PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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D. R. Johnston

Phil. Trans. R. Soc. Lond. B 1975 **271**, 101-114
doi: 10.1098/rstb.1975.0038

Phil. Trans. R. Soc. Lond. B. **271**, 101–114 (1975) [101]
Printed in Great Britain

Tree growth and wood production in Britain

By D. R. Johnston
Forestry Commission, Research and Development Division, Alice Holt Lodge, Wrecclesham, Farnham, Surrey

Trees are measured in cubic metres. By convention the measurement is usually over bark and to a top diameter limit. Crop growth is classified in Britain by mean annual increment classes, the classes being separated by steps of 2 m^3/ha. Thus a crop of yield class 12 will produce an average yield of 12 $m^3\ ha^{-1}\ year^{-1}$ on the rotation of maximum volume production. Yield class depends upon species, soil, climate and treatment.

The actual production of a crop depends upon yield class, initial spacing, thinning treatment and age of felling. Various characteristics of wood quality may be influenced by treatment.

The average yield class of all hardwoods in Britain is about 5 and of conifers about 10. The conifer value compares with about 3 in Scandinavia and about 18 in New Zealand.

Current annual production in Britain is $3.75 \times 10^6\ m^3$. This will rise to about $8.7 \times 10^6\ m^3$ by the year 2000.

Growth measurement

Before discussing tree growth in Britain it is necessary to explain how growth is measured. A biologist might be interested in the total dry matter production, in the carbon dioxide uptake or in the level of microbiological activity, while a landscape architect might be more interested in the height growth or spread of the crown. A forester, however, is interested in the quantity of usable wood and over the years a number of world-wide measurement conventions have become established.

Sawlogs are usually sold by volume but smaller material such as pulpwood or pitwood is often sold by weight or by diameter and length. Trees in the forest, however, are always measured by volume for the obvious reason that any other parameter is virtually impossible to measure. Even if it were possible to weigh standing trees, weight would be an unsatisfactory measure from the point of view of forest planning and management because the water content and hence the relative density of trees varies from site to site and from season to season.

For the purposes of forest planning and management the volume of the main stem alone is measured. The branches and the root system are ignored. Furthermore the stem is measured to a top diameter limit which in Britain and many other countries is 7 cm. Some new manufacturing process, however, utilize the branches, twigs and leaves in the manufacture of board material and the traditional measuring conventions may have to be modified for some purposes. The ratio of dry material in the measured stem to the total dry matter of the tree including roots and leaves varies considerably according to the species and conditions of growth. For the average conditions in Britain the ratio is about 1:1.25 excluding the root system and about 1:1.5 including the roots.

Trees in the forest are always measured overbark, again for the obvious reason that it is impracticable to measure growing trees underbark. This convention is universally accepted and when planning future wood supplies or when buying standing timber allowances are made for the volume of the bark which is generally of the order of 8–15 % of the stem volume.

To sum up, therefore, foresters in Britain as in most parts of the world measure the stems of growing trees by volume overbark to a top diameter limit of 7 cm.

Growth patterns

Like most living things individual trees show a sigmoidal growth curve. Their annual rate of growth at first accelerates, reaches a maximum and then falls off. If trees are planted in even-aged crops, as most forest trees in Britain are, the crop as a whole shows the same growth pattern. This sigmoidal curve is known as the current annual increment curve (c.a.i.)

The mean annual increment (m.a.i.) of a stand of trees is the total cumulative volume production from thinnings and standing volume or final felling divided by the age of the stand. The mean annual increment curve rises more slowly than the current annual increment curve but it continues to rise so long as the current annual increment exceeds the mean annual increment. This is illustrated in figure 1.

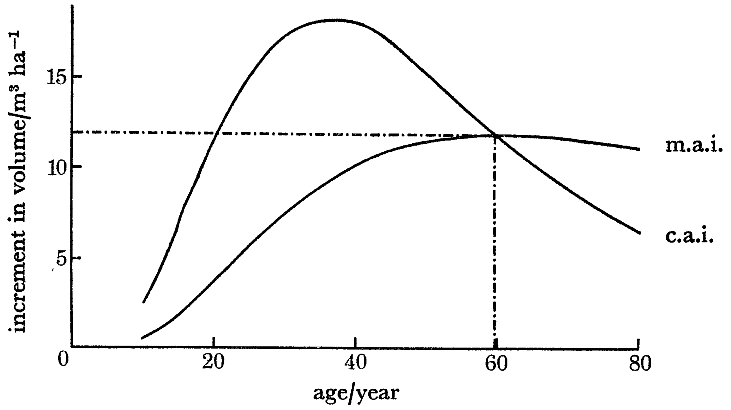

Figure 1.

Mean annual increment culminates when it equals current annual increment. Thereafter the diminishing current annual increment depresses the mean annual increment. It follows that the greatest total production from a stand will be obtained by clear felling at the age of maximum mean annual increment – for example, an average annual production of 12 m^3 at age 60 in figure 1. Although the stand will continue to increase in volume beyond age 60 there will be a greater production over time if the stand is cut at age 60 and replanted with young trees which will in turn achieve a mean annual increment of 12 m^3 in 60 years.

Different species of tree show very different growth patterns even if they have the same mean annual increments. Poplar grows very fast in early youth and the mean annual increment culminates at about 35 years. Douglas fir grows more slowly at first and Norway spruce slower still. Figure 2 shows representative mean annual increment curves for three stands each of which is assumed to have the same mean annual increment. Two rotations of this particular stand of poplar would thus produce the same total production as one rotation of the spruce stand.

Different stands of trees within a species also have different growth patterns according to their absolute rates of growth. Fast growing stands culminate earlier than those which grow more slowly. This is illustrated in figure 3.

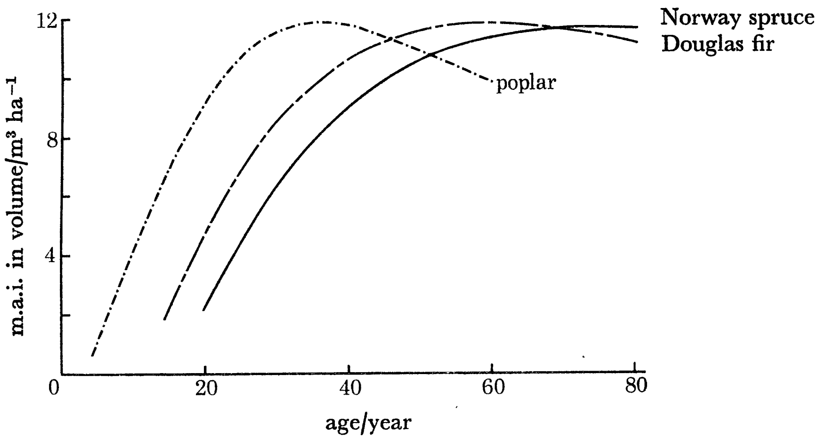

FIGURE 2. Mean annual increment curves of poplar, Douglas fir and Norway spruce.

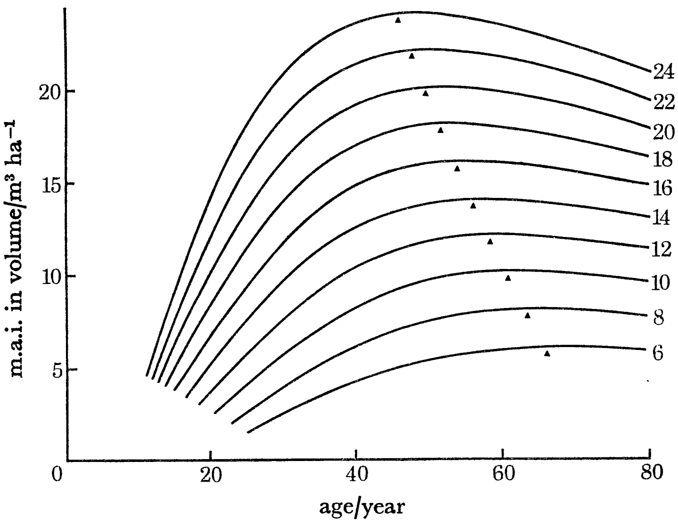

FIGURE 3. Mean annual increment curves of fast and slow growing crops.

GROWTH CLASSIFICATION

The Forestry Commission has since 1919 maintained a large number of permanent sample plots covering the principal forest species and sites in Britain. These plots which now number about 1200 are carefully managed and periodically measured. From the data so obtained each species has been classified into mean annual increment classes, the classes being separated by steps of 2 m^3/ha. For convenience the classes are referred to as yield classes. Thus a crop of yield class 12 will produce an average yield from thinning and felling, or from final felling alone if the crop is not thinned, of 12 m^3 ha^{-1} $year^{-1}$. This assumes that the crop is felled at the age of maximum volume production – that is, at the age when mean annual increment culminates.

It has been observed that there is a consistent correlation between the rate of height growth of the largest trees in a stand (by convention the mean height of the 100 largest girth trees per hectare known as the top height) and maximum mean annual increment. Height at any age can therefore be used as an easily measured index of potential volume production because the pattern of height growth with age for each yield class has been calculated for each species. The

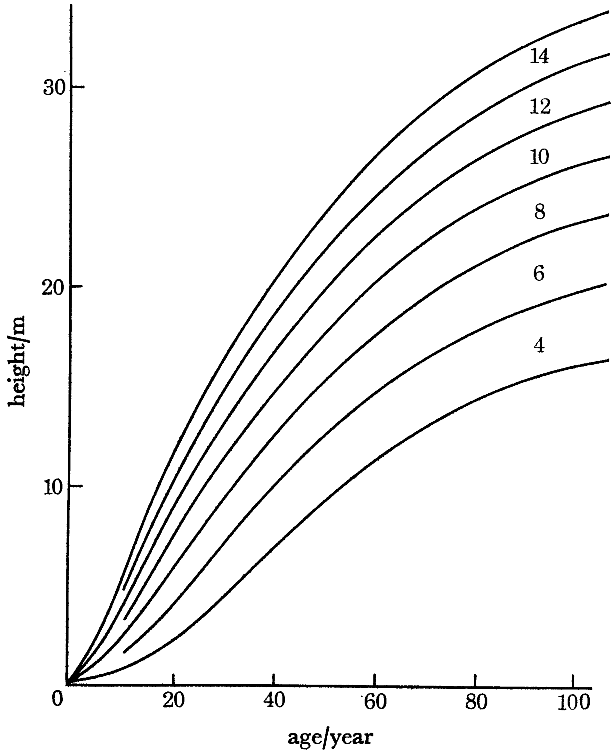

FIGURE 4. Height/age curves for Scots pine.

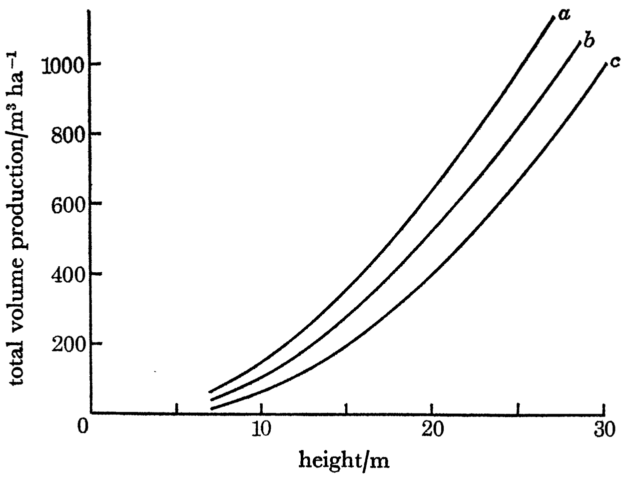

FIGURE 5. Production class curves.

yield class curves for Scots pine are shown in figure 4. Thus a Scots pine stand having a top height of 16 m at age 50 will have a yield class of 8.

It has been found, however, that there is sufficient variation in the relationship between height at any age and maximum mean annual increment to introduce an error of about plus or minus one yield class within a forest if the yield class is estimated from the height/age relation alone. But it is possible to eliminate or at least reduce this error if an estimate can be made of the total volume production at a given height. This is usually very difficult in practice, partly because it takes time to measure carefully the volume of a growing crop and partly because the volume of

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trees previously removed as thinnings may not have been reliably recorded. It is practicable, however, to make an indirect estimate by finding the mean girth of the 100 largest girth trees, the top height trees, per hectare. The relations between mean girth and total volume production have been tabulated.

If yield class is estimated from the height/age relation alone it is known as a general yield class. Each general yield class is subdivided into three production classes *a*, *b* and *c* on the basis of total volume production for a given height – figure 5. The production classes are also separated by steps of 2 m^3 ha^{-1} $year^{-1}$. If allowance is made for production class the general yield class is converted into a local yield class. Thus general yield class 12 production class *a* becomes local yield class 14. This is illustrated in figure 6.

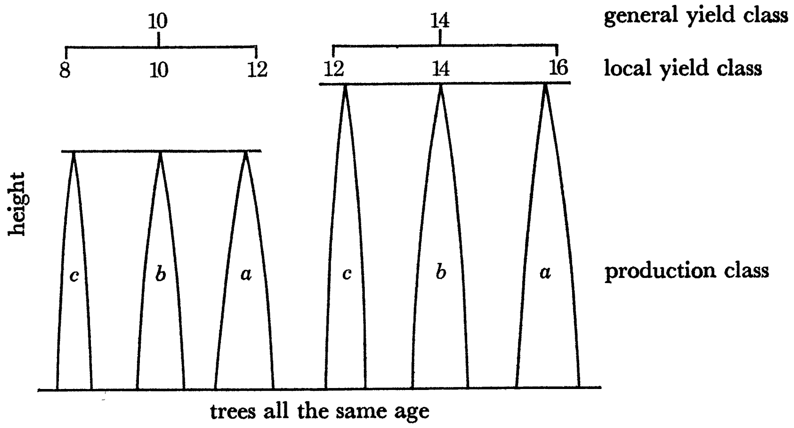

FIGURE 6. Effect of production class on general yield class.

Factors influencing growth

Yield class, like human ability, is determined partly by genetics and partly by the environment. Although the yield classes of the various species overlap there are some species which generally achieve higher yield classes than others and with few exceptions conifers have higher yield classes than broadleaves. Within species there are genetical differences and one of the objects of tree selection and tree breeding is to produce higher yielding crops. Furthermore, within a species, yield class is determined by soil and site conditions which may be influenced by the forester, and by climate.

The reasons for production class differences are less well understood. Genetics and soil or site conditions may have some influence but the principal factor appears to be elevation or exposure. Exposure to wind inhibits height growth more than diameter growth. For a given height, therefore, trees in exposed situations are likely to be larger in girth than trees on more sheltered sites. To take an extreme example, the production class of a crop is immediately increased if the tops of the trees are blown off. This is because the height is reduced but the volume affected hardly at all.

Factors influencing production

A crop of local yield class 12 will not necessarily produce an average yield of 12 m^3 ha^{-1} $year^{-1}$. The yield class tables were compiled from data obtained from crops managed according to the standard practices of the Forestry Commission. There are three aspects of management which can influence total production from a given yield class. These are initial spacing, thinning treatment and age of felling.

If trees are planted very close together they will produce a greater total volume production per hectare than trees planted wider apart. Since, however, with closer spacing there are more trees there will be more tops below 7 cm diameter and the difference in measurable volume will be less than the difference in total volume. For this reason and within the range of planting distances normally considered practicable the effect of planting distance on production is relatively small but with unusually wide spacing it becomes significant. The effect is shown in figure 7.

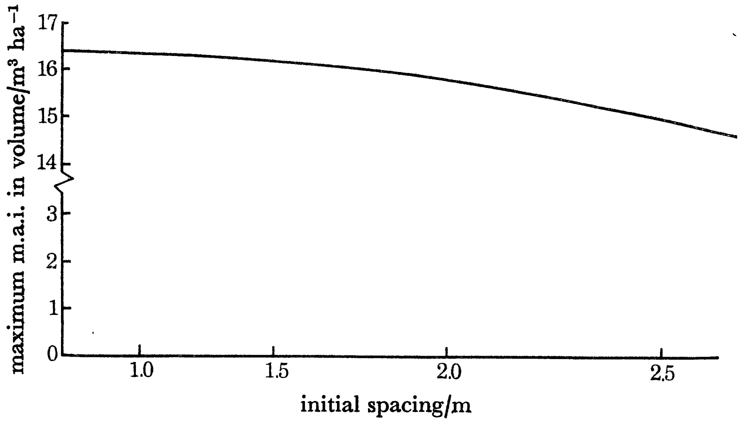

FIGURE 7. Relations between initial spacing and volume production.

It is usually worth while from an economic point of view to plant many more trees than are required for the final crop and to remove them in a series of thinnings. It is, moreover, virtually impossible to establish a young crop with the trees at a final spacing. For these reasons it is a well established practice to plant about 2000 young trees per hectare and to reduce this number to about 350 by the end of the rotation.

There are, in a thinning regime, four component factors which can influence total production. The most important of these is thinning intensity, which may be thought of in relative terms as the proportion of total production which is removed in thinning. The other component factors are the type of thinning (a description of the types of tree removed in a thinning compared with the types of tree left standing) the thinning cycle (the period between successive thinnings) and the weight of each thinning (the volume removed in each thinning). It follows that for a given thinning intensity the longer the cycle the greater the weight of each thinning.

At the risk of over-simplification, volume production will be reduced with a type of thinning in which the larger and more vigorous trees are removed in preference to the smaller ones. For a given thinning intensity long thinning cycles with, consequentially, heavier thinnings will also tend to depress total volume production.

Over the range of thinning intensities normally used in Britain total volume production does not vary greatly. If a stand is not thinned at all some of the trees will die and rot. Therefore the total merchantable volume production is increased by a low thinning intensity. With increasing intensity total production falls and this is more marked in older than in younger crops. The most economic intensity is likely to result in some loss in total production.

These relations are illustrated in figure 8. Curve A represents the relation between thinning intensity and total volume production in a young stand while curve B shows the same relation in an older stand. The dotted line C indicates in a generalized way the sort of thinning intensity usually applied in Britain while the dotted line D indicates the sort of intensity likely to be optimum on purely economic grounds. Thinning tends to be somewhat less intensive in private woods than in state forests. If crops are felled before or after the age of maximum mean annual increment the actual mean annual increment will be less than the yield class.

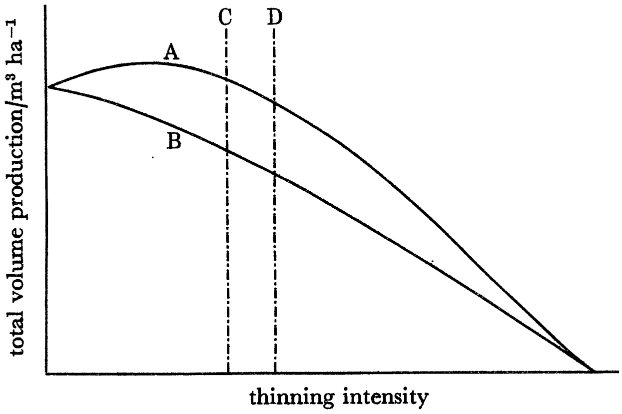

Figure 8. Relation between thinning intensity and total volume production.

Factors influencing wood quality

The treatment given to a crop influences not only volume production but also wood quality. In general, treatments which tend to depress total volume production also tend to depress wood quality. Thus, with wide initial spacing and a high thinning intensity growth is concentrated on to a smaller number of faster grown and larger trees. Since the height growth of trees is little influenced by spacing or thinning the smaller number of larger trees will have more tapered stems which size for size yield a smaller recovery of sawn timber. Faster grown trees also have larger branches and wider annual rings. Larger branches produce larger knots which are regarded as a disadvantage for almost all of the commercial uses of wood. They can only be avoided by relatively expensive pruning. In conifers, but not generally in hardwoods, density is correlated with strength and wide-ringed wood tends to be less dense than narrow-ringed wood.

Another aspect of quality is stem straightness. Many conifers will produce straight stems whether they are grown close together or far apart. Some, however, such as Scots pine together with most broadleaved species produce straighter stems if they are planted close together and thinned to a low intensity than if they are allowed to grow more freely.

There is one important aspect of quality which is enhanced by treatments which encourage faster growth and which concentrate growth on to a smaller number of larger trees. This is tree size. The larger the tree the lower the harvesting, transporting and handling costs and the higher the sawn out-turn per unit volume.

The various systems of crop management which have been evolved in Britain may be regarded as attempts to reach a realistic compromise between maximum volume production, maximum tree size and optimum quality, in order to achieve the best economic return. The more widely used regimes involve a relatively modest compromise with volume production and wood quality. It would, however, be possible to grow very much larger individual trees with a sacrifice of total volume production and wood quality.

The distribution of woodland in Great Britain

There is precise information about the distribution of species by area, age and yield class for the Forestry Commission and somewhat less precise information for the private sector. In round figures the Forestry Commission has 750000 ha of high forest plantations and about 25000 ha of scrub. The private owners have 710000 ha of high forest plantations, 30000 ha of coppice and 395000 ha of scrub about 60000 ha of which could be regarded as inferior broadleaved high forest. There are also many trees growing in hedgerows and small copses of 0.4 ha or less which are equivalent in volume to a woodland area of about 220000 ha. These trees are mostly broadleaves and they are concentrated in the southern part of Great Britain.

Of the total area of 1460000 ha of high forest, 325000 ha are broadleaved and 1135000 ha are coniferous. The Forestry Commission has 710000 ha of conifers and 40000 ha of broadleaves, while the distribution is more evenly balanced in the private sector where there are 425000 ha of conifers and 285000 ha of broadleaves. This distribution reflects the historical development of the forest estate in Britain. Apart from a relatively small area of old Crown woods such as the New, the Dean, Bere, Hazelborough and Delamere, the Forestry Commission estate has been planted since 1919 and indeed largely since 1945 with species required by industry and capable of growing successfully on poor upland sites. Most of the large area of broadleaved high forest is in the private sector in England, where it occurs on a range of sites, some of them very fertile. The distribution of forest types is shown in tables 1 and 2.

Table 1. Distribution of forest types in Great Britain (March 1973)

	10^3 ha
conifer high forest	
Forestry Commission	710
private	425
total	1135
broadleaved high forest	
Forestry Commission	40
private	285
total	325
coppice	
Forestry Commission	0
private	30
total	30
scrub	
Forestry Commission	25
private	395
total	420

By far the most important species in the broadleaved high forest is oak, which occupies almost half of the total area. Beech comes second with about 20% while ash and sycamore each occupy about 10%. The only other species which account for more than 1% of the total broadleaved area are birch, sweet chestnut, poplar and elm. Within the relatively small area of broadleaved Forestry Commission woodlands beech is rather more abundant than oak.

The two most important conifer species are Scots pine and Sitka spruce, Scots pine in the private sector and Sitka spruce in the Forestry Commission woodlands. The species which come next in importance are Lodgepole pine, larch and Norway spruce. The only other species of any importance are Corsican pine and Douglas fir. The distribution of species by area is shown in table 3.

Table 2. Distribution of forest types by countries (March 1973)

	10^3 ha			
country	conifer	broadleaved	coppice	scrub
England	370	265	30	235
Scotland	615	35	—	140
Wales	150	25	—	45
total	1135	325	30	420

Table 3. Distribution of high forest species in Great Britain (March 1972)

	10^3 ha		
species	private sector	Forestry Commission	total
Scots pine	148	112	260
Corsican pine	11	35	46
Lodgepole pine	16	75	91
Sitka spruce	78	280	358
Norway spruce	54	78	132
European larch	40	14	54
Japanese and hybrid larch	45	60	105
Douglas fir	20	30	50
other conifers	13	26	39
total conifers	425	710	1135
oak	140	15	155
beech	43	16	59
other broadleaves	102	9	111
total broadleaves	285	40	325
total	710	750	1460

There is a fairly clear regional distribution of species. The spruces are planted mainly in the wetter parts of the country – that is, in the north and west. Scots pine is ubiquitous but is concentrated in the northeast. Corsican pine is mainly restricted to the eastern and southern parts of England. Lodgepole pine is planted in the more exposed areas, particularly in the north and west of Scotland. Larch is found all over the country on the better drained sites while Douglas fir is concentrated on the better sites of the south and west.

A large part of the hardwood high forest is in the southern half of England. There are, however, large areas of birch scrub in Scotland. Table 4 shows the area distribution of the major species in England, Scotland and Wales.

It can be seen from the pattern of recent planting that the proportions of species are changing with time. For a number of decades both the Forestry Commission and the private owners have been planting many more conifers than broadleaves. For example, for the years 1971–3 the Forestry Commission planted 77000 ha of conifers and 1000 ha of broadleaves, while the private owners planted 68000 ha of conifers and 3500 ha of broadleaves. The areas and proportions of the principal species are shown in table 5.

Within the spruces and pines there were significant differences between the Forestry Commission and the private owners. Sitka spruce and Lodgepole pine were the principal species in the Forestry Commission whereas in the private sector Norway spruce, Scots pine and Corsican pine were relatively more important.

The age-classes of the tree crops in Britain are very unbalanced, about 70% of the conifers being less than 33 years old and about 60% of the broadleaves being more than 75 years old. The distribution of crops by planting years is shown in tables 6 and 7.

TABLE 4. DISTRIBUTION OF HIGH FOREST SPECIES BY COUNTRIES (MARCH 1972)

species	England (10^3 ha)	Scotland (10^3 ha)	Wales (10^3 ha)	Great Britain (10^3 ha)
Scots pine	95	157	8	260
Corsican pine	38	4	4	46
Lodgepole pine	12	72	7	91
Sirka spruce	58	234	66	358
Norway spruce	49	62	21	132
European larch	34	17	3	54
Japanese and hybrid larch	34	49	22	105
Douglas fir	29	10	11	50
other conifers	21	10	8	39
total conifers	370	615	150	1135
oak	131	11	13	155
beech	48	7	4	59
other broadleaves	86	17	8	111
total broadleaves	265	35	25	325
total	635	650	175	1460

TABLE 5. AREAS AND PROPORTIONS OF SPECIES PLANTED IN GREAT BRITAIN FROM 1971 TO 1973

species	Forestry Commission: area (10^3 ha)	Forestry Commission: %	private owners: area (10^3 ha)	private owners: %
spruces	47.7	61	34.0	48
pines	20.0	25	20.0	28
larches	3.9	5	6.8	9
Douglas fir	2.3	3	3.4	5
other conifers	3.1	4	3.4	5
broadleaves	1.0	2	3.5	5
total	78.0	100	71.1	100

TABLE 6. AGE-CLASS DISTRIBUTION OF CONIFERS IN GREAT BRITAIN (MARCH 1973, 10^3 ha)

	planting years: post-1970	1961–70	51–60	41–50	31–40	21–30	11–20	01–10	pre-1900
F.C.	64	220	220	87	70	44	2	1	2
private	65	142	105	26	30	32	9	6	10
total	129	362	325	113	100	76	11	7	12

TABLE 7. AGE–CLASS DISTRIBUTION OF BROADLEAVES IN GREAT BRITAIN (MARCH 1973, 10^3 ha)

	planting years								
	post-1970	1961–70	51–60	41–50	31–40	21–30	11–20	01–10	pre-1900
F.C.	1	4	13	6	5	2	1	1	7
private	4	10	12	10	10	13	16	24	186
total	5	14	25	16	15	15	17	25	193

THE GROWTH RATES OF FOREST CROPS IN GREAT BRITAIN

Britain has a relatively favourable climate for tree growth. The average yield class for all conifers is about 9.5 and for all broadleaves about 5.0. The conifer yield class compares with a Scandinavian average of about 3.5 and a New Zealand average of about 18.0 for their plantations of *Pinus radiata*. In some of the long established and well managed broadleaved forests in France and Germany beech achieves an average yield class of about 7 and oak of about 5. Tropical high forests composed entirely of broadleaved species have yield classes of about 5–10 but the utilizable production is very much less. The yield class of Malayan dipterocarp forests may, in some areas, be as high as 22. Higher yield classes are found in conifer plantations on favourable sites in tropical regions, where such genera as *Agathis*, *Araucaria*, *Cupressus* and *Pinus* can achieve yield classes of up to 50. Eucalyptus plantations can reach yield classes of up to 60 on very favourable sites.

There is considerable variation in yield class both between and within species. Among the conifers spruce, Corsican pine and some less commonly planted species such as Douglas fir and Grand fir have higher average yield classes than Scots pine, Lodgepole pine or the larches. Among the broadleaves, beech has a higher average yield class than oak. The average yield classes of the various species in Forestry Commission and private woodlands are shown in table 8.

The differences in yield class between the Forestry Commission and the private sector are not very significant. The private sector yield classes are given in whole numbers because there

TABLE 8. AVERAGE YIELD CLASSES IN GREAT BRITAIN

species	Forestry Commission	private	G.B.
Scots pine	7.9	8	8.0
Corsican pine	11.2	11	11.2
Lodgepole pine	6.7	—	6.7
Sitka spruce	11.2	13	11.5
Norway spruce	11.4	11	11.2
European larch	6.7	7	6.9
Japanese and hybrid larches	8.3	9	8.6
Douglas fir	12.9	14	12.4
other conifers	13.4	8	11.5
total conifers (weighted average)	10.0	9	9.6
oak	4.2	4	4.0
beech	5.7	6	5.9
other broadleaves	4.7	5	5.0
total broadleaves (weighted average)	4.9	5	5.0
total all species (weighted average)	9.7	7	8.3

is less precise information about them. In general, the private woods tend to be on better sites but the proportions of the higher yielding species such as Corsican pine and Sitka spruce are lower.

There is a regional pattern of growth rates in Britain. In general, growth within species is better in the south and west than in the north and east. Average yield classes are therefore higher in England and Wales than in Scotland. The average Forestry Commission yield classes of the various species in England, Scotland and Wales are given in table 9.

It can be seen from table 10 that in the Forestry Commission estate the highest average yield classes for all species except Corsican pine are found in southwest or southeast England. Corsican pine achieves its highest average yield class in east England. There is a similar pattern

Table 9. Average forestry commission yield classes in England, Scotland and Wales

species	England	Scotland	Wales
Scots pine	10	7	8
Corsican pine	12	7	9
Lodgepole pine	7	7	7
Sitka spruce	11	11	11
Norway spruce	11	11	12
European larch	7	6	7
Japanese and hybrid larch	9	7	10
Douglas fir	13	12	13
other conifers	14	11	14
all conifers (weighted average)	11	9	11
oak	4	4	4
beech	6	4	5
other hardwoods	5	4	5
all hardwoods (weighted average)	5	4	5
all species (weighted average)	10	9	11

Table 10. Distribution of average forestry commission yield classes by conservancies

	England					Scotland				Wales	
species	NW	NE	E	SE	SW	N	E	S	W	N	S
Scots pine	9	**8**	10	**11**	10	7	7	7	7	8	8
Corsican pine	11	9	**13**	12	10	6	6	8	6	9	9
Lodgepole pine	7	6	9	**10**	9	7	6	7	7	7	7
Sitka spruce	11	10	11	13	**14**	10	11	11	12	12	11
Norway spruce	12	10	11	**13**	**13**	11	10	12	12	12	12
European larch	7	7	7	**8**	**8**	6	6	6	7	6	9
Japanese and hybrid larches	9	7	**8**	**11**	**11**	7	6	8	8	9	10
Douglas fir	**15**	10	11	13	**15**	13	11	12	11	13	14
other conifers	15	12	13	15	**16**	8	11	11	13	14	14
total conifers (weighted average)	10	9	11	12	**13**	8	8	10	11	11	11
oak	4	4	4	4	4	4	4	4	3	4	5
beech	5	5	5	**6**	**6**	4	5	4	4	5	5
other bıoadleaved	4	4	4	5	**6**	3	5	4	4	5	6
total broadleaved (weighted average)	5	4	4	5	5	4	5	4	4	5	5
total all species (weighted average)	10	9	10	10	11	8	8	10	11	11	11

in the private woodlands except that the highest yield classes of the larches are recorded in east Scotland. The relatively large areas of broadleaves in southwest and southeast England reduce the weighted average yield class for all species in these two regions.

The highest yield class recorded in Britain is 32 for a stand of Grand fir but it can be seen from table 11 that yield classes above 20 are rare. About 87 % by area of all the conifers have yield classes between 6 and 14 and about 84 % by area of all broadleaves have yield classes between 4 and 6. There are, however, a few broadleaved stands of poplar and southern beech, *Nothofagus procera*, with yield classes of about 18 or 20.

Table 11. Percentage distribution of yield classes within species in forestry commission woodlands (10^3 ha)

species	yield class 28	26	24	22	20	18	16	14	12	10	8	6	4	2
Scots pine	—	—	—	—	—	—	0.1	2.0	8.4	23.0	28.0	28.0	9.0	1.5
Corsican pine	—	—	—	—	0.3	2.1	10.0	18.0	22.0	22.0	17.0	6.0	2.3	0.3
Lodgepole pine	—	—	—	—	—	—	—	0.2	1.2	6.0	32.3	45.3	14.0	1.0
Sitka spruce	—	0.1	0.1	0.3	0.8	2.5	5.3	13.1	27.0	31.0	13.0	5.6	0.9	0.3
Norway spruce	—	—	—	0.3	1.0	3.0	8.0	17.5	24.1	24.2	15.5	5.0	1.1	0.3
European larch	—	—	—	—	—	—	—	—	3.2	12.0	30.0	31.0	18.2	5.6
Japanese and hybrid larch	—	—	—	—	—	—	0.5	5.0	12.0	21.0	27.0	23.0	10.0	1.5
Douglas fir	—	—	0.3	0.7	2.3	6.0	15.0	24.0	25.0	19.0	6.0	1.4	0.3	
other conifers	0.4	0.4	1.0	2.4	4.4	9.0	14.5	25.0	18.5	9.0	7.0	5.0	3.0	0.4
total conifers	0.02	0.04	0.1	0.24	0.7	1.9	4.7	10.5	18.0	23.0	20.0	15.0	5.0	0.8
oak	—	—	—	—	—	—	—	—	—	—	1.5	15.5	73.0	10.0
beech	—	—	—	—	—	—	—	—	—	1.9	15.2	50.0	31.0	1.9
other broadleaved	—	—	—	—	—	—	—	—	1.1	2.3	7.0	24.0	55.0	10.6
total broadleaved	—	—	—	—	—	—	—	—	0.2	1.3	9.0	31.0	52.0	6.5
total all species	0.02	0.04	0.44	0.2	0.7	2.0	4.1	10.0	17.0	22.0	18.5	16.0	8.0	1.0

Present and future production

The total volume of wood harvested in Great Britain in 1973 was 3 720 000 m³. This amounted to 7.8 % of total consumption, the round wood equivalent of which was 48 000 000 m³. Production from the existing estate will rise steadily until after the end of the century. It is expected to be about 8 700 000 m³ by 2000, by which time consumption is expected to have risen to about 82 000 000 m³. By that date, therefore, home production will account for about 10.5 % of total consumption.

It can be seen from table 12 that the hardwood production is likely to remain constant in the future at about 1 400 000 m³ per annum while the softwood production is expected to rise from 2 370 000 m³ in 1973 to about 7 300 000 m³ in 2000. Most of this increase will come from the large area of post-war Forestry Commission plantations which are not yet in production.

The sustained yield from the existing forest estate depends upon future treatment and management but would be something of the order of 10 000 000 m³/year. Actual levels of production in the more distant future will depend also upon the extent of future new planting. Forecasts of consumption in the more distant future are very uncertain but on present evidence it seems unlikely that home production in the foreseeable future will ever provide more than about 12 % of total consumption.

TABLE 12. PRESENT AND PREDICTED CONSUMPTION AND PRODUCTION (10^6 m^3)

	production			
	actual	predicted		
	1973	1980	1990	2000
Forestry Commission				
softwood	1.56	2.50	3.90	5.40
hardwood	0.04	0.05	0.05	0.05
total	1.60	2.55	3.95	5.45
private sector				
softwood	0.81	1.10	1.50	1.90
hardwood	1.31	1.35	13.5	1.35
total	2.12	2.45	2.85	3.25
Great Britain				
total home production	3.72	5.00	6.80	8.70
total consumption (round wood equivalent)	48.00	57.00	70.00	82.00

Discussion

P. J. WOOD (*Department of Forestry, University of Oxford*)

Mr Johnston has quoted us some very impressive figures for the yields from tropical plantations and 50 or even 60 m^3/ha are attainable on many sites. Some countries, such as New Zealand, will undoubtedly manage to retain large areas of the fertile well-watered sites that are capable of these yields for a very long time to come. In other countries, however, particularly those in the tropics with rapidly growing populations, such as Kenya and Tanzania, the volcanic highlands will be in demand for permanent agriculture and it is difficult to see how large scale forestry can avoid being pushed into the drier less productive areas. If this happens, the *average* yields that are attained will be rather lower, and much closer to the *maximum* yields that can be obtained in Britain, i.e. 20–25 m^3 ha^{-1} year^{-1}.

In answer to a question from Mr Johnston on the expected yields of *Gmelina arborea* plantations, these were put at 25–35 m^3 ha^{-1} year^{-1} with most areas in Nigeria in this range.

G. D. HOLMES (*Forestry Commission, 25 Savile Row, London W1X 2AY*)

Mr Johnston has described the features of the growth of species in pure stands. Is it possible by an admixture of tree species of the same or different age to increase the wood volume produced per unit area of land?

MR JOHNSTON replied that there is no evidence that the yield from an even or uneven aged mixed stand is any different from the weighted average yield obtained from pure stands of the species comprising the mixture.