the maximum mean annual increment of cumulative timber volume achieved by a given tree species growing on a given site and managed according to a standard prescription. It is measured in units of cubic metres per hectare per year. In Figure A3.2, there are 10 mai curves representing yield classes of 6 to 24, which cover the productivity range commonly observed for Sitka spruce in Britain.

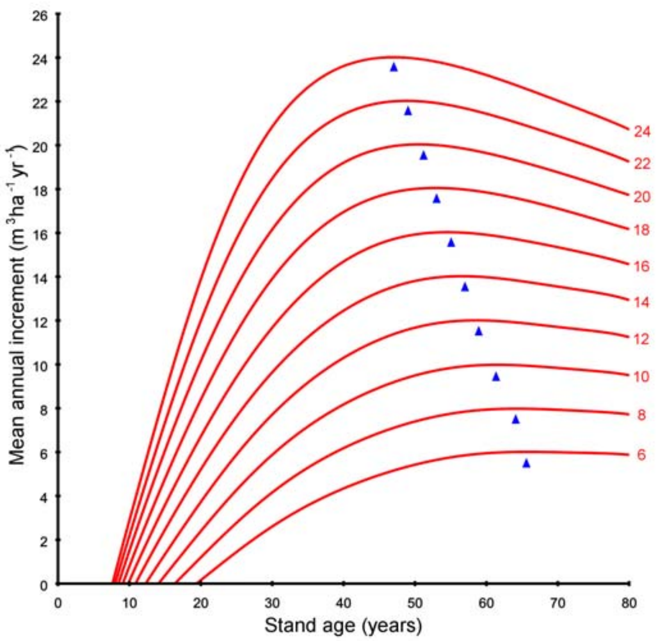


Figure A3.2 Illustration of a set of growth curves for describing development of mean annual increment with respect to stand age, showing 10 distinct productivity classes (yield classes). The curves shown are based on the Forestry Commission Booklet 48 yield models for Sitka spruce.

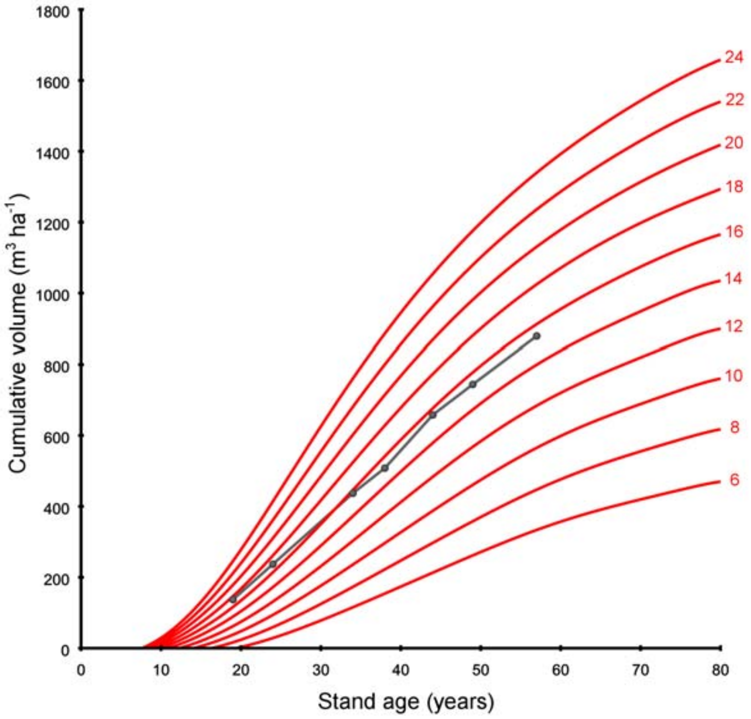


Figure A3.3 Illustration of a set of growth curves for describing development of cumulative volume production with respect to stand age, showing 10 distinct productivity classes (yield classes). The curves shown are based on the Forestry Commission Booklet 48 yield models for Sitka spruce. The black points illustrate cumulative volume as measured in an actual stand (Table A3.1) which can be compared with the model curves.

The yield class of a stand can be assessed by directly monitoring cumulative volume production and comparing with standard growth curves of a yield model. An estimate of yield class derived in this way is known as 'Local Yield Class' (LYC).

In Figure A3.3 cumulative volume measurements from Table A3.1 are plotted to allow comparison with the model curves. The first measurement of cumulative volume at age 19 is closest to the model curve for yield class 18 but later measurements are around the curve for yield class 16. This illustrates how yield models can be used to predict future growth for an actual stand, and also shows the limitations of such a prediction. On the one hand, making a prediction is a very simple procedure – the curve that best represents (i.e. is closest to) the measured cumulative volume is selected and can be used to estimate the future cumulative volume increment in the stand. On the other hand, a prediction made in this way will only be an approximation of the actual development of cumulative volume in a particular stand because, in general, stands will not grow exactly according to the pattern described by the model curves.

A big problem with an approach to yield class estimation based on assessment of cumulative volume production is that cumulative volume is difficult and expensive to measure. As a consequence, estimating Local Yield Class from direct measurement of cumulative volume as described above is rarely attempted in practice. Fortunately studies of forest growth have shown that cumulative timber volume production is closely related to top height growth in most tree species when grown as even aged stands.

For example, the relationship assumed between cumulative volume production and top height in the yield models for Sitka spruce is shown in Figure A3.4. It is striking and very useful that this relationship can be described with reasonable precision by a single curve, which was called a 'master table' relationship by the original developers of the yield models (Hummel and Christie, 1957; Christie, 1972).

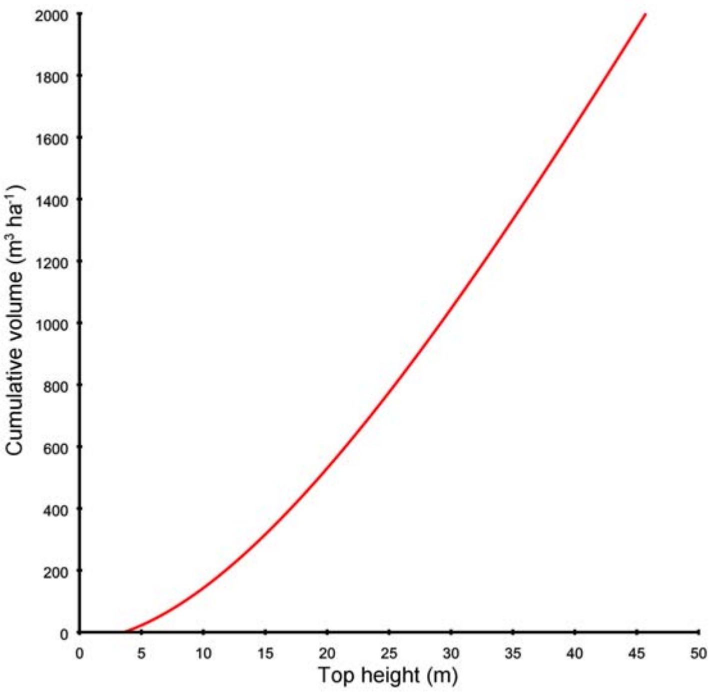


Figure A3.4 Illustration of the 'master table' relationship assumed in the Forestry Commission Booklet 48 yield models for Sitka spruce between cumulative volume production and top height development.

The existence of the master table relationship between cumulative volume and top height makes it possible for yield class to be estimated from an assessment of stand top height and the stand age. The top height assessment is compared with a standard set of top height curves as illustrated in Figure A3.6. This type of estimate is known as 'General Yield Class' (GYC).

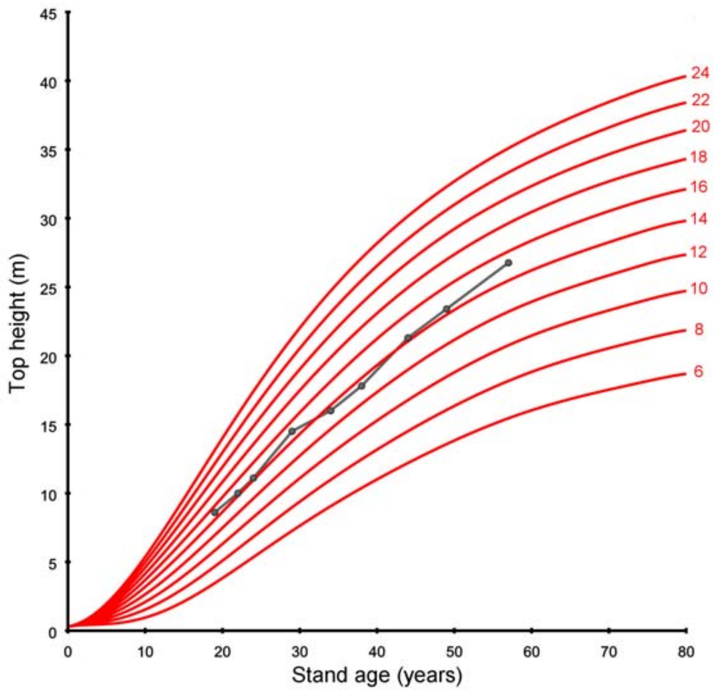


Figure A3.5 Illustration of a set of growth curves for describing development of top height with respect to stand age, showing 10 distinct productivity classes (yield classes). The curves shown are based on the Forestry Commission Booklet 48 yield models for Sitka spruce. The black points illustrate top height as measured in an actual stand (the same one as in Table A3.1) which can be compared with the model curves.

In Figure A3.5 top height measurements for the sample plot referred to in Table A3.1 (top height data not shown in the table) are plotted to allow comparison with the model curves. Six out of nine assessments lie close to the curve for yield class 14, while just three are closer to the curve for yield class 16 or mid-way between the yield class 14 and 16 curves. Overall this suggests a General Yield Class estimate of 14, one class down from the Local Yield Class estimate of 16 obtained earlier (Figure A3.3). This illustrates how GYC is not an exact estimate of LYC. The application of GYC in forestry practice relies on the assumption that GYC will be an unbiased estimate of LYC on average over many stands. However, the possibility exists that GYC may systematically overestimate or underestimate LYC in certain situations, for example due to the particular growth characteristics of stands of a certain species growing in a certain region or managed in a certain way.

Thinning in woodlands

Typical patterns of thinning

Generally speaking, patterns of thinning involve either a sequence of 'selective' thinnings, or an initial line thinning followed by a sequence of 'selective' thinnings. Detailed thinning prescriptions can be defined by:

- The type of selective thinning carried out
- The amount of stem volume per hectare removed in thinnings ('thinning yield')
- The timing of the first thinning
- The time between thinnings ('thinning cycle').

Types of selective thinning

'Selective' thinning types all involve selecting certain sorts of tree for removal as thinnings, while favouring other sorts of tree for retention, allowing them to grow on. Selective thinning methods therefore require a way of classifying the different sorts of tree forming a stand, which is then used to make decisions about which trees to choose as thinnings and which to keep in the stand. Silviculturists have developed many such tree classification systems; for over 50 years the Forestry Commission has referred to a relatively simple system as illustrated in Figure A3.6. This identifies 7 classes of tree in terms of their competitive status (or 'dominance class') and/or their broad stem quality characteristics (see Table A3.5).

Table A3.5 A simple way of categorising trees in a stand (see Figure A3.1).

Tree class	Description
1. Dominant	The tallest trees in the stand but not necessarily the straightest.
2. Co-dominant	Trees in the upper canopy but below the level of the dominant trees.
3. Sub-dominant	Trees which do not hold a place in the upper layer of the canopy but which still retain access to light.
4. Suppressed	Trees which have their leading shoots directly under some portion of the crown of another tree and as a consequence are denied access to light.
5. Wolf	Mis-shapen trees with large crowns which both outgrow and damage their neighbours.
6. Whips	Slender stems without stability which damage neighbouring trees when they sway.
7. Dead and dying	Suppressed or diseased trees that have died or are dying, including leaning and blown trees.

Figure A3.6 Illustration of the seven classes of tree forming a stand.

Different types of selective thinning treatment can be defined, depending on how these different classes of trees are emphasised for thinning or retention. The management prescriptions commonly practiced in British forestry involve two types of selective thinning:

1. Crown thinning
2. Intermediate thinning.

Intermediate thinning combines ideas from the crown thinning type with those for another type, called low thinning. All three types are described in Table A3.6. Prescriptions involving a sequence of intermediate thinnings are most commonly practiced in Britain.

Table A3.6 Descriptions of different thinning types.

Thinning type	Description
Low	Trees are removed primarily from the lower canopy, i.e. suppressed and sub-dominant trees, and from among the smaller diameter trees. The aim of low thinning is to concentrate potential for growth onto the larger diameter trees by removing competing smaller trees. Low thinning tends to result in relatively dense stands of evenly distributed trees, although clumps of dominant trees can develop. Wolf trees, which are usually of relatively large diameter are not usually removed in a strict low thinning. Small diameter whips will often be included in low thinnings. Normally the mean diameter of early thinnings will be quite small compared to that of the stand before thinning – in extreme cases the mean dbh of thinnings might be only one half that of the standing trees. As the number of trees removed in a low thinning is increased, trees are removed from among progressively larger diameter classes so that the mean dbh of thinnings gets bigger.
Crown	Trees are removed primarily from the upper canopy, i.e. some dominants and co-dominants. The aim of a crown thinning is to give selected dominants freedom to grow rapidly by gradual removal of competing trees. Some trees may also be removed from the lower canopy if they are in the proximity of selected dominants. The choice of the selected dominants is not fixed but judged subjectively at successive thinnings. Poorly formed wolf trees will be identified for removal in early thinnings. Whips will be removed if they interfere with the crowns of selected dominants. A true crown thinning cannot be maintained throughout the rotation of a stand of trees because repeated crown thinnings tend to result in too few dominants remaining to select between, while smaller trees get left in dense groups and growth becomes suppressed. As a result, later crown thinnings are often closer to intermediate thinnings. The mean dbh of early crown thinnings will be very similar to the mean dbh of the standing trees, and sometimes greater.
Intermediate	This involves a combination of the ideas behind low and crown thinning (hence the name intermediate). As in low thinning, most of the suppressed and sub-dominant trees are removed to favour the growth of the larger trees; at the same time, as in crown thinning, the canopy is opened up and a uniform stand structure is maintained by breaking up groups of competing dominants and co-dominant trees. Poorly formed wolf trees will be identified for removal in early thinnings. Small diameter whips will often be included in thinnings. The mean dbh of early thinnings will usually be somewhat smaller than that of the standing trees, but bigger than observed in low thinnings. Intermediate thinning is generally preferred among the selective thinning types, and is the most commonly used, because a pragmatic view of thinning is taken, encouraging the development of better trees in the stand while maintaining diameter growth and developing a fairly open and stable stand structure. At later ages, stands which have been subjected to intermediate thinning will tend to develop into a characteristically grand overstorey of well spaced, large trees, sometimes referred to as a 'cathedral of trees'.

Stem volume removed in thinnings (thinning yield)

The volume removed in most selective thinning operations as generally practiced in Britain is fixed at a constant quantity, which is calculated from the yield class for the model. The method used to calculate this thinning volume from yield class is based on the assumed existence of a 'marginal thinning intensity', as explained below.

A thinning operation can be described as 'light' or 'heavy', depending on how much basal area or stem volume is removed in the thinning, or how many trees are thinned. 'Thinning intensity' is a measure of the 'lightness' or 'heaviness' of a thinning, usually (but not always) expressed in terms of the amount of volume per hectare removed.

A very light thinning is likely to result in standing trees remaining densely packed, with the consequence that diameter growth will become reduced and trees may die due to competition. Heavier thinning will release the trees left standing from competition and their diameter increment should increase (or at least not decrease due to competition). However very heavy thinning is likely to leave only a few trees behind, with the result that overall increment of the remaining stand (in terms of volume per hectare) will be reduced compared to lighter thinnings. Somewhere between the extremes of very light and very heavy thinning, there ought to be an 'optimum' intensity of thinning which releases the standing trees from competition and increases their diameter increment, while retaining sufficient growing stock to capture the available light resource and maintain overall stand volume growth.

From the earliest days of the Forestry Commission, trials and experiments formed of groups of permanent mensuration sample plots were established in stands of different tree species, to permit the impacts of thinning treatments at different intensities to be investigated. In the 1960s the results of these experiments were analysed to see whether an 'optimum thinning intensity' of the sort discussed above could be identified. The analysis was difficult because the trials and experiments did not conform to a coherent statistical design (in fact they were very diverse), while the main method of analysis at the time involved hand-drawing graphs of stand growth over time and then inspecting them to look for common trends or other consistent features. Despite these difficulties, as reported in FC Booklet 16, *Forest Management Tables* (Bradley, Christie and Johnston, 1966), it was possible to ascertain that total volume production seemed to remain fairly constant across a fairly wide range of thinning intensities (and indeed thinning types). A broad-brush (and momentous) conclusion was reached, which involved defining an optimum thinning intensity, regardless of tree species, in terms of the yield class of stands. This intensity is frequently referred to as the 'marginal thinning intensity', because it is supposed to be the heaviest intensity of thinning that can be carried out in a stand without compromising the continued growth of the remaining growing stock. The adoption of the marginal thinning intensity as the standard for thinning should also have the effect of maximising diameter increment while maintaining maximum volume production.

For a particular stand, the volume removed in a selective thinning at marginal intensity can be calculated very simply as,

Volume removed in thinning = 0.7 x GYC x Time to next thinning (or 'thinning cycle', years).

For example, if the GYC of the stand is 12 and the thinning cycle is 5 years, then the volume removed in the thinning is,

$0.7 \times 12 \times 5 = 42\ m^3\ ha^{-1}$.

The value of 0.7 times (or 70% of) the yield class is sometimes referred to as the "annual thinning yield", as it represents the volume that would be removed if thinnings were carried out every year. (For the example this is 0.7 x 12 = 8.4 $m^3\ ha^{-1}\ yr^{-1}$.) When thinnings are carried out every 5 years, the volume to be removed is 5 times the annual thinning yield (sometimes called a 5 year cut); if thinnings were to be carried out every 7 years then the volume to be removed would be 7 times the annual thinning yield (a 7 year cut), i.e. for the example,

$0.7 \times 12 \times 7$ or $8.4 \times 7 = 58.8\ m^3\ ha^{-1}$.

Because the marginal thinning intensity is the standard intensity assumed for selective thinnings in the majority of Forestry Commission yield tables (which were once called 'Management Tables'), it is sometimes referred to as 'Management Table Intensity', or 'MTI'.

Light and heavy thinnings can be expressed as multiples or percentages of MTI, for example a light thinning might be 0.8 MTI or 80% MTI while a heavy thinning might be 1.2 or 120% MTI. For the example above and assuming 5 years between thinnings, these are:

$0.8 \times 0.7 \times 12 \times 5$ or $0.8 \times 8.4 \times 5 = 33.6\ m^3\ ha^{-1}$

and $1.2 \times 0.7 \times 12 \times 5$ or $1.2 \times 8.4 \times 5 = 50.4\ m^3\ ha^{-1}$.

Timing of first thinning

Thinning prescriptions involving a sequence of thinnings cover three options in terms of the timing of the first thinning:

1. Thinning starts at 'MT thinning age'
2. Thinning starts 5 years after 'MT thinning age' (MT thinning age + 5 years)
3. Thinning starts 10 years after 'MT thinning age' (MT thinning age + 10 years).

MT (Management Table) thinning age is effectively a recommended time to start thinning. The value of MT thinning age is selected to result in a desired level of standing volume per hectare being left after thinning, given that thinning is being carried out at Management Table Intensity. For the vast majority of situations, a relationship was characterised between the desired level of standing volume per hectare and stand top height, as illustrated in Figure A3.7. These relationships were developed by graphical analysis of observations of standing volume and top height made in mensuration sample plots. For the most part, decisions about when to thin and how much volume to remove in these plots were down to the silvicultural judgements of the foresters managing the sample plots. The levels of standing volume were therefore the outcome of a process in which foresters aimed to develop a growing stock over time according to a pattern which was considered to be 'right' in terms of subjective and qualitative criteria. The application of a characteristic relationship between standing volume and top height in determining the time to start thinning is therefore a quantitative method for achieving a strictly qualitative outcome. (However, many would agree that the amounts of standing volume and general appearance of stands resulting from this process somehow do feel right. When considering 'sustainable yield' in terms of mean annual increment, the volume productivity of British forests is among the highest in Europe, so the approach seems to work.)

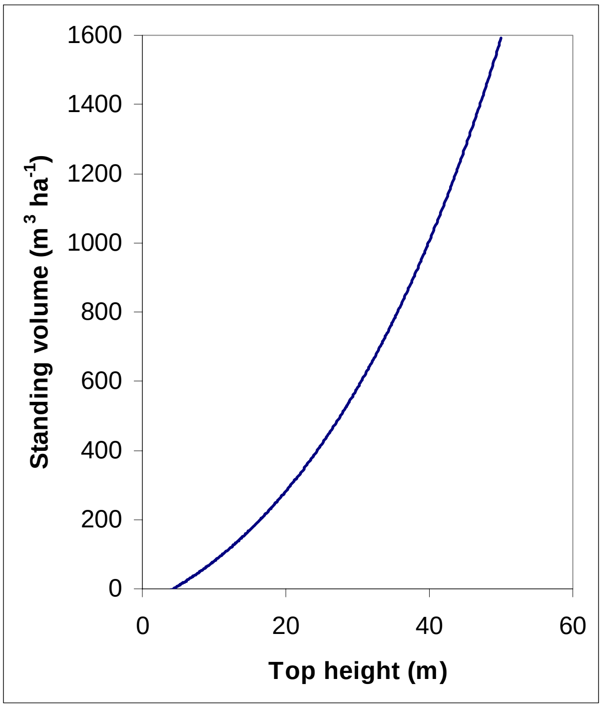


Figure A3.7 Standard relationship for standing volume per hectare after thinning plotted against top height, based on entries in yield models for Scots pine, initial spacing 1.4 m and involving a sequence of intermediate thinnings at Management Table Intensity (Edwards and Christie, 1981).

The standard relationship between standing volume and top height varies slightly with initial spacing, and for a few tree species varies with yield class. In stands of narrow spacing, the setting of MT thinning age also takes account of the need for stands to have achieved a mean diameter big enough to justify thinning (somewhere in the range 7 cm to 10 cm mean dbh).

Time between thinnings (thinning cycle)

The time between thinnings is usually constant and is commonly referred to as the thinning cycle. The faster the rate of growth in a stand of trees, the more frequently it is possible to thin the stand without compromising the growing stock. Thinning cycles of relevance to growing conditions in Britain are in the range 3 to 7 years (sometimes with cycles of 10 years appropriate when stands have grown well beyond the time of maximum mean annual increment).

Generally thinning prescriptions adopt a thinning cycle of 5 years as a standard treatment. For the most part, this means the schedule of thinnings starts at MT thinning age, with further thinnings every five years.

Appendix 4 thinning cut and wood fuel potential calculation protocol.

The following procedures are to be used in estimating the potential for production of wood fuel from a parcel of stands either through clearfelling or thinning.

Field assessments

Carry out field assessments and calculations as described in the Measurement Protocol.

Calculation protocol

For each stand/stratum forming the parcel of trees, carry out two sequential procedures:

1. Estimation of target production
2. Estimation of wood fuel production.

1. Estimation of target production

This involves estimating target values for stem volume, basal area and numbers of trees per hectare for production. This procedure needs to be carried out even if the plan is to produce wood fuel from tree components other than stem wood.

- If an operational decision has been taken to clearfell the stand or stratum being considered, then the target values are those for the whole growing stock obtained from field assessments as derived using the Measurement Protocol (Appendix 2). Skip immediately to the procedure for estimation of wood fuel production and use these values directly in the calculations.
- If it is the intention to produce wood fuel from thinnings, the following calculation steps should be carried out. The data recording form in Annex 1 of this Calculation Protocol may be used for this purpose.

a. Record the assessments of top height and standing volume per hectare as found by field assessments.
b. Using the table in Annex 2 of this Calculation Protocol, find the ‘benchmark standing volume’ for a stand of the species and top height being considered. If the precise value of top height being worked with is not available in the table, use the value in the table for the next higher value of top height.
c. Subtract the benchmark standing volume from the assessment of volume per hectare to find the ‘standing volume margin’.

d. If the standing volume margin is less than 5 cubic metres per hectare then the stand is unsuitable for thinning for production of wood fuel at the present time and no further calculations should be carried out; otherwise carry on to step e.
e. Record the age of the trees forming the stand/stratum. If this is not known precisely, assume a value at the top end of the probable range. For example, if the age of the trees is believed to be in the range 30 to 50 years, then select a stand age of 50 years.
f. Use the Forest Yield software to estimate the General Yield Class (GYC) of the stand/stratum from the top height and age.
g. A value is required for the 'maximum thinning intensity' to be permitted in the stand/stratum. This will need to be selected so as to meet local strategic and/or operational objectives and is likely to be the subject of a formal decision-making process carried out in advance of any survey. A value of 1.0 is equivalent to the marginal or Management Table thinning intensity and in some circumstances may be considered appropriate as a default, while a value of zero implies no thinning and negates the need for these calculations. The value of maximum thinning intensity should not be set greater than 1.4.
h. Calculate the 'maximum thinning cut' using the equation:

   Maximum thinning cut = maximum thinning intensity x GYC x 0.7 x 5.

i. Assign a target thinning volume for the stand/stratum. This is taken to be the smaller of either the minimum of the standing volume margin or the maximum thinning cut.
j. Use the Thinning Calculator software to estimate the target basal area and number of trees per hectare for thinning, and the target mean dbh for thinnings.

A worked example (based on the example field assessments in Annex 2 of the Measurement Protocol) is given in Annex 1 of this Calculation Protocol. A screenshot showing the Thinning Calculator software with relevant inputs and outputs is also included in Annex 1.

2. Estimation of wood fuel production

a. Enter the gross area and gross:net ratio for the stand/stratum into the relevant input fields of the FieldBSORT software tool. The gross:net area ratio needs to be reliable if Abbreviated Tariff Procedure B6 has been used. If Abbreviated Tariff Procedure A6 has been used, then the accuracy of the gross:net area ratio is less important – in this case if a reliable estimate is not known and only the gross area has been assessed, then a value of 1.0 may be entered for the ratio.

b. Enter the per-hectare estimates of target numbers of trees, basal area and volume per hectare into the relevant input fields of the FieldBSORT software tool.
c. Select appropriate settings for the 'stand type' inputs of the FieldBSORT tool. (Choose between 'planted or regenerated' and choose a thinning type which most closely describes how the stand/stratum has been thinned in the past. Choose a value for initial spacing which describes the density of the trees when first established, either by planting or regeneration.)
d. Enter appropriate input values to the FieldBSORT tool for specifying the types of product that might be cut (the mean height to which stumps will be cut, fixed or random length sawlogs to a specified overbark or underbark top diameter, fixed length roundwood to a specified top diameter overbark). Note that the length input field for sawlogs represents the constant length for fixed-length logs, or the minimum length for random-length logs. The top diameter for roundwood can be any value down to 7.0 cm, but a value less than 7 cm must not be entered. If there is no interest in sawlogs or roundwood products then just enter very large values for the top diameters (say, 300 cm). All of the stemwood will then be included with the stem tips (see step e).
e. Press the "RUN" button. The FieldBSORT tool will now display biomass estimates for components of the trees forming the stand/stratum:

- Roots (the coarse woody roots of the trees)
- Stumps (the tree stumps above ground level)
- Sawlogs (according to the specification entered)
- Roundwood (according to the specification entered)
- Stem tips (the woody material in the main stem from the top diameter of the roundwood down to 0 cm)
- Branch wood
- Foliage (if selected).

The biomass estimates are displayed in units of oven dry tonnes and cubic metres. (Estimates expressed in green tonnes are not available in the current version of FieldBSORT. The estimate for potential wood fuel production will be a combination of some of the results from FieldBSORT, depending on what types of material have been selected as a source of wood fuel.

The screenshot in Annex 3 shows an example of FieldBSORT calculations based on the example field assessments in Annex 2 of the Measurement Protocol and the worked example of a thinning calculation in Annex 1 of this Calculation Protocol.

Annex 1 Production target calculation and recording form.

A. Standing stem volume per hectare (from field assessment) .... (m^3/ha)

B. 'Benchmark standing volume' (from Appendix 2) .... (m^3/ha)

C. Standing volume margin (A – B) .... (m^3/ha)

D. If the standing volume margin is less than 5 m^3 ha then do not thin. There is no need to continue with calculations for this stand/stratum.

E. Top height (from field assessment) .... (m)

F. Stand/stratum age .... (years)

G. General Yield Class (GYC) ....

H. Maximum thinning intensity (between 0 and 1.4) ....

I. Origin of value for selected thinning intensity ....

J. Maximum volume cut (Maximum thinning intensity x GYC x 0.7 x 5)

.... (m^3/ha)

K. Target thinning volume (smallest of C and J) .... (m^3/ha)

L. If the target thinning volume is less than 5 m^3 ha then do not thin. There is no need to continue with calculations for this stand/stratum.

M. Target thinning basal area (from Thinning Calculator) .... (m^2/ha)

N. Target thinning number of trees (from Thinning Calculator) .... (stems/ha)

O. Target thinning mean dbh (from Thinning Calculator) .... (cm)

Annex 1 (cont) Production target calculation and recording: worked example.

Appendix 1. Production target calculation and recording form

A. Standing stem volume per hectare (from field assessment) ..105.6.. (m^3/ha)

B. 'Benchmark standing volume' (from Appendix 2) ....65.......... (m^3/ha)

C. Standing volume margin (A – B) ....40.6.......... (m^3/ha)

D. If the standing volume margin is less than 5 m^3 ha then do not thin. There is no need to continue with calculations for this stand/stratum.

E. Top height (from field assessment) ....10.9.......... (m)

F. Stand/stratum age ....35..........(years)

G. General Yield Class (GYC) ....4..........

H. Maximum thinning intensity (between 0 and 1.4) ....0.6..........

I. Origin of value for selected thinning intensity ..SPECIFIED BY PROJECT BOARD

J. Maximum volume cut (Maximum thinning intensity x GYC x 0.7 x 5)

..........8.4.......... (m^3/ha)

K. Target thinning volume (smallest of C and J) ....8.4.......... (m^3/ha)

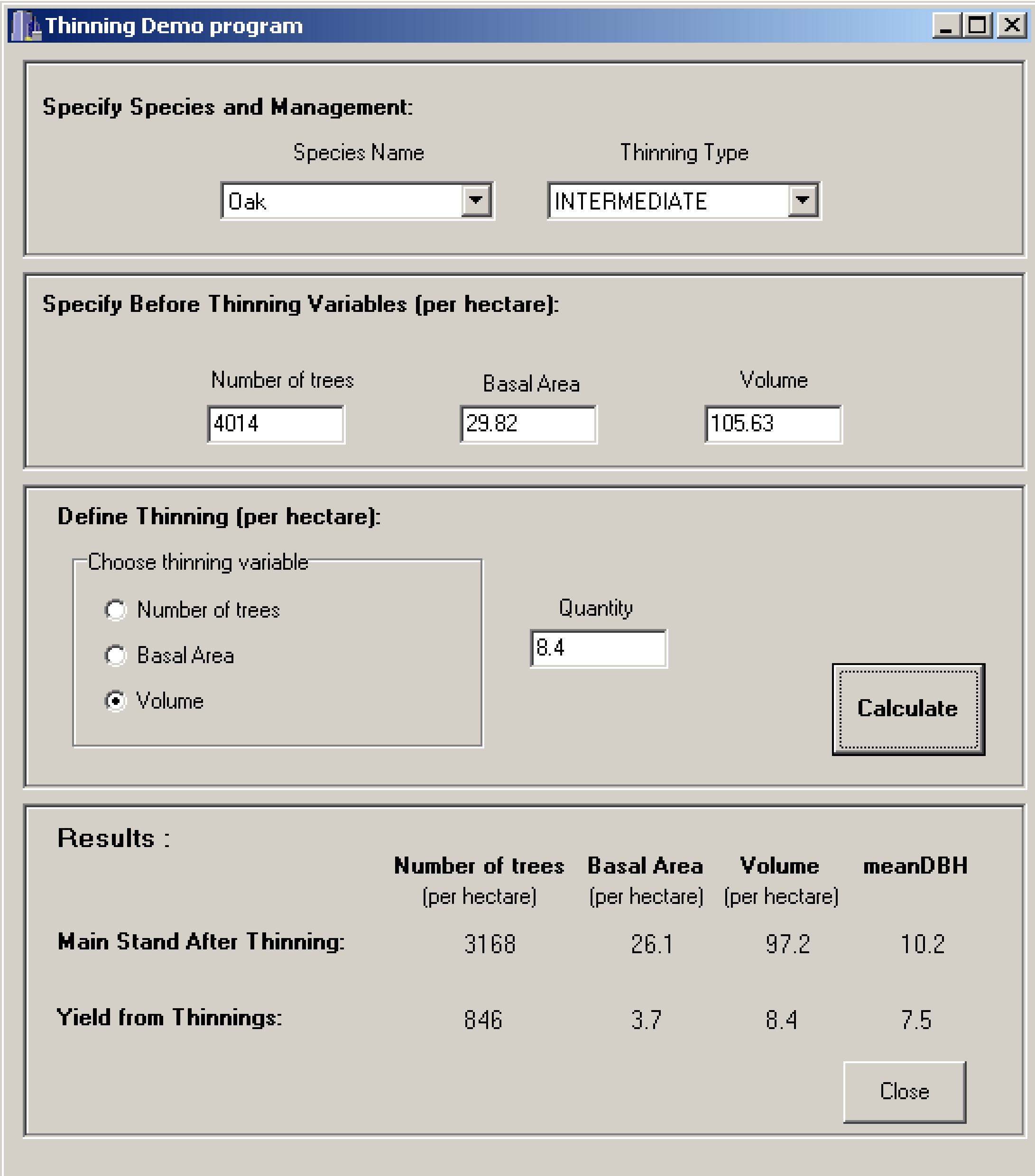
L. If the target thinning volume is less than 5 m^3 ha then do not thin. There is no need to continue with calculations for this stand/stratum.

M. Target thinning basal area (from Thinning Calculator) ....3.7.......... (m^2/ha)

N. Target thinning number of trees (from Thinning Calculator) ..846.. (stems/ha)

O. Target thinning mean dbh (from Thinning Calculator) ....7.5.......... (cm)

Annex 1 (cont) Example of thinning calculator inputs and outputs.



Annex 2 Benchmark standing volumes.

Top height	OK	SY	SS	NS	SP	LP	CP	JL	EL	WH	RC	DF
10	52	24	97	71	79	102	119	66	55	72	94	71
10.5	58	30	107	82	87	110	127	73	62	84	109	77
11	65	37	117	94	95	118	136	80	69	96	124	83
11.5	72	43	127	106	104	125	145	87	76	108	139	90
12	79	50	137	118	112	133	154	94	83	120	154	96
12.5	86	57	147	130	121	141	163	101	90	132	169	103
13	93	64	158	142	130	148	172	109	97	144	185	109
13.5	99	71	168	154	140	156	182	116	104	156	200	116
14	106	79	178	166	149	164	191	123	112	168	215	123
14.5	113	87	189	178	159	171	201	131	119	180	231	130
15	120	95	199	190	169	179	211	138	127	193	246	137
15.5	127	104	209	202	179	187	221	146	135	205	261	145
16	134	113	220	214	189	194	231	153	142	217	277	152
16.5	140	122	230	226	199	202	241	161	150	229	292	160
17	147	131	241	239	210	210	252	168	158	241	307	168
17.5	154	141	252	251	221	217	262	176	166	253	323	176
18	161	151	262	263	232	225	273	184	174	266	338	184
18.5	168	161	273	275	244	233	284	191	182	278	354	193
19	175	172	284	288	255	241	295	199	191	290	369	201
19.5	182	183	295	300	267	248	306	207	199	302	385	210
20	188	195	305	313	279	256	318	214	207	315	400	219
20.5	195	206	316	325	292	264	329	222	216	327	416	228
21	202	218	327	338	304	271	341	230	225	339	432	237
21.5	209	231	338	350	317	279	353	238	233	352	447	247
22	216	243	349	363	330	287	365	246	242	364	463	257
22.5	223	257	361	376	343	294	378	254	251	377	479	266
23	229	270	372	389	357	302	390	262	260	389	494	277
23.5	236	284	383	402	371	310	403	270	269	402	510	287
24	243	298	394	415	385	317	416	278	278	414	526	297
24.5	250	313	406	428	399	325	429	286	288	427	542	308
25	257	328	417	441	414	333	442	294	297	439	557	319
25.5	264	344	429	454	429	340	455	302	306	452	573	330
26	270	360	440	468	444	348	469	311	316	464	589	341
26.5	277	376	452	481	460	356	483	319	326	477	605	353
27	284	393	463	495	475	363	497	327	335	490	621	365
27.5	291	411	475	509	491	371	511	336	345	502	637	377
28	298	428	487	523	508	379	525	344	355	515	653	389
28.5	305	447	499	537	524	387	540	352	365	528	669	402
29	311	466	511	551	541	394	555	361	376	540	685	414
29.5	318	485	523	566	558	402	570	369	386	553	701	427
30	325	505	535	580	576	410	585	378	396	566	717	441

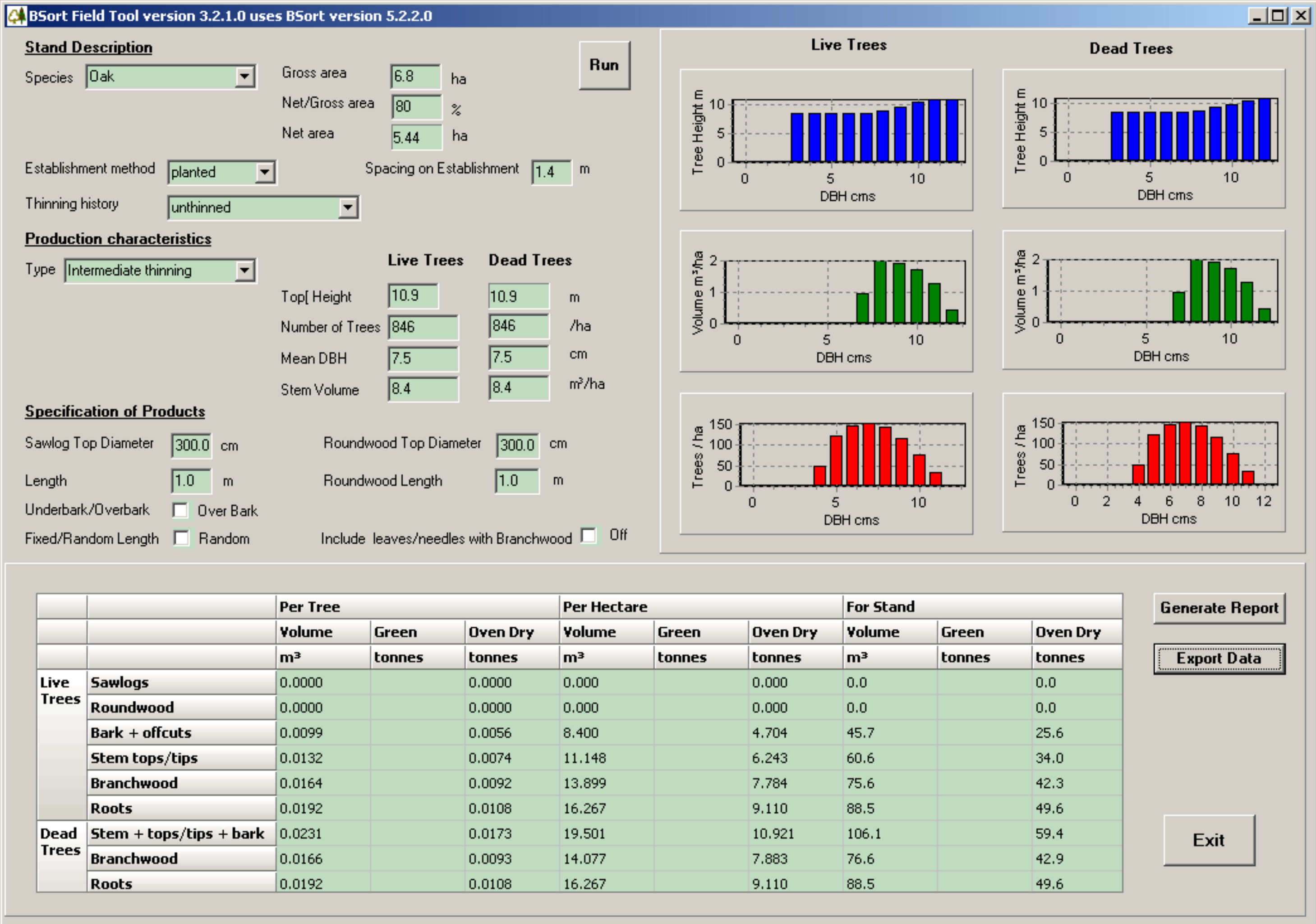
For species not in the table refer to Annex 4.
When applying to a mixture of species in one stratum, choose the table entry for the most common species.

Annex 2 (cont) Benchmark standing volumes.

Top height	OK	SY	SS	NS	SP	LP	CP	JL	EL	WH	RC	DF
30.5	332	525	547	595	594	417	601	387	407	579	733	454
31	339	546	559	610	612	425	616	395	417	592	749	468
31.5	346	567	571	625	630	433	632	404	428	605	765	482
32	352	589	584	641	649	440	648	413	439	618	782	496
32.5	359	612	596	656	668	448	664	421	450	631	798	511
33	366	635	608	672	688	456	681	430	461	644	814	526
33.5	373	659	621	688	707	463	698	439	472	657	830	541
34	380	683	634	705	728	471	715	448	483	671	847	556
34.5	387	708	646	722	748	479	732	457	495	684	863	572
35	393	734	659	739	769	486	749	466	506	697	879	588

For species not in the table refer to Annex 4.
When applying to a mixture of species in one stratum, choose the table entry for the most common species.

Annex 3 Example of FieldBSORT inputs and outputs.



		Per Tree			Per Hectare			For Stand		
		Volume	Green	Oven Dry	Volume	Green	Oven Dry	Volume	Green	Oven Dry
		m³	tonnes	tonnes	m³	tonnes	tonnes	m³	tonnes	tonnes
Live Trees	Sawlogs	0.0000		0.0000	0.000		0.000	0.0		0.0
	Roundwood	0.0000		0.0000	0.000		0.000	0.0		0.0
	Bark + offcuts	0.0099		0.0056	8.400		4.704	45.7		25.6
	Stem tops/tips	0.0132		0.0074	11.148		6.243	60.6		34.0
	Branchwood	0.0164		0.0092	13.899		7.784	75.6		42.3
	Roots	0.0192		0.0108	16.267		9.110	88.5		49.6
Dead Trees	Stem + tops/tips + bark	0.0231		0.0173	19.501		10.921	106.1		59.4
	Branchwood	0.0166		0.0093	14.077		7.883	76.6		42.9
	Roots	0.0192		0.0108	16.267		9.110	88.5		49.6

Annex 4 Benchmark standing volume for different/other species.

Common name	Abbreviation	Yield model
Noble fir	NF	✓
Grand fir	GF	✓
European silver fir	-	NF
Siberian fir	-	NF
Nordmann fir	-	NF
Douglas fir	DF	✓
Western hemlock	WH	✓
Norway spruce	NS	✓
Sitka spruce	SS	✓
Omorika spruce	OMS	NS
Oriental spruce	-	NS
White spruce	-	NS
Englemann spruce	-	NS
Blue spruce	-	NS
Japanese larch	JL	✓
European larch	EL	✓
Hybrid larch	HL	✓
Scots pine	SP	✓
Corsican pine	CP	✓
Lodgepole pine	LP	✓
Maritime pine	-	LP
Monterey pine	-	CP
Ponderosa pine	-	SP
Weymouth pine/(Eastern) white pine	-	SP
Western red pine	-	CP
Bishop pine	-	CP
Coast redwood	-	GF
Wellingtonia/Giant sequoia	-	GF
Monterey cypress	-	RC
Lawson cypress	LC	✓
Nootka cypress	-	RC
Western red cedar	RC	✓
Leyland cypress	-	RC

Annex 4 (cont) Benchmark standing volume for different/other species.

Common name	Abbreviation	Yield model
Black-poplar	-	✓
Hybrid black poplar	-	✓
Silver birch	BI	SAB
Downy birch	BI	SAB
Common alder	-	SAB
Grey alder	-	SAB
Italian alder	-	SAB
Hornbeam	-	BE
Beech	BE	✓
Roble	-	✓
Raoul	-	✓
Sweet chestnut/Spanish chestnut	-	BE
Red oak	-	BE
Sessile oak	OK	✓
Pedunculate oak	OK	✓
Wych elm	-	BE
English elm	-	BE
Wild cherry	-	SAB
Bird cherry	-	SAB
Norway maple	-	SAB
Field maple	-	SAB
Sycamore	SY	SAB
Horse chestnut	-	SAB
Ash	AH	SAB
Hazel	-	-
London plane	-	-

Appendix 5 Operational assessments and volume and wood fuel calculations for trial woodlands in Woolhope Dome.

Field data and subsequent thinning calculations for Mains wood
(See Appendix 2 and the first stages of Appendix 4 for details of procedure)

Abbreviated Tariff B6

Woodland name	Mains Wood	Gross Area	11
Stand	107	Gross:net area	0.95
Species	DF/NS	Net area	10.5
Age	30		
Tariff number	28	Total area of plots:	0.1 ha

	Count of trees										Total trees for plots	Total trees per ha	Basal area per tree (m2)	Basal area per ha in class (m2)	Volume per tree (m3)	Volume per ha in class (m3)
	Plot number															
Dbh (cm)	1	2	3	4	5	6	7	8	9	10						
7		1						1			2	20	0.0038	0.076	0.005	0.1
8	1	2				1	1				5	50	0.005	0.25	0.015	0.75
9	1	1				1	1		1		5	50	0.0064	0.32	0.027	1.35
10						1		1			2	20	0.0079	0.158	0.040	0.8
11	3	1				2				2	8	80	0.0095	0.76	0.055	4.4
12	1		1	1							3	30	0.0113	0.339	0.071	2.13
13	3	2	1	1			1	2		1	11	110	0.0133	1.463	0.088	9.68
14		1			1				2		4	40	0.0154	0.616	0.108	4.32
15	3	2			1	1	2	2	2	2	15	150	0.018	2.7	0.126	18.9
16	1	5	1	1	2	1			4	2	17	170	0.02	3.4	0.148	25.16
17	2					1		1		1	5	50	0.023	1.15	0.170	8.5
18	2	1		4		1	1	1			10	100	0.025	2.5	0.195	19.5
19	2	1			2		1		1		7	70	0.028	1.96	0.220	15.4
20	1			1			1	1		1	5	50	0.031	1.55	0.247	12.35
21		2	2	2		2	1	1			10	100	0.035	3.5	0.280	28
22					2	2					4	40	0.038	1.52	0.300	12
23				1			1			1	3	30	0.042	1.26	0.340	10.2
24		1					1		1		3	30	0.045	1.35	0.370	11.1
25			1	2	1						4	40	0.049	1.96	0.400	16
26				1			1		1		3	30	0.053	1.59	0.440	13.2
27					1	1					2	20	0.057	1.14	0.470	9.4
28				1							1	10	0.062	0.62	0.510	5.1
29								1			1	10	0.066	0.66	0.550	5.5
36			1								1	10	0.102	1.02	0.860	8.6
Totals per hectare												1310		31.862		242.44
Totals for stand												13689.5		332.958		2533.5

Total heights (m)

1	2	3	4	5	6	7	8	9	10
18.1	18.9	18.9	19	20.2	20.3	19.4	20.3	20.4	19.4

Top height (mean of total heights)	19.5
Estimated mean basal area	0.024
Mean dbh (estimated from mean basal area	18

THINNING CALCULATIONS

A. Standing stem volume / ha =	242.44	m^3 ha^{-1}	
B. Benchmark standing volume =	210	m^3 ha^{-1}	(DF)
C. Standing vol. margin =	32.44	m^3 ha^{-1}	
D. Thin? =	YES		
E. Top height =	19.5	m	
F. Stand age =	30	yrs	
G. General Yield Class =	16	m^3 ha^{-1} yr^{-1}	
H. Max. thinning intensity =	1		
I. Origin of thinning intensity =	Default		
J. Max. vol. cut =	56	m^3 ha^{-1}	
K. Target thinning volume =	32.44	m^3 ha^{-1}	
L. Thin? =	YES		
M. Target thinning B.A. =	4.7	m^2 ha^{-1}	
N. Target thinning no. of trees =	290	stems ha^{-1}	
O. Target thinning mean dbh =	14.4	cm	

Field data and subsequent thinning calculations for Park Coppice.

Abbreviated Tariff B6

Woodland name	Park Coppice	Gross Area	18.7
Stand	80	Gross:net area	0.95
Species	DF/NS	Net area	17.8
Age	45		
Tariff number	37	Total area of plots:	0.2 ha

	Count of trees										Total trees for plots	Total trees per ha	Basal area per tree (m2)	Basal area per ha in class (m2)	Volume per tree (m3)	Volume per ha in class (m3)
	Plot number															
Dbh (cm)	1	2	3	4	5	6	7	8	9	10						
16							1				1	5	0.02	0.1	0.19	0.97
25						1					1	5	0.049	0.245	0.53	2.65
27			1								1	5	0.057	0.285	0.63	3.15
28					2	1				2	5	25	0.062	1.55	0.68	17
30	1	1		1							3	15	0.071	1.065	0.78	11.7
31					1	2			2		5	25	0.075	1.875	0.84	21
32		1						1			2	10	0.08	0.8	0.89	8.9
33	1						1				2	10	0.086	0.86	0.95	9.5
34		2		1						1	4	20	0.091	1.82	1.01	20.2
35	1		1	2			1			1	6	30	0.096	2.88	1.08	32.4
36		1		1	1			2			5	25	0.102	2.55	1.14	28.5
37			1			1				1	3	15	0.108	1.62	1.21	18.15
38		2			2						4	20	0.113	2.26	1.28	25.6
39	1		2				1		1		5	25	0.119	2.975	1.35	33.75
40	1						2				3	15	0.126	1.89	1.42	21.3
41	2					1			1	1	5	25	0.132	3.3	1.49	37.25
42		1	1						1		3	15	0.139	2.085	1.57	23.55
43	1					1			1	1	4	20	0.145	2.9	1.65	33
44			2				2	1			5	25	0.152	3.8	1.73	43.25
45			1	1			1		1		4	20	0.159	3.18	1.81	36.2
46								1			1	5	0.166	0.83	1.89	9.45
49					1						1	5	0.189	0.945	2.15	10.75
50				1							1	5	0.196	0.98	2.24	11.2
52										1	1	5	0.212	1.06	2.43	12.15
53								2			2	10	0.221	2.21	2.52	25.2
											Totals per hectare	385		44.065		496.77
											Totals for stand	6839.53		782.815		8825.12

Total heights (m)

1	2	3	4	5	6	7	8	9	10
28.2	26.5	25.3	28.9	23	26.4	30.3	27.6	28.6	29.3

Top height (mean of total heights) 27.4

Estimated mean basal area 0.114

Mean dbh (estimated from mean basal area 38

THINNING CALCULATIONS

A. Standing stem volume / ha =	496.77	m^3 ha^{-1}
B. Benchmark standing volume =	377	m^3 ha^{-1} (DF)
C. Standing vol. margin =	119.77	m^3 ha^{-1}
D. Thin? =	YES	
E. Top height =	27.4	m
F. Stand age =	45	yrs
G. General Yield Class =	16	m^3 ha^{-1} yr^{-1}
H. Max. thinning intensity =	1	
I. Origin of thinning intensity =	Default	
J. Max. vol. cut =	56	m^3 ha^{-1}
K. Target thinning volume =	56	m^3 ha^{-1}
L. Thin? =	YES	
M. Target thinning B.A. =	5.1	m^2 ha^{-1}
N. Target thinning no. of trees =	62	stems ha^{-1}
O. Target thinning mean dbh =	32.4	cm

Field data and subsequent thinning calculations for Canwood Knoll.

Abbreviated Tariff B6

Woodland name	Canwood Knoll	Gross Area	3.9
Stand	73?	Gross:net area	0.95
Species	DF	Net area	3.7
Age	20		
Tariff number	20	Total area of plots:	0.08 ha

	Count of trees										Total trees for plots	Total trees per ha	Basal area per tree (m2)	Basal area per ha in class (m2)	Volume per tree (m3)	Volume per ha in class (m3)
	Plot number															
Dbh (cm)	1	2	3	4	5	6	7	8	9	10						
7	2	4	1	4	3		2	4			20	250	0.0038	0.950	0.005	1.25
8	2	1	2		2	1	3	1			12	150	0.005	0.750	0.012	1.80
9	4	2	2	1		2	2	3			16	200	0.0064	1.280	0.021	4.20
10	1	2	1	5	2	1	2	2			16	200	0.0079	1.580	0.030	6.00
11	2	2	2	3	1	2	3				15	187.5	0.0095	1.781	0.040	7.50
12		1	3	4	2	3	1	2			16	200	0.0113	2.260	0.052	10.40
13	5	2		1	3	2	1	2			16	200	0.0133	2.660	0.064	12.80
14		1	2	3	1	1	3	2			13	162.5	0.0154	2.503	0.077	12.51
15	1	1	3	2		2					9	112.5	0.018	2.025	0.092	10.35
16	1		3		1	2	1	1			9	112.5	0.02	2.250	0.107	12.04
17		1				1					2	25	0.023	0.575	0.123	3.08
18								1			1	12.5	0.025	0.313	0.140	1.75
21					1						1	12.5	0.035	0.438	0.200	2.50
											Totals per hectare	1825		19.3638		86.175
											Totals for stand	6761.63		71.7427		319.278

Total heights (m)

1	2	3	4	5	6	7	8	9	10
12.4	13.7	13.4	11.4	12.7	13.1	13.7	12		

Top height (mean of total heights)	12.8
Estimated mean basal area	0.011
Mean dbh (estimated from mean basal area	12

THINNING CALCULATIONS

A. Standing stem volume / ha =	86.175	m^3 ha^{-1}	
B. Benchmark standing volume =	109	m^3 ha^{-1}	(DF)
C. Standing vol. margin =	-22.825	m^3 ha^{-1}	
D. Thin? =	NO		
E. Top height =	12.8	m	
F. Stand age =	20	yrs	
G. General Yield Class =	16	m^3 ha^{-1} yr^{-1}	
H. Max. thinning intensity =	1		
I. Origin of thinning intensity =	Default		
J. Max. vol. cut =	56	m^3 ha^{-1}	
K. Target thinning volume =	-22.825	m^3 ha^{-1}	
L. Thin? =	NO		
M. Target thinning B.A. =		m^2 ha^{-1}	
N. Target thinning no. of trees =		stems ha^{-1}	
O. Target thinning mean dbh =		cm	

Field data and subsequent thinning calculations for Cherry Hill (Fownhope).

Abbreviated Tariff B6

Woodland name	Fownehope (Cherry Hill)	Gross Area	29.4
Stand	168	Gross:net area	
Species	Oak/Ash	Net area	29.4
Age	100		
Tariff number	31	Total area of plots:	0.5 ha

	Count of trees										Total trees for plots	Total trees per ha	Basal area per tree (m2)	Basal area per ha in class (m2)	Volume per tree (m3)	Volume per ha in class (m3)
	Plot number															
Dbh (cm)	1	2	3	4	5	6	7	8	9	10						
27		1						2	1		4	8	0.057	0.456	0.52	4.16
28					1				1		2	4	0.062	0.248	0.57	2.28
30		2			2					1	5	10	0.071	0.71	0.65	6.5
31	1				2						3	6	0.075	0.45	0.70	4.2
33					2						2	4	0.086	0.344	0.80	3.2
34		1			1	1			1	2	6	12	0.091	1.092	0.85	10.2
35					1	1	1		1		4	8	0.096	0.768	0.90	7.2
36			1	1	1		1		1	1	6	12	0.102	1.224	0.96	11.52
37	1	1			1						3	6	0.108	0.648	1.03	6.18
38				2	1	1	1				5	10	0.113	1.13	1.07	10.7
39	1	3				2	2	1		1	10	20	0.119	2.38	1.13	22.6
41		1	1						1		3	6	0.132	0.792	1.25	7.5
42			1		1						2	4	0.139	0.556	1.31	5.24
43	1		1				1				3	6	0.145	0.87	1.38	8.28
44	1				3	1	2	1			8	16	0.152	2.432	1.45	23.2
45				1				1	1		3	6	0.159	0.954	1.51	9.06
46			1	2						1	4	8	0.166	1.328	1.58	12.64
47						1			1	2	4	8	0.173	1.384	1.65	13.2
50	2							1	1		4	8	0.196	1.568	1.88	15.04
54		1	1	2				1			5	10	0.229	2.29	2.19	21.9
56	1									1	2	4	0.246	0.984	2.36	9.44
57							1				1	2	0.255	0.51	2.45	4.9
59			1							1	2	4	0.273	1.092	2.63	10.52
63	1		1					2			4	8	0.312	2.496	3.00	24
66							1	1			2	4	0.342	1.368	3.29	13.16
71			1								1	2	0.396	0.792	3.82	7.64
											Totals per hectare	196		28.866		274.46
											Totals for stand	5762.4		848.66		8069.12

Total heights (m)

1	2	3	4	5	6	7	8	9	10
24.7	23.5	25.7	24.8	22.8	21.7	22.6	29.7	26	24.6

Top height (mean of total heights)	24.6
Estimated mean basal area	0.147276
Mean dbh (estimated from mean basal area	43

THINNING CALCULATIONS

A. Standing stem volume / ha =	274.46	$m^3\ ha^{-1}$
B. Benchmark standing volume =	257	$m^3\ ha^{-1}$ (OK)
C. Standing vol. margin =	17.46	$m^3\ ha^{-1}$
D. Thin? =	YES	
E. Top height =	24.6	m
F. Stand age =	100	yrs
G. General Yield Class =	6	$m^3\ ha^{-1}\ yr^{-1}$
H. Max. thinning intensity =	1	
I. Origin of thinning intensity =	Default	
J. Max. vol. cut =	21	$m^3\ ha^{-1}$
K. Target thinning volume =	17.46	$m^3\ ha^{-1}$
L. Thin? =	YES	
M. Target thinning B.A. =	1.9	$m^2\ ha^{-1}$
N. Target thinning no. of trees =	16	stems ha^{-1}
O. Target thinning mean dbh =	37.8	cm

Estimated biomass potential for trial woodlands in Woolhope Dome:
Outputs from Field BSORT based inputs from thinning calculations (see Appendix 4 for details)

Author Ewan Mackie
Date 27/07/2009

Output for Woolhope Dome
Mains Wood, Polygon No. 107
DF/NS (DF used). STAND LEVEL RESULTS

Stand Description:

Species	Douglas fir
SpecificGravity	0.41
GrossArea	11
Net/Gross area ratio	95.45
Net Area	10.4995
Establishment Method	planted
Spacing on Establishment	2.0

Thinning history: Intermediate thinned

Production Characteristics:

Type Intermediate thinning

	Live	Dead
Top Height	19.50	19.50
Number of Live trees	290.00	290.00
DBH Mean Live	14.40	14.40
Stem Vol Live	32.44	32.44

Specification of Products:

Sawlog Top Diameter 18.00   Sawlog Length 0.00
Roundwood Top Diameter 7.00 Roundwood Length 0.00

UnderBark/OverBark OverBark
Fixed/Random Length Random
Foliage included with Branchwood No

Production:

		Per Tree Volume m³	Per Tree Green tonnes	Per Tree Oven Dry tonnes	Per Hectare Volume m³	Per Hectare Green tonnes	Per Hectare Oven Dry tonnes	For Stand Volume m³	For Stand Green tonnes	For Stand Oven Dry tonnes
Live	Sawlogs	0.01		0.00	1.69		0.69	17.73		7.27
Trees	Roundwood	0.11		0.04	30.71		12.59	322.48		132.22
	Bark + offcuts	0.00		0.00	0.04		0.02	0.39		132.22
	Stem tops/tips	0.00		0.00	1.37		0.56	14.34		0.16
	Branchwood	0.02		0.01	5.75		2.36	60.36		5.88
	Roots	0.03		0.01	10.01		4.10	105.06		5.88
Dead	Stem+tops/tips+bark	0.12		0.11	33.81		13.86	354.94		43.07
Trees	Branchwood	0.02		0.01	5.75		2.36	60.36		145.53
	Roots	0.03		0.01	10.01		4.10	105.06		145.53

Author Ewan Mackie
Date 27/07/2009

Woolhope Dome
Park Coppice, Polygon No. 80
DF/NS (DF used). STAND LEVEL RESULTS

Stand Description:

Species Douglas fir
SpecificGravity 0.41

GrossArea 18.7
Net/Gross area ratio 95.20
Net Area 17.8024

Establishment Method planted
Spacing on Establishment 2.0

Thinning history: Intermediate thinned

Production Characteristics:

Type Intermediate thinning

	Live	Dead
Top Height	27.40	27.40
Number of Live trees	62.00	62.00
DBH Mean Live	32.40	32.40
Stem Vol Live	56.00	56.00

Specification of Products:

Sawlog Top Diameter 18.00 Sawlog Length 0.00
Roundwood Top Diameter 7.00 Roundwood Length 0.00

UnderBark/OverBark OverBark
Fixed/Random Length Random
Foliage included with Branchwood No

Production:

		Per Tree			Per Hectare			For Stand		
		Volume m³	Green tonnes	Oven Dry tonnes	Volume m³	Green tonnes	Oven Dry tonnes	Volume m³	Green tonnes	Oven Dry tonnes
Live	Sawlogs	0.80		0.33	49.63		20.35	883.62		362.28
Trees	Roundwood	0.10		0.04	6.35		2.60	113.07		46.36
	Bark + offcuts	0.00		0.00	0.01		0.01	0.25		46.36
	Stem tops/tips	0.00		0.00	0.24		0.10	4.32		0.10
	Branchwood	0.12		0.05	7.42		3.04	132.02		1.77
	Roots	0.25		0.10	15.24		6.25	271.29		1.77
Dead	Stem+tops/tips+bark	0.91		0.90	56.24		23.06	1001.25		111.23
Trees	Branchwood	0.12		0.05	7.42		3.04	132.02		410.51
	Roots	0.25		0.10	15.24		6.25	271.29		410.51

Author Ewan Mackie
Date 27/07/2009

Output for Woolhope Dome
Cherry Hill, Fownehope. Polygon No. 168
OK/AH - Oak used. STAND LEVEL RESULTS

Stand Description:

Species Oak
SpecificGravity 0.56

GrossArea 29.4
Net/Gross area ratio 100
Net Area 29.4

Establishment Method planted
Spacing on Establishment 2.0

Thinning history: Intermediate thinned

Production Characteristics:

Type Intermediate thinning

	Live	Dead
Top Height	24.60	24.60
Number of Live trees	16.00	16.00
DBH Mean Live	37.80	37.80
Stem Vol Live	17.50	17.50

Specification of Products:

Sawlog Top Diameter 18.00 Sawlog Length 0.00
Roundwood Top Diameter 7.00 Roundwood Length 0.00

UnderBark/OverBark OverBark
Fixed/Random Length Random
Foliage included with Branchwood No

Production:

		Per Tree			Per Hectare			For Stand		
		Volume m³	Green tonnes	Oven Dry tonnes	Volume m³	Green tonnes	Oven Dry tonnes	Volume m³	Green tonnes	Oven Dry tonnes
Live	Sawlogs	1.02		0.57	16.26		9.10	478.00		267.68
Trees	Roundwood	0.08		0.04	1.24		0.69	36.38		20.37
	Bark + offcuts	0.00		0.00	0.00		0.00	0.11		20.37
	Stem tops/tips	0.00		0.00	0.06		0.03	1.77		0.06
	Branchwood	0.36		0.20	5.68		3.18	167.01		0.99
	Roots	0.59		0.33	9.45		5.29	277.95		0.99
Dead	Stem+tops/tips+bark	1.10		1.10	17.56		9.83	516.27		155.65
Trees	Branchwood	0.36		0.20	5.68		3.18	167.01		289.11
	Roots	0.59		0.33	9.45		5.29	277.95		289.11

Note: The stand-level results in oven dry tonnes given in the FieldBSORT outputs above are inconsistent and some of the results are incorrect. This is a consequence of software errors in the early version of the FieldBSORT software used. The correct values can be calculated by multiplying the stand-level volumes given by the assumed specific gravity given in the initial stand descriptions for each output file.