Thinning control

Key to procedures

Determine the yield class of the stand
(page 4)

Choose the thinning type
(page 8)

Choose the thinning intensity
(page 9)

Choose the thinning cycle
(page 10)

Calculate the thinning yield
(page 10)

Check the stand is ready for thinning
(page 16)

Start by marking out a representative
corner of the stand

Measure the volume marked
(page 28)

Adjust the size, or number, or both, of the trees being marked accordingly ← Y — Is the volume marked greater or less than the specified thinning yield?

N

Continue marking making only occasional checks

Forestry Commission

Field Guide

Thinning control

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Introduction

Thinning in forestry is the selective removal of a proportion of trees growing in a forest in order to provide more growing space for the remaining trees. The usual aim is to increase the total yield of usable timber over the lifetime of a stand of trees and to provide an intermediate supply of timber. However, thinning may also be carried out for other reasons, for example to increase biodiversity or to improve the resilience of trees to environmental stresses or outbreaks of pests or diseases.

If a stand of trees is to be thinned, there are choices to be made on the age of first thinning, the type of thinning, the intensity of thinning, the thinning cycle, the thinning yield, and the age at which thinning should cease. These choices will depend on such factors as management objectives, timber markets available at the time and likely to be available in the future, the quality of the stand, its liability to wind damage and the cost of harvesting the timber.

The main objectives of thinning control are usually to combine maximum timber yield in the long term with the maintenance of a regular supply of material from thinnings. Failure to control the volume removed as thinnings can result in over cutting which leads to a loss in volume production, or under cutting which depresses profitability. Such failure to control the thinning may also produce an erratic supply of timber to the market.

The precision of control will depend upon the expertise and resources available, as well as the nature of the tree stand being thinned. Normally it should be possible to control yields to within 15% of the target thinning yield, but achieving this degree of control may be expensive in mixtures or stands that are very variable in other ways. Note that effective thinning practice depends upon the appropriate application of the guidance under a wide range of conditions. For example, it may pay to thin an understocked stand because of contractual commitments, despite the loss of increment that is likely to result.

This Field Guide provides guidance on the control of volume to be removed when marking a thinning and a guide to thinning yields. There are four main sections: the first describes the yield class system and how yield class is assessed in a stand. The second covers thinning practice, including the type, intensity and cycle of thinning, how to calculate the thinning yield, the timing of thinning, and how the thinning is controlled. The third describes the field procedures for estimating top height, basal area and volume marked, and how to calculate mean diameter. The final section presents general yield class curves for a selection of common species. A summary of the office and field procedures to be followed when marking a thinning is printed on the inside front cover.
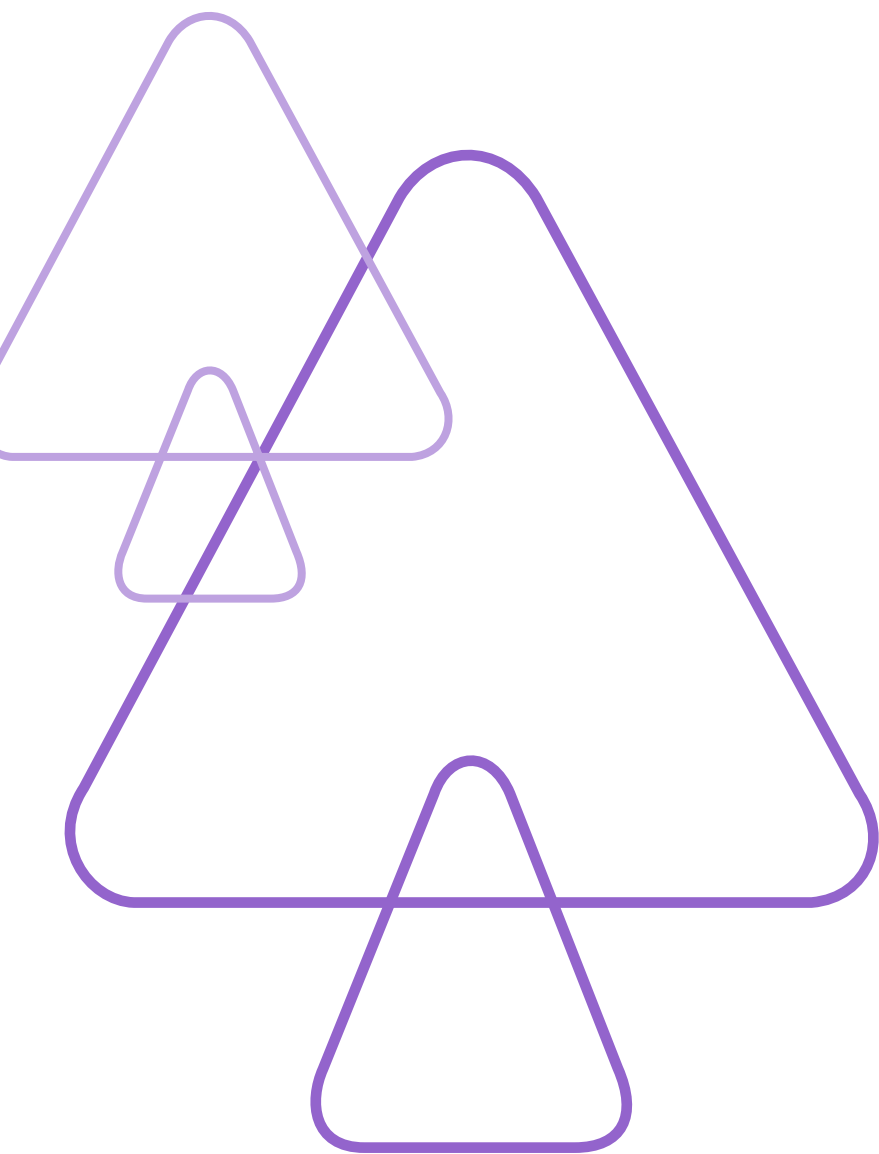
Yield class

The concept of yield class

Before you can decide on an appropriate thinning regime for the various crops that make up the forest in question, you will need information about the current and future rates of tree growth. This may be measured in terms of increases in height, diameter, volume or weight. Of these, volume is the most meaningful for purposes of management.

In an even-aged stand the cumulative volume production, including dead trees and thinnings, divided by the age of the stand is referred to as the mean annual increment (MAI). After planting, MAI increases during the early years of vigorous growth, reaches a maximum, and then declines with increasing age. The point at which the MAI curve reaches a maximum is the maximum average rate of volume increment which a particular stand can achieve, and this indicates the yield class. For example, a stand with a maximum MAI of 14 cubic metres per hectare has a yield class of 14.

In order to assess yield class it is possible to avoid the direct measurement or prediction of cumulative volume production because there is a good relationship between top height and cumulative volume production of a stand. The relationship allows yield class to be read directly from top height/age curves (see pages 39–55). The yield class for species other than those for which curves are provided can be estimated by using the curves suggested in Table 1.

Table 1 Suggested top height/age curves for other species.

For these species:		Use curves for:
Maritime pine	*Pinus pinaster*	Lodgepole Pine
Weymouth pine	*Pinus strobus*	Scots Pine*
Monterey pine	*Pinus radiata*	Corsican Pine
Bishop pine	*Pinus muricata*	Corsican Pine
Serbian spruce	*Picea omorika*	Norway Spruce*
Silver fir	*Abies alba*	Noble Fir
Coast redwood	*Sequoia sempervirens*	Grand Fir*
Wellingtonia	*Sequoiadendron giganteum*	Grand Fir*
Alders	*Alnus* spp.	Sycamore, ash and birch
Norway maple	*Acer platanoides*	Sycamore, ash and birch
Hornbeam	*Carpinus betulus*	Beech
Sweet chestnut	*Castanea sativa*	Beech
Red oak	*Quercus rubra*	Beech

* The yield class is likely to be one greater than that derived using the General Yield Class curves.

Yield class obtained through top height and age of the stand alone is termed General Yield Class (GYC). Yield class obtained from some measure or prediction of the actual mean annual volume increment of the stand is termed Local Yield Class (LYC). Where LYC is known, it should be used in preference to GYC for thinning control. (see the booklet accompanying *Forest Yield: a pc-based yield model for forest management in Britain* for further information).

Assessing general yield class

1. Estimate the top height of the stand (see page 22).
2. Determine the age of the stand (the number of growing seasons since planting).
3. Use the top height/age curves on pages 39–55 to determine the General Yield Class of the stand (e.g. if the top height of a stand of Sitka spruce is 19 m at an age of 40 years then, using the top height/age curve on page 42, the GYC is 14).

> Forestry Commission convention is to estimate and report yield class as even numbers only (for example 4, 6 or 8), therefore GYC is rounded to the nearest even whole number. For example, a stand of yield class 14 has a maximum MAI of about 14 m^3 per hectare (greater than 13 m^3 per hectare but equal to or less than 15 m^3 per hectare). A value of exactly 13 is rounded to yield class 12.

Where there is more than one species in the stand, the GYC of each species should be assessed separately. It may be necessary to increase the number of sample plots to estimate top height so that the minimum number of top height trees is measured in each species. The average yield class of the stand can be obtained by averaging the component yield classes according to the proportion of the canopy each occupies. For example, if one species occupies 40% of the canopy and has a GYC of 10, while a second species of GYC 14 occupies 60% of the canopy, the average GYC is:

$$\frac{(10 \times 40 + 14 \times 60)}{100} = 12.4 \text{ (which rounds to 12)}$$

Uneven-aged stands are treated in a similar way in that the yield class of each component is assessed separately, and the average yield class again obtained, weighted according to the proportion of the canopy occupied by each component.

When, for any reason, the rate of height growth has changed appreciably in the life of the stand (e.g. because it has been in check, or because it has been fertilised), an adjusted age should be used instead of the actual age. Further information on yield class assessment is given in the booklet accompanying *Forest Yield: a pc-based yield model for forest management in Britain*.

Further information on height measurement is given in *Forest Mensuration: a handbook for practitioners* (section 3.3).
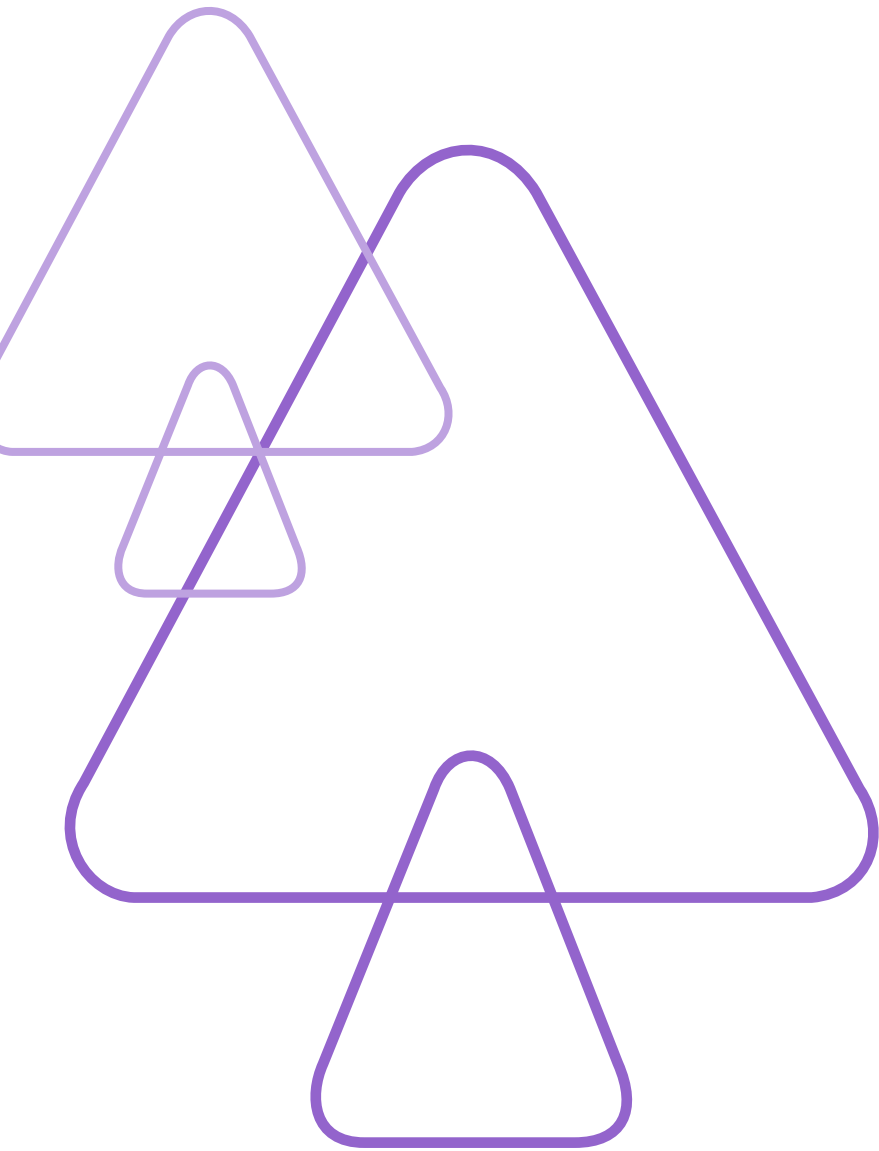
Thinning practice

Thinning type

Thinnings may be either **selective** or **systematic**.

Selective thinning

Selective thinning is a thinning in which trees are removed or retained on their individual merits.

The most common type of selective thinning is known as **intermediate** thinning. It involves the removal of most of the suppressed and sub-dominant trees, and also the opening up of the canopy by breaking up groups of competing dominant and co-dominant trees. This encourages the development of the better trees and leaves an open and fairly uniform stand.

In **low** thinning, trees are removed predominantly from the lower canopy, i.e. the suppressed and sub-dominant trees. Low thinning tends to result in relatively dense stands of evenly distributed trees. In **crown** thinning trees are removed predominantly from the upper canopy, i.e. some dominants and co-dominants, with the aim of giving selected trees freedom to grow rapidly. Some trees may also be removed from the lower canopy. Crown thinnings are often used at the first and second thinnings, especially for shade-tolerant trees, to increase the average size of trees being removed as thinnings, and to encourage the growth of the remaining trees where very large trees are more valuable. However, a true crown thinning cannot be maintained throughout a rotation, because too few competing trees remain to give a reasonable thinning yield. Over a rotation, the distinction between low and crown thinnings tends to become academic. For example, even if a low thinning is used, some thinning in the upper canopy is usually inevitable in order to release the better dominant trees, which will ultimately form the main crop of the stand. A stand could be thinned by removing the dominant trees, but this would result in a considerable reduction in total volume production over the rotation.

Systematic thinning

Systematic thinning is a thinning in which trees are removed according to a predetermined system which does not permit consideration of the merits of individual trees.

Systematic thinnings are usually one of the varieties of **line** thinning such as **row** thinning, **strip** thinning, **chevron** thinning, or some combination of these, and are commonly used for the first, and sometimes the second, thinning. Systematic thinning is usually cheaper and easier to manage than selective thinning, but the operation may leave parts of the crop unthinned and may result in losses of volume production

and reduced stand stability. Systematic thinning should only be considered where the saving in cost is greater than the likely loss of future revenue.

Thinning intensity

The thinning intensity is the rate at which volume is removed, e.g. 10 m³ per hectare per year. It should not be confused with the thinning yield which is the actual volume removed in any one thinning.

Over a wide range of thinning intensities the cumulative volume production of usable timber is unaffected. At low intensities, stands will be overstocked, unless the initial plant spacing is very wide, and the cumulative production of usable timber is reduced because some trees die before they are harvested. At high intensities, stands do not fully utilise the growing space created by the thinnings, so that cumulative production is reduced. The maximum thinning intensity which can be maintained without causing a loss of cumulative volume production is known as the **marginal thinning intensity**. For most species this critical intensity, assessed from the time the stand has reached the threshold basal area (see page 17) up to the time of maximum mean annual volume increment, (see pages 37–56), is about 70% of the maximum mean annual volume increment per year (i.e. 70% of the yield class is removed each year). Thus, the marginal thinning intensity of a stand of yield class 20 is 14 m³ per hectare per year (70% of 20).

The choice of thinning intensity depends on the location of the stand, the markets available, and the objectives of the owner. Higher intensities will be reflected in greater increases in mean diameter of the main-crop trees. In addition, the greater thinning yields resulting from higher intensities provide greater revenues. Taken together, these features tend to make higher thinning intensities more profitable, although the reduced volume of the final crop has to be taken into account. The marginal thinning intensity is often chosen as it produces high thinning yields without reducing the total volume production over the rotation, but there are circumstances when it will not be the best choice. For example, if thinnings are difficult to sell, thinning may not be carried out, or a lower thinning intensity may be adopted. If large sized trees are required as soon as possible, a higher thinning intensity may be adopted even though total volume production will be reduced.

Thinning cycle

The thinning cycle is the interval in years between successive thinnings.

For the purpose of determining the thinning yield (defined below), the cycle is the number of years before the next thinning, not the number of years since the last

thinning which has little relevance to future growth. The cycle has an influence on profitability as the value per cubic metre of any single thinning depends in part on the scale of the operation. Long cycles involve heavier single thinnings which are usually more profitable, but may increase the risk of windthrow owing to an opening up of the canopy. In extreme cases they may result in some loss of volume production. The choice of thinning cycle will usually depend on local management considerations and on the yield class of the crop. The usual length of thinning cycle is from 4–6 years in young or fast growing crops, and about 10 years in older or slower growing crops.

Thinning yield

The thinning yield is the actual volume removed in any one thinning. If a fully stocked stand is thinned at the marginal thinning intensity, the thinning yield will be 70% of the maximum mean annual increment (i.e. 70% of the yield class) multiplied by the cycle. For example, the thinning yield for a stand of yield class 14 being thinned at the marginal thinning intensity on a 5-year cycle is:

$$70\% \times 14 \times 5 = 49 \text{ m}^3 \text{ per hectare}$$

If the marginal thinning intensity has been chosen, the normal thinning yield can be read from Table 2 according to the yield class and thinning cycle.

These thinning yields can be taken from the time that the threshold basal area is reached up until the time of maximum mean annual increment, which is indicated on the top height/age curves (pages 37–56).

If the marginal thinning intensity has not been chosen, the actual thinning intensity can be used to calculate the thinning yield. For example, the yield from a stand of yield class 14, being thinned at an intensity of 80% of the marginal thinning intensity on a 5 year cycle is:

$$80\% \times 70\% \times 14 = 39.2 \text{ m}^3 \text{ per hectare}$$

In all cases, the thinning yield should not be so heavy that it opens up the stand to the risk of windthrow, or to invasion by other woody species, and thinning should not take all the dominant and good quality trees so that none are left to form a reasonable crop after thinning.

Table 2 Thinning volumes per hectare (cubic metres overbark to 7 cm top diameter).*

Yield class	Thinning cycles**						
	3	4	5	6	8	10	12
4					22.4	28	33.6
6			21	25.2	33.6	42	50.4
8		22.4	28	33.6	44.8	56	67.2
10	21.0	28.0	35	42.0	56.0	70	84.0
12	25.2	33.6	42	50.4	67.2	84	
14	29.4	39.2	49	58.8	78.4		
16	33.6	44.8	56	67.2	89.6		
18	37.8	50.4	63	75.6			
20	42.0	56.0	70	84.0			
22	46.2	61.6	77				
24	50.4	67.2	84				
26	54.6	72.8					
28	58.8	78.4					
30	63.0	84.0					

*Thinning volumes given in the table are expressed on the basis of net area (see section on Net and gross areas).

**Number of years before next thinning, not since the last.

Net and gross areas

The thinning yields in this Guide refer to fully stocked areas. The gross area which includes roads, rides, or other non-productive land should be reduced to a net area which excludes such land, before the volume per hectare is calculated for the purposes of thinning control. The training and supervision of markers is easier if estimates of the volume marked per net hectare are made. For example, extraction racks should not be included in the area being marked, as the thinning yield should be controlled in the productive area between the racks. When the racks themselves are marked it will usually be easiest to control the volume marked in the normal way between the racks, and to estimate the total volume removed by adding on the extra volume removed from the racks.

Understocked stands

Understocked is a subjective term used to describe a stand composed of either trees with significant open (and by implication 'unproductive') space between their crowns; or trees where stocking density is less than a specified target level, for example as obtained from a standard yield table; or both.

The normal thinning yields are intended for use with fully stocked stands, so some reduction in yield will be necessary for stands which are understocked, perhaps caused by over-thinning in the past. However, it will usually be more practical to leave such stands until they have reached full stocking again (see 'Timing of thinning' on page 16). If it is decided to thin an understocked stand, recovery of full stocking will be delayed much less if the thinning yield is reduced by at least one year's cut. For example, it may be best to take a 3-year cut even if it is proposed to thin again in 4 years' time.

Overstocked stands

Overstocked is a subjective term used to describe a stand composed of either trees where continued growth is constrained by extensive competition between their crowns; or trees where the stocking density is greater than a specified target level, for example as obtained from a standard yield table; or both.

In stands which are overstocked, perhaps because of a lack of thinning in the past, or a delay in the time of first thinning, the thinning yield can be increased to reduce the stocking level. For example, a 6-year cut may be taken even if it is proposed to thin again in 5 years' time. If the stand is still overstocked at the next thinning, the procedure may be repeated so as to achieve a controlled reduction in stocking. Where there is a choice, short rather than long cycles should be used when thinning overstocked stands. This is particularly relevant where there is a risk of windthrow.

Species mixtures

The thinning yield from stands with mixtures of species should be determined in the same way as for stands of single species, except that a 'weighted mean' yield class should be used, i.e. weighting each species according to the percentage of the canopy of the stand that it is expected to occupy after the thinning. For example, if the stand after thinning is expected to be 75% Sitka spruce – yield class 16, and 25% Lodgepole pine – yield class 8, then the thinning yield at the marginal thinning intensity on a 5-year cycle is:

$$(75\% \times 16 + 25\% \times 8) \times 70\% \times 5 = 49 \text{ m}^3 \text{ per hectare}$$

Uneven-aged stands

In two storey single-species stands, the thinning yield should be calculated in the normal way using the weighted mean yield class of both the components. However, in all-aged stands the whole of the maximum mean annual increment can be removed each year. For example, if the yield class is 12, then on a 5-year cycle each 'thinning' yield would be $12 \times 5 = 60$ m³ per hectare. The yield will consist of trees of all ages and all sizes, and the largest trees will be of, or past, rotation age.

Diseased stands

In diseased stands, the thinning yield may have to be reduced or thinning may be suspended altogether. The correct treatment will depend on the nature and extent of the disease.

Stands with patchy growth or partial check

When parts of a stand are ready for thinning, but others are not, thinning will usually only be started when the thinnable parts are large enough for economic working. Usually, the full thinning yield will be taken from fully stocked parts of the stand, while the other areas may be left unthinned. For example, if a stand is only 65% fully stocked, then only 65% of the thinning yield will be available.

Line thinning

In selective thinnings, the thinning intensity is usually controlled by fixing the thinning cycle and adjusting the thinning yield. However, in line thinnings, it is not always practicable to make precise adjustments to the thinning yield. For example, the harvesting method may reduce the options for varying the thinning yield, if maximum efficiency of harvesting is to be achieved. Therefore in line thinnings it is usually more convenient to control the thinning intensity by adjusting the thinning cycle.

If there are overriding management reasons why the thinning cycle cannot be adjusted, then the scope for modifying the thinning yield, given a fixed cycle, is restricted in the case of row thinnings. For example, if it is desired to thin by removing single rows, then the options are: removal of every fourth row (25%), every third row (33%) or every second row (50%). In chevron patterns of thinning the possibilities of adjusting the thinning yield are greater. Examples of two common situations are given below. They show the various steps required to derive an appropriate thinning pattern for a fixed cycle. A worked example is included in brackets after each step.

Row thinning

1. Determine the yield class of the stand (16).

2. Choose the thinning type (row thinning).

3. Choose the thinning intensity (marginal thinning intensity).

4. Choose the thinning cycle (6 years).

5. Work out the thinning yield (70% × 16 × 6 = 67.2 m³ per hectare).

6. Estimate the volume per hectare before thinning (150 m³ per hectare).

7. Express the thinning yield as a percentage of the estimated volume per hectare before thinning.

$$\left(\frac{67.2}{150} \times 100 = 44.8\% \right)$$

8. Choose a row removal pattern appropriate to this thinning percentage. (In this example, the nearest equivalent for a single row removal pattern would be to remove every second row (50%).)

9. If the percentage resulting from the chosen row removal pattern is greater or less than the required percentage, the thinning cycle should be altered, or the thinning yield at the next thinning should be reduced or increased, or the removal pattern reconsidered. (In this example, the removal of every second row would cause some loss of increment and it would be necessary to extend the thinning cycle by about 2 years. Alternative approaches would be to take a smaller cut after the planned cycle of 6 years, or to remove every third row on a 5 year cycle.)

Chevron thinning

1. As for row thinning.

2. Choose the thinning type (chevron thinning).

3–7. As for row thinning.

8. Choose the spacing between main racks, and the number of rows to be removed (every 20th row removed) to create main racks.

9. Deduct the volume percentage removed by creating the main racks (1 in 20 = 5%) from the target percentage (44.8 – 5 = 39.8%). Note that if the main racks are not parallel to the rows, the percentage removed is in effect the mean rack width expressed as a percentage of the distance between racks.

10. The remaining volume must be removed from the side racks. As the remaining fully stocked portion of the stand is less than the total area (in this example 95%), then the proportion of the remaining growing stock to be removed is:

$$\left(\frac{39.8}{95} \times 100 = 41.9\% \right)$$

11. The thinning yield is controlled through varying the side rack width, the angle of the side rack to the main racks, or the distance between the side racks, so that the required percentage of the fully stocked area is removed. Given two of these factors, the third can be found as follows:

$$d = r \times \frac{f}{p} \qquad r = d \times \frac{p}{f} \qquad f = d \times \frac{p}{r}$$

where p is the proportion of the fully stocked area required to be removed from the side racks (see Step 10 above).

d is the distance between side racks.

r is the mean rack width.

f is a factor which varies according to the angle of the side rack with the main rack:

Angle	30°	35°	40°	45°	50°	55°
Factor (f)	200	174	156	141	130	122

For example, if the mean rack width is 2 m, and the angle between main and side racks is 40°, then the distance between side racks is:

$$2 \times \frac{156}{41.9} = 7.45 \text{ m}$$

A line-thinned stand may take longer to reach the basal area required before a further thinning is justified than would be the case with a selective thinning.

Timing of thinning

A stand will not normally be thinned unless it is fully stocked. This may be judged by visual inspection or, more objectively, by using the following procedure:

For conifers

1. Estimate the top height of the stand (see page 22).

2. Estimate the basal area per hectare (see page 22).

3. Compare the basal area with the threshold basal area given in Table 3.

For broadleaves

1. Estimate the top height of the stand (see page 22).

2. Determine the yield class of the stand (see page 4).

3. Estimate the basal area per hectare (see page 22).

4. Compare the basal area with the threshold basal area given in Table 3.

If the basal area is equal to, or greater than, the value in the table, the stand is fully stocked and therefore ready for thinning. If the basal area is less than the value in the table, the stand is not fully stocked. If however, it is still intended to thin the stand, then the thinning yield should be reduced to compensate, or the thinning cycle should be extended to allow the stand time to recover.

If the thinning yield is more than 60 m³ per hectare, the threshold basal area in Table 3 should be increased before comparing it with the actual basal area. If the thinning yield is between 60 and 80 m³ per hectare, increase the Table value by 10%. If it is over 80 m³ per hectare, increase the Table value by 20%.

Time of first thinning

The time of first thinning will vary depending on the species, yield class and initial spacing of the stand, the thinning intensity, the yield of the first thinning, and harvesting and marketing considerations.

The earliest age at which thinning can take place without losing cumulative volume production is known as the standard thinning age. This is not necessarily the recommended first thinning age and there may be good reasons for starting thinning at other ages.

The standard thinning age is later in more widely spaced stands and also for a heavy first thinning, as otherwise the stocking will be reduced to a level which would cause a loss of cumulative volume production. There are many circumstances where the most profitable treatment will be to begin thinning later than the standard thinning

Table 3 Threshold basal areas for fully stocked stands (square metres per hectare).

Species	Yield class	Top height (metres)										
		10	12	14	16	18	20	22	24	26	28	30
Scots pine		26	26	27	30	32	35	38	40	43	46	
Corsican pine		34	34	33	33	33	34	35	36	37	39	
Lodgepole pine		33	31	31	30	30	31	31	32	33	34	
Sitka spruce		33	34	34	35	35	36	37	38	39	40	42
Norway spruce		33	33	34	35	36	38	40	42	44	46	49
European larch		23	22	22	22	23	24	25	27	28	30	
Japanese and hybrid larch		22	22	23	23	24	24	25	27	28	29	
Douglas fir		28	28	28	29	30	31	32	34	35	37	40
Western hemlock		32	34	35	36	36	36	37	38	38	39	40
Red cedar			49	50	51	53	55	57	60	63	66	70
Grand fir			39	39	39	39	39	39	40	41	43	45
Noble fir			45	46	46	47	48	49	51	52	54	
Oak	4	24	24	23	23	24	24					
	6		26	25	24	24	25	25	25	25		
	8		27	25	24	24	24	25	26	26	26	
Beech and sweet chestnut	4		22	23	25	27	30					
	6		24	25	25	27	29	31	33	36		
	8		–	27	27	27	28	29	31	33	35	37
	10		–	28	28	27	27	28	29	31	33	35
Sycamore, ash, birch and alder	4		17	17	18	21						
	6		17	18	19	22	25					
	8		17	18	20	22	25	28				
	10		18	19	20	23	26	30	33			
	12		19	20	21	24	27	31	35			

age, notably where the standing value of the trees in such a thinning is low. If the first thinning is delayed, it will need to be heavier, i.e. give a higher thinning yield, so that the stand returns to the correct growing stock level, consistent with that for the standard thinning age. It may not be possible to do this in one operation if the thinning has been considerably delayed, as this could lead to loss of volume production or stand instability. Subsequent thinnings will also need to be heavier than normal to compensate. Delaying the first thinning is unlikely to cause any reduction in cumulative production of usable timber unless the thinning is delayed so long that trees start dying, but it will affect the mean diameter of the trees. The standard thinning age for a wide range of species, yield classes and initial planting spacings is given in Table 4.

Table 4 Standard thinning ages (years).

| Species	Spacing (m)	Yield class													
		30	28	26	24	22	20	18	16	14	12	10	8	6	4
Scots pine	1.4									21	23	25	29	33	40
	2.0									22	24	27	31	35	45
	2.4									24	26	29	34	39	49
Corsican pine	1.4						18	19	20	21	23	25	28	33	
	2.0						19	20	21	22	24	27	30	36	
	2.4						20	22	23	25	27	30	34	41	
Lodgepole pine	1.5									19	21	23	26	31	40
	2.0									20	22	25	28	34	44
	2.4									21	24	27	31	38	48
Sitka spruce	1.7				18	18	19	20	21	22	24	26	29	33	
	2.0				18	19	20	21	22	23	25	27	30	35	
	2.4				19	20	21	22	24	25	28	30	34	40	
Norway spruce	1.5					20	21	22	23	24	26	28	31	35	
	2.0					21	22	23	25	26	29	31	35	41	
	2.4					23	24	25	27	28	31	34	39	46	
European larch	1.7										18	20	22	26	32
Japanese larch	1.7									14	15	17	19	22	26
Hybrid larch	2.0									15	16	18	20	23	27
	2.4									16	17	19	21	25	30
Douglas fir	1.7				16	17	17	18	19	21	23	25	28		
	2.0				16	17	18	19	20	22	24	27	30		
	2.4				17	18	19	20	22	24	27	30	34		
Western hemlock	1.5					19	20	21	22	24	26	28			
Western red cedar/ Lawson cypress	1.5					21	22	23	24	26	28	30			
Grand fir	1.8	19	20	20	21	21	22	23	24	25					
Noble fir	1.5					22	23	25	27	29	31				
Oak	1.2												24	28	35
Beech	1.2											26	29	32	37
Sycamore/ash/birch	1.5										14	15	17	20	24

Control of thinning

Thinning can be controlled in terms of the number of trees, the basal area, or the volume, either remaining after thinning, or removed in the thinning. In many situations, control of thinning based on a target for the basal area or volume to be removed is preferable, because:

- It is easier to do.

- It tends to produce a constant and predictable yield of timber which is useful for planning purposes.

In general, referring to a target quantity (either to remove or to leave standing) discourages drastic reduction of the level of the growing stock which can lead to windthrow or other damage caused by a sudden opening up of the canopy.

Therefore, it is recommended that, normally, thinning should be controlled by determining a target for the basal area or the volume to be removed. It is essential that the stocking of all stands should be checked before thinning, to see that it is adequate (see 'Timing of thinning' on page 16). This Guide assumes that the thinning will be controlled by the volume removed. This is easier than using basal area as, for a given thinning intensity, the recommended volume to be removed is constant up to the age of maximum mean annual increment, whereas the basal area removed declines as the stand gets older. A summary of office and field procedures to be followed when marking a thinning is printed inside the front cover.

It is important to note that thinning control based on a simplistic target for the number of trees (either removed or left standing) is not recommended, because the outcome, and therefore the target that needs to be set for the thinning, is very dependent on the thinning type. For example, if a specified number of the smallest trees in a stand are removed during a thinning, then the (larger) trees left standing will still occupy much of the available canopy, so the effect on growing space will be limited. On the other hand, if the same number of larger trees is removed, this may leave large holes in the canopy. It is, therefore, difficult to specify simple and generally applicable targets for thinning over the rotations of stands of trees, expressed in terms of numbers of trees.
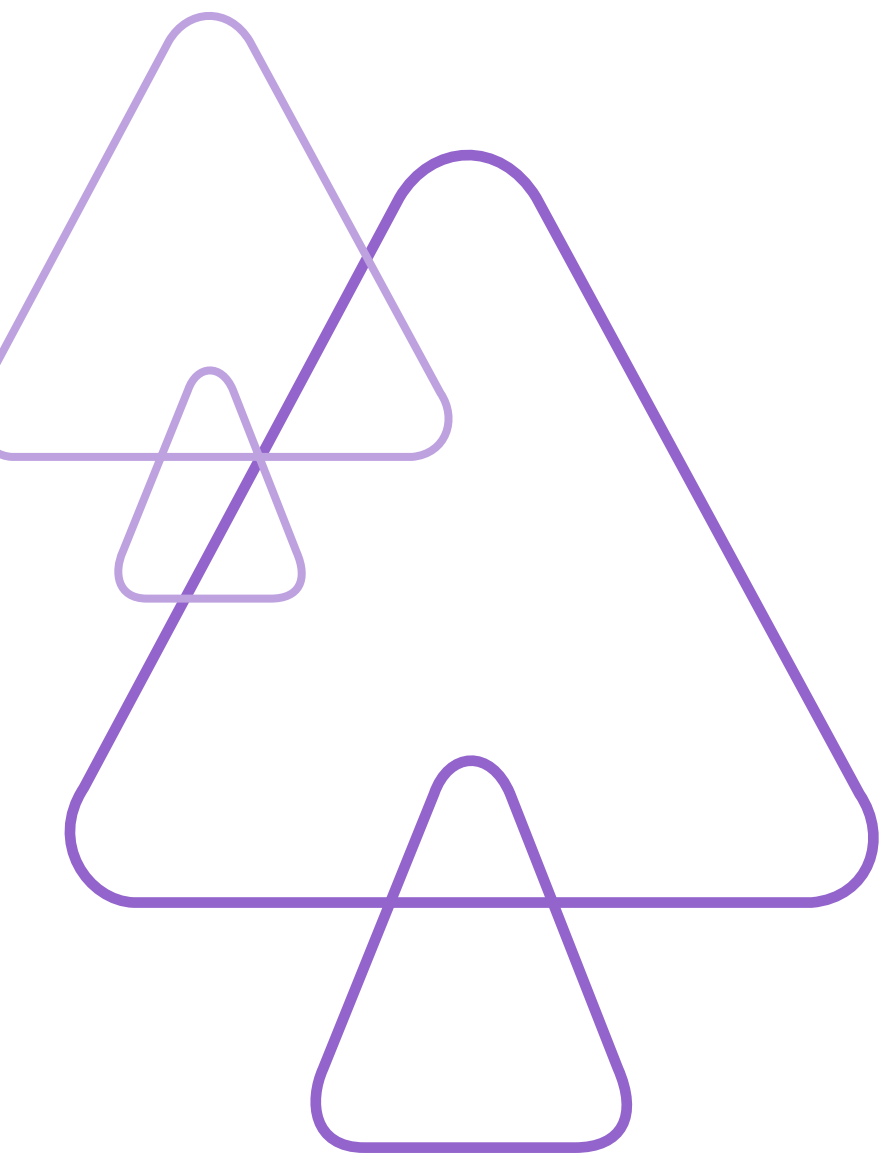
Field procedures

Measuring top height

The top height of a stand is the average total height of the 'top height trees' in the stand. The top height trees are formed by the 100 trees of largest diameter at breast height (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. Table 5 gives the likely minimum number of trees required to give an adequate estimate of top height.

Top height assessment

1. Select points at random throughout the stand. The number of points is equal to the desired number of top height trees from Table 5, based on the area of the stand.

2. Measure the height of the tree with the largest dbh within a radius of 5.6 m from each point. If there are no trees within 5.6 m of a point then a new point should be selected at random.

3. Take the average of the heights measured to give an estimate of the top height of the stand.

Table 5 Number of top height trees.

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

Measuring basal area

To check whether a stand has reached the threshold basal area (Table 3) it is necessary to take simple measurements using a relascope or sample measurements using a relascope or sample plots as described below.

Using a relascope

Choose the number of sample points, using Table 6 as a rough guide. Select this number of points, preferably systematically or with a point sampling grid on the map, throughout the area being assessed. Each point should be at least the minimum distance from the edge of the area given in Table 7.

Table 6 Number of relascope sweeps.

Area (ha)	Uniform crop	Variable crop
0.5–2	12	16
2–10	16	24
Over 10	20	32

Table 7 Minimum distances (in metres) of sample points from edge of stand.

Maximum likely dbh of trees (cm)	Minimum distance from edge of stand (m)	
	Relascope factor 2	Relascope factor 0.5
20	7	14
30	11	21
40	14	28
50	18	35
60	21	42
70	25	49
80	28	56

A relascope assessment or 'sweep' needs to be made at each sampling point. This involves using the relascope to count or discount the trees which are within visible range of the sampling point. The exact method depends on the type of relascope being used. Further information can be found in *Forest Mensuration: a handbook for practitioners* (pages 39–42 and Appendix 1).

At each point, make a 360° sweep with the relascope, and record the number of trees counted. Only trees with a dbh of at least 7 cm should be counted. If an estimate of the basal area of only part of the stand is required, e.g. marked trees, then only these trees should be counted. Note that accurate use of a relascope requires practice.

If the sampling point is on sloping ground, multiply the count by the correction factor to the angle of the slope, as given in Table 8.

Work out the average count, and multiply this by the relascope factor. The result is the estimated average basal area per hectare of the stand.

In stands with a regular pattern of variation, notably line mixtures, the sample points should not be chosen at random, but chosen so that they give equal weighting to each component. For example, in 3-row broadleaf : 3-row conifer mixtures, all the

sample points should be midway between a row of conifers and a row of broadleaves. In more complex line mixtures it is advisable to place equal numbers of sample points between each pair of lines.

Table 8 Correction factors for sloping ground.

Angle of slope (degrees)	Correction factor (secant)	% slope (tangent x 100)
5	1.004	8.8
7.5	1.009	13
10	1.015	18
12.5	1.024	22
15	1.035	27
17.5	1.049	32
20	1.064	36
22.5	1.082	41
25	1.10	47
30	1.15	58
35	1.22	70
40	1.31	
45	1.41	100
50	1.56	
55	1.74	
60	2.00	173

Using sample plots

Choose a plot size which includes 7–20 measurable trees. use rectangular plots where the planting rows are still clearly visible, and circular plots in all other stands. Tables 9 and 10 give the dimensions of a range of plots.

Table 9 Circular and square plot sizes.

Shape	Length in metres to give plot area (ha)							
	0.005	0.01	0.02	0.05	0.10	0.20	0.50	1.00
Circular (radius)	4.0	5.6	8.0	12.6	17.8	25.2	39.9	56.4
Square (sides)	7.1	10.0	14.1	22.4	31.6	44.7	70.7	100.0

Table 10 Rectangular plot sizes in plantations where rows are clearly visible.

Average spacing between rows (m)	3 rows wide		4 rows wide	6 rows wide	9 rows wide
	Distance in metres along the row to give plot area (ha)				
	0.005	0.01	0.02	0.05	0.10
1.5	11.1	22.2	33.3	55.6	74.1
1.6	10.4	20.8	31.2	52.1	69.4
1.7	9.8	19.6	29.4	49.0	65.4
1.8	9.3	18.5	27.8	46.3	61.7
1.9	8.8	17.5	26.3	43.9	58.5
2.0	8.3	16.7	25.0	41.7	55.6
2.1	7.9	15.9	23.8	39.7	52.9
2.2	7.6	15.2	22.7	37.9	50.5
2.3	7.2	14.5	21.7	36.2	48.3
2.4	6.9	13.9	20.8	34.7	46.3
2.5	6.7	13.3	20.0	33.3	44.4
2.6	6.4	12.8	19.2	32.1	42.7
2.7	6.2	12.3	18.5	30.9	41.2
2.8	6.0	11.9	17.9	29.8	39.7
2.9	5.7	11.5	17.2	28.7	38.3

Note: Doubling the number of rows doubles the plot area, and similarly halving the distance halves the plot area.

Lay out plots throughout the stand. Table 11 gives a guide to the number needed. Plots should be laid out with care. The centre point of each circular plot must be chosen at random. The location of rectangular plots must also be chosen at random, but two of the sides of each plot must be parallel to the rows, and both must be

midway between two adjacent rows. The boundary of each plot must be at least 5 m from the edge of the stand. Where stands have been chosen subject to line thinning that has left large gaps in the canopy that will not close by the time of next thinning, the felled lines should be regarded as open ground and should not form part of a plot. However, plot boundaries can be less than 5 m from felled lines within the stand.

The dimensions of the plots should be measured horizontally. If this is not possible on sloping ground, multiply the dimension given in Table 9 or 10 by the correction factor from Table 8. Use this corrected dimension for measuring directly up or down the slope.

Table 11 Number of sample plots.

Area of stand (ha)	Uniform crop	Variable crop
0.5–2	6	8
2–10	8	12
Over 10	10	16

Measure the dbh of all the trees in the plot, and record the number of trees in each dbh class of 7 cm or more.

Use Table 12 to find the basal area appropriate to each dbh class, and multiply by the number of trees in each dbh class to give the total basal area in each class.

Add all these basal areas together and divide by the number of plots, to give an average basal area per plot.

Divide the average basal area per plot by the individual plot area to give the estimated average basal area per hectare of the stand.

Further information on basal areas is given in *Forest Mensuration: a handbook for practitioners* (pages 39–46).

Table 12 Basal areas.

DBH or diameter (cm)	Basal area or cross-sectional area (m²)	DBH or diameter (cm)	Basal area or cross-sectional area (m²)
7	0.0038	34	0.091
8	0.0050	35	0.096
9	0.0064	36	0.102
10	0.0079	37	0.108
11	0.0095	38	0.113
12	0.0113	39	0.119
13	0.0133	40	0.126
14	0.0154	41	0.132
15	0.018	42	0.139
16	0.020	43	0.145
17	0.023	44	0.152
18	0.025	45	0.159
19	0.028	46	0.166
20	0.031	47	0.173
21	0.035	48	0.181
22	0.038	49	0.189
23	0.042	50	0.196
24	0.045	51	0.204
25	0.049	52	0.212
26	0.053	53	0.221
27	0.057	54	0.229
28	0.062	55	0.238
29	0.066	56	0.246
30	0.071	57	0.255
31	0.075	58	0.264
32	0.080	59	0.273
33	0.086	60	0.283

Measuring the volume marked

Having chosen the thinning yield (see page 10), the marker should proceed to mark the stand, and from time to time checks the yield of thinning marked, modifying the marking as necessary. The check is essentially very simple.

To estimate the volume per hectare which is being marked it is necessary to take sample measurements. This is achieved either by using a relascope to estimate basal area which is converted to volume using an estimated form height, or by measuring the basal area of thinnings which fall within sample plots of known area, and converting to volume using an estimated tariff number. These two procedures are described below:

Using a relascope

1. Estimate the top height of the stand (see page 22).

2. Estimate the form height of the stand using the top height to form height tables on pages 31–33 (Table 13).

3. Select four random points in the marked area.

4. At each point, do a 360° sweep with the relascope, and record the number of marked trees counted. Only trees with a dbh of at least 7cm should be counted. If the point is on sloping ground, multiply the count by the secant of the angle of slope, from Table 8 on page 24.

5. Work out the average count, and multiply this by the relascope factor. The result is the average basal area marked per hectare.

6. Multiply by the form height to give the estimated volume marked per hectare.

Using sample plots

1. Estimate the top height of the stand (see page 22).

2. Estimate the tariff number of the stand using the top height/tariff number tables on pages 34–35 (Table 14). Add 1 if a crown or systematic thinning has been marked.

3. Select two random plots of the same size which contain between 7–20 marked trees (see page 25). Measure the dbh of all the marked trees of 7cm or more in the plots, and calculate the mean dbh (see pages 29–30).

4. Use the estimated tariff number and mean dbh to derive an estimate of mean volume. This can be done in any one of three ways:

- Refer to the tariff tables in *Forest Mensuration: a handbook for practitioners* (Table 46, pages 283–294).

- Refer to Equation 1 in *Forest Mensuration: a handbook for practitioners* (Appendix 8, page 321). Note: the equation uses basal area rather than dbh.

- Refer to the tariff number alignment chart printed on the inside back cover of this guide.

5. Work out the average number of marked trees in these two plots, and divide by the plot area to give the estimated number of marked trees per hectare.

6. Multiply the mean volume by the number of marked trees per hectare to give the estimated volume marked per hectare.

If the stand is being line thinned, it may be simpler to estimate the volume per hectare of the stand before thinning, and to calculate the volume removed as a percentage of that volume. The volume per hectare should be estimated using either of the above procedures, but measuring all trees in the plots instead of only the marked trees. For example, if one row in four is being removed, and the volume before thinning is 128 m^3 per hectare, the thinning yield will be:

$$\frac{128}{4} = 32 \text{ m}^3 \text{ per hectare}$$

The ultimate objective is for the marker to be able to mark the correct thinning yield without needing to use the above procedures, except when a new crop type is encountered. Even so, it is recommended that occasional checks should be made to confirm the accuracy of marking. If checks show that the thinning yield has not been marked correctly, it is usually simpler to correct the over- or under-stocking at the next thinning than to mark the stand again.

Calculating mean diameter

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.

Using a table of basal areas (Table 12)

1. Convert each dbh into a basal area.

2. Add all the basal areas together.

3. Divide by the number of trees, to give the mean basal area.

4. Convert this to the mean dbh.

Using a calculator or computer

1. Square each dbh.

2. Add all the squared values together.

3. Divide by the number of trees, to give the mean squared dbh.

4. Calculate the square root of this value to give the mean dbh.

Table 13 Thinning form height (m) based on top height.

Top height (m)	Species						
	SP	CP	LP	SS	NS	EL	JL/HL
8.0	2.26	2.52	2.72	2.83	2.52	1.70	2.35
8.5	2.50	2.77	2.94	3.04	2.74	1.97	2.63
9.0	2.75	3.03	3.17	3.26	2.97	2.25	2.91
9.5	2.99	3.28	3.40	3.48	3.19	2.52	3.19
10.0	3.23	3.53	3.63	3.69	3.42	2.79	3.47
10.5	3.47	3.78	3.85	3.91	3.64	3.07	3.75
11.0	3.71	4.03	4.08	4.13	3.87	3.34	4.03
11.5	3.95	4.28	4.31	4.34	4.09	3.61	4.31
12.0	4.19	4.54	4.53	4.56	4.32	3.89	4.59
12.5	4.43	4.79	4.76	4.78	4.54	4.16	4.87
13.0	4.67	5.04	4.99	5.00	4.77	4.43	5.15
13.5	4.91	5.29	5.21	5.21	5.00	4.70	5.43
14.0	5.15	5.54	5.44	5.43	5.22	4.98	5.71
14.5	5.40	5.80	5.67	5.65	5.45	5.25	5.99
15.0	5.64	6.05	5.89	5.86	5.67	5.52	6.27
15.5	5.88	6.30	6.12	6.08	5.90	5.80	6.55
16.0	6.12	6.55	6.35	6.30	6.12	6.07	6.83
16.5	6.36	6.80	6.57	6.52	6.35	6.34	7.11
17.0	6.60	7.05	6.80	6.73	6.57	6.62	7.39
17.5	6.84	7.31	7.03	6.95	6.80	6.89	7.67
18.0	7.08	7.56	7.26	7.17	7.02	7.16	7.95
18.5	7.32	7.81	7.48	7.38	7.25	7.44	8.23
19.0	7.56	8.06	7.71	7.60	7.48	7.71	8.52
19.5	7.80	8.31	7.94	7.82	7.70	7.98	8.80
20.0	8.05	8.57	8.16	8.03	7.93	8.26	9.08
20.5	8.29	8.82	8.39	8.25	8.15	8.53	9.36
21.0	8.53	9.07	8.62	8.47	8.38	8.80	9.64
21.5	8.77	9.32	8.84	8.69	8.60	9.08	9.92
22.0	9.01	9.57	9.07	8.90	8.83	9.35	10.20
22.5	9.25	9.83	9.30	9.12	9.05	9.62	10.48
23.0	9.49	10.08	9.52	9.34	9.28	9.89	10.76
23.5	9.73	10.33	9.75	9.55	9.50	10.17	11.04
24.0	9.97	10.58	9.98	9.77	9.73	10.44	11.32
24.5	10.21	10.83	10.20	9.99	9.96	10.71	11.60
25.0	10.45	11.08	10.43	10.21	10.18	10.99	11.88

Table 13 Thinning form height (m) based on top height (continued).

Top height (m)	Species						
	DF	WH	RC	LC	GF	NF	OMS
8.0	2.22	2.90	2.35	1.47	2.21	3.16	2.78
8.5	2.43	3.13	2.56	1.90	2.46	3.37	3.07
9.0	2.64	3.36	2.77	2.34	2.70	3.58	3.36
9.5	2.85	3.59	2.97	2.76	2.95	3.79	3.65
10.0	3.06	3.82	3.18	3.18	3.20	4.00	3.94
10.5	3.28	4.06	3.39	3.60	3.44	4.21	4.23
11.0	3.49	4.29	3.59	4.01	3.69	4.42	4.52
11.5	3.70	4.52	3.80	4.41	3.94	4.63	4.81
12.0	3.91	4.75	4.01	4.81	4.18	4.84	5.10
12.5	4.12	4.99	4.21	5.20	4.43	5.04	5.39
13.0	4.33	5.22	4.42	5.59	4.67	5.25	5.68
13.5	4.54	5.45	4.63	5.97	4.92	5.46	5.97
14.0	4.75	5.68	4.83	6.34	5.17	5.67	6.26
14.5	4.96	5.91	5.04	6.71	5.41	5.88	6.55
15.0	5.18	6.15	5.25	7.08	5.66	6.09	6.84
15.5	5.39	6.38	5.45	7.43	5.91	6.30	7.13
16.0	5.60	6.61	5.66	7.79	6.15	6.51	7.42
16.5	5.81	6.84	5.87	8.13	6.40	6.72	7.71
17.0	6.02	7.07	6.07	8.47	6.65	6.93	8.00
17.5	6.23	7.31	6.28	8.81	6.89	7.14	8.29
18.0	6.44	7.54	6.49	9.14	7.14	7.35	8.58
18.5	6.65	7.77	6.69	9.46	7.38	7.55	8.87
19.0	6.86	8.00	6.90	9.78	7.63	7.76	9.16
19.5	7.07	8.24	7.11	10.09	7.88	7.97	9.45
20.0	7.29	8.47	7.31	10.40	8.12	8.18	9.74
20.5	7.50	8.70	7.52	10.70	8.37	8.39	10.03
21.0	7.71	8.93	7.73	10.99	8.62	8.60	10.32
21.5	7.92	9.16	7.93	11.28	8.86	8.81	10.61
22.0	8.13	9.40	8.14	11.56	9.11	9.02	10.90
22.5	8.34	9.63	8.35	11.84	9.36	9.23	11.19
23.0	8.55	9.86	8.55	12.11	9.60	9.44	11.48
23.5	8.76	10.09	8.76	12.38	9.85	9.65	11.77
24.0	8.97	10.33	8.97	12.64	10.10	9.85	12.06
24.5	9.19	10.56	9.17	12.89	10.34	10.06	12.35
25.0	9.40	10.79	9.38	13.14	10.59	10.27	12.64

Table 13 Thinning form height (m) based on top height (continued).

Top height (m)	Species		
	Oak	Beech and sweet chestnut	Sycamore, ash, birch and alder
8.0	1.00	1.04	0.50
8.5	1.28	1.36	0.85
9.0	1.56	1.72	1.24
9.5	1.85	2.05	1.63
10.0	2.13	2.40	2.00
10.5	2.41	2.70	2.38
11.0	2.70	3.00	2.76
11.5	3.00	3.26	3.13
12.0	3.28	3.52	3.50
12.5	3.55	3.78	3.83
13.0	3.84	4.04	4.16
13.5	4.12	4.30	4.48
14.0	4.41	4.56	4.80
14.5	4.70	4.82	5.10
15.0	4.98	5.08	5.40
15.5	5.26	5.31	5.69
16.0	5.53	5.54	5.98
16.5	5.86	5.82	6.26
17.0	6.19	6.02	6.50
17.5	6.50	6.26	6.75
18.0	6.82	6.50	7.00
18.5	7.13	6.75	7.24
19.0	7.44	7.00	7.48
19.5	7.76	7.21	7.69
20.0	8.07	7.42	7.90
20.5	8.37	7.65	8.12
21.0	8.67	7.88	8.34
21.5	8.94	8.09	8.53
22.0	9.21	8.30	8.72
22.5	9.47	8.52	8.94
23.0	9.73	8.74	9.17
23.5	9.96	8.95	9.33
24.0	10.19	9.16	9.49
24.5	10.42	9.37	9.64
25.0	10.65	9.58	9.79

Table 14 Tariff numbers based on top height.

Top height (m)	Species						
	SP	CP	LP	SS	NS	EL	JL/HL
8.0	16	15	14	15	15	13	15
8.5	16	15	15	15	16	14	15
9.0	17	16	15	16	17	14	16
9.5	17	17	16	17	17	15	17
10.0	18	17	17	17	18	16	17
10.5	18	18	18	18	18	17	18
11.0	19	19	18	18	19	17	19
11.5	19	19	19	19	19	18	19
12.0	20	20	20	20	20	19	20
12.5	20	21	20	20	21	19	21
13.0	21	22	21	21	21	20	21
13.5	21	22	22	22	22	21	22
14.0	22	23	23	22	22	21	23
14.5	23	24	23	23	23	22	23
15.0	23	24	24	23	23	23	24
15.5	24	25	25	24	24	24	25
16.0	24	26	25	25	25	24	25
16.5	25	26	26	25	25	25	26
17.0	25	27	27	26	26	26	27
17.5	26	28	27	26	26	26	28
18.0	26	29	28	27	27	27	28
18.5	27	29	29	28	28	28	29
19.0	27	30	30	28	28	28	30
19.5	28	31	30	29	29	29	30
20.0	28	31	31	29	29	30	31
20.5	29	32	32	30	30	30	32
21.0	29	33	32	31	30	31	32
21.5	30	33	33	31	31	32	33
22.0	30	34	34	32	32	33	34
22.5	31	35	35	32	32	33	34
23.0	31	36	35	33	33	34	35
23.5	32	36	36	34	33	35	36
24.0	32	37	37	34	34	35	36
24.5	33	38	37	35	34	36	37
25.0	33	38	38	35	35	37	38

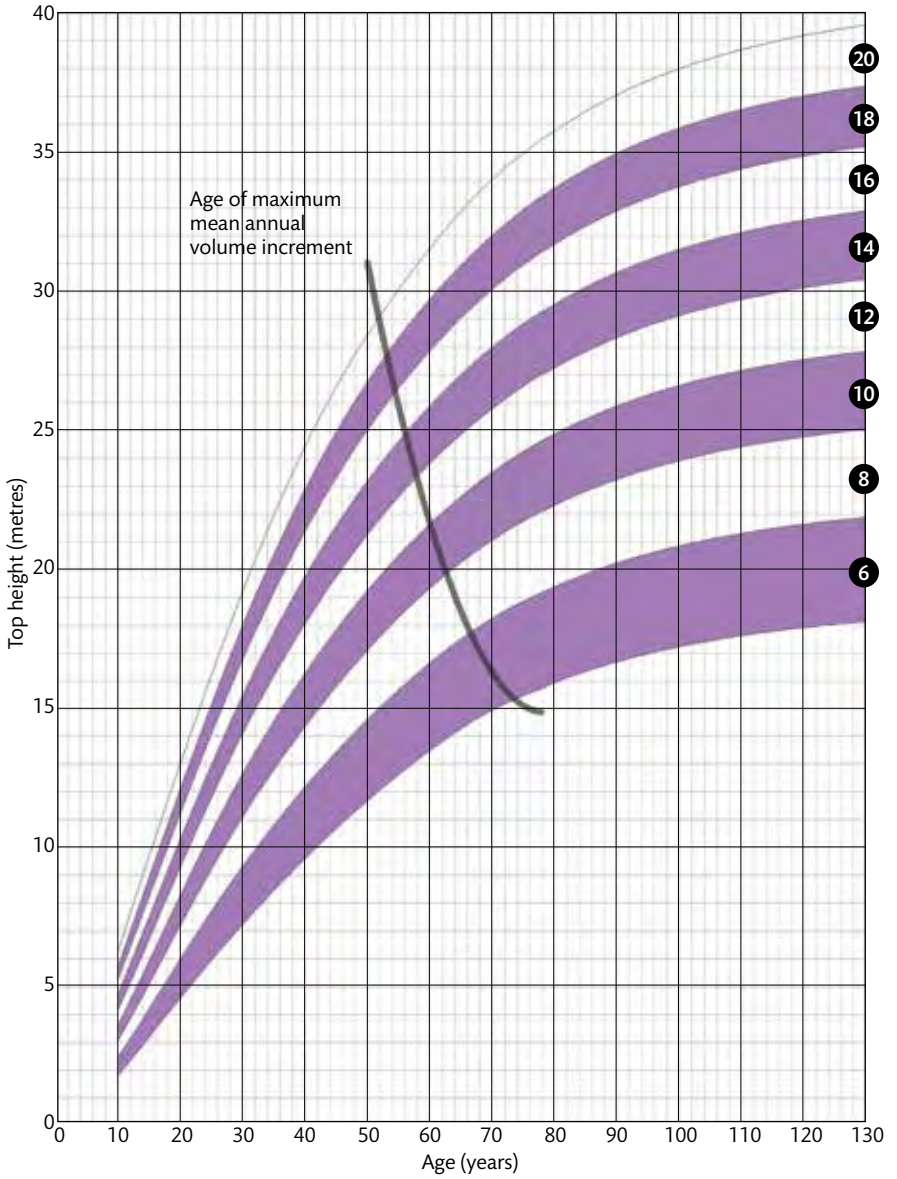Add 1 to the tariff number for crown or systematic thinning

Table 14 Tariff numbers based on top height (continued).

Top height (m)	Species						
	DF	WH	RC	GF	NF	Oak, beech, ash elm, alder and sweet chestnut	Birch, sycamore and poplar
8.0	14	16	13	13	13	15	13
8.5	15	16	13	14	14	16	13
9.0	15	17	14	15	15	16	14
9.5	16	18	14	15	15	17	14
10.0	16	18	15	16	16	17	15
10.5	17	19	15	17	17	18	15
11.0	17	19	16	17	17	18	16
11.5	18	20	16	18	18	19	16
12.0	19	21	17	19	19	19	16
12.5	19	21	17	19	20	20	17
13.0	20	22	18	20	20	20	17
13.5	20	23	18	21	21	21	18
14.0	21	23	19	22	22	21	18
14.5	21	24	20	22	22	22	19
15.0	22	24	20	23	23	22	19
15.5	23	25	21	24	24	23	20
16.0	23	26	21	24	24	23	20
16.5	24	26	22	25	25	24	21
17.0	24	27	22	26	26	24	21
17.5	25	27	23	26	26	24	21
18.0	25	28	23	27	27	25	22
18.5	26	29	24	28	28	25	22
19.0	27	29	24	28	28	26	23
19.5	27	30	25	29	29	26	23
20.0	28	30	25	30	30	27	24
20.5	28	31	26	30	30	27	24
21.0	29	32	26	31	31	27	24
21.5	29	32	27	32	32	28	25
22.0	30	33	28	33	32	28	25
22.5	30	34	28	33	33	29	26
23.0	31	34	29	34	34	29	26
23.5	32	35	29	35	34	29	26
24.0	32	35	30	35	35	30	27
24.5	33	36	30	36	36	30	27
25.0	33	37	31	37	36	30	27

Add 1 to the tariff number for crown or systematic thinning
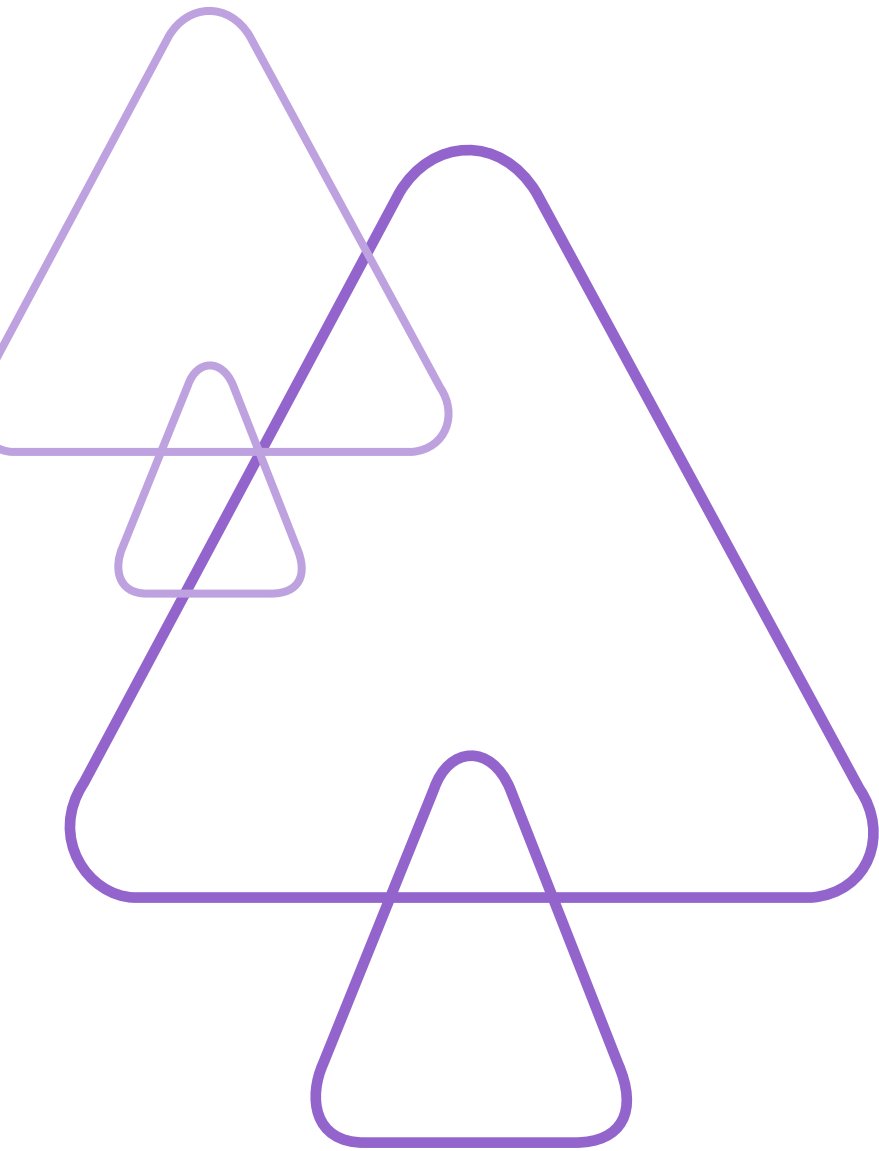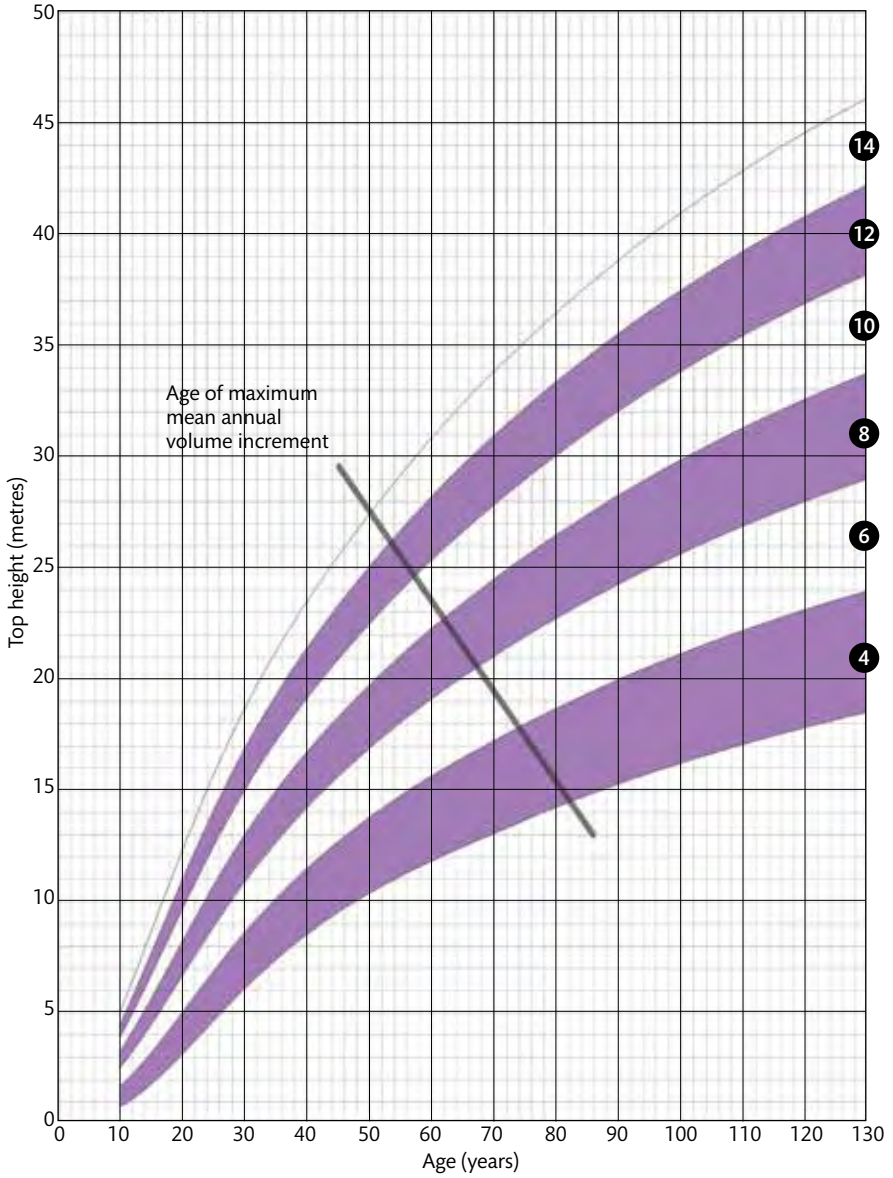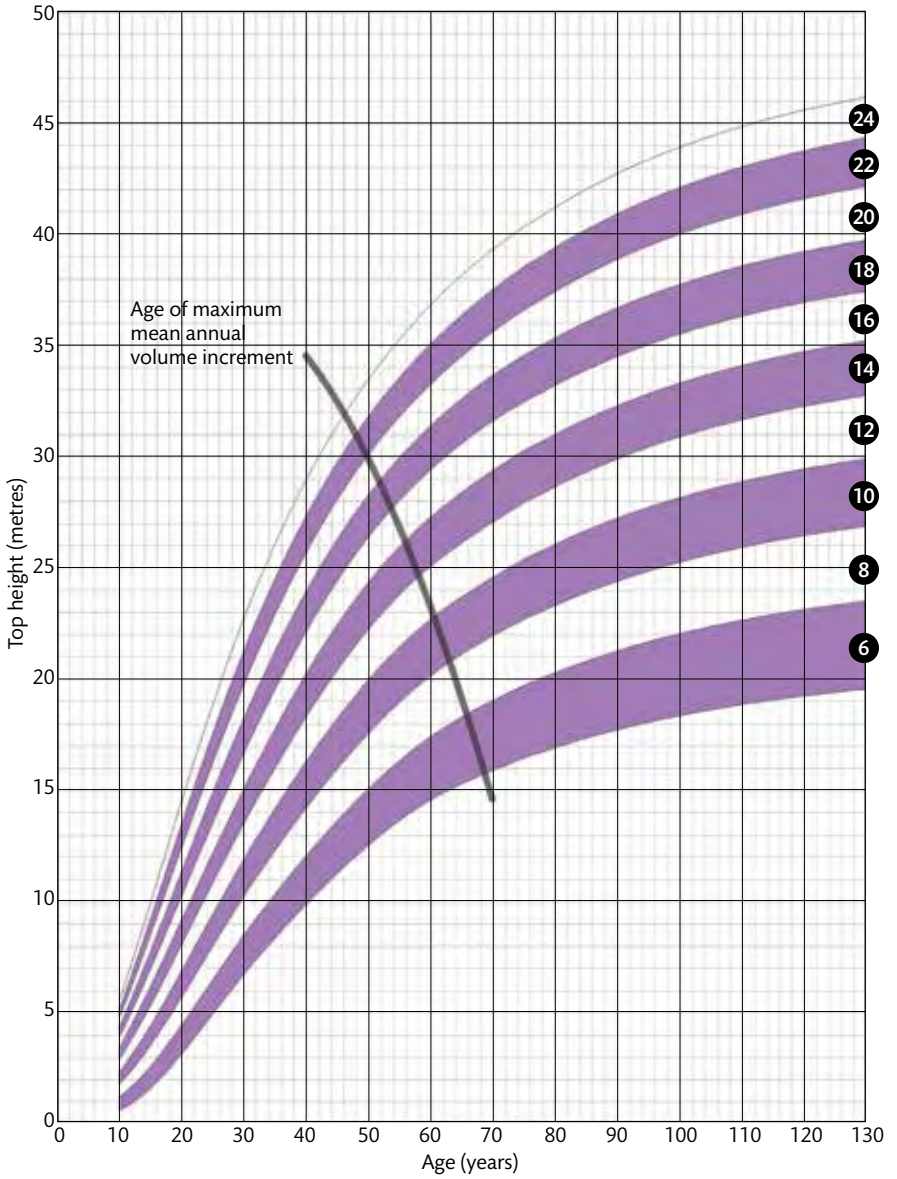
General yield class curves

Scots pine

Age of maximum
mean annual
volume increment

Top height (metres)

Age (years)

Corsican pine

Age of maximum
mean annual
volume increment

Y-axis: Top height (metres)

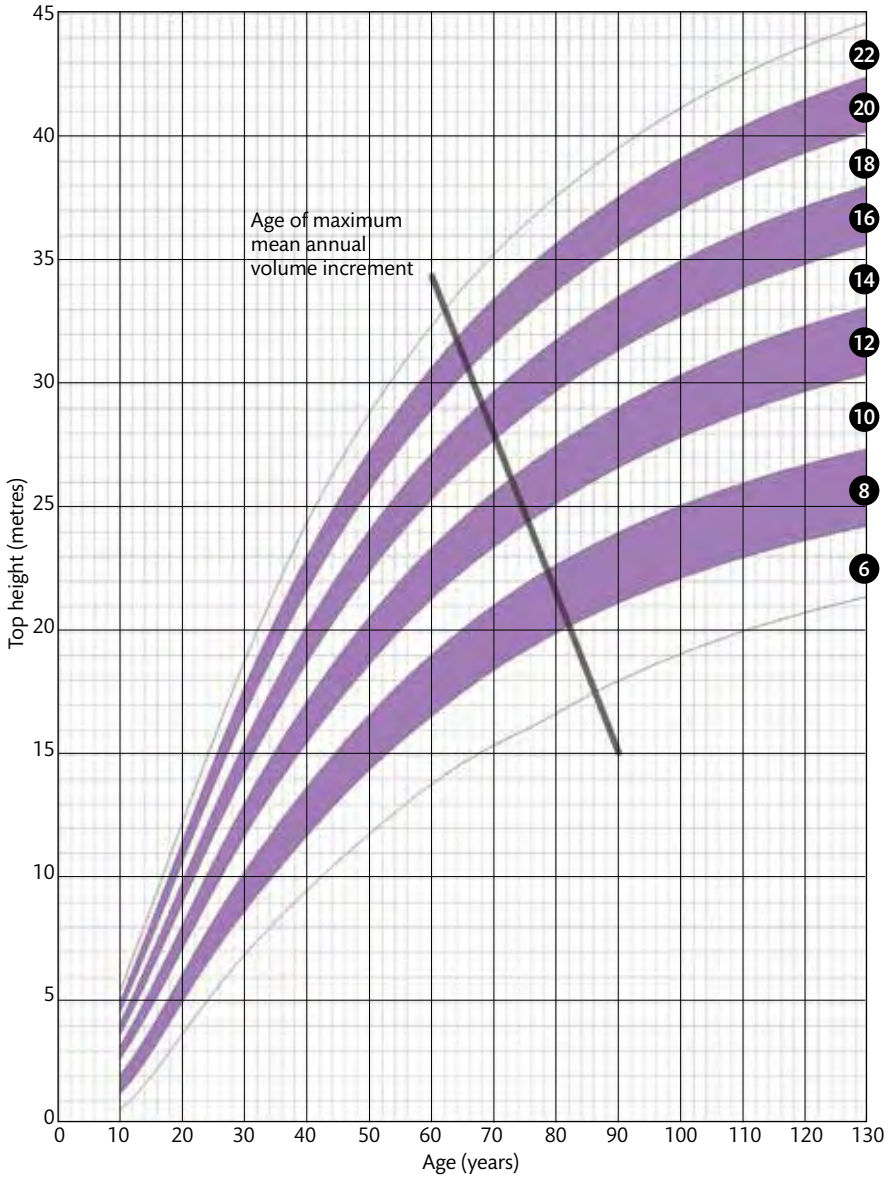*X-axis: Age (years)*

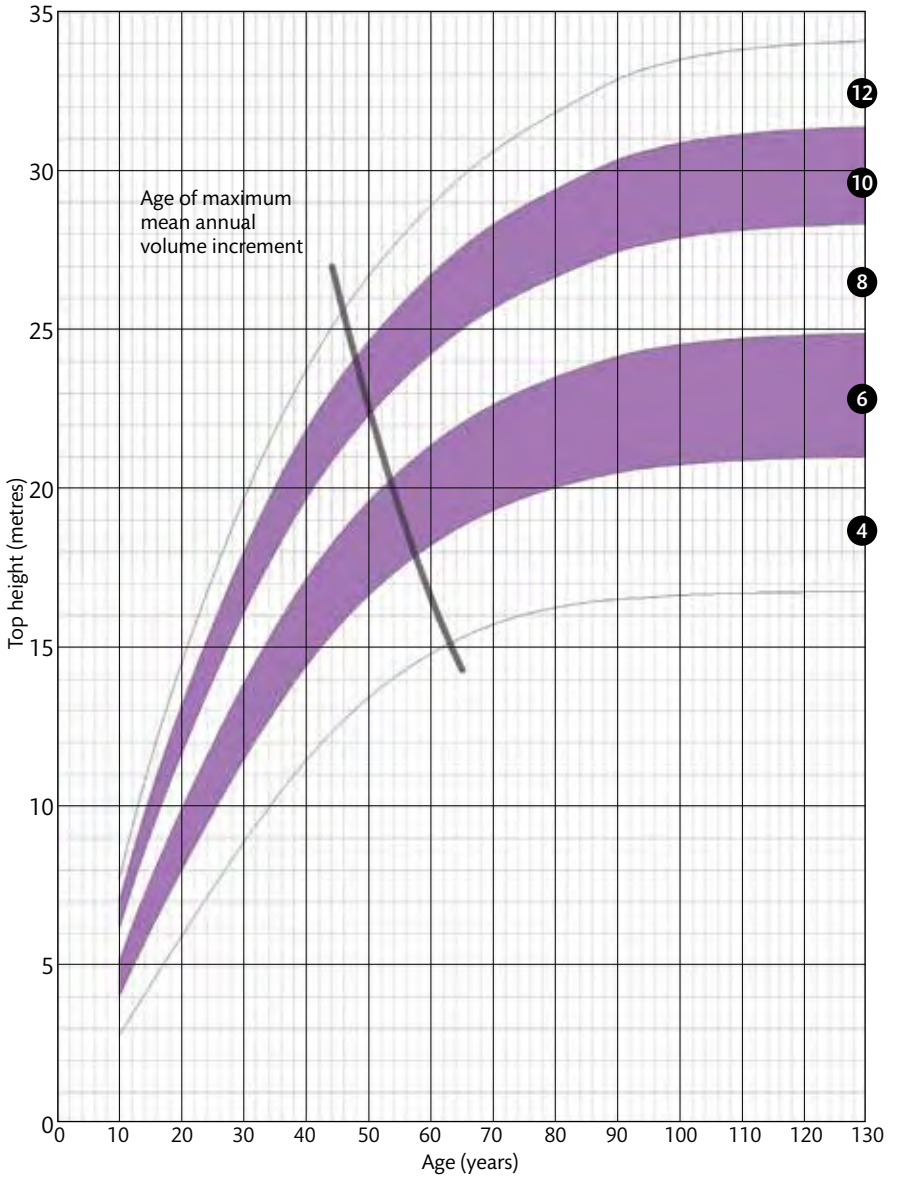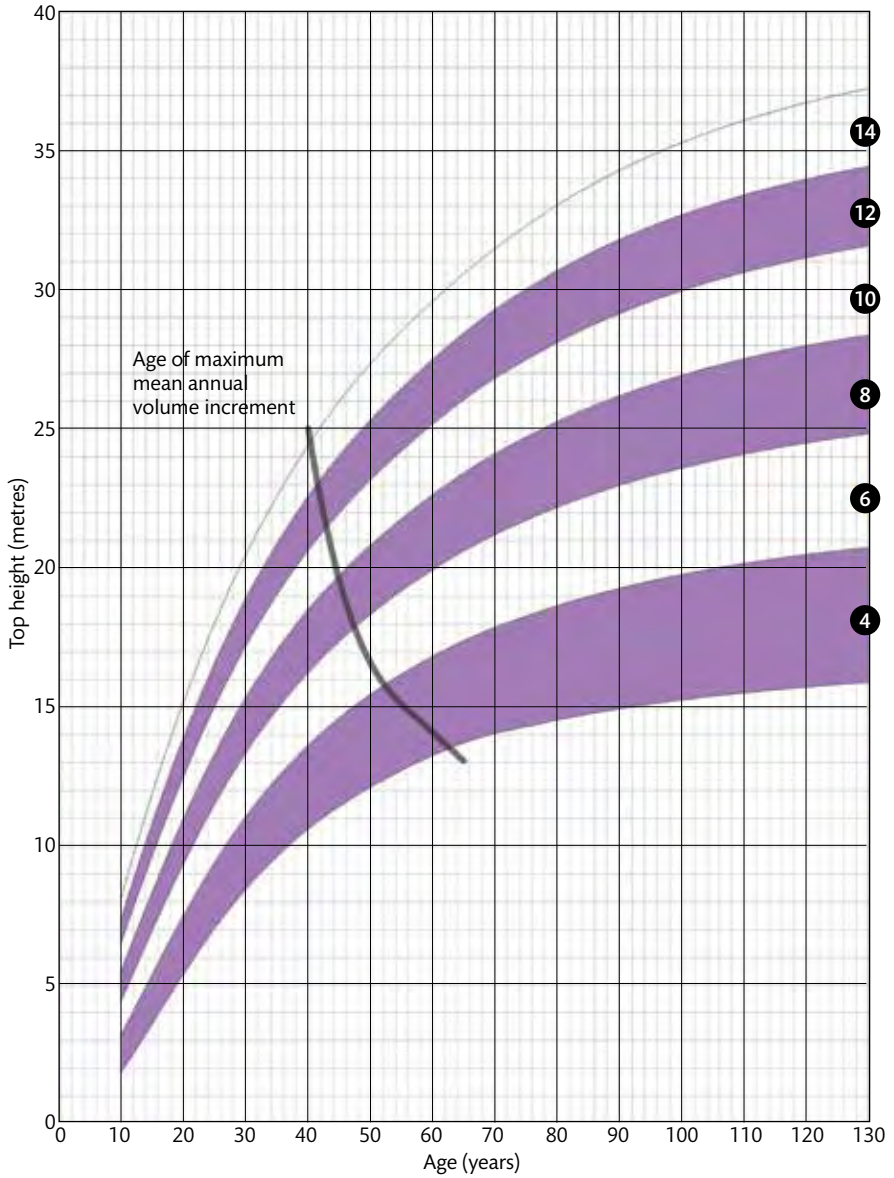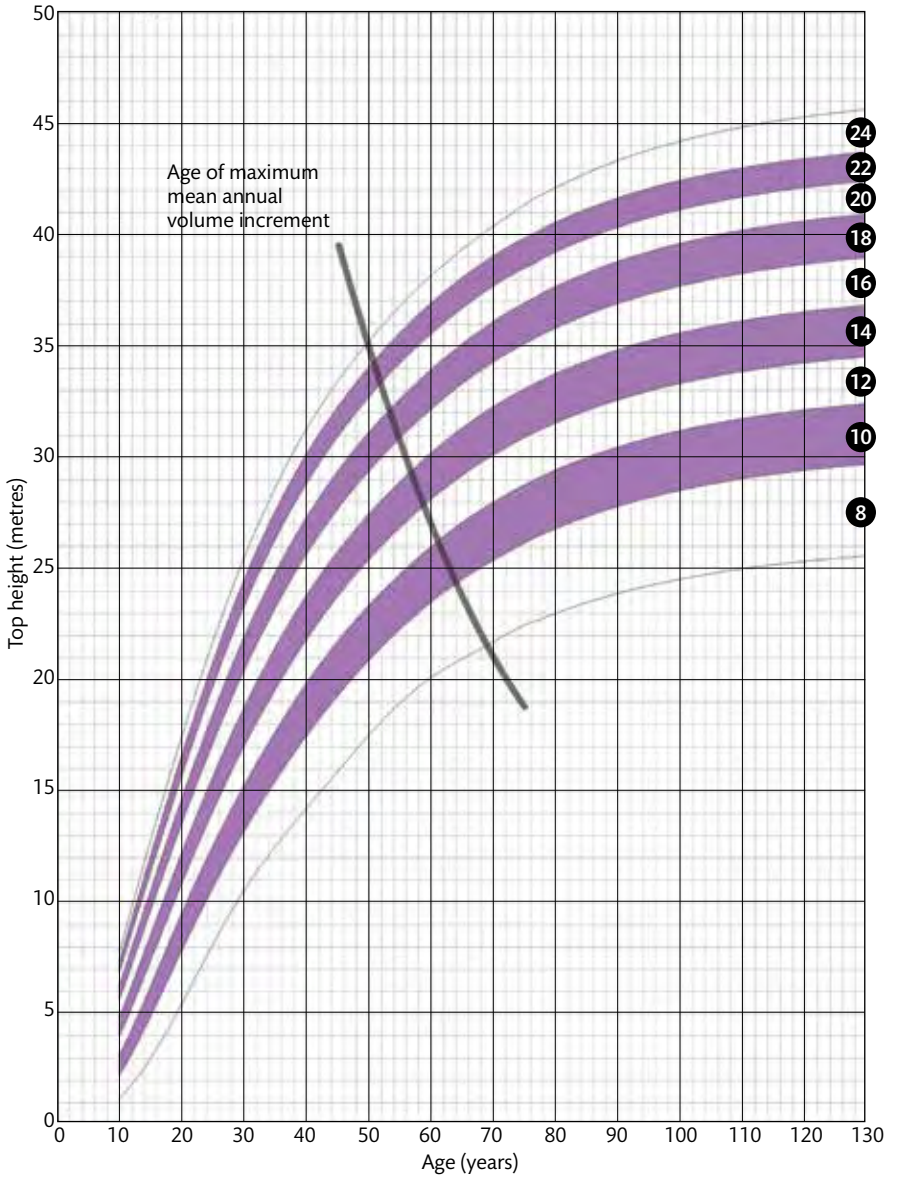*Curve labels (right): 20, 18, 16, 14, 12, 10, 8, 6*
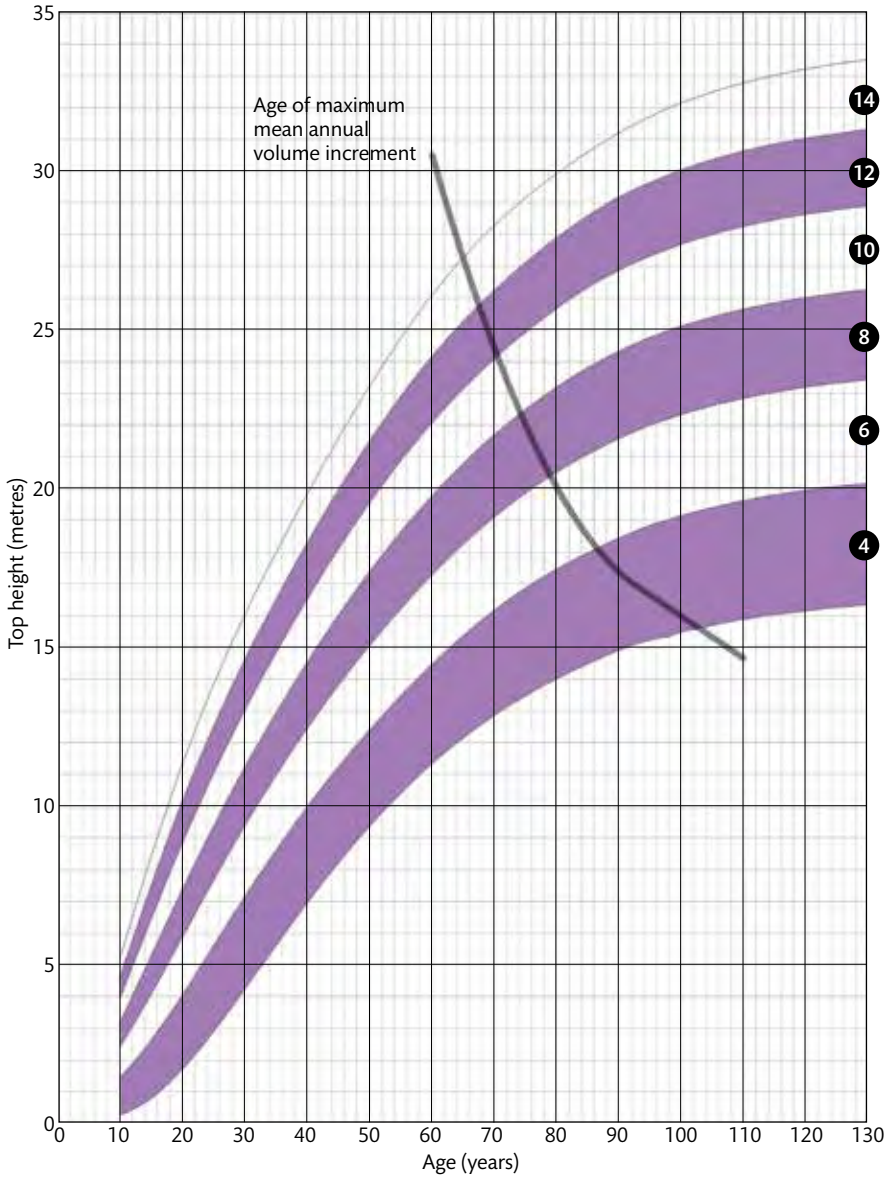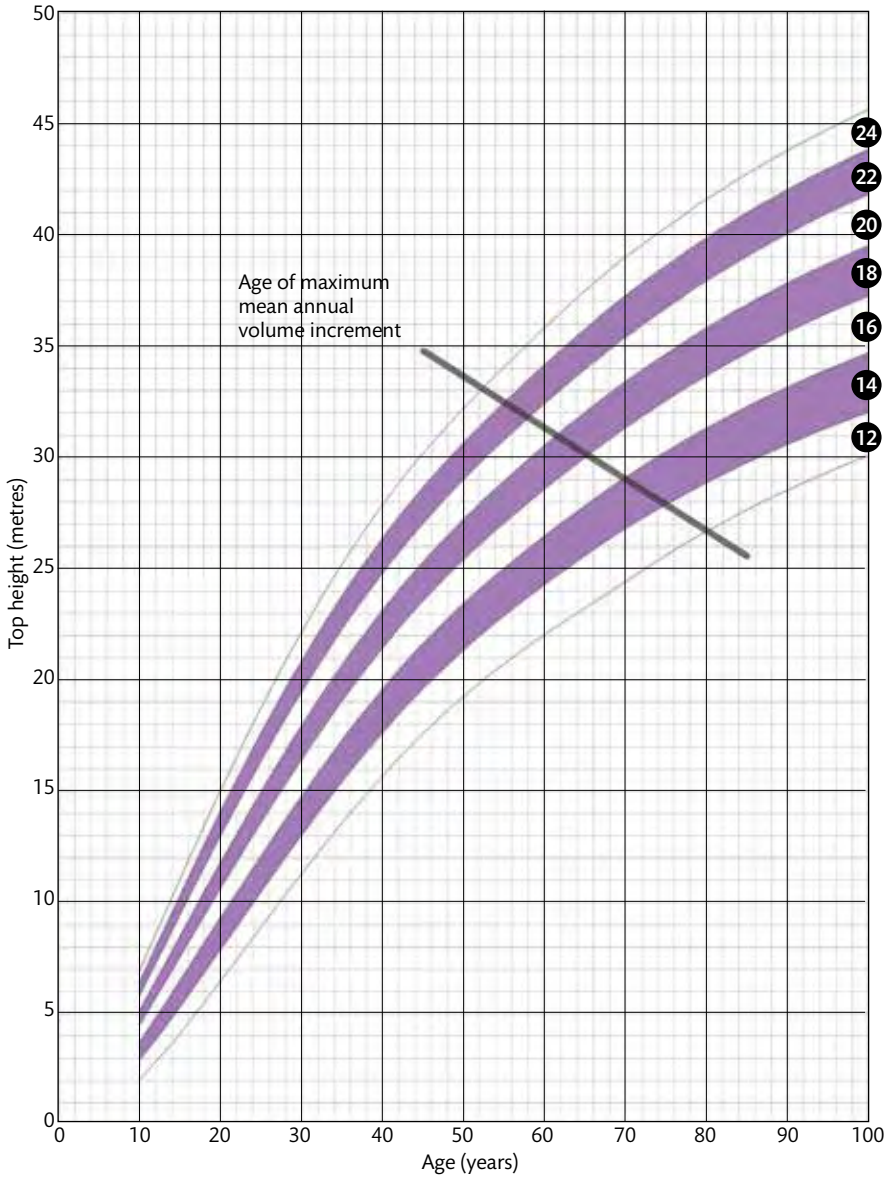
Lodgepole pine

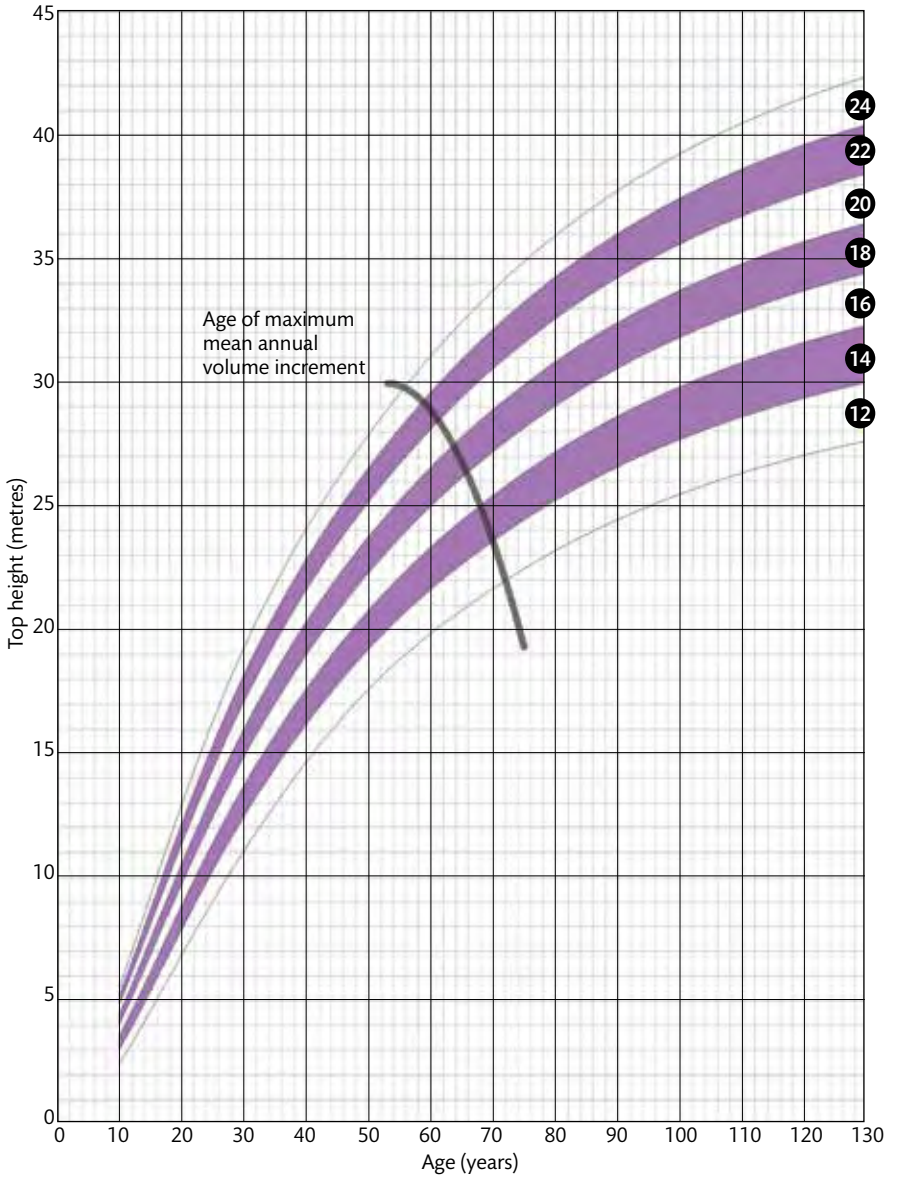Sitka spruce

Norway spruce

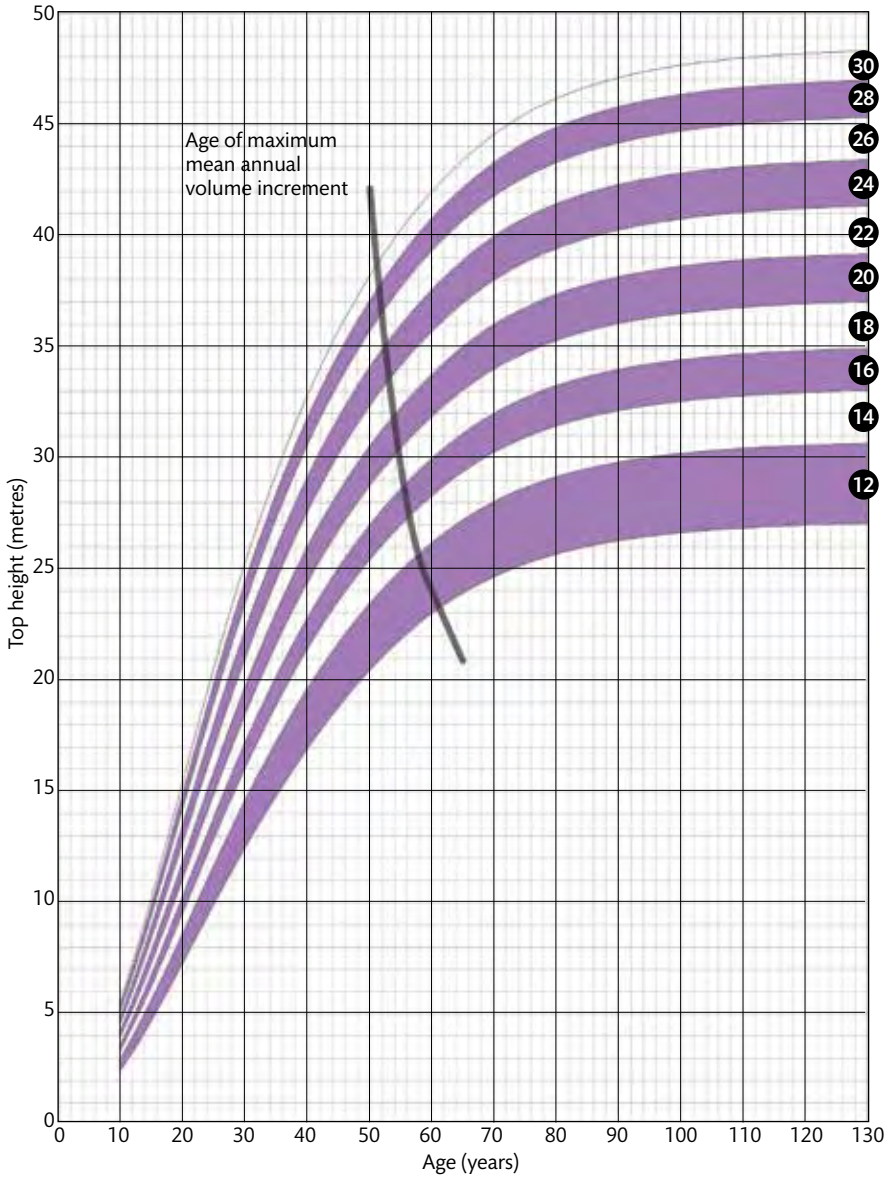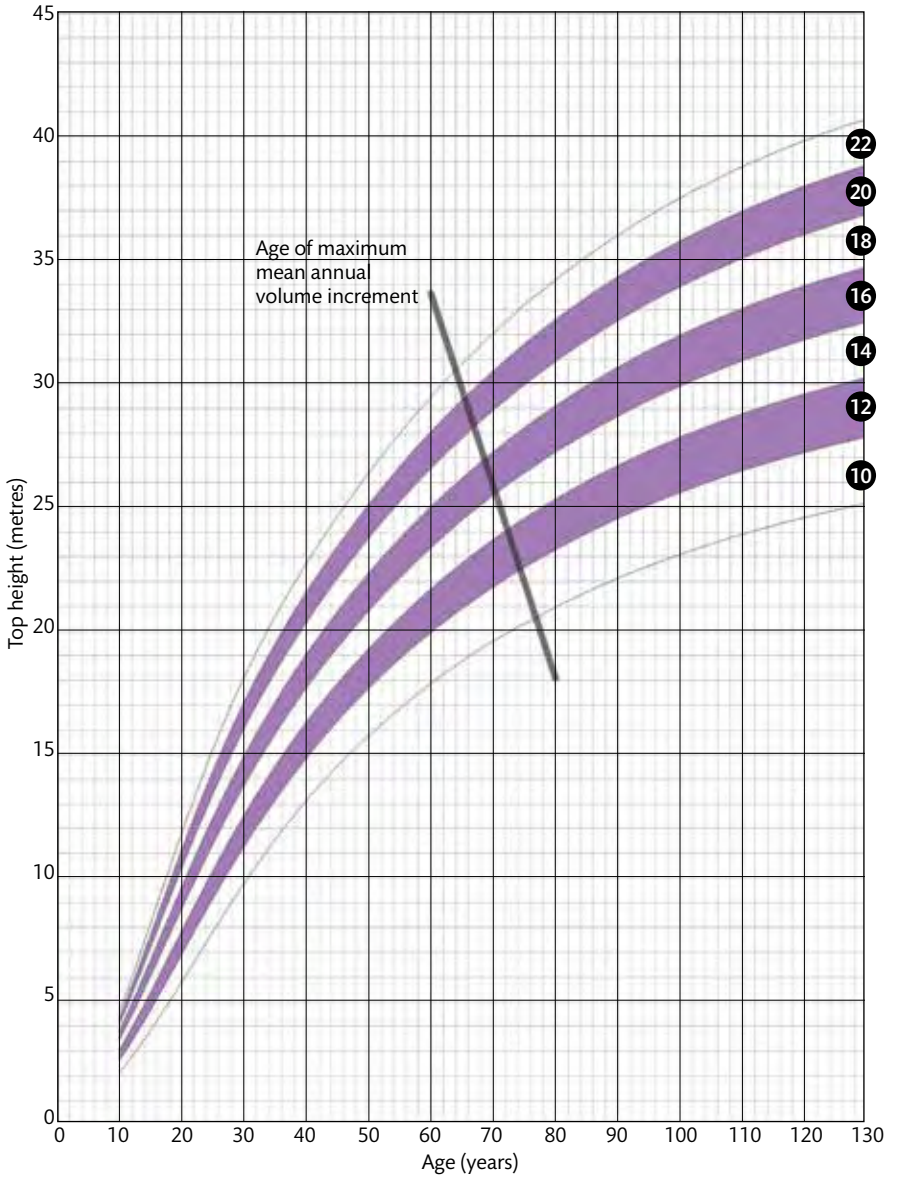European larch

Japanese and hybrid larch

Douglas fir

Age of maximum
mean annual
volume increment

Western hemlock

Age of maximum
mean annual
volume increment

Top height (metres)

Age (years)

Western red cedar and Lawson cypress

Age of maximum
mean annual
volume increment

Grand fir

Noble fir

Age of maximum
mean annual
volume increment

Y-axis: Top height (metres)
X-axis: Age (years)

Oak

Age of maximum
mean annual
volume increment

Top height (metres)

Age (years)

Beech

Age of maximum mean annual volume increment

Top height (metres) — Age (years)
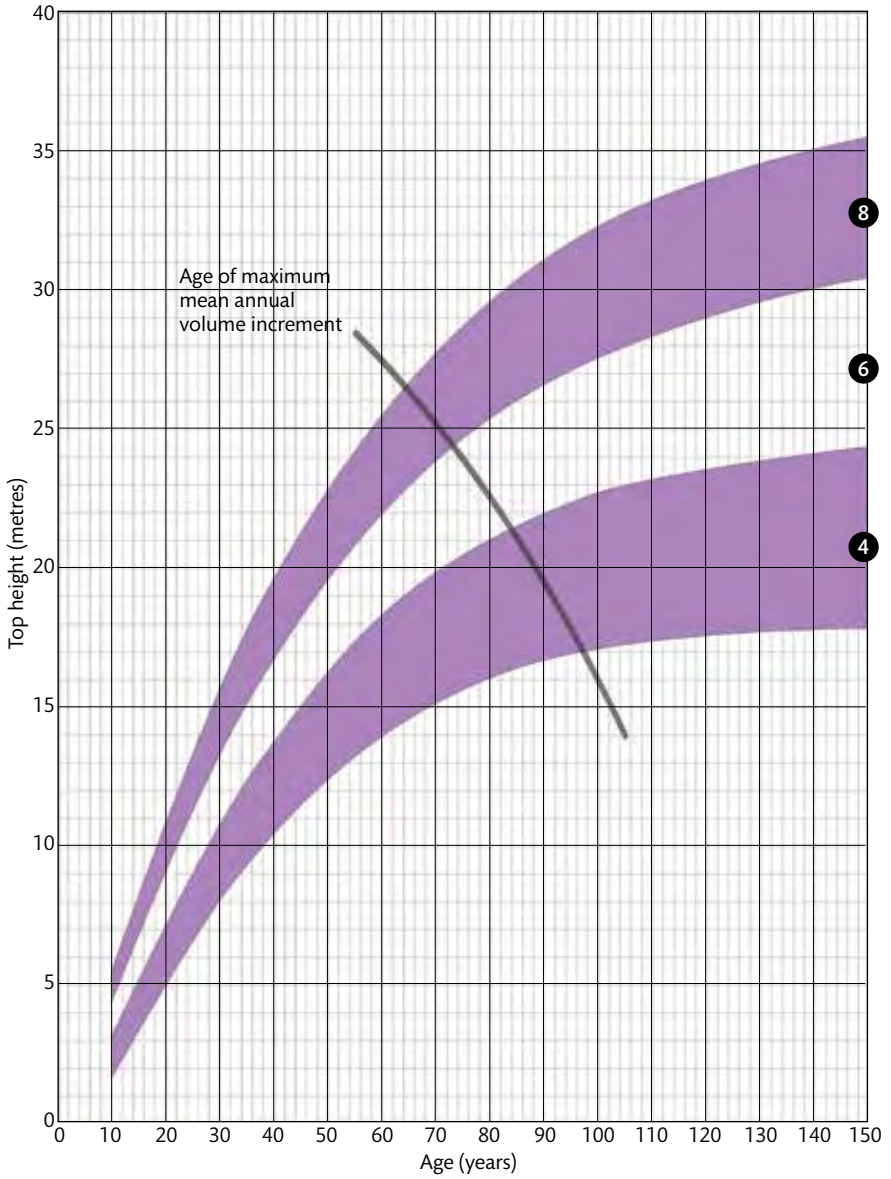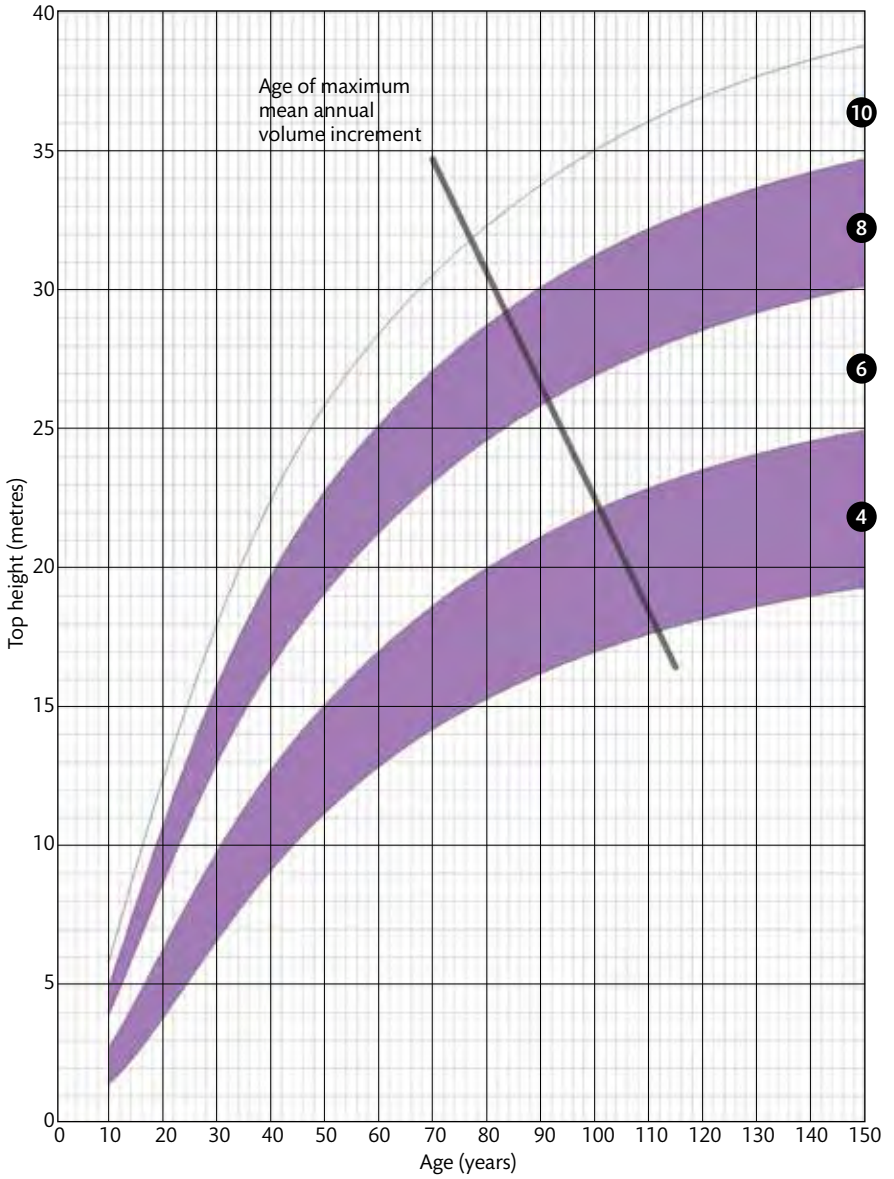
Sycamore, ash and birch

Poplar

Nothofagus

Age of maximum
mean annual
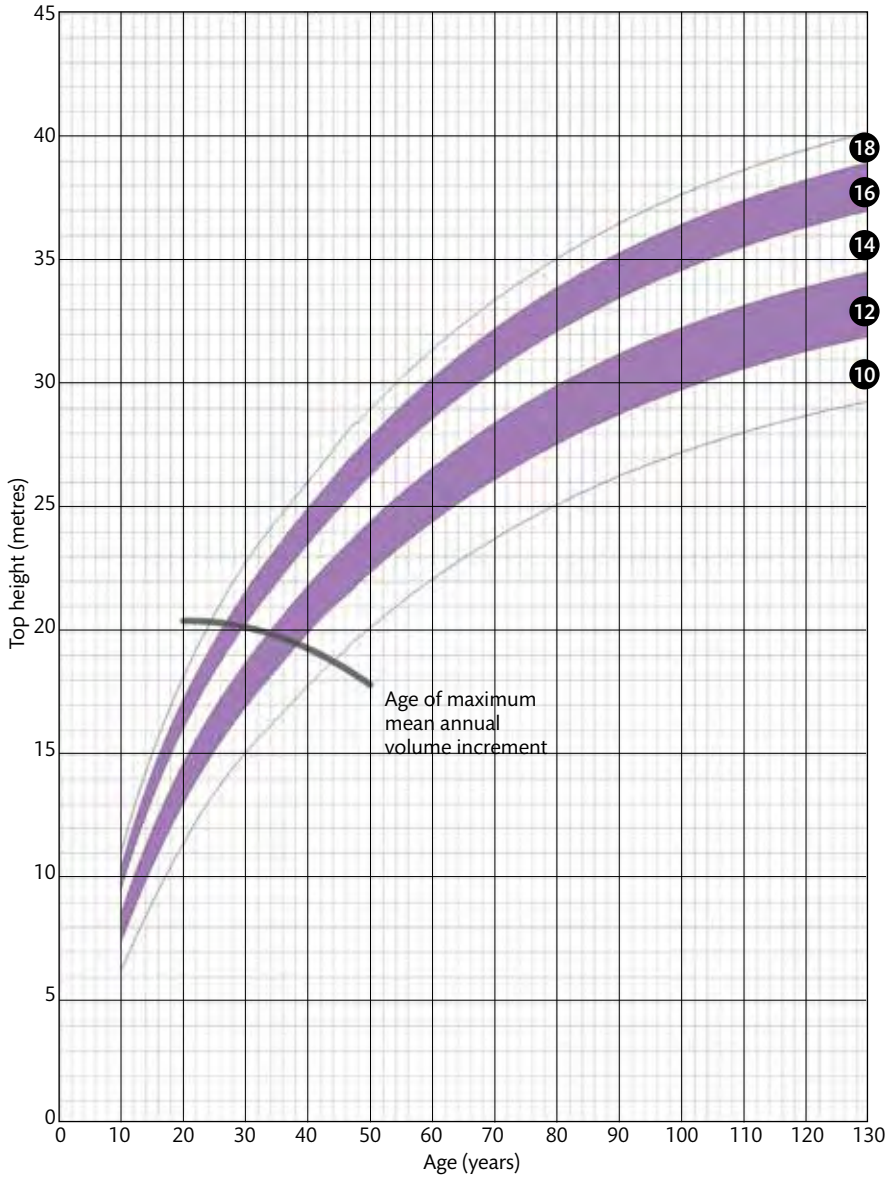volume increment
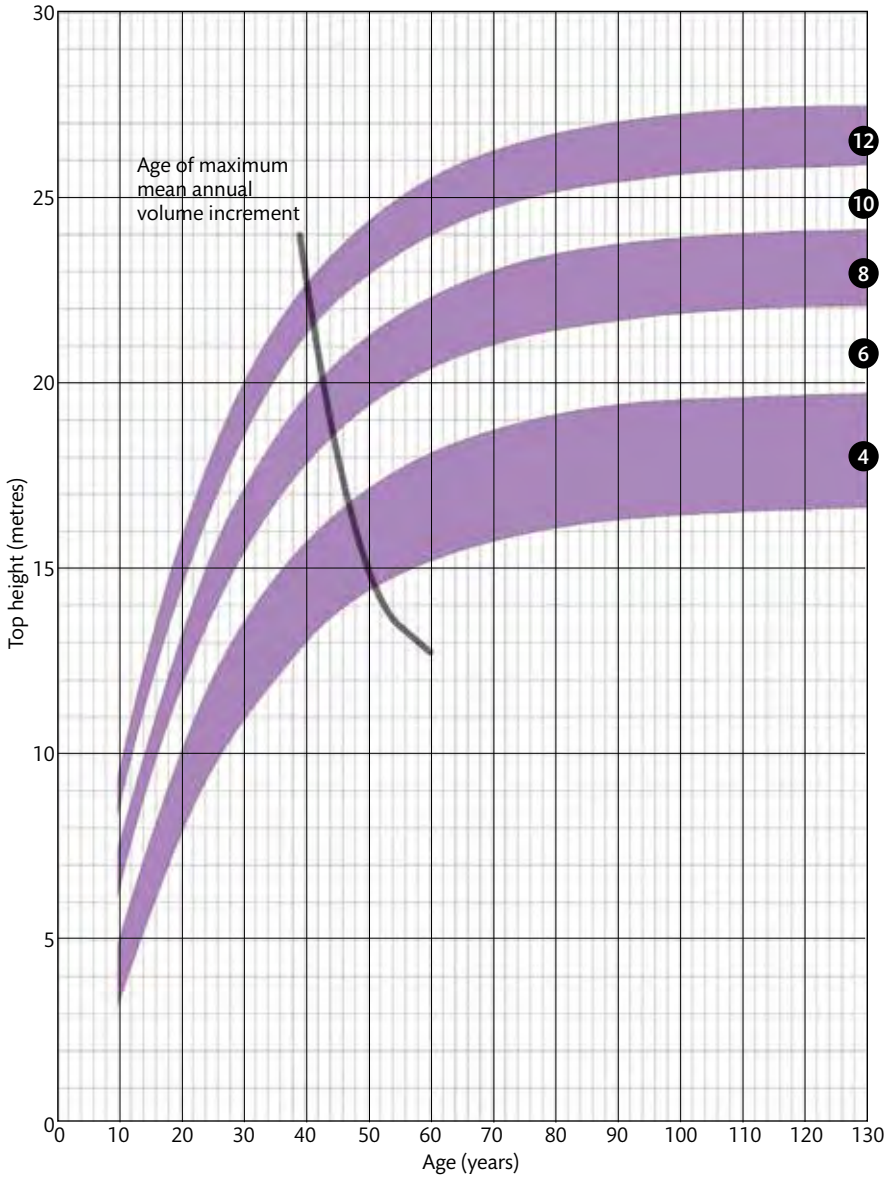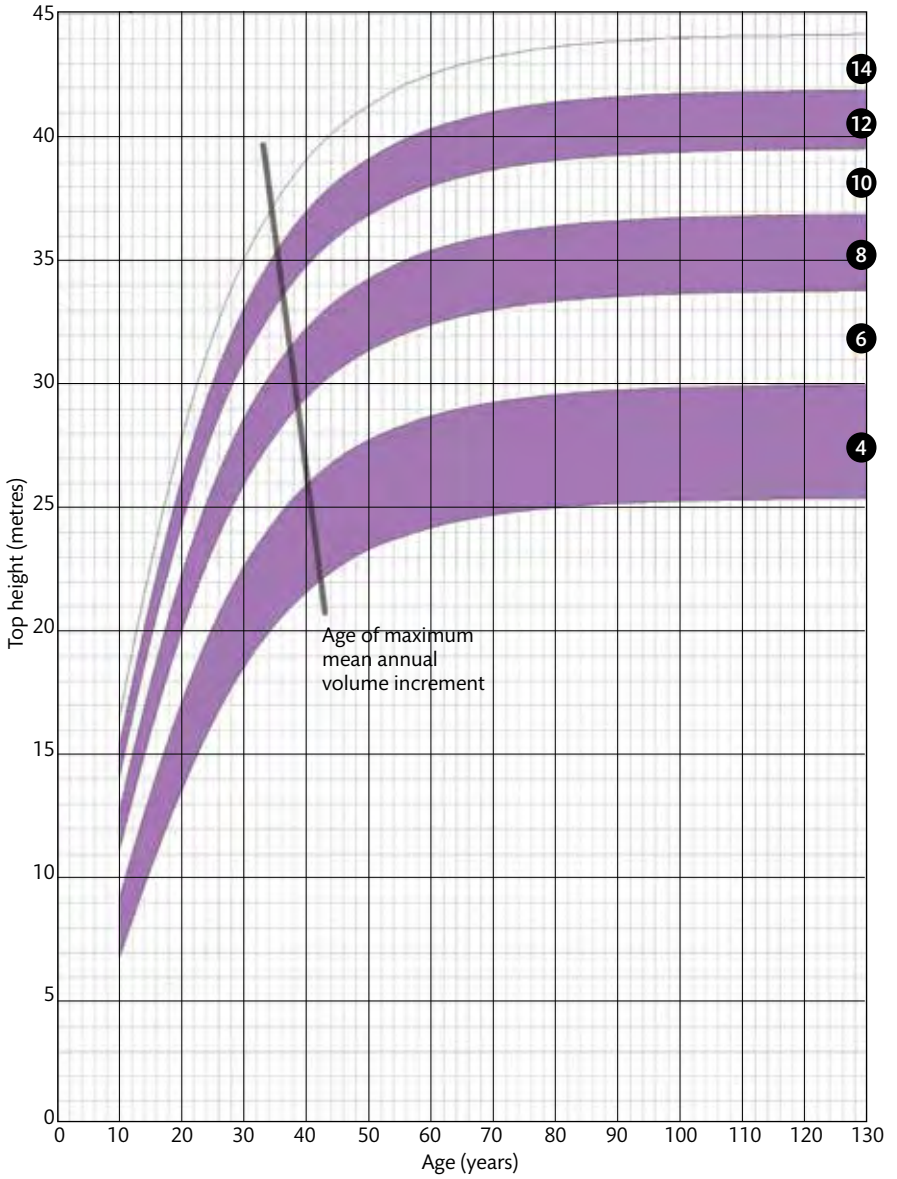
Further reading and useful sources of information

Forestry Commission publications on forest mensuration, growth and yield include:

• Forest Mensuration: a handbook for practitioners

  An essential, practice-based handbook designed to help all those working in the timber trade and forestry understand how to measure trees and timber.

Field Guides

• Timber measurement

  A concise guide emphasising the Information needed for field assessments of standing and felled timber.

• Classification and presentation of softwood sawlogs

  A guide to classifying softwood sawlogs into qualitative categories for sale purposes.

• Roundwood and sawlog volume tables

  A concise guide to the mid and top diameter methods of estimating the volume of felled timber, including volume tables based on length and mid or top diameter measurements.
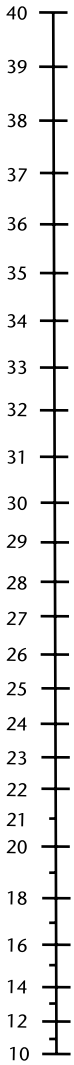
Software

Forestry Commission software for modelling forest growth and yield includes:

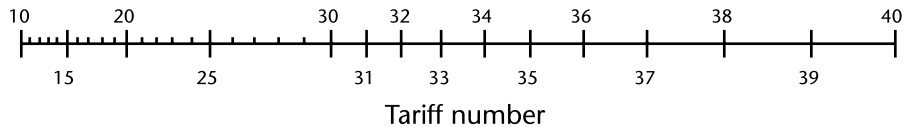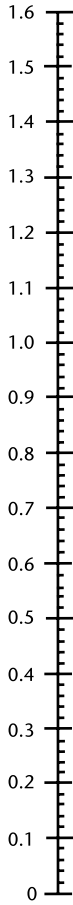• Forest Yield: a PC-based yield model for forest management in Britain.

  Forest Yield contains all of the yield tables previously published in Forestry Commission Booklet 48 *Yield models for forest management*.

dbh
(cm)

Tariff number chart

40 —
39 —
38 —
37 —
36 —
35 —
34 —
33 —
32 —
31 —
30 —
29 —
28 —
27 —
26 —
25 —
24 —
23 —
22 —
21 —
20 —

18 —

16 —

14 —

12 —

10 —

Volume
(m³)

1.6 —
1.5 —
1.4 —
1.3 —
1.2 —
1.1 —
1.0 —
0.9 —
0.8 —
0.7 —
0.6 —
0.5 —
0.4 —
0.3 —
0.2 —
0.1 —

0 —

10   20   30 32   34   36   38   40

15   25   31 33   35   37   39

Tariff number

Forestry Commission