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STUDIES ON BRITISH BEECHWOODS

LONDON: HER MAJESTY'S STATIONERY OFFICE

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1953

FOREWORD

This bulletin presents the results of a comprehensive survey of British beechwoods carried out by Mr. J. M. B. Brown, B.Sc., during the years 1948 to 1950. The importance of the beech in our woodlands is generally realised, and it is hoped that these studies will prove of value to all concerned with its silviculture.

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Chapter 1

HISTORY OF BEECH IN BRITAIN

THE EARLIEST extant mention of *Fagus*, or beech, in Britain was the negative record of Julius Caesar (*De Bello Gallico*, V.12) who observed that *Fagus* did not occur in Britain. Insofar as Caesar's expedition must have covered much territory where beech is and has long been a common tree, his evidence about the status of beech in England at first carried some weight. But Elwes and Henry (1906) have suggested that *Fagus* to Caesar probably meant the sweet chestnut, which doubtless provided a useful supplement to the food of the Roman soldier. It is widely believed by botanists that beech in Britain is indigenous in the Southern counties only and reaches its western natural extent in the woods on Carboniferous limestone flanking the Wye in Gloucestershire. There is, however, considerable evidence from the examination of pollen in post-glacial peats that beech occurred in the midlands and eastern England some 4,000 years ago in Sub-Boreal times and that it, therefore, spread to these areas by natural means (Godwin, 1940). There is some evidence too that beech is a natural immigrant into South-east Wales. Beech occurs there with some frequency on the outcrops of Carboniferous limestone and Old Red Sandstone and, in the *Flora of Glamorgan* (Trow, 1911), beech in this locality is declared to be "clearly native".

In his recent survey, the present writer noted one wood of beech in mixture with hardwoods at Ruperra (Mon.) which had many of the characters of natural beechwood. Elsewhere the beechwoods recorded in Wales, Scotland and the northern and midland counties of England had every appearance of an origin by planting. The uniformity of age, the frequent relics of a coniferous nurse, and the absence of seral stages suggested an artificial origin. On soils derived from calcareous parent materials, the profile was commonly shallow and rich in free calcium carbonate, with little sign of the leaching of the chalk and development towards a brown forest soil that might be expected under centuries-old beechwood. In no case did place names or other local records testify to a local refuge of natural beechwood. There are, nevertheless, some suggestive place names of Saxon origin in the north and west of Britain, e.g., Buxton, Bickleigh.

Such evidence about extant beechwoods does not of course settle the question whether beech has spread naturally beyond the southern counties of England. But it does strongly suggest that in most parts any natural beechwoods were swept away when forests were cleared. Because of the poor regeneration from the stool and of the preference given to the more valuable oak and ash, beech would have suffered most in deforestation. Here and there ravines, or steep escarpment slopes, of the limestone formations, offered refuge; but, even on these sites, the increase of the rabbit in the past century may have prevented the beech from maintaining itself. It may be noted that much of the existing beech on the South Downs appears to have been planted. Uniformity of age for large areas of beech on an estate, and the relics of former mixture with larch or pine point in that direction: while the relative immaturity of the soil appears to indicate that the plantations were made on land which had long been cleared of trees even if it had been under beechwood in olden times.

In this connection a distinction may be drawn between the dip slopes and the steep escarpment slopes. In general, the escarpment slopes were too steep for cultivation and natural beechwood, in which ash, yew and whitebeam are often conspicuous, covers many of these slopes to this day. The dip slopes of the chalk in the Goodwood area of Sussex and the chalk plateau of Hampshire are dissected by many dry chalk valleys where natural beechwood, accompanied by stages in the succession from chalk grassland, occurs frequently—or did so until much was clear-felled in the past 35 years. On the Oolitic limestone of the Cotswold Hills a very similar distribution of planted and apparently natural beech can be traced. Woods that show the character of natural beechwood are common along the escarpment slopes from Chipping Sodbury to Cheltenham in Gloucestershire, being conspicuous in the narrow steep-sided valleys which are a feature of this region. On the contrary the Cotswold plateaux and the gentler slopes have long been under agriculture, and beech occurs almost exclusively as a planted tree. There are some extensive beechwoods planted about 150 years ago and numerous shelter belts and small clumps on the exposed plateaux.

The third main area of beech in Britain has a different character. In the Chiltern Hills, there has been deforestation for agriculture in past times and some existing woods are known to have been sown or planted. But the method of management by selection and natural regeneration is of old standing, applying equally to the plateaux and chalk slopes. Thus the Chilterns area appears to differ from the Cotswolds and the chalk downs south of the Thames in that natural beechwood is not more or less restricted to steep escarpment slopes and valley sides which were unsuited to tillage, but occupies a large area of the plateau and the gentler dip slopes to the south-east. One reason for this may be the sticky flinty nature of the soil on the Chilterns plateau. There is, however, evidence that some of the beechwoods were artificially established and there is the possibility that considerable areas of what is now beechwood on the Chiltern Hills were at one time pasture or arable. In any case the Chiltern beechwoods appear to offer the only large area where the climax beechwood soil can be seen: in other localities natural beechwood is mainly found on steep chalk or limestone slopes, where erosion delays or hinders the natural evolution of the soil from rendzina towards a brown forest soil.

The replanting with beech of many long-denuded areas in the Southern counties and the remarkable extension of beechwood to Northern England and Scotland were due to a variety of causes. The latter half of the eighteenth and the early years of the nineteenth century were times of great tree-planting activity in England and in Scotland. Enclosure of common lands, the lay-out, or expansion, of country estates, the serious shortage of timber, and agricultural depression, all fed this zeal for planting trees. Beech often contributed little to these new forests and in general appears to have been planted much more for amenity than for profit. But there was evidently a great vogue for the planting of ornamental woods and shelterbelts of beech. In England this interest in beech was most noteworthy in the second half of the eighteenth century and may have owed much to the architect of the gardens of Versailles and his English copyists. The south and east of the country were more affected than the North-west, but the planting of beech was not restricted to calcareous soils. Many more English beechwoods date from the first half of the nineteenth century, but there appears to have been very little beech planting between 1850 and the first world-war.

In Scotland most of the existing stands of beech were planted also at this time, i.e., between 1750 and 1830; but Walker (quoted by Watt, 1931) states that beech was widely planted in Scotland in the middle of the seventeenth century, while a few specimens were planted one hundred years earlier. A few existing stands are nearly 250 years old. These Scottish beech plantations were mainly restricted to the policy woods adjacent to the great houses and frequent shelterbelts for farmlands in exposed places. Little consideration appears to have been given to the edaphic needs of the tree and in some instances podsolic heath sands were planted. Scottish beech is, however, largely concentrated in the eastern half of the country, though there are several considerable stands in the south west and a few in the far north. As in England, beech planting in Scotland was practically suspended after 1840 and only on a few estates in the border counties has beech been planted much in recent years. A small area of sub-spontaneous beech twenty to thirty years old was examined near Elgin: there are more such, but the prevalence of rabbits, in alliance with adverse climatic and edaphic factors, greatly restrict the possibilities of beech regeneration (Watt, 1931). In Wales beech has not been planted on any large scale, but there are considerable areas of beechwood in the counties near the English border. These generally range in age from 120 to 200 years, or slightly more, but there are also some young plantations. The likelihood that some beechwoods in south-east Wales are spontaneous was noted above.

It may be concluded from this review that, outside the southern counties of England, of the natural beechwood which once existed very little outlived the period of deforestation for agriculture. If there are such relict beechwoods in the midlands and north of England they are probably to be found as small patches in steep-sided limestone valleys. Small areas of sub-spontaneous beech occur in most parts of Britain and fertile seed is set in the far north of Scotland. There is no firm evidence that, until the extensive plantings of the last few hundred years, beech occurred in historic times in Britain outside the southern counties of England and perhaps south-east Wales. The absence or rarity of native beech in the midlands and north of Britain may be connected with the relatively late immigration of the tree, which the fossil evidence is thought to reveal. Beech is also a slow colonist and would not easily penetrate the mixed oakwoods of the midland counties, established many centuries before. In view of the widespread distribution of beech on chalk and limestone in the southern counties, the lack of prehistoric evidence of beechwood in these areas is strange. It is indeed the case that the peculiarly rich growth of Neolithic and Bronze Age cultures on the chalk uplands of the south (and north-east) of England suggests that these did not carry forest—or at least continuous forest—at that time. It has, therefore, been suggested that, in the drier climate of Sub-Boreal times, the shallow soils of the chalk and limestone were too dry for the persistence of beech forest which, therefore, only became fully established in these tracts of country in the ensuing moister climate. (Tansley, 1939). Where peat bogs are few and far between, it is not to be expected that pollen analysis will reveal many secrets. The present evidence suggests great changes in the natural distribution of British beechwoods in comparatively recent times.

Chapter 2

NOTES ON SYSTEMATY, PHENOLOGY, AND DISTRIBUTION

SYSTEMATIC NOTES ON BEECH

The genus *Fagus* comprises about eight species inhabiting the temperate regions of the Northern hemisphere. Only one, *Fagus grandifolia*, occurs naturally in the New World. The common beech, *F. sylvatica* L., is widely distributed throughout western, central and southern Europe, extending as far east as East Prussia and the Caspian Sea. In Asia Minor and the south-eastern part of the European range, the beech is represented exclusively, or mainly, by a distinct form, recognised by many as a separate species, *F. orientalis* Lipsky. The systematic position and distribution of *F. orientalis* are discussed by Hanna Czeczott and E. V. Wulff, in a symposium on European beechwoods (Rübel, 1932). Where both species occur in the same region, *F. sylvatica* occupies the higher altitudinal zone. Pardé (1941) states that the Asiatic species of *Fagus*, although often in a high degree ornamental, are in no way superior silviculturally to the European beech.

There are several well-known varieties and forms of beech, some of them of considerable ornamental value. The fastigiate Dawyck beech (*Fagus sylvatica Dawyckii* Hesse) is familiar to many British foresters. The purple beech (*F.s. purpurea*) originates as a very rare sport. Unlike the Dawyck sport, purple beeches produce seed freely, but the seedlings show a variety of leaf tints, including many coppery colours: in course of growth some resume the normal green colour. The rare fern-leaved beech (*F.s. asplenifolia*) is a very inconstant tree. Individuals may vary slightly from year to year in form of leaf, or particular branches may differ from the rest, and revert branches are common. Of more importance to silviculture are the various malformed tortuous spreading or even creeping forms of beech (*F.s. tortuosa*), known in Germany as "Süntelbuche" (from a district in W. Hanover where the aberration first attracted notice). Similar undesirable forms have been identified in Denmark ("Vrange Bøge") and other localities. Inheritance doubtless plays a part in the perpetuation of these forms, but some investigators believe that they are phenotypes adapted to very exposed positions. However these spreading beeches originated, there seems little doubt that wind, and, perhaps, the dense shade of beechwoods, conferred on them survival value. In two publications Oppermann (1909, 1930) gives some account of the Danish "Vrange Bøge" while Tschermak (1929) notices a very similar form in Austria and Ney (1912) in Alsace. An inventory of the recognised varieties of the beech is given by Kanngiesser (1931).

PHENOLOGICAL NOTES

Beech is a tree of the temperate deciduous forest zone, coming into leaf about the same time as the oak and before the ash. The flushing date varies with the latitude and the spring weather from mid-April to the end of May, and there are wide individual differences. Young trees tend to come into leaf before the mature trees: this is particularly noticeable with natural regeneration under shelter, but seems also to affect young beech in the open. Shoot elongation takes place in May and June: height increment of beech seedlings is slow at first but increases up to, or rather beyond, the twentieth year, by which, on favourable sites, increments averaging eighteen inches or more a year are often recorded. Afterwards the rate of height growth falls off, but is still considerable in stands more than 100 years old. Lammas shoots are practically confined to young beeches, where the occurrence is much less general than with oak. Lammas growth takes different forms on different trees, and two contrasted types may be recognised, though these probably do not cover the whole range of phenomena observed. In many cases there is elongation, often of several inches, after only a short pause, but with very evident contraction of the internodes. In other cases there is formed a definite bud, which, late in the summer, swells and elongates, producing a short, thick, fleshy and very hairy shoot, with a well marked ring of bud-scars at the base. Sometimes the prolongation is scarcely perceptible. Such late summer shoots are probably fundamentally different from the July shoots, or true Lammas shoots. They are of silvicultural interest because of their liability to frost and insect attack, to which some reference will be made when the stem form of beech is considered in a later section.

After changing to a glorious reddish colour the leaves of the beech fall in October or the first half of November. Occasionally the green colour is lost by individual trees in August or September, as a result of long summer drought, or, as in 1950, of the exhausting production of fruit. Young trees frequently retain their withered leaves throughout the winter.

It is commonly stated in the literature that beech in forest stands does not begin producing seed in quantity until the age of sixty to eighty years. Flowers and fertile seed are, however, occasionally observed on much younger stands. In 1950 some fruit was produced on a twenty-eight-year old stand of copper beech at Alice Holt (Hants.) and on a thirty-year stand of beech (with oak) near Leeds: there were actually some seedlings (presumably from the 1948 mast) under the latter. It may be that fruit production at this age is a sign of ill-health, and it is broadly true that beeches in close canopy do not normally produce seed freely until about the age of sixty years. From this age fertile seed is produced at intervals until the trees are well over 200 years old. The intervals between successive masts vary enormously, the decisive factors being summer temperature and the occurrence of spring frosts. The relationship to summer temperature was clearly exemplified in recent years in Britain. The cool wet summers of 1946 and 1948 were followed by failure of beech mast in 1947 and 1949; whereas abundant seed was produced in 1948 and 1950, after the warm, dry sunny summers of 1947 and 1949. It is possible to distinguish between full and partial masts: in 1946, for example, there was very considerable seed production in the Chiltern Hills and in south Scotland but little elsewhere. 1944 was also a good beech mast year in southern England, especially on the South Downs, where some stands bore a full mast. Both these years were preceded by comparatively good summers. Latitude, altitude and aspect influence seed production, and in more than one instance it has been observed that beeches on a southerly, or neutral, aspect bore freely, while those on a steep north-facing slope bore little seed or none. For a similar reason, isolated beeches, whether park trees, or in a stand which has been heavily thinned, bear seed more freely than beeches in full canopy. Like the foliage, the flowers of beech are sensitive to frost, and it occasionally happens that spring frosts destroy the promise of an abundant flowering.

These two factors, especially the factor of summer temperature and sunshine, are of very great importance in relation to the collection of beech seed and particularly to the natural regeneration of the tree. It appears, however, that the irregular fruiting can to some extent be controlled artificially by girdling (Lantelme, 1933).

Beech is a moderately long-lived tree. Several stands about 250 years old have been recorded during the survey, but none older. There are doubtless many park trees considerably more than 250 years old, but certain records appear to be few. and it is likely that beeches more than 300 years old are exceptional. On sites liable to drought, as well as on very wet sites, root disease shortens life considerably.

DISTRIBUTION OF BEECH IN BRITAIN AND EURASIA

The common beech, *Fagus sylvatica*, is distributed throughout the greater part of Europe, from Britain and northern Spain in the west as far east as a line running approximately from Brandenburg to the Black Sea. Beech does not occur, however, in northern Scandinavia, while, towards the south-eastern limit of its range, it becomes increasingly replaced by the closely related *F. orientalis* Lipsky. The centre of the tree's range, is, therefore, in western Germany, in the Baltic vegetation zone, where the climate is neither oceanic nor continental, though perhaps nearer the oceanic type. In Sweden, Lindquist (1931) records that beech extends to 60° North latitude in the west, but not so far north in the lower rainfall area of the east. In Spain, Cuatrecasas (1932) notes that beech is rare south of 42° North; the distribution appears to show a similar southern boundary in the east, but is confused there by the presence of *F. orientalis*, which thrives in a rather warmer climate. In the Alps, beech ascends to 1,600 metres (5,250 feet) (Tschermak 1929) and in the Pyrenees a little higher, but it is noted that above 1,000 metres (3,270 feet) the height growth falls off very sharply and, towards the upper altitudinal range, the beech is shrub-like in form. In Germany, where the upper limit of beech forest ranges from 750 metres (2,400 feet) in the Harz Mountains to 1,350 metres (4,400 feet) in the Bavarian Alps, Markgraf (1932) has traced a connection between the altitudinal range and the mean July temperature, the upper limit corresponding with the isotherm of 13°C. (55.4° F.). At higher altitudes beech is superseded by spruce forest, beech however occurring at first as a frequent associate of the spruce. There is no lower altitudinal limit for beech in Germany but in the Danubian lands beech gives place at the lower altitudes to oak-hornbeam forest, including a variety of other deciduous trees. In the northern part of its range, beech is a tree of the lower altitudes. Watt and Tansley (1932) have summarised records of the occurrence of beech in mountainous regions of Britain. These show that beech will grow at 400 metres (1,300 feet) in Aberdeenshire and at 500 metres (1,600 feet) in the Pennines. In the extreme north of Scotland, however, beech is found only at low altitudes.

The natural distribution of beech is determined mainly by climatic factors. Where the climate is markedly continental in character, as in eastern Europe, beech fades out. There is evidence that the frequency and lateness of spring frosts, rather than the low temperature of winter, determine the eastern range of beech (Markgraf, 1932). Tschermak (1929) has shown that the recession of beech in the central Alps is associated with the continental type of climate. Frequency of spring frosts explains also the absence of beech from deep mountain valleys in the Alps and elsewhere. In southern Europe the growth of beech is restricted by deficient rainfall and low atmospheric humidity. Low rainfall is also cited by Lindquist (1931) as a reason for the scarcity of beech in south-east Sweden, but the important climatic factors at the northern edge of natural beech forest were found to be the time of arrival of spring, which determines the length of the growing season, and the summer temperature, upon which the production of flowers depends.

The second, but subordinate, factor upon which the distribution of beech depends is edaphic. In general beech is not found in low-lying areas, with permanently high water-table, or liable to flooding. Otherwise, where climate is near the optimum, the tree is indifferent to soil conditions; though it has been found in the Solling and other districts of Germany that, on acid sands, regeneration of beech is impaired by the tendency to mor formation. Near the southern limit of its range, beech occurs mainly on fine-textured, somewhat compacted soils, which are retentive of water. On the contrary, in northern, cool moist districts beech forest is linked with soils derived from calcareous materials, or other soils which are warm, permeable and dry.

In Britain this suspected importance of soil conditions is borne out by the actual distribution of apparently natural beechwood; this, as indicated earlier, is practically confined to the chalk and Jurassic limestone of the Southern counties, with possible small areas on sandstone formations in south-east England and south-east Wales. It has, however, been shown that this limited distribution of natural beechwood in Britain is largely a joint result of Pleistocene glaciation and human activities. In recent years evidence has accumulated that the greater part of Britain is climatically suited to the beech. Even at 58° North latitude in Scotland planted beech grows to large size, lives for more than 150 years and sets fertile seed. The same holds good for southern Scotland, northern England and Wales. There is, however, no certain evidence that any of these beechwoods are survivals from a period when beech had a much wider range in Britain, although some may be naturally derived from planted parents. Broadly, the present distribution of British beech appears to be due only in small degree to the climatic and edaphic needs of the tree, but mainly to the activities of man and the animals which he has domesticated or casually encouraged. This does not, however, imply that climate and soil are not of the greatest interest in relation to the present growth and vitality and the future prospects of beech in Britain. It has been suggested by Watt (1931, 1934) that on soils poor in bases the accumulation of undecomposed litter under beech may render the soil unfit for the reproduction of the wood. An important part of current investigations is to obtain information about the growth of beech on different soils within the climatic range of Britain, and to elucidate if possible the reaction of beech on the soil.

PART II. A SURVEY OF BRITISH BEECHWOODS, 1948-1950

Chapter 3

OUTLINE OF METHODS USED IN THE SURVEY OF BRITISH BEECHWOODS

THE GENERAL AIM of this survey of British beechwoods carried out between 1948 and 1950, was, by inspection of representative beechwoods in all districts of Britain where beech occurs with some frequency, to relate the performance of the tree with such characteristics of climate, topography, soil and vegetation as could be readily observed in the field. In the location of stands of beech great help was obtained from the Conservators of forests and their State and Private Woodlands Officers. Most of the investigations in older beechwoods were, however, necessarily conducted on estates in private ownership. In all cases an approach to the owners of these woods resulted in the ready grant of facilities: in most instances also owners, agents and foresters gave valuable assistance in the form of guidance through the woods, or records of planting or later treatment. Notes on general procedure follow.

Rate of Growth

Growth was assessed in terms of height at a given age. This was not wholly satisfactory, in view of (*a*) uncertainty of the age of some stands where there had been no recent thinning, and (*b*) doubt about the influence of treatment on height growth. Nevertheless in most cases trustworthy estimates of age and height allowed of a satisfactory appraisal of the site in relation to the height growth of beech. In view of the evident flattening of the age-height curve in stands more than 100 years old, an approximate value for the age of older stands was regarded as satisfactory.

Volume

In fully stocked stands, the number of stems per acre in the different canopy classes was determined, as a basis for an estimate of volume and as an index of thinning and of conditions on the forest floor. For this purpose a temporary plot (normally one-fifth acre in area in the older stands) was marked out, and on all the included trees the girth at breast height was measured and the timber height estimated. The Abney level was used in the estimation of total height, timber height and height to lowest fork or big bough. Actual volumes were then obtained from volume tables.

Stem Form

In many of the older stands, including all of notably good appearance, detailed information on the form of the beech included records of forking, stem bending, fluting, bark and crown characters: in other cases, the average height of clean bole and some general notes sufficed to characterise the quality of the beech. In young beech crops, where it was possible to investigate the causes of defects of form, more detailed records were in some cases made.

Disease and Injury

Notes were made of damage by rabbits and squirrels; of the incidence of Felted Beech Coccus (*Cryptococcus fagi*); of bark canker; and of insect damage to the foliage or tips of young trees. Scarcity of current fellings precluded any systematic record of butt decay.

Composition

A careful record was made of the present composition, as well as the probable original composition, of the stand. This often gave useful information both about the origin and treatment of the beech and the relative growth rates of beech and associated trees.

Regeneration

Beech regeneration, in the form of seedlings of various ages and of older saplings, was recorded and related to environmental factors. Notes were also made of seed crops in recent years.

Site description

The site was fixed by national grid reference, and the topography briefly described in terms of altitude, aspect, slope of ground, shelter by relief or adjacent older trees, and a note on the local configuration.

Soil Profile

A soil profile pit was dug in every plot investigated, after a check had been made on the pedological uniformity of the site. This profile was described according to the methods recommended in the *Soil Surveyor's Handbook*, and in most cases samples were collected for further study. Frequent reference was made in the field to the one-tenth inch to mile geological map, which helped in interpreting the soil profile and defining the parent material of the soil. In doubtful cases reference was made to one-inch-to-mile drift maps in the Museum of Practical Geology, South Kensington.

Ground Flora

The dense shade of beech and corresponding poverty of the ground flora often proves a difficulty when attempts are made to use the natural vegetation in characterising beech site types. A fairly full reconnaissance was, therefore, made of each wood and its surrounds, and the floral list made under beech canopy was supplemented by notes on the flora of gaps and margins and of adjacent heaths, or woods of light-foliaged trees. Special attention was given to plants indicative of important ecological factors—e.g., dryness, water-logging, lime, acidity, wind. Combined with the soil profile description, these data permitted a fairly full characterisation of the site; but the great variation in density of canopy precludes any exact linkage of the subordinate vegetation with site types. In the young beech areas there was, however, often a relict natural flora of the site before planting, yielding information both about soil conditions and the previous state of the land.

History

Every effort was made to obtain information about such matters as:—

(*a*) The date of planting, to confirm direct evidence of age and to indicate whether the wood was naturally or artificially established.

(*b*) The previous use of the land, whether beech, other types of woodland, heath or agricultural.

(*c*) The method of establishment and subsequent treatment.

(*d*) Disease or other troubles, or other points of local interest.

Except for plantations under twenty years old, this information was customarily very scanty: there were, however, some shining examples of the careful preservation of silvicultural records.

Chapter 4

ECOLOGICAL CLASSIFICATION OF BRITISH BEECHWOODS

Watt (1923-25) first proposed a classification of beechwoods of the South Downs, and later (1934) elaborated his scheme to embrace the more varied conditions of the Chilterns. A more limited scheme for the Ditcham Woods was proposed by Adamson (1922). Watt's arrangement formed the basis of the classification of British beechwoods in *Die Buchenwälder Europas* (Rübel, 1932) a publication based on the symposium at the International Botanical Congress in Cambridge in 1930. In this Watt and Tansley recognised the following four major types:

1. Beechwoods on chalk.
2. Plateau beechwoods on non-calcareous soil over the chalk.
3. Heath beechwoods on sandy soils.
4. Scottish herbaceous beechwoods: these last were described by Watt (1931) on several Old Red Sandstone sites in East Scotland. Closely comparable beechwoods had not then been recognised outside this locality.

In Watt's and Tansley's scheme the chalk beechwoods were subdivided into Sanicle and Mercury beechwoods, in which the soils differed in depth and in richness in carbonates and organic matter of the A horizon. The group of plateau beechwoods comprised a wide range of soils, from shallow loams over the chalk, to deep, acid, markedly leached brown forest soils showing some tendency to surface mor formation. Pedologically these included soils derived by direct leaching of the chalk, as well as soil weathered from more recent deposits of glacial drift, alluvium and Eocene sediments. A common feature was the frequency of bramble in the ground flora. Heath beechwoods were subdivided into woods on the sandy soils of southern England and those on podsolised glacial drift in Eastern Scotland. In soil and flora the beechwoods of Group 4 were distinct from plateau and from heath beechwoods.

In *The British Islands and their Vegetation* Tansley further developed the classification outlined above, giving it more precision. Thus there emerged three basic classes defined as: *Fagetum calcicolum*, *Fagetum rubosum* and *Fagetum ericetosum*. The first comprised all beechwoods developed on highly calcareous soils. The second group corresponded with the plateau beechwoods of the previous arrangement: to them were appended the beechwoods on sands and light loams of good base status (including principally the woods on Old Red Sandstone in Scotland described by Watt). *Fagetum ericetosum* was the name given to the heath beechwoods on podsolised sands and gravels.

No particular consideration need be given to the work of continental ecologists in distinguishing beechwood types in regions differing in climate and vegetation from the British Isles. In the Hanover beechwoods, of which alone the writer has a little experience, the difference between the beechwoods on limestone and the beechwoods on acid sands was everywhere clear and generally acknowledged silviculturally. The difference between calcareous and non-calcareous parent materials should be given due weight in any classification of beechwoods, even although it is found in practice that the widespread occurrence of superficial drifts and the evolution of the soil itself tend to obscure the distinction. The other most influential factors appear to be:—

(1) The permeability of the soil, as determined mainly by texture and drainage.
(2) Temperature, which is influenced by latitude, altitude and aspect, and proximity to the coast, especially the west coast.
(3) Exposure to the prevalent winds.

The topography has an important indirect influence on beechwood development through its effect on soil genesis, temperature and exposure. Rainfall is also a factor to be considered, inasmuch as the range of yearly rainfall is large in Britain, though in fact the range for the many beechwoods examined was only from twenty-three to fifty inches. Rainfall is, however, only one of several factors which control the water economy of vegetation: the capacity of the soil to retain water, and the evaporation from the soil and transpiration through plants during the growing season (or "evapo-transpiration" as these are sometimes collectively termed) are no less important. Rainfall *per se* is, therefore, a very unreliable basis for a classification of site types. Temperature is known to influence the growth and natural distribution of beech in several ways and in Germany Markgraf (1932) has linked the altitudinal range of beechwoood with the mean July temperature. This factor is, however, not so much important for the growth of beech and the development of the beechwood association as for the ripening of seed and the survival of the seedlings through the frosts of winter and early spring. The critical July temperature of 13°C. (55.4°F.) which Markgraf found for the German mountains is surpassed in all lowland Britain, with the exception of the extreme north coast of Scotland. Further consideration will be given to climatic factors when the data are discussed. For the purpose of classification, soil character will form the basis of the types recognised. It has been argued by Duchaufour (1950) that, on permeable calcareous parent materials, the climax is represented by beechwood on a slightly leached brown forest soil. On this view, beechwood soils with free calcium carbonate in the profile, and a condition of base saturation, are essentially immature. Special conditions, of which the most important are the rejuvenation by erosion of soils on steep slopes and the impermeability of some marls, tend to hinder the natural evolution and keep the soil rich in lime: in normal circumstances evolution proceeds until the soil becomes robbed of free calcium carbonate to a considerable depth and slightly desaturated.

In the course of the survey of beechwoods, soils conforming to the typical rendzina were rarely seen, being generally confined to recently afforested grassland. Beechwoods were, however, often found on soils where a thin upper horizon with very little free calcium carbonate, or none at all, was followed by a layer of chalky loam before the calcareous parent material was reached: a distinctly calcicole ground flora is usually associated with these soils. This type may be termed a rendziniform forest soil. Lastly some soils derived from calcareous parent materials were found to be free from calcium carbonate (or with a trace only in the lowest layer), until the parent material was reached, and at the same time partly desaturated in the A horizon. The ground flora then no longer consists exclusively, or principally, of calcicoles, but of a variety of basiphile and indifferent plants, blackberry being conspicuous. Essentially brown forest soils, these soils may fittingly be distinguished from brown forest soils derived from non-calcareous parent materials, in which calcium is not abundantly offered to the deeper roots of trees. In localities where superficial drifts occur it is not easy to distinguish residual soils derived by direct leaching of chalk or limestone, from soils derived from thin sedimentary or transported non-calcareous deposits. Examination of many profiles has, however, brought out some points of difference, which will, it is believed, serve to distinguish the two in the great majority of cases. From the point of view of practical silviculture, however, brown forest soils in which a thin layer of drift overlies chalk or limestone at a depth of less than two to three feet are best grouped with brown forest soils originating by leaching of the chalk.

Every gradation may be found between the raw rendzina and the well-developed brown forest soil with a slightly leached A horizon. Consequently the four types of soil derived from calcareous parent materials which will be described are merely arbitrary stages in the development of the rendzina. These types are:

R_0: Rendzina, carrying grassland, scrub, or young planted beech.

R_1: Forest rendzina, usually bearing first crops of beech.

R_2: Rendziniform forest soil, in which most of the calcium carbonate has been dissolved out of the A horizon.

R_3: Brown forest soil formed by leaching of calcareous parent materials.

These soils form a natural series. A comprehensive review of all sites in which free calcium carbonate plays a significant role in the economy of beech will demand the inclusion of two other classes of soil, viz.:—

(1) Chalky boulder-clay soils (R_1, R_2 or R_3).

(2) Soils formed from very shallow non-calcareous drift over chalk or limestone.

In the tabulated records the beechwoods on calcareous soils are listed in Appendix I.

The beechwoods on non-calcareous soils have been grouped for descriptive purposes into those on loams or clay-loams and those on sandy soils. No beechwoods were seen on peat. Gleying was commonly slight ; occasionally gleying was observed in stiff clay-loam soils, but it was rather more frequent in soils derived from silty glacial drift. These beechwood soils with drainage impedance had more the character of gleyed brown forest soils than of typical gleys, and the relevant stands have been grouped with the beechwoods on loam. Other non-calcareous soils showed every gradation from brown forest soils relatively rich in electrolytes, with mull well developed, to typical podsols, and it is not possible to effect a clear differentiation of beechwoods on brown forest soils from beechwoods on podsols. It is important to consider that many of the existing mature stands of beech in Britain, particularly those on non-calcareous soils, are first crops on land which did not formerly carry beechwood. It is, therefore, reasonable to assume that equilibrium between soil and vegetative cover has not been reached, and that the development of the soil profile has often been determined more by the character of the vegetation during many foregoing centuries than by the century or two during which beech has grown on it.

In the field it is convenient and important to recognise beechwoods with mull as distinct from beechwoods with mor. The development of mull or mor under beech is, however, greatly affected by local conditions, and could not serve as a primary division of beechwood types. Characteristically, the beechwoods on loam show a brown forest soil profile with mull. Mor formation is, however, quite common, and there may occasionally be slight bleaching of the top of the A horizon. Beechwoods on loam are well developed on the deep leached or drift soils over the chalk outcrop in the southern counties where beech is native. It has been suggested that a brown forest soil can develop in suitable circumstances from chalk or limestone, but in these cases the chalky parent material is found at no great depth. Under forest the soil profile is of rather indefinite extent, and trees may make use of chalk which is too deep to affect the herbage.

In this review of beechwoods, soils in which free calcium carbonate, whether residual or transported, occurs within the upper two feet (60 cm.) are included with the calcareous soils. In other areas of Britain beechwoods on loamy soils usually occupy the sites of former broad-leaved woodland (oak principally) or of pasture. Collectively the beechwoods on loam have affinities with the meadow beechwoods of Lindquist (1931), but in Britain the floristic and soil features are probably much influenced in many cases by the fact that beech is new to the site. Beechwoods on sandy soils do not correspond exactly with Lindquist's heath beechwoods, because they include, besides many beechwoods on more or less leached sands and gravels, a number of woods planted on base-rich sands derived, in many cases, from river alluvium, or fluvio-glacial drift. Under these a brown forest soil is found and, where the canopy is not very dense, there will appear many of the mull plants characteristic of the beechwoods on loam.

In the tabulated records the beechwoods on loams in England and Wales (Appendix II) have been listed separately from the Scottish beechwoods on loams (Appendix III). In the case of the beechwoods on sandy soils the English and Scottish records have likewise been listed separately (Appendices IV and V) and the brown forest soils have been put before podsols. Figures in brackets indicate reference numbers in the Appendices.

CHALK BEECHWOODS (Appendix I, page 78)

Rendzina

The typical rendzina is a very shallow soil with a single horizon not more than twenty-five centimeters (ten inches) thick over the fissured and fragmented chalk or limestone. The soil is usually finely loamy in texture, dark in colour with organic matter, rich in fragments of calcium carbonate and with well-developed crumb structure. The characteristic vegetation, which is, however, only maintained by grazing against the encroachment of scrub, is chalk or limestone grassland, consisting partly of shallow-rooted grasses, partly of herbs furnished with long tap roots, which descend to the chalk rubble. A good example of rendzina soil was recorded in Tunworth Park, Hampshire, in November, 1949. The site was the top of a low chalk ridge, at 500 feet; the vegetation was grassland with some scrub and occasional young natural beeches. Hawthorn (*Crataegus monogyna*) was the principal shrub: *Rosa* spp., *Corylus*, *Fagus* and *Quercus* occurred here and there. *Helictotrichon pratense* was dominant in the field layer, with *Carex flacca* co-dominant: associated with these was a wealth of herbs and a more or less close mat of the moss *Brachythecium purum*. Under this mossy carpet the soil profile showed the following layers.

A_1, 0 to 7 cm. (0 to $2\frac{1}{2}$ in.) Dull blackish brown fine loam with rare flints and well developed large crumb structure; spongy, friable, moist. The soil was rich in organic matter and intensely rooted, by grasses and sedge mostly. Superficially free from chalk fragments, the soil reacted vigorously with acid and later showed a calcium carbonate content of 31 per cent: pH 7.5.

A_2, 7 to 21 cm. ($2\frac{1}{2}$ to $8\frac{1}{2}$ in.) Dark brown loam with frequent flints and small chalk fragments becoming increasingly frequent with depth: good crumb structure, porous, friable, moist and rich in incorporated organic matter. Roots of *Crataegus* were frequent, and roots of grasses and herbs were also present: earthworms were plentiful in this and the preceding layer. Carbonates composed 37% of the sample and the pH was 7.85.

This layer merged into a thin (21 to 25 cm.= 8 to 10 in.) A/C horizon, consisting of a mixture of brown loam and chalk with only rare roots of *Crataegus*. Below 25 cm. (10 in.) the profile showed the fissured and fragmented chalk with a little loam in the fissures.

When soils of this character are directly planted with trees, the extreme shallowness and dryness of the soil make it difficult for the young trees to cover their water loss, while the high concentration of lime may cause chlorosis. Many flints further restrict the effective volume of soil. Under woody vegetation, in particular under beech, the soil becomes opened up by the deeper roots. Percolation is increased and, under the influence of the forest climate and the more acid litter, solution and leaching of calcium carbonate are considerably accelerated. In the forest rendzina, now to be described, there is still, however, much free carbonate and the reaction is markedly alkaline. Adjacent to the grassland and scrub on The Hummock in Tunworth Park is a small planted beechwood, 110-120 years old. The beeches were evidently raised with conifer nurses (pine and spruce, now almost all gone): they are eighty to ninety feet tall and about 45 inches in mean girth at breast height. The ground beneath the trees has a cover of beech leaves and a generally sparse flora of *Hedera* (creeping) and calcicole herbs, including *Sanicula*, *Asperula*, *Hordelymus earopaeus*, *Viola reichenbachiana* and *V. riviniana*, *Brachypodium sylvaticum*, *Cephalanthera damasonium*, *Listera ovata* and other orchids. Beech seedlings, up to five years old, were frequent, especially in breaks in the canopy. Under a carpet of fresh leaves, held in place especially by the creeping ivy stems, there were only very scanty remains of the leaf fall of past years. The mully A_1 horizon consisted of 10 cm. (4 in.) of dark blackish loam rich in humus, with good porosity and crumb structure. There were occasional flints and small chalk fragments, and abundant fine beech roots; worms and worm holes were conspicuous. The soil reacted violently with acid and subsequent examination showed a calcium carbonate content of 24.2% and pH 8.0. This merged into the next (A_2) horizon consisting of 18 cm. ($7\frac{1}{2}$ in.) blackish-brown fine loam. This horizon was similar to the A_1, differing principally in the lower content of organic matter and somewhat greater richness in chalk (29%): pH 8.3. The A/C horizon, about 7 cm. ($2\frac{1}{2}$ in.) thick, consisted of a mixture of chalk (73%) and orange-brown loam, with occasional beech roots. At a depth which varied from 35 to 50 cm. (14 to 20 in.) there was soft white chalk, with a little loam and rare beech roots in the numerous fissures. The foremost characteristics of this soil are:—

(*a*) restricted depth;
(*b*) base saturation;
(*c*) abundant free calcium carbonate;
(*d*) plentiful organic matter, well distributed through the profile;
(*e*) good structure and aeration;
(*f*) free drainage;
(*g*) relatively rapid break-down of beech litter.

Rendziniform Forest Soil

This class includes a wide range, from soils a little deeper and rather less chalky than the one described, to soils in which the A horizon, while remaining more or less base saturated, has been deprived of free calcium carbonate. Such soils are common in the beechwoods of the Goodwood area of the South Downs in Sussex. A comparatively immature (chalky) variety was encountered in West Dean Park and other woods on the same estate:

a much more developed variety was examined near Arundel. The parts of West Dean Park where observations were made are situated at 400 to 480 feet altitude on a moderate northerly slope. Beech, planted with conifers 125 years ago, now forms a pure crop about 100 feet in height. Under the deep shade there is little ground vegetation except ivy (*Hedera*), which forms in many places a thin carpet over the ground. *Viola reichenbachiana* and *Asperula* occur here and there. Beneath the fresh beech leaves there was locally a thin layer of mouldering beech leaves with a little mineral soil, bound by numerous fine mycorrhizal beech roots; a *Lactarius* toadstool was associated with the mycorrhiza. This slow break-down of the leaves was doubtless a reflection of the dense shade. Elsewhere a good crumb mull was found, some 5 cm. (2 in.) deep, with a trace (ca. 0.5%) of free chalk and pH 7.5. This was followed by about 20 cm. (8 in.) dark blackish-brown loam with numerous flints and fragments of chalk. This layer had excellent crumb structure and porosity, much organic matter and abundant fine and larger roots: pH measurements averaged 8.1 and the free chalk content ranged from 0.55 to 4.23 per cent. This layer merged into the A/C horizon, which was 10—20 cm. (4 in.) thick: the chalk content was 40 to 50 per cent. and the fine loam mixed with the chalk fragments contained a considerable number of beech roots. The A horizon, about 25 cm. (10 in.) in total depth was thus only a little deeper than in the "forest rendzina" described from Tunworth Park. The chalk content was, however, significantly lower (less than 5%, as compared with nearly 30%), while the A/C horizon, i.e., the zone opened up by tree roots and in course of transformation from parent material into soil, was a good deal deeper.

The soil profile recorded near Arundel showed a further stage in evolution. The site was on the gentle slope of a dry chalk valley, 120 feet above sea level, with east-south-east aspect. A very fine, albeit somewhat overmature, crop of 170 year old beech, 110 feet in height, with an occasional larch, formed the tree crop. *Hedera* (la) and *Sanicula* (o/f) were most conspicuous in the sparse ground flora: *Mecurialis* and *Arum* occurred locally and freshly germinated beech seedlings were frequent in May, 1949. Under the fresh leaf fall of October, 1949, there was again a layer, 3 to 4 cm. (1 to 1½ in.) thick, of partly humified leaves with a little mineral soil, matted by fine beech roots (pH 6.6). This was followed by a mully layer with mouse tunnels, and an A horizon, 28 cm. (11 in.) in total thickness. This was a sticky clay-loam, porous and of good structure, but becoming very tenacious with depth and abounding in small and large sub-angular flints. Chalk fragments were few and small and laboratory test showed 0.7% chalk (slightly more in the mull) and a reaction of pH 7.2. The soil was very moist and intensively penetrated by beech roots. The A/C horizon, extending from 28 to 50 cm. (11 to 20 in.) in the profile, contained 57% chalk and, for the rest, a pale brown clay-loam with occasional beech roots. As compared with the profile last described, the chief points to note about this soil are:—

(*a*) The slightly greater depth of A horizon.
(*b*) The further reduction in the amount of free chalk.
(*c*) The reduction in pH from approximately 8 to 7: this indicates a slight desaturation of the colloids.
(*d*) The close sticky lower part of the A horizon, which appears to denote some movement of fine clay particles from the surface and an incipient differentiation of a "B" horizon.

Further progress in these directions results in a brown forest soil, in which free calcium carbonate is lacking until the parent chalk is reached, while the colloids are partly desaturated, and the deflocculation and downward movement of clay particles has produced a recognisable B horizon. Such brown forest soils have been examined under beech at Buriton (Hants), Singleton (Sussex) and elsewhere. The Singleton site is at 550 feet on the chalk dip slopes with 4° slope to south-west. The tree crop consists of natural beech, 90 years old and 90 feet in height, following a former beechwood. There are occasional ashes, oaks and planted larches. The calcicole ground flora of the woods hitherto mentioned is replaced by a flora (scanty under close canopy) of *Rubus*, *Oxalis*, *Dryopteris austriaca* and *Hedera*, of which only the last was common on the chalky sites. The soil profile showed the following layers under 3 cm. (1 inch) of loose, spongy beech leaves, fresh and partly broken down.

A_1	0 to 5 cm. (0 to 2 in.)	Dark grey-brown mully loam, good crumb structure, spongy, friable, with a few small flints. Worm casts and many mycorrhizal fine beech roots present. No chalk. pH 5.8.
A_2	5 to 15 cm. (2 to 6 in.)	Grey-brown loam, with much humus, crumby, porous friable; occasional large flints. Abundant beech roots, some mycorrhizal. No chalk. pH 5.4.
B_1	15 to 38 cm. (6 to 15 in.)	Pale brown loam, good structure, porous, friable, with a few large flints. A few worm holes and frequent beech roots. No chalk. pH 5.7.
	38 to 47 cm. (15 to 19 in.)	Red-brown clay-loam, with a few flints and some small chalk pieces below. Roots rare. Chalk 0.16%. pH 7.4. Beneath this horizon was

fissured chalk with a little loam in the fissures.

Soils conforming to one of these four types, or their transitional forms, are widely distributed in England, wherever the chalk outcrops. They occupy, however, an area much less than that of the outcrop of chalk shown on the map of solid geology. North of the Thames, glacial drift (sometimes highly calcareous) covers much of the chalk land: in the Chiltern Hills and southern counties the re-sorted remains of Eocene sediments cover the greater part of the chalk plateaux. Among the definitely calcareous soils, particular notice must be taken of those on the steep escarpment slopes supporting the "beech hangers" of Sussex and Hampshire. On these sites, and on the steep slopes of many valleys in the chalk, the soil does not develop in the way outlined. Under the influence of gravity and water erosion, the natural evolution of the soil by leaching of the chalk is arrested. The "topographical climax" is then a highly calcareous soil, very shallow on the steep gradients, but often of satisfactory depth on the moderately steep slopes. A good example of a beech hanger was recorded at Selborne, Hants., where the beech, about 150 years old, and presumably the direct descendants of the trees referred to by Gilbert White (Letter 1, 1789), had attained a height of 80 to 90 feet. The site where the soil was examined stood at 600 feet on a northerly slope of 24°. The A horizon was only about 16 cm. (6 in.) in depth and very chalky throughout: the A/C horizon, consisting of chalk rubble with a little loam, merged into the soft white chalk at a depth of 30 to 35 cm. (12 to 14 in.).

In relation to beech growth, the significant ecological property of rendzina soils is their water-supplying power. Even within one restricted region, like the chalk areas of Southern England, the height growth of beech varies very considerably in accordance with the manner in which local conditions modify a tendency to water shortage in summer dry periods. Bourne (1931) adduces data for the growth of beech in relation to soils and topography in the Chilterns; and Watt (1923, 1934) gives figures for the mean height of mature beech on the Chilterns and South Downs. Watt's types, or seres, are based mainly on soil depth: the corresponding mean height of beech ranges from 67 feet on the shallow, dry chalky soil, with sanicle dominant in the field layer, to 95 feet on the deeper chalk-free loam with *Rubus* dominant. Bourne shows the significance of topographic features in relation to soil formation and the growth and health of beech. In his view, stratigraphy has a considerable influence on the moisture conditions of the chalk soils: in particular, water seepage at the outcrop of Chalk Rock at the base of the Upper Chalk is a very important cause of the differences observed at different levels on steep slopes. Bourne's data from Chiltern beechwoods show a range in the height of beech at maturity from 50 to 60 feet on the shallow dry soils of steep chalk slopes, to 80 to 90 feet on the deeper soils found on gentle slopes of ridges and spurs.

In Appendix I (page 78) are gathered together summaries of the data from beechwoods 50 years old and upwards on calcareous soils collected during the recent survey, together with a few records made during a survey of war fellings. The sites have been grouped according to the character of the parent material:

viz. A: Cretaceous chalk;
B: Jurassic limestones;
C: Permian limestones and marls;
D: Mountain limestone of Lower Carboniferous age;
E: Mixed chalky glacial drift.

Because a wide range of ages is involved, within each group the stands have been arranged in order from the youngest to the oldest. Essential topographical data are included, as well as the depth of the A and A/C horizons and, where available, measurements of pH and percentage of calcium carbonate. A careful examination of this table will show first that, whereas the finest growth is on the deeper more mature R_2 and R_3 soils, very good height growth may in certain circumstances be found on relatively shallow immature rendzina soils; secondly that the influence of aspect and exposure may outweigh the influence of soil differences; and thirdly that beech grows better on the western part of the South Downs than on any of the other chalk districts surveyed. The influence of topography is most marked on the shallow chalky soils: slopes facing between south and north-west do not yield high quality beech, particularly where, as at Wendover (No. 44), the slope is steep, and erosion and excessive drainage accentuate the liability to drought. The four sets of data from the Goodwood Plantation (Nos. 39-42) illustrate the influence of aspect and exposure very clearly. These all refer to a stand of uniform age on the same soil throughout, and at practically uniform altitude. The two samples on the sheltered east slope of the spur averaged 100 and 105 feet respectively in height at maturity, the two samples on the west-south-west slope, fully exposed to winds from the English Channel, averaged only 76 and 80 feet. The beeches on the sheltered sites were also bigger, but this was related to the somewhat lower density.

Wind affects the growth and health of beech both by increasing water-loss by transpiration, and by reducing the available water and nutrients in the soil. On sheltered sites, the leaf-fall protects the mineral soil surface from wind and sun, and the humus resulting from the break down of the litter enriches the A horizon and increases its water-holding capacity. On exposed sites the leaves are scattered, evaporation from the soil is increased (Heinrich, 1950) and much valuable humus is lost to the soil. At Goodwood the soil on the sheltered slope was enriched with organic matter to a much greater depth than the soil on the exposed slope, where much of the leaf-fall was blown away. It is possible that in sheltered woods a significant increase in the carbon dioxide content of the atmosphere may promote more active photosynthesis. On deeper soils, more retentive of moisure, the influence of wind on the height growth of beech appears not so great, though still evident.

The superior height of the South Downs beech is probably in part a reflection of climatic factors. In rainfall, atmospheric humidity and length of growing season, the locality compares favourably with the Chiltern Hills and the East Riding of Yorkshire. It should be emphasised, however, that the area investigated at Goodwood, in particular the West Dean Estate, includes some exceptionally favourable sites—deep valleys in the chalk between the main escarpment and the parallel ridge where Goodwood Racecourse stands. It seems also that the silvicultural treatment results in faster growth than in the selection forest of the Chilterns, but it is questionable if this factor would affect the final height.

Before the chalk beechwoods are left it should be noted that, on the drier sites, there is a considerable mortality. Dieback of beech was widespread, though nowhere calamitous, following the droughts of 1947 and 1949: it was noted on a wide range of sites, but was particularly associated with shallow, excessively drained, chalk soils. Bourne (1931) considers that on very dry warm chalk slopes, beechwood, owing to frequent deaths in dry periods, is incapable of maintaining itself, the natural successor being yew-wood with some ash.

BEECHWOODS ON THE OLDER LIMESTONES (Appendix I, page 78)

Next in importance to the chalk are the Jurassic limestones, which form an outcrop of varying width almost throughout the length of England from Lyme Regis to Whitby. In the Midlands and Yorkshire, where glacial drift covers much of the outcrop, beech is not common. The country between Burford and Bath, on the other hand, has many fine beechwoods. There can be no reasonable doubt that some of these beechwoods are very ancient, while others, although planted, are on sites formerly occupied by natural climax beechwood. These Cotswold beechwoods have not been investigated in detail, as have the chalk beechwoods of the south-east; but the paper by Tansley and Adamson (1913) contains some information.

The limestones of the Jurassic vary much in lithological character, both vertically and horizontally, hard bedded limestones and marls often occurring within one wood. In the well-wooded area the Great Oolite is much the most important outcrop, and most of the woods investigated occurred on it. One wood stood on Forest Marble clay and shelly limestone, the uppermost bed of the Oolite, and one on the Hinton Sand facies of the same stratum. The limestone of the Great Oolite is a buff-coloured, shelly, oolitic limestone, with well-developed bedding planes and vertical joints. It is harder than the chalk and yields a greater proportion of insoluble residue on weathering. The same evolutionary trend in soil development as has been described for the chalk was traced also in the Cotswolds. Here, however, the solution of calcium carbonate takes place predominantly in the joints and bedding planes where the rainwater percolates. Increase in depth of the A horizon appears to proceed more slowly than on the chalk; but there is commonly a great depth of brashy A/C horizons. Beech roots extend into the loamy fissures in the limestone to a remarkable depth: in an exposure in the wooded part of Cirencester Park, Glos., the fissured, partly weathered, limestone was seen to be four to six feet (about 150 cm.) deep, and fine roots of beech had penetrated the layer fairly thoroughly.

Sweet Hill plantation in Cirencester Park (No. 46) provided an example of beechwood on comparatively shallow rendzina derived from oolitic limestone. The tree crop consisted of beech, over 100 feet tall, planted 110 years ago, probably with conifer nurses. The site is a broad plateau, 440 feet above sea level, sloping gently to the south. Under the freshly fallen beech leaves, the following soil profile was recorded.

0 to 5 cm. (0 to 2 in.)	Dark grey-brown mully fine loam, good nutty structure and porosity; occasional small fragments of oolitic limestone. Fine beech roots very abundant: earthworms (*Allolobophora turgida*) at work. Laboratory test showed a calcium carbonate content of 4.5% and pH 7.8.
5 to 18 cm. (2 to 7 in.)	Warm reddish-brown clay-loam; crumb structure, porous, friable, with very many angular fragments of limestone. Beech roots abundant. Carbonates 19.7%. pH 8.5. This layer distinct from:—
18 to 40 cm. (7 to 16 in.)	Oolite limestone brash with similar reddish-brown clay-loam in interstices. Frequent beech roots: pH 8.8; car-

bonates 56.1 %. This was succeeded by more than 30 cm. (12 in.) of limestone brash, with much buff-brown gritty calcareous loam, loose and very porous. This layer was very freely drained, much drier than those above and contained only a few roots. The carbonate content was 81.5% and pH 9.05.

The dominant plants under the Cotswold beech do not differ from those on the South-eastern chalk. *Hedera* and *Sanicula* are conspicuous on the very calcareous soils under rather close canopy and *Mercurialis* may be very abundant where there is shelter from the wind and a little more light. *Asperula*, *Viola* and *Brachypodium sylvaticum* are characteristic; *Rubus* comes in under the older stands on more mature soils approaching the brown earth type. On the whole the soils are very resistant to surface degradation and mor formation, perhaps more so than the Cretaceous chalk. Nevertheless a tendency to mor formation was observed in three woods, under the combined influences of excessive shade and exposure to the drying action of wind.

In north-east England several beechwoods were recorded on the oolitic limestone in Yorkshire. The data from these, as well as those from the Cotswold beechwoods, have been summarised in Appendix I. Only the Kingthorpe, Yorks., site (No. 55) was free from drift: here the height of the beech (87 feet) was satisfactory, but clearly inferior to the Cotswold beech. A very remarkable mixed hardwood stand in Duncombe Park, Yorks., (No. 62) was on thin calcareous glacial drift over the oolite. The soil was shallow, but evidently well watered and fertile: a luxuriant ground flora of *Allium* and *Mercurialis* was in keeping with the dimensions of the trees. The beech were 106 feet in average height and of large diameter. The associated ash were more noteworthy: several were over 110 feet in height and 8 to 12 feet in girth at breast height. There were also some big sycamores, 100 feet in height. Attention may also be drawn to the record of mature beech near Grantham, Lincs. (Peascliff Tunnel Wood, No. 50) on one of the calcareous beds of the Middle Lias: this impressive wood was the only beechwood recorded on the Jurassic between Oxfordshire and the North Riding of Yorkshire.

Magnesian Limestone (Permian)

The dolomitic limestone of Permian age forms an outcrop averaging about five miles in width between Sunderland and Nottingham. Beechwoods on this limestone are concentrated in South Yorkshire, between Wetherby and Doncaster, where a number of fine mature woods have survived the 1939 war fellings. Some of the outcrop is covered with a thin layer of glacial drift, but all the soils examined were highly calcareous and most of them appeared to have weathered *in situ*. As compared with the chalk, the interesting point about the dolomitic limestone is the relatively feeble solubility of magnesium carbonate. It is sometimes found that the soil effervesces very gently with hydrochloric acid, whereas subsequent examination shows a high proportion of carbonates. In determinations of carbonates, no attempt was made to differentiate magnesium and calcium carbonates, the total content being expressed as $Ca\ CO_3$. Where much dolomite is present, this involves a slight overestimate of the proportion of carbonates: analyses quoted in Rastall's *Agricultural Geology* showed 35.33 per cent. of $Mg\ CO_3$ in the magnesian limestone rock of County Durham.

The natural flora of the magnesian limestone, being determined mainly by the more soluble calcium ions, differs very little from that of the East Riding chalk. Beech also thrives on the magnesian limestone: mature heights of 100-120 feet were recorded at Bramham, Yorks., and in Parlington Park, Yorks. The sites at Ledston, Yorks, (Sheldon Hill) were on a somewhat exposed knoll: one of the sites, on a steep slope with south aspect, was evidently subject to drought and the height of the beech was moderate (82 feet at age 110). It is noteworthy that the beechwoods investigated on the magnesian limestone were all close to the South Yorkshire coalfield and the industrial areas dependent on the coalfield. The sooty boles of the beech and the contaminated ground flora and humus layers were an index of this factor, which was doubtless associated with the unhealthy appearance of the few coniferous plantations in the locality. It seemed that beech was among the more tolerant trees in relation to smoke pollution.

Some records of beech on Magnesian Limestone are summarised in Appendix I.

Carboniferous Limestone

Limestones of Lower Carboniferous age cover a very large area in Wales (North and South), Somerset and Gloucestershire, and particularly in the Pennine range of hills. North of Derbyshire, however, the limestone beds of the Lower Carboniferous become less important, although they are very prominent in the Ingleborough district of East Lancashire and West Yorkshire. In the central valley of Scotland, limestones of Lower Carboniferous age occur also, but, as in Northumberland, non-calcareous strata are more characteristic of this series. Throughout the north of England the mountain limestone is commonly covered by glacial drift, except on the escarpments, steep valley sides and the grikes, or fissures, formed by solution of the limestone. In Derbyshire and West Yorkshire there are, however, considerable areas of relatively level upland, mostly bearing limestone grassland. In spite of this wide distribution of calcareous soils derived from the mountain limestone, beechwoods are by no means frequent on this formation except in the limestone valleys of West Gloucestershire and Monmouthshire. The small areas of beech on the carboniferous limestone in South Wales are of interest as the most westerly representatives of natural beech woodland in Britain (Tansley, 1939, p. 366).

The hard limestone of the Lower Carboniferous, sometimes with a considerable proportion of dolomite, weathers more slowly than the chalk. The rock is highly fissured, and rain water tends to drain away through the fissures, enlarging them as it goes and producing a very uneven surface. Under woody vegetation, however, the deeper root penetration, forest litter and forest microclimate bring about a more even solution of the limestone, and the soil becomes gradually deeper and superficially less alkaline. Only two mature beechwoods were recorded on the Carboniferous limestone: on an exposed site at nearly 800 feet in the Mendip Hills of Somerset the beech were 90 feet in height at an age of 110-120 years, but it appeared that there was a very thin extension of Lias clay over the limestone on this site. 73 feet at age 120 was recorded on a fully exposed site in the Grassington district of Yorkshire on a highly calcareous soil (No. 73). Near Skipton, a height of 83 feet at maturity was recorded on a relatively deep soil from which most of the limestone had been leached (No. 74). Several immature beechwoods were examined on the mountain limestone of the Bristol Channel area: only the Penhow site (Appendix VI, No. 74) showed a shallow soil approaching the rendzina type. This bore a 30 to 35 year old crop of beech, 45 feet in dominant height, with occasional ash. There was a markedly calcicole ground flora, with *Hedera* (very abundant), *Mercurialis*, *Brachypodium sylvaticum*, *Viola* and young ash seedlings. The soil profile under thin layers of fresh and mouldering beech leaves, with a slight tendency to mor formation locally showed the following layers:

0 to 5 cm. (0 to 2 in.)	Dark brownish-black mully loam with good crumb structure, friable and porous. Rare angular fragments of limestone. Abundant fine beech roots and ivy roots. Carbonates 2%. pH 7.1.
5 to 18 cm. (2 to 7 in.)	Dark reddish-brown fine loam, good crumb structure, porous, friable. Frequent large and small limestone fragments: abundant beech roots. pH 7.8. (Carbonates formed 18.8% of the sample collected with the exclusion of large stones.)
18 to 40 cm. (7 to 16 in.)	Similar reddish friable loam with boulders dominant; occasional roots: grading into fragmented and fissured limestone.

The other beechwood soils examined on Carboniferous Limestone showed a deep reddish loam or clay-loam, retentive of moisture and evidently of high fertility. On the more sheltered sites, they appeared capable of growing excellent ash.

CALCAREOUS GLACIAL DRIFT

A review of limestone beechwoods would not be complete without some reference to the occurrence of beech on the chalky boulder-clay which covers very extensive areas in the East Midlands, Lincolnshire and East Anglia. The soils derived from these deposits vary much in depth, texture and amount of calcium carbonate: in character they resemble the rendziniform forest soil, or the brown forest soil with chalky subsoil, as described above, rather than the forest rendzina. Although there are extensive outcrops of Jurassic limestones in the regions named, the calcareous material is in most places mainly derived from the Cretaceous chalk. Impeded drainage in the subsoil is a feature of many sites; particularly in depressions, or areas of flat topography, overlying the clay outcrops (Lias, Oxford and Kimmeridge).

Primarily agricultural, these soils are also very suitable for hardwoods, particularly the more exacting species like ash, wych elm and lime. It is not surprising that fast growth of beech was recorded on several sites, where there was a satisfactory depth of porous well-drained soil. Beech appears to be generally absent from woods on soils showing marked gleying, where oak with some ash was dominant. The woods seen had every appearance of having been planted, and it is difficult to judge how far the absence or rarity of beech on gleyed soils is due to survival of the fitter oaks, and how far to the conscious selection of trees better adapted to local conditions. The occurrence of a small proportion of somewhat inferior beech in two oak woods on the Lias suggests that some of the selection has been natural.

BEECH WOODS ON NON-CALCAREOUS LOAMS (Appendices II and III, pages 81 to 84)

In the consideration of beechwoods on calcareous soils it was suggested that in course of time a brown forest soil profile may develop naturally under beech forest, by the progressive leaching of the chalk. The improved water supply, and the elimination of chalk from the surface soil, which are the most significant results of the change, are usually signalled by the appearance of brambles in the ground flora. Many calcicole herbs remain, but their frequency and vigour are adversely affected by competition with the taller *Rubus*. Beechwoods on these leached calcareous soils form one end of a series which includes woods on loams and clays of a wide range of fertility. In English beechwoods bramble is very commonly present, often dominant, in the field layer—so much so that, in *The British Islands and their Vegetation*, Tansley (1939) has defined the association as *Fagetum rubosum*. In Scottish beechwoods brambles are curiously rare, even where the soil is loamy in texture. The success of *Rubus* in southern woods is doubtless connected with the evergreen habit under canopy. Sunny periods in autumn, and more especially in early spring, before the beech leaves unfold, must allow a valuable measure of photosynthesis. In the north the bramble is not normally evergreen, nor could it make such use of spring sunshine in higher latitudes. Nevertheless *Rubus* is so characteristic of beechwoods on loams and clays, throughout their main area of distribution, and withal of so much silvicultural importance, that the designation *Fagetum rubosum* is apt.

A second characteristic of this group of beechwoods, in which they differ from the chalk beechwoods, is that there is frequently an admixture of ash, or oak, or both. Although the height growth of beech is rather better than on rendzina soils, the height of these other hardwoods is so much improved that the superiority of beech is diminished. Ash is a successful competitor only on the more basic loams; oak occurs throughout the plateau woods and more especially on the somewhat acid loams. On well-drained sites, however, beech remains the climax dominant.

Chiltern Hills

The *locus classicus* for the study of the *Fagetum rubosum* is the Chiltern Hills, where Watt (1934) investigated the floristic and soil features and the natural succession, while Bourne (1931) made an important contribution to our knowledge of the different kinds of soil and their relation to silviculture. Watt (1923-25) has also investigated beechwoods of this type in West Sussex. Allied to the beechwoods on brown forest soils derived directly from the chalk are beechwoods on shallow drift over chalk, such as are found close to the escarpment of the Chilterns. A good example was examined in High Wood, near West Wycombe, standing on the slopes of a valley in the chalk, some distance south-east of the main escarpment. The present wood was planted in 1815, but the ash and cherry and perhaps the oak were probably derived from self-sown seed. The canopy is dominated by beech, averaging 100 feet in height, but there are occasional fine oaks and ashes attaining the height of the canopy, and there is a scattered underwood of suppressed beech, yew, sycamore and holly. At the lower (northern) margin of the wood, chalk comes to the surface, and the flora consists of calcicole herbs. Elsewhere, two feet or more of clay-with-flints overlies the chalk and, where the shade is not too dense, *Rubus* is dominant in the field layer. With the bramble are associated a number of exacting herbs: *Galeobdolon luteum*, *Circaea lutetiana*, *Euphorbia amygdaloides*, *Arum maculatum*, *Asperula odorata*, *Veronica chamaedrys* and *Dryopteris filix-mas*: of these *Galeobdolon* was much the most frequent. Examination of the soil profile showed the following layers under a moderately thick layer of fresh beech leaves.

0 to 8 cm. (0 to 3 in.)	Dark grey-brown fine loam with much incorporated humus: good crumb structure and porosity. Frequent flints: vole tunnels and earthworms common and fine beech roots very abundant. pH 4.9.
8 to 30 cm. (3 to 12 in.)	Dull dark yellow-brown clay loam, with abundant sub-angular flints of all sizes, including some very large ones. Good nutty structure; abundant beech roots. pH 5.2.
30 to 65+ cm. (12 to 26+ in.)	Reddish-brown loamy clay, with very frequent flints as above. Cloddy, tenacious, closed; beech roots common to 40 cm. (16 in.). There were rare small chalk fragments in the bottom of the pit, but none in the sample taken from the horizon, which showed a pH value of 5.3.

Over much of the Chiltern plateau the drift cover is deeper and somewhat less fertile and more acid. Numerous woods were seen on these plateau soils, and many records were obtained of the growth of beech: Compared with the wood just described these woods generally showed the following characters:

(1) Ash is very rare, but oak is a frequent associate of the beech, though tending to become less frequent as the wood matures.

(2) The beech is inferior in height, rarely attaining 100 feet, although the average height varies greatly in accordance with the degree of exposure.

(3) Basiphile plants disappear from the ground flora. *Rubus* is dominant except under deep shade, or in places exposed to wind, and the characteristic associates are: *Oxalis acetosella*, *Luzula pilosa*, *Deschampsia caespitosa*, *Milium effusum*, *Endymion nonscriptus* and the moss *Polytrichum formosum*. *Pteridium* often colonises gaps.

(4) The soil is a deep flinty loam, with variable proportions of clay and sand and wholly free from chalk to a depth of several feet. In the surface layers, the reaction may be very acid. (pH 4 or under).

(5) In favourable circumstances mull may be formed, but a tendency to mor formation, often pronounced, is commonly observed. In extreme cases there may be a layer of very acid mor and detectable bleaching of the surface mineral soil. Accumulation of undecomposed litter depends on several factors besides the basic character of the soil, in particular on the density of the canopy, the exposure to wind and the activities of the soil fauna: this will be discussed more fully in a later section.

(6) The vigour of the bramble is often an index both of the fertility of the soil and of the difficulty attending the natural regeneration of the beech. Whereas on the moderately acid loams *Rubus* readily colonises each gap with a luxuriant growth capable of smothering the beech seedlings, on the very acid infertile soils the bramble is shorter and thinner, or may be wholly absent, so that, provided mor has not formed, regeneration is easier.

The Southern Counties

Records of *Fagetum rubosum* from other parts of Britain are rather fragmentary. Reference has been made to the West Sussex Downs, where, on the dip slopes and ridges, brown forest soils are sometimes found. In recent years however, the mature beechwoods in this area have largely been felled, and the woods seen were nearly all on chalky soils. Further west, in Hampshire and Wiltshire, extensive tracts of the chalk outcrop (as defined on the "solid" maps of the Geological Survey) are covered with a flinty loam drift. In some cases the drift is of great depth, while in other places the chalk is exposed at two or three feet and is thus within range of the roots of the trees. It is on such soils that many of the new State beech forests are being established, and considerable importance is, therefore, attached to their nature and potentialities. In the course of a survey of young beech plantations, numerous profile pits were examined and described in Micheldever, Collingbourne and other forest areas. In spite of the variation in the depth of the drift, the soils showed a considerable family resemblance. The texture is a medium loam or clay loam, friable, porous and usually with well-developed crumb structure in the surface layers. Flints are present, but not as abundant as in most of the Chiltern drifts. pH values are usually between 4.5 and 5.0, with little differentiation down the profile: readings between 4.0 and 4.5 were rarely obtained, whereas readings over 5 were sometimes recorded when the chalk was not far down.

The areas where these soils were examined formerly bore poor quality oak, with some hazel coppice and natural birch or ash. The subsidiary vegetation is now, pending the formation of beech canopy, a rich mixture of shrubs and herbs in which *Rubus* is commonly predominant. *Lonicera*, *Euphorbia amygdaloides* and *Deschampsia caespitosa* are very constant; *Fragaria*, *Glechoma hederacea*, *Endymion*, *Ajuga reptans*, *Mercurialis*, *Hypericum perforatum*, *Anemone*, *Viola riviniana* and other characteristic herbs of oak woods are frequently found. On thin drift over the chalk, calcicole shrubs (*Cornus*, *Ligustrum* et al.) are often conspicuous: and on places where the former canopy was very open, *Pteridium*, or *Holcus* and *Agrostis tenuis* may be firmly entrenched. There is every reason to believe that these plantations will ultimately have brambles dominant in the field layer and they may provisionally be assigned with some confidence to the *Fagetum rubosum*.

In these Southern counties only two mature beechwoods on loamy drifts were examined. One of these was Winchester Wood, south-west of Alton, Hants., where a fine 120-year-old stand had lately been thinned. The soil was a deep, acid (pH 4.4) loam, changing to a clay with depth: there was no sign of chalk at 80 cm. (32 in.) The average height of the beech was 105 feet: the rare oaks in the stand were generally inferior. At Slindon Park in Sussex, a remarkably fine, if over-mature, stand of beech was recorded on a very flinty, acid (pH 4.0 at the surface, 4.8 at 40 cm. (16 in.)) loam. The trees, now widely spaced and very large, are 115 feet in average height at an age of over 200 years. *Rubus* is dominant in the ground flora, except in gaps where bracken has come in, and in places exposed to the wind, where mosses are almost the only vegetation under the trees. (Appendix II, nos. 88-91, page 81.)

The beechwoods recorded on loams and clays in other parts of Britain were scattered over a very large area and a wide range of sites. The summarised data will be found in Appendices II and III, (pages 81 to 84) and a few notes for each district must suffice here.

South-west England

In this region most of the beech seen on non-calcareous loams occurred on the Devonian "shillit". The best example was on a hill site at Cothelstone, near Taunton, Somerset, (Nos. 85-87) where the height of the beech at 130-140 years ranged from 85 to 100 feet, in accordance with altitude and exposure. A few ashes, of good size and almost as tall as the beech, occurred in these woods. The considerable rainfall and altitude here neutralise the influence of the warm climate in promoting humus decomposition, and a tendency to mor formation was observed. Height growth was good also on the other two Devonian sites examined (Nos. 82, 83). A fine stand was seen on a very exposed site on the Mendips

(No. 84), where there was a very thin overlap of Lias clay on the Carboniferous limestone.

East England

The summarised records from over thirty Chiltern beech sites will be found in Appendix II: the stands have been placed in order from the youngest to the oldest. These show a considerable range in height growth from 63 feet in Hale Wood, Bucks. (No. 101) to 100 feet in High Wood, Bucks. (No. 105) and Oakengrove, Bucks. (No. 112) and 110-115 feet in the somewhat older Frithsden Beeches at Ashridge, Bucks. (No. 119-121). Stands on the exposed escarpment slopes showed poor growth (Crowell Hill, Oxon. No. 94; Hale Wood, Bucks): but at 800 feet, a very short distance south-east of the main escarpment, heights of 80-90 feet were recorded in Hailey and Cowleaze Woods, Oxon. (Nos. 111, 116). Poor growth was also recorded on some sites not very exposed as at Lackmore, (Oxon. No. 100), where were noted a slightly bleached A horizon, accumulation of mor and a flora of calcifuge mosses. In reference to sites like this, the expression "beech sick" has been heard more than once.

A further interesting point about many of the Chiltern stands recorded is that felled logs showed extremely close annual rings for ten, twenty or even thirty years. This is doubtless an indication that the saplings grew up under a canopy much too dense for satisfactory growth, and obtained release only when natural death or selection felling removed some of the shade. Many Chiltern beechwoods are planted and accordingly not all felled trees showed these very close rings.

Apart from the Chiltern Hills, there are potentially important areas of Jurassic clays (mostly transported soils) in Lincolnshire and the adjacent counties. These soils often contain calcium carbonate, and are thus in this respect suited to beech: they are, however, often sticky and compacted, and the site drainage is commonly unsatisfactory, so that gleying is a frequent feature. Some records of beech growth on the limestone formations or on chalky drift will be found in the schedule of calcareous sites (Appendix I, Nos. 75, 76, 78, 80). On other soils there is very little mature beech in the locality: young plantations of beech established by the Forestry Commission on boulder clay in Lincolnshire are showing promise, but the behaviour of older beech on the stiff clays or gleyed silty-loam soils awaits detailed investigation.

Midlands

In the east Midland counties beech is not a frequent tree, occurring sparingly in mixture with other broadleaved trees on basic drift soils derived from Triassic or Jurassic material. On these sites lime, ash and elm usually grow somewhat faster than beech, which is liable, therefore, to become reduced in frequency during the development of the wood. In the west Midlands, beech occurs, or occurred, rather more frequently, either as park trees, or in small shelter-belts or clumps, often in exposed positions. Beech on loamy soils is found mainly on outcrops of Silurian or (less frequently) Devonian or Ordovician rocks. These give rise to finely loamy soils, comparatively rich in silicate minerals. The few records summarised in Appendix II indicate that beech will grow to good size in the Welsh border counties and tolerate considerable exposure. The Gatley Clump, Herefordshire, stand (No. 128) is particularly noteworthy in this regard. The larger Croft Castle, Herefordshire, stand (Nos. 124-5) is interesting as an example of successful natural regeneration: the beech are on the whole of good form and should make a fine crop if carefully thinned.

Wales

Silurian soils and considerable exposure were also prominent in the records of mature beech from Wales. The beech avenue at Powys Castle, Montgomery, (Nos. 135-6), about 200 years old, showed encouraging height and diameter growth on a very exposed ridge. Stand No. 136 was partly oak, including some very well-formed oaks. The beech at Penbedw, near Mold, Flintshire, (Nos. 137-139), also of great and uncertain age, showed a range of height growth from 80-110 feet according to position. On the sheltered site (137), as well as Coedarhydyglyn, near Cardiff (133), where almost equally good height growth was recorded, the soil was derived from mixed drift, probably chiefly Carboniferous limestone. A fine stand was also seen on Old Red Sandstone near Brecon (No. 132). The inferior stand at Llanover, Glam. (No. 131) was near a colliery, and may have been affected by smoke as well as by the infertile acid soil. The records from Wales suggest that, in high rainfall areas, the growth of beech may be influenced more by soil fertility and less by exposure to the drying influence of the wind than is the case in the drier east.

Northern England

The few records from North-west England included but one on loam. This was of a 200-year-old clump growing on an upland site at 1,100 feet with full exposure all round. In these circumstances a height of 80 to 90 feet is remarkably good: it is a further indication that in areas of high rainfall soil fertility may count for more than protection from the full blast of the wind.

The more plentiful records from North-east England refer mostly to glacial drift sites, where the soil texture was commonly a silty sandy-loam, sometimes with a relatively impervious clay or silt-loam layer beneath. There were no signs of gleying in the upper 12 to 18 inches, and it appeared that, in these conditions, beech would make fairly good growth and keep healthy for about 200 years. The height growth was, however, generally inferior to that of beech on limestone soils, or on deep sands or sandy loams, in the North-east.

South-west Scotland

This region is climatically distinct from the following three: the high rainfall (40 inches or more), humidity of the atmosphere, strong westerly winds, mild winters and rather cool cloudy summers differentiate south-west Scotland from any of the other localities in Britain where beechwoods were examined. The two loamy sites (Nos. 162, 163) were both in some degree sheltered from the prevailing winds and height growth of the beech was good (90 to 95 feet). On both sites there was some mor formation, more pronounced at Shambellie, Kirkcudbrightshire, where the canopy was close. One tree in this wood had a top height of 109 feet and very good form.

Border and Lothians

During the eighteenth and early nineteenth centuries beech was very widely planted in the Lothians and Border Counties of Scotland: Some of the plantations occupy comparatively sheltered sites in the policy woods, but for the most part they occupy more exposed sites on the slopes of ridges and spurs and the upper slopes of valleys. These conditions preclude the development of a characteristic beechwood flora: brambles are invariably absent, even on the less exposed loamy sites, and herbs and ferns are very rare. Often the canopy is open enough, or the side light adequate, to admit grasses, of which *Deschampsia flexuosa* and *Holcus mollis* are much the commonest. Otherwise the ground flora is restricted to calcifuge mosses—*Mnium hornum*, *Hypnum cupressiforme*, *Eurhynchium myurum* and a few others. The sites are nearly all drift-covered, but the boulder till in this region is commonly sandy or a light or medium loam: silt-loam or clay soils were rarely seen. The glacial drift is variously derived from Devonian, Silurian, Lower Carboniferous, or intrusive igneous rocks. The loamy soils of the beechwoods seen (Nos. 149-159) were all moderately to highly acid (pH 4 to 5), more or less degraded brown forest soils: there were rarely indications of a bleached A horizon. Mull was usual, except under stands which were overstocked, or much exposed to the prevailing winds. The range of mean height of the mature beech (120 years and upwards) was from 66 feet on the fully exposed site at Grumphies Scar, Roxburghshire (No. 153) to 98 feet in the valley site at Floors Castle, Roxburghshire (No. 159). It is evident that beech is well suited to the conditions in this locality and will, on favourable sites, grow to large size. Fertile seed is also produced at intervals.

East Scotland—Aberdeenshire to Angus

This region is characterised by moderate rainfall, rather cold winters and a short growing season. Nevertheless the introduced beech is very much at home, and on the very sheltered site at Dunottar, Kincardine (No. 168) a mean height of over 100 feet was recorded. The beechwood soils were derived from Old Red Sandstone, or Aberdeen Granite, material and were usually deficient in the smaller particle sizes. At Hallyburton, Angus, (Nos. 164-166) a silty sandy loam was encountered: because of its rather impervious nature this has been grouped with the loams and clays. The effect of drainage impedance was evident in a shallow depression in the middle of the wood, where the soil was saturated with stagnant water and the beeches were dying.

Counties adjoining Moray Firth

All the beechwoods examined in this area were on sandy soils and will, therefore, be considered in the next section. This is also an area of moderate rainfall and short summers, but the winters are rather less severe than in the Aberdeen district. Further north, in Ross and Cromarty and in Sutherland, there are a few small beech stands, but it was not found possible to extend the survey to these.

It is difficult to characterise in a general way the beechwoods on loam of Scotland and the North of England. Clearly the term *Fagetum rubosum* is inappropriate, since bramble is very rarely recorded from them. Relatively sheltered beechwoods, on deep loams derived from Old Red Sandstone, have been described by Watt (1931, pp. 154-6) under the name of Scottish Herbaceous Beechwoods. The Dunottar beechwood was a fair example of this: here there was a good mull, bearing, in the lighter places, certain mull herbs (*Urtica*, *Geranium*), ferns (*Dryopteris filix-mas*, D. *austriaca*), and the better mosses (*Mnium undulatum*, *Eurhynchium praelongum*, *Catharinea undulata*). On alluvial soils, the great wood rush (*Luzula sylvatica*) is often dominant. In the sites recorded during the present survey, the ground vegetation was largely controlled by the wind, which excluded most herbs. In more sheltered conditions, with adequate opening up of the canopy, it might be expected that the beechwoods on loams in Scotland and northern England would show mull humus with ferns (*Dryopteris* spp.) and a variety of the moderately exacting herbs and grasses dependent on the good nitrification. Blagdon, Garden Wood, Northumberland, (No. 146), shows what might be expected on soils of moderate acidity. *Allium*, *Fragaria*, *Mercurialis*, *Epilobium montanum*, *Chamaenerion angustifolium*, *Stachys sylvatica*, *Scrophularia*, *Rumex sanguineus* and *Zerna ramosa* were all recorded from this wood. The occurrence of *Rubus* (frequent to locally dominant) shows that bramble may dominate the field layer of a mature beechwood as far north as Tyneside. It is possible that the presence or absence of *Rubus* in northern beechwoods depends on the vegetational history of the site as well as on the climate.

BEECHWOODS ON SAND (Appendices IV and V, pages 85 to 87)

Beechwoods on sand occur in almost every part of Britain and embrace a wide range of soils and sites. At the one extreme are sands of relatively high base status in the southern counties, where a brown forest soil with good mull can be seen even under a full canopy of beech. At the other extreme are well-developed podsols with a thick layer of mor. Between these extremes are all gradations from slightly degraded brown forest soils with a tendency to mor, to podsols with distinct bleached A horizon and a B horizon enriched in iron and finer soil particles, but without a "humus B" layer. Characteristically, beechwoods on sand show a degraded brown forest soil profile with slight mor formation, but no distinct bleached layer. In favourable circumstances there may be mull and no profile differentiation. On the other hand, in unfavourable conditions, especially on the more acidic sands, leaching of sequioxides may proceed and a weakly podsolised soil results. There is evidence that a fully matured podsol with "humus B" and soft iron pan will not develop under beech. Such soil profiles were seen only rarely, in circumstances where there is some likelihood of a pre-existing podsol. Much depends, however, on the local factors, and it is difficult to obtain information on this point from beechwoods which are probably all planted and doubtless mostly first crops. Records from 36 English beechwoods on sandy soils have been summarised in Appendix IV, page 85. These have been tentatively arranged on the basis of the soil profile development, so that brown forest soils with mull (B) come first in the table. These are followed by somewhat degraded brown forest soils usually with mor (D); weakly podsolised soils (P) and, lastly, strongly developed podsols (PP). Scottish beechwoods on sandy soils have been summarised separately in Appendix V, page 87.

Brown Earth

Beechwood on a sandy mull soil was examined at Powderham, near Exeter, Devon, (No. 174). The soil was derived from sandstone and conglomerate of Permian age, and the following horizons were identified under a moderately deep layer of beech and other leaves:

0 to 5 cm. (0 to 2 in.)	Mull layer of dark brown loamy sand and organic matter; fine crumb structure, porous, friable. Abundant *Mercurialis* roots and rhizomes and fine beech roots.
5 to 30 cm. (2 to 12 in.)	Reddish-brown fine sand with some humus; granular structure, porous. Rare sandstone fragments: abundant beech roots.
30 to 60 cm. (12 to 24 in.)	Dark brownish-red fine sand, friable, porous, granular structure. Occasional sandstone fragments, and one piece of granite. Beech roots frequent to 50 cm. (20 in.), occasional below.
60 to 70+ cm. (24 to 28+ in.)	Similar, but stonier, red sand.

The soil was sub-neutral in reaction, and supported a sparse ground vegetation of *Mercurialis*, *Iris foetidissima*, *Hedera*, *Euphorbia amygdaloides*, ferns (*Dryopteris* spp.), *Ligustrum* and seedlings of sycamore and ash. There is a mixture of broadleaved trees 130 to 140 years old, but beech predominates. The beeches are of large size and well over 100 feet in average height, but often of rough form; one of the largest is 133 inches in girth at breast height and 120-125 feet tall. Many of the chestnuts are 100-110 feet in height: the oak dominants are 90 to 100 feet.

Sites like the one described are not common on sandy soils. They may be found on sandstones of the Devonian or Permo-Trias systems, on immature alluvial soils, or sometimes on coarse-textured glacial drift with much basic material. Such sites are apt to be considered by foresters too good for beech, but a number of records of beech on sandy brown forest soils have been summarised in Appendix V. In Scotland, too, brown forest soils were rarely encountered on glacial drift derived from Old Red Sandstone (Nos. 205, 206, 207). These occurred only on sites sheltered from the wind, with a slightly open canopy, or bearing a mixture of oak and beech. Under a full canopy of beech, or when exposed to the wind, raw humus tends to form, and the mull plants are driven out. In favourable circumstances, as the data show, excellent growth of beech may be expected on these soils, which are warm, deep and well drained. On exposed sites, as at Mulgrave Castle near Whitby, Yorks, (No. 176), or at high elevation, as at Chagford, Devon, (Nos. 171, 172, 183) the rate of growth drops sharply.

Degraded Brown Forest Soils

Many of the beechwoods on sand which were examined during the survey showed a soil profile which could be best described as a degraded brown forest soil. Most of the stands were first crops of beech on land which previously carried a variety of types of vegetation—forest, pastoral, or waste. It appeared certain that the soil had not approached a condition of equilibrium with the new vegetation, so that, as evidence about the original vegetation was scanty and unreliable, many of the profiles described are not of great interest fundamentally.

On sandy soils a tendency to mor formation is almost invariably observed under beech. On sites exposed to the drying action of the wind, this is almost inevitable, although the mor layer will be thin, because the leaves are scattered. On more sheltered sites, mor formation can usually be prevented by a more open canopy. The mor layer is always very acid in reaction (pH 3.5-4.2) and, as it accumulates, the process of leaching is initiated. In the soils classed as degraded brown earths, there was, however, only slight profile differentiation, and the reddish-brown tints of the ferric oxides were evident even in the surface mineral soil. The ground flora becomes greatly impoverished, the most conspicuous elements being: (*a*) several grasses (*Deschampsia flexuosa*, *Holcus mollis*, *Poa*, spp., *Agrostis tenuis*, *Anthoxanthum odoratum*), these being most conspicuous in shelterbelt beechwoods, or near the margins of stands; (*b*) calcifuge mosses including many species, of which *Mnium hornum* is the most constant and abundant; and (*c*) where there is no thick accumulation of mor, a few low-growing herbs (*Veronica officinalis*, *V. chamaedrys*, *Oxalis acetosella*, *Galium hercynicum*, *Viola riviniana*). *Luzula pilosa* is common in many woods, and the fern *Dryopteris austriaca* is found in moist sheltered places. The growth of beech on these degraded soils may be little inferior to growth on brown forest soils with mull, as the records from Raby, Durham, (Bath Wood, No. 192), Nunwick Park, Northumberland, (Nos. 193-194), and Dunsinnan, Perth, (No. 219), indicate. The soils are in fact generally brown earths, showing the influence of the slow break-down of beech litter on acid parent material. The long-term results of this influence would be more considerable and would, perhaps, show themselves in reduced growth of beech.

Sandy Podsols

In these there is always a considerable accumulation of undecomposed litter forming a very acid mor. There is also a bleached A horizon, which may be very shallow. The illuvial horizon shows rusty mottling, and is more or less compacted; above it there may be a thin chocolate-coloured layer (humus B layer) but this was rarely seen in the beechwoods examined. Wherever there is more than one or two centimeters of mor, there are many fine (mycorrhizal) beech roots in the mor. Wittich (1947) states that beech does not show the marked tendency to root in the mor layer of podsols, such as is characteristic of spruce: yet it has been constantly observed in the present investigation that mor layers are more or less intensively exploited by beech roots. This is perhaps undesirable, inasmuch as mor layers are liable to dry out in summer drought: it also doubtless means that the nutrients from the B and C horizons are being less effectively drawn upon.

In England, beechwoods on sandy podsols were recorded on the Bagshot and Bracklesham formations of the Tertiary, on Lower and Upper Greensand formations, on the Trias and on glacial drift of Yoredale (Lower Carboniferous) material. In Scotland the parent material of the podsolised sands was usually Old Red Sandstone drift. The records will be found summarised in the appendices: a few typical examples are described in more detail below.

Weakly podsolised sands (P)

Example (1) Penny Hill, Bagshot, Surrey,(No. 197). This is a very sheltered site, and in spite of rather unfavourable soil conditions, the beech had grown 100 feet in 100 to 130 years. There is very little vegetation under the full canopy of beech, only patches of calcifuge mosses (*Mnium hornum*, *Dicranum scoparium*, *Dicranella heteromalla*, *Campylopus flexuosus*) near the bases of the trees. Under a rather thick layer of fresh leaves and a thin layer of mouldering leaves, these layers were identified:

3 to 0 cm. (1 to 0 in.)	Black spongy fibrous mor with abundant fine roots of beech: pH 3.5.
0 to 3 cm. (0 to 1 in.)	Dull dark ashy-grey fine sand, deeply humus-stained; structureless, porous, friable. No stones. A few fine beech roots. pH 4.0.
3 to 6 cm. (1 to 2½ in.)	Similar paler ashy-grey fine sand. Rare flinty stones; rare roots. pH 4.0.
6 to 30 cm. (2½ to 12 in.)	Dull greyish-brown fine sand, structureless, friable, porous; occasional rounded and sub-angular flints. Beech roots abundant. pH 3.5.
30 to 52 cm. (12 to 21 in.)	Yellow-brown, slightly coarser sand. More frequent small flinty stones: structureless, porous, friable. Beech roots frequent throughout. pH 4.0.
52 to 80+ cm. (21 to 32+ in.)	Pale greenish-grey glauconitic fine sand, with brown streaks, soft, loose, porous. Stones rare, roots very rare. pH 4.2.

It will be noted that beech roots were abundant in the mor and scarce in the leached upper layers of mineral soil. It seems likely that this soil was leached before the beech was planted in it.

Example (2): Jockscairn, Roxburgh (No. 229). A fully exposed upland site in the border district of Scotland will furnish an example of the other extreme of beech growth on weakly podsolised sands (61 feet at age 130). The beech had been planted with Scots pine, of which nearly all were gone. *Deschampsia flexuosa* was frequent to abundant, with some *Galium hercynicum*: no other plants were noted in the wood. Under the influence of the wind there was very scanty litter. The mor layer, about 7 cm. (3 in.) thick and matted by the roots of grasses and fine beech roots (mycorrhizal), showed a pH of 3.7. Under this were the following layers:—

0 to 12 cm. (0 to 5 in.)	Dull ashy grey sandy loam; structureless, loose; occasional small rounded stones. Frequent beech roots. pH 4.2.
12 to 31 cm. (5 to 12 in.)	Greyish-white bleached sandy loam; structureless, porous; occasional small stones. Beech roots moderately frequent. pH 4.4.
31 to 50+ cm. (12 to 20 in.)	Red-brown fine loam, compact, occasional beech roots to 40 cm. pH 4.8.

Jockscairn Plantation is a fully exposed example of the beech shelter belts and clumps which are very common in the Scottish Border district. Some of the beech plantations were made on pasture, and some on ground carrying oak scrub. There was evidence that Jockscairn previously bore a crop of Scots pine: the marked leaching of the soil may have taken place at this time.

Strongly podsolised sands (PP):

Example (3) Witham Park, Maiden Bradley, Wilts., (No. 202). This small wood was remarkable for the good height growth and good forms of the beech on an unpromising site. It was also interesting on account of the soil variation observed. The beech on the podsol site stand on a rather exposed spur at 625 feet; yet the mean height is nearly 100 feet at age 140 and the forms, following an improvement thinning, are distinctly good. There is a scanty ground flora of *Festuca ovina* and calcifuge mosses (*Dicranum scoparium, Leucobryum glaucum, Mnium hornum*), the mosses covering most of the considerable area swept bare of leaves by the wind. Examination of the soil showed these horizons:—

F layer of undecomposed beech and moss remains.

6 to 0 cm. (2 to 0 in.) (more or less)	Brownish-black mor with plentiful mycorrhizal beech roots. Rather dry. pH 3.3.
0 to 12 cm. (0 to 5 in.)	Greyish-black deeply humus-stained podsolised sand; structureless, friable. A few small pieces of chert. Frequent fine and larger beech roots. pH 3.8.
12 to 41 cm. (5 to 16 in.)	Pale ashy-grey leached sand: frequent chert fragments; few beech roots. pH 3.8.
41 to 77 cm. (16 to 31 in.)	Yellow-brown sand with chocolate-coloured compact humus pan layers above and below and humus veins pervading the yellowish sand which was fully penetrated by beech roots. pH 4.0.
77 to 88+ cm. (31 to 35+ in.)	Greenish-brown sand, with a few stones (chert). Roots very rare. pH4.2.

The soil was also examined in another part of the same wood, about 150 yards from the first pit (cf. stand No. 185). Instead of a well-defined podsol, there was a slightly leached brown-earth. The site had a slope of 20° to the west and it is possible that the soil was, by erosion, an immature or truncated podsol. Alternatively, the difference may be accounted for by differences in the former vegetative cover of the two sites: the podsol may have borne heath before the beech was planted, the degraded brown forest soil, birchwood like the adjoining ground to south.

Example (4): Letterfourie, Banff (No. 232). Although immature, this was the best example seen of a Scottish heath beechwood on podsol. *Calluna, Vaccinium*, young *Sorbus aucuparia* and heath grasses occurred frequently in gaps and at the margin. Under the beech canopy were only calcifuge mosses, which covered about 50 per cent. of the ground. Apart from an occasional birch, the beech, 60 feet tall at 76 years, were the only trees. The soil was a well-developed podsol, with the following layers:—

5 to 0 cm. (2 to 0 in.)	Chocolate-brown spongy mor, with many fine beech roots.
0 to 27 cm. (0 to 11 in.)	Pale grey-brown fine sand; faint granular structure, porous, friable. Occasional sub-angular pieces of sandstone; abundant fine and larger beech roots.
27 to 43 cm. (11 to 17 in.)	Buff-brown fine silty sand, with some rusty streaks; structureless, friable, porous. Many fragments of Devonian sandstone; abundant beech roots. This layer was generally followed, but not always with a sharp boundary, by
43 to 47 cm. (17 to 19 in.)	Brownish-black sand, with a few small stones ("Humus B")
47 to 80+ cm. (19 to 32+ in.)	Pale grey brown, somewhat silty, fine sand with rusty mottling above; structureless, loose. Abundant stones and boulders; beech roots occasional to 55 cm.

This is evidently akin to the soil under the pre-existing heath. It is possible that the rusty mottling noted between 27 to 43 cm. (11 to 17 in.) may indicate the beginning of a new illuvial horizon in stability with the new vegetative cover.

No other examples of well-formed podsols were seen in the Scottish beechwoods examined: but the soil at Gordon Castle, Morayshire, (No. 230) was perhaps prevented by the steep (30°) slope from developing further in that direction. As noted previously, it is believed that mature podsols under beech are always a relic of former conditions—usually a pinewood, *Calluna* heath, or pine heath vegetation. In such cases, beech would not, of course, transform the podsol, but might stem the process of leaching. On the other hand, under continued crops of beech, it is likely that degraded brown forest soils would become further leached, unless very careful management was attended to. The result would depend much upon climate and the parent material of the soil, as well as upon the treatment.

On base-deficient sands the climax soil under beechwood is probably a weakly podsolised soil such as was seen on the Tertiary and Cretaceous sands in Surrey and Sussex. The numerous records from soils of this type (denoted by P in column 16 of Appendices) indicate that beech will give a good account of itself. On mature podsols the height is probably inferior, but the data are too scanty for any general statement. In Burnham Beeches, Bucks., on Reading sands with some glacial sand and gravel, the trees rarely exceed 60 to 70 feet in height (Tansley, 1939). Where, however, the soil is deep, freely drained and without a hard iron pan, it appears that a height of 90 feet may be attained in favourable situations (cf. the data from Witham Park, Silwood Park and Edmond Castle). In view of the good height growth of beech often recorded on these leached southern sands, it may be asked why beech is not a more frequent constituent of the woods. The stands recorded were in small blocks, in some cases evidently planted. One reason is, of course, that beech was cut out in favour of oak, as happened also on better soils. But it is also a fact that beech will not regenerate freely, once a thick layer of mor has formed: left to themselves beechwoods on podsolised sands, or on other kinds of soil where continuous mor has formed, degenerate to heath.

Chapter 5

REVIEW OF SITE FACTORS IN RELATION TO THE GROWTH OF BEECH

In the preceding review of beechwoods recorded in all parts of Britain, soil characters were made the basis of classification. There are no records from peats, but otherwise the soils examined include a comprehensive assortment, ranging from shallow rendzinas through deep brown forest soils to strongly podsolised sands. The rate of growth of the beech varies much, though there is a tendency for the poorest growth to be at the extremes, more especially, as far as these data go, at the rendzina extreme. Closer inspection of the tables will make it evident that, apart from soil, the two factors upon which height growth mainly depends are latitude and exposure, of which the former governs the general climate and the latter profoundly influences the local climate of the stand. Collectively, these two climatic factors override the effect of soil factors, so that, on sheltered sites in the south, the growth of beech on the poorer soils (rendzinas and podsols) is often better than the growth on the best soils on more exposed sites in the north. Climate (including microclimate) and soil are, however, closely interdependent in their action: temperature and wind affect the water-supplying capacity of a soil, rainfall affects the leaching process and so on. This interaction must always be kept in view when the individual factors are considered.

It will not be out of place here to examine the reliability of height at maturity as an index of quality in beech crops. It has been found in the case of conifers that height is practically independent of treatment, and a fair reflection of the capabilities of the site. In well-stocked stands, the same appears to hold true for beech, but there is some doubt whether this applies to open-grown crops. In the present survey, a few stands which appeared to have grown in rather open conditions throughout the rotation were not relied upon in the assessment of height quality. Many other of the older stands had been much opened out at the date of inspection, but there was good evidence that they had grown in full canopy until height growth was practically at an end.

In the appendices, top heights which, on account of inadequate stocking, may not do full justice to the site, have been placed in brackets.

SOIL FACTORS

For rendzina soils, the limiting factor is usually the water-supplying power. On shallow, highly calcareous, soils, particularly where the aspect is southerly, beech may suffer from chlorosis; but it appears that chlorosis is exceptional, and that in many cases an unhealthy colour of beech foliage (on old or young trees) and the associated die-back of twigs can be ascribed to drought. The water-supplying capacity of chalk and limestone soils depends on a number of factors, of which the most important are connected with the profile, the arrangement of the rock strata and the topography. Depth, stoniness, and organic matter content are the chief variables in the soil profile, and it has been indicated in a previous section how, in the evolution of calcareous soils under woody vegetation, the changes in these properties may gradually improve the water capacity and retention of the soil. As regards stratigraphy, it must first be noted that chalk and the fissured limestones are highly pervious, so that water drains away vertically through them. The strata may, however, differ considerably in permeability, and there may be substantial lateral seepage at the level of relatively impermeable marly strata. The Chalk Rock at the base of the Upper Chalk is a layer of this kind, and there are corresponding marly strata in the Jurassic limestones. The consequence is that, on the dip slopes, the normal supply of soil water is locally enriched by seepage at the outcrops of these strata, whereas on the escarpment slopes vegetation is deprived of much of the water stored in the chalk as a result of winter rains. The fine growth of beech on the dip slopes of the South Downs may be partly ascribed to this circumstance. On the corresponding escarpment, the tendency to water famine is mitigated by the northerly aspect and locally by patches of loamy drift. Less favourable conditions are found on the Chiltern escarpment, facing generally north-west, but, locally, south-west, west or north; there the westerly winds aggravate a natural tendency to drought. Aspect, slope and degree of exposure to the westerly winds are the significant topographical factors which influence the water-supplying power of rendzina soils. On steep slopes there may be erosion, which results in patches of very shallow soil above and patches of deeper soil below. Unless the slope is so steep as to facilitate erosion, it seems unlikely that the natural drainage through a permeable parent material like chalk is much increased above that on level ground. In summer, beech forms a dense canopy, so that the influence of aspect on summer soil temperature is relatively small. For the same reason, the influence of wind is greater than in stands of light-crowned trees: the growth of a cover of ground vegetation which would halt its free passage over the forest floor is prevented by the deep shade. Consequently evaporation from the ground under a beechwood is determined more by exposure to the wind than by exposure to the summer sun.

Brown forest soils of loamy texture have a much more favourable water-balance. They are deeper than rendzinas, more retentive of water and not readily leached. There are, however, two sets of conditions in which the growth of beech may be adversely affected. Where there is much clay or silt, there may be deficient aeration in the deeper soil, and the fine roots of beech will then be restricted to the upper freely drained and well-aerated horizons. The results of this are slower growth in height and diameter, and sometimes increased danger of drought, should the superficial root-bearing soil dry out in summer. Gleying was usually only slight in the beechwood soils examined: most instances were on glacial drift soils containing much silt. In these cases the freely drained superficial soil was retentive of moisture and of good fertility, and the height of the beech was little inferior to that on deep freely drained brown forest soils. In two cases the fatal effect on the beech of small depressions causing seasonal waterlogging of the surface soil was manifest.

The second set of conditions in which unsatisfactory growth of beech may be found on brown forest loams or clays results from the slow break-down of beech litter on base-deficient soils. Where the canopy is dense, the natural coldness of heavy soils is aggravated, and the break-down of the acid litter is retarded. Mor accumulates and the turn-over of nutrients is halted. This condition is made much worse where there is any impedance of drainage: in this case the beech will not draw the minerals from the G horizon, so that the tendency to acidity will be increased. The roots exploit mainly the upper well-drained soil, which may, therefore, dry out in summer. If that happens, not only is the health of the trees affected, but the biological processes are checked by lack of moisture at a season when the temperature is optimum. These factors, namely the natural acidity of the soil, low temperatures under dense beech canopy and, in some cases, imperfect drainage seem to be at the root of the mor formation and the so-called "beech sickness" in some parts of the Chilterns. Except under the two sets of conditions which have been described, the growth of beech on brown forest soils of loam or clay-loam texture is excellent, surpassing, in otherwise equal environmental conditions, that on any other kind of soil. Best of all are the brown forest soils immediately overlying calcareous rocks, for in these the maintenance of fertility and healthy soil conditions under beech is not in doubt.

Basic sands and sandy loams which give a brown forest soil profile also provide first-class soils for beech, as for may other species. Warm, well-drained and deeply exploited by roots, these soils promote relatively fast early growth and compensate by their depth for feeble water retention. In Scotland, very good height growth of beech was recorded on fertile sands or sandy loams derived from Old Red Sandstone. More acid sands and gravels, which are more important and extensive, become readily leached under beech, with the formation of mor and an unevenly distributed root-system. Provided there is no compact humus or iron pan, beech sends its roots deeply and makes moderately good growth (as at Witham Park, Cowdray, Longleat, Dunsinnan, etc.). More unfavourable conditions may be provided on sandy soils with much silt, where, as a result of the washing down of the finer particles, a rather impervious silty layer is formed, which prevents deep rooting. The fine roots of beech then become confined to the mor and the impoverished A horizons. These tendencies were observed on most of the drift soils, especially in North-east England and Scotland. But these soils are young and in some cases originally rich in bases, so that leaching of nutrients and the formation of an impervious silty layer have not proceeded far enough to interfere seriously with the growth of beech.

Summing up one may say that the growth of beech is restricted at one end of the scale by lack of moisture due to excessive drainage on many rendzina sites; and at the other end by drainage impedance, which is commonly an indirect result of acidity and the washing down of silt and clay particles.

LATITUDE

Although beech is native only in the southern counties of Britain, the remainder of this island is well within its climatic range. The extreme north of Jutland has the same latitude, 57° 40′, as the southern shores of the Moray Firth, where a good deal of well-grown beech, 80 feet or more in height, was seen during the present survey. But beech occurs naturally considerably farther north in southern Sweden, where, until the deforestation carried out in recent centuries, it was one of the commonest trees, reproducing with great freedom. It is also noteworthy that the Chiltern Hills share a latitude of 51° 50′ with Solling, in the heart of the European beech forest: in respect of latitude, the southern counties of England are very favourably situated in the range of European beech forests. It is true that the proximity of the Atlantic Ocean causes summers rather cooler than those of Western Germany: but this is again compensated by the lower altitude of the beechwoods of Southern England. It is not, therefore, surprising that, on favourable sites on the South Downs, the performance of beech is equal to that in the beech forests of Hanover. It is also to be expected that the height growth will fall off as one moves north into northern England and then into Scotland, just as one observes a fall off in Denmark, as compared with West Central Germany. It is difficult to estimate the magnitude of this fall-off in height growth, when variations in soil and exposure are almost inextricably bound up with it: in particular, the chalk sites of the South Downs cannot be compared with anything further north than Yorkshire. On the Yorkshire chalk outcrop, the Warter Priory and Londesborough stands (86 and 79 feet at 115 years) may be compared with the moderately exposed West Dean stands in Sussex (93 and 91 feet at 125 years). Kingthorpe on the Yorkshire Oolite (87 feet at age 140) bears comparison with Kingscote (100 feet at age 135), or Badminton (106 feet at age 140) on the Gloucestershire Oolite.

On sandy soils little difference is discernible in the data from North and South Britain. Mean heights of 120 feet at maturity are recorded from both Durham and Westmorland on sheltered sites: Scotland's best is 105 feet at Dunsinnan, Perth., but this site was much less sheltered. On the less favoured sandy sites, however, 90 foot beech is of common occurrence in the south, whereas 80 feet is barely attained in East Scotland. Most of the records of southern beech on loamy brown forest soils are from the Chiltern Hills, where the height of the beech varies considerably: there was some evidence that naturally-regenerated crops long held back under the shade of the parent trees never quite attained the height proper to the site. On good mull soils with moderate exposure a height of 100 feet at 150 years was commonly attained: in North-east England 85 to 95 feet was usual on corresponding sites and an equal height was not uncommon in southern and eastern Scotland.

It appears, therefore, that one whole quality class is a rough measure of the difference between beech in southern England and beech on equivalent sites in eastern Scotland. No attempt has been made to correlate height growth with temperature. Without much laborious manipulation, the available statistics of temperature do not lend themselves for this purpose. It is probably the summer temperature which is significant for beech growth and, insofar as the mean temperatures for July are an indication of summer warmth, they can be compared for the weather stations adjacent to the beechwoods investigated. In Germany, Markgraf (1932) claims to have found a fairly close correlation between the altitudinal range of beech forest and the July isotherm of 13°C. (=55.4°F.). All the sites recorded during the present survey, including those in Easter Ross and the high elevation sites, appear to have July temperatures equal to or exceeding 55.4°F.: further north some places in Caithness lie just outside this range. Stations in East Scotland, between Strathpeffer and Aberdeen, have a mean July temperature of 56 to 57°F. as compared with 60 to 62.5°F. for stations in the southern counties of England. There is a rather smaller difference (3 to 4°F.) in the yearly mean temperatures for these two districts.

TOPOGRAPHY

Topography influences the growth of trees through the soil and, mainly, through climatic factors. The interaction between topography and soil was referred to when soil conditions were considered, and it was pointed out that steep slopes may greatly modify the normal profile developments and aspect the soil temperature. On exposed sites, the wind often has an important drying influence on the surface soil, thus affecting both the available water for tree growth and the biological activity; by scattering the leaves wind also influences the organic matter content. In the case of soils with an impervious subsoil, the topography may determine whether serious drainage impedance will affect the healthy development of the beech root system. The influence of topography on the local climate is of greater and more direct significance for the growth of beech. As regards altitude, it is of interest that the four stands recorded at about 1,000 feet were all at least 80 feet in height. These were situated in Somerset (Cothelstone, No. 85); Hereford (Gatley Clump, No. 128); Flint (Penbedw, No. 139) and Westmorland (Whale Moor, No. 140). None of these sites had any considerable shelter from the wind, and the data witness to the suitability of beech as a shelter-belt tree on exposed upland sites. This is confirmed by the numerous records of satisfactory height growth and wind-firmness at altitudes of 500 to 800 feet in South Scotland, Wales and the North and West of England. There is very little beech in western coastal districts, and no records were secured.

Aspect is important chiefly on dry chalk soils or excessively drained sands, where southerly aspects aggravate soil drought. It might be supposed that north aspects would prove unfavourable in the north of Britain, by delaying the beginning of growth in spring: there is no clear evidence of this in the data, which are however, insufficient for any definite statement. An important influence of aspect is observed in spring, before the beech has formed canopy, when the sun is able to warm the surface soil and litter and stimulate biological activity. On north aspects a tendency to mor formation has been observed even on shallow chalky soils, where the sun scarcely penetrates in spring and the heavy canopy maintains a low soil temperature in summer.

A more generally significant effect of topographical position is exercised through exposure to the prevalent winds. Exposure to wind is dependent on altitude, aspect, and the presence of near or distant higher land, or in some cases of adjacent woods: it is, therefore, often very difficult to assess on the ground. In the summaries the degree of exposure has been expressed on a 0 to 4 scale, the extreme figures being reserved for fully sheltered and severely exposed sites. Inspection of the tables will show the considerable fall-off in the height growth of beech on exposed as compared with sheltered sites. In several instances it is, however, possible to make more direct comparisons on adjacent sites. At Raby, in Co. Durham, heights of 114 and 120 feet were attained on sheltered sites in Bath Wood: a short distance away, on Middle Ridge, at slightly higher elevation with considerable exposure to south-west winds, the mature height was 83 feet. A better comparison was available in Sussex on the Goodwood Estate, where several assessments were made in a uniform stand at uniform altitude. On the sheltered east slopes of the spur, the beech were 105 feet in height at age 170: on the slope exposed to west-south-west the height was only 78 feet. Wind influences the water-supplying power of the soil on exposed sites, as has been mentioned. But its main effect is doubtless on the humidity of the atmosphere and the rate of transpiration. On extremely exposed mountain sites beech assumes a stunted shrubby form, with one-sided development of branches: these wind forms have not been seen in any of the localities examined.

Topographical factors are of much importance in beech silviculture, in relation to frost damage. Beech forest is generally absent from frosty valley bottoms and depressions. In the Chiltern beechwoods, where, under a selection system of management, canopy is maintained over the young growth for many years, beech was, however, found on a number of valley sites which would certainly have been difficult to reforest with beech after a clear felling.

Topographical factors thus affect the growth of beech in many ways. A thorough appraisal of any site must have regard to these influences, which may determine the choice of species and the results to be expected from it.

RAINFALL

Rainfall data are included in the summaries for all beechwood sites recorded. There is no evidence of any general correlation between average annual rainfall and the height growth of beech, and mean heights of 100 feet or more were recorded for several sites where the rainfall is under 30 inches yearly. It was suggested above that, on many beech soils, in particular shallow rendzinas and coarse sands, soil water is an important limiting factor to beech growth. On these soils there can be no doubt that the normal rainfall, particularly where a large proportion falls in the winter months, is often below the optimum. These conditions apply to many sandy sites in the south and east and perhaps also to the Bunter sand areas of the Midlands, all of which have a yearly rainfall of less than 30 inches. The same applies to the Chiltern chalk sites, the rendzina sites on Magnesian limestone or chalk in Yorkshire, and some of the calcareous sites in the rain-shadow of the Cotswolds. The chalk dip slopes in the Goodwood area, Sussex, receive about 35 inches, and are thus more favourably treated than most of the limestone beechwood sites encountered. Beech was not examined in the very high rainfall areas of the West, but for a number of sites recorded the mean annual rainfall is 45 to 50 inches. Apart from the greater likelihood of podsolisation, there is no reason for supposing that beech is unsuited to areas of high rainfall.

Chapter 6

HEIGHT GROWTH OF YOUNG BEECH CROPS

In Appendix VI, page 88, the available records of young British beech crops up to the age of 50 years have been summarised. These show a wide range in rate of height increment, from about 0.25 feet to 1.6 feet yearly and they are not easily analysed, though they are often very instructive about the factors upon which the successful establishment of beech depends. These factors include: repeated frosting; temporary dominance of competing natural vegetation during the 1939-45 war years; excessive shade from an overhead shelter crop; lack of thinning.

In the examination of the data, attention should be concentrated first on the height-age relation and the remarks column. The records have been tabulated in order from youngest to oldest and they may be reviewed in the following classes:

(1) 5 to 14 years (the first three very young plantations being passed by).
(2) 15 to 24 years.
(3) 25 to 34 years.
(4) 35 to 48 years.

Group (1) comprises 37 stands with an average age of 9: group (2) 28 stands with an average age of 19.5: group (3) 12 stands with an average age of 29.3; and group (4) 20 stands with an average age of 39.8 years.

(1) The mean increment in the youngest age class was 0.88 feet (about 10½ inches, or 27 centimetres) yearly. (No allowance has been made for the height gained in the nursery.) Several stands had grown relatively much more slowly, in particular Nos. 236, 243(*a*), 248, 253, 261, 271. In the sample from Gardiner, Wilts., (C 18, 2.9 feet at age 5) a dry soil and severe root competition from privet and dogwood caused very poor growth. The poor sample at Raby, Durham, the Folly (2.4 feet at 7 years), came from an exposed area with dense competing herbaceous vegetation (*Deschampsia flexuosa*). In both these cases good comparisons are available with beech growing in more favourable circumstances. Charlton, Sussex, (C.17, 4.7 feet at 9 years) and Micheldever, (C.21, 6.8 feet at 14 years) both suffered from neglect of weeding during the war years. Collingbourne, Wilts., (C.9, 4.2 feet at 8 years) and Buriton, Hants., War Down (6.2 feet at 11 years) were both difficult downland sites, with strong competition from the ground vegetation and probably some frost damage. On the other hand, there are some crops showing a mean height of well over a foot a year. Such are Coxalls Knoll (No. 238); Dalkeith, Midlothian (No. 247); Haldon, Devon (No. 256); Collingbourne, Wilts. (C.5, Nos. 268, 269); and Buriton, Hants., (C.6, No. 270). Of these six it is noteworthy that the last four were all underplantings, even if the temporary shelter had since been removed.

(2) For the 28 stands in the age range 15 to 24 years, the mean increment is practically the same, viz., 0.89 feet per annum. In this group again there are several crops where frost, or the competition of the associated vegetation, have resulted in very slow establishment and a mean increment of little more than six inches yearly. In compt. 6, Charlton,

Sussex (Nos. 272, 273), two adjoining plots showed respectively mean heights of 8.6 feet and 16 feet at 15 years: the former plot carried a dense flora of woody species, whereas the latter had mainly a herbaceous woodland flora. No. 274, Buriton (8.7 feet at 15 years) suffered from lack of weeding during the war years; No. 285, Buriton (10.3 feet at 20 years) from repeated frosts; and No. 276, Micheldever (7.2 feet at 16 years) from frost and weed competition. Some of the Crawley Forest, Hants., samples showed the worst growth of all, e.g., No. 288 (4.3 feet at 21 years). No. 291 (6.1 feet at 22 years) and No. 293 (5.5 feet at 22 years). Drought and frost were jointly concerned in this poor performance. The slow growth at Ebworth, No. 280 (9 feet at 18 years) appeared a fair reflection of the dry soil and exposure. Most of the remaining stands showed mean yearly increments of more than a foot. Some of the best are two Buriton plantations established under light shelter (Nos. 276, 278) and the Thetford, Norfolk, sample (No. 288), where Corsican pine, planted at the same time, had sheltered and drawn up the beech. But very good growth was recorded also for some beech plots established without overhead shelter on the site of former broad-leaved woodland. Examples are: No. 297, Duns Castle, Berwick, (39 feet dominant height at 23 years); No. 298, Alice Holt, Hants., copper beech, (43 feet at 24 years); No. 295, Powys, Montgomery, (29 feet at 22 years). In these cases soil moisture conditions were favourable and there was often some lateral shelter from standing woods.

(3) A mean rate of height growth of 1.36 feet yearly was recorded for the 12 stands in the 25-34 years age group. The poorest had grown at a mean rate of more than a foot a year and the best Dean Forest (Glos.) stands (Nos. 308, 311) at about 18 inches yearly.

(4) In the last group, where the age range is from 35 to 48 years, the mean increment shows a wider range from stand to stand. The average is 1.24 feet yearly and the rate is more than a foot a year for all except the following four: No. 319, Dalkeith (30 feet at age 38 years); No. 325, Lambton (37 feet at 40 years); No. 326, Eildon Hall (40 feet at 40 years); and No. 328, Cirencester Park, Glos., (39 feet at 43 years). In two of these the beech had been planted under oak (No. 319), or pine (No. 326) and appeared to have been held back a little by shade. In the other two stands the beech were suffering from competition with the faster growing ash (No. 325), or larch (No. 328). Excluding these four, we find a mean yearly increment of 1.34 feet (16 inches, 41 centimetres) for the 28 stands aged 25 years and over. These do not include any sites where the soil is very shallow and dry, or the exposure extreme.

GROWTH IN RELATION TO SITE CHARACTERS

In the Appendix VI B the 99 records have been classified on the basis of soil and of the former vegetation of the site. The five soil types recognised are:—

1. *Chalk rendzinas*: i.e., more or less shallow, highly calcareous, soils directly weathered from the Cretaceous chalk.
2. *Shallow loams on chalk*: sub-neutral loamy soils, with or without chalk in the profile, resting on chalk at a depth of two feet or less.
3. *Other limestone soils*: Soils derived from the Jurassic, Permian and Carboniferous limestones, varying a good deal in depth and texture, but usually fairly shallow and alkaline or neutral.
4. *Acid loams*: A large class, including many downland soils, where a considerable depth of flinty loam overlies the chalk, as well as loams derived from Carboniferous and Silurian rocks, or boulder-till.
5. *Sands and sandy-loams* : of variable origin and fertility.

The sites have been further subdivided according as the land formerly carried:

A: Pasture or heath.
B: Scrub.
C: Woodland.
D: Arable crops.

The woodland sites have been split into those (C1), where a clear felling preceded the planting of the beech and those, (C) where some trees were left on the ground, usually for the purpose of sheltering the beech. In several of the older stands, the previous use of the land is conjectural, and it is likely that some of the scrub and arable sites may recently have borne woodland. Whether this is so or not, it is evident that the great majority of the recorded beech crops were raised on former woodland sites.

Some of the environmental factors suspected of influencing the early growth of planted beech will now be shortly considered.

Former vegetation

It is clear that the old woodland sites have produced much better growth than the pasture or scrub sites. Practically all the examples of fast early growth come from woodland sites: and in the case of some exceptions to this rule (Hackwood, Hants., No. 324, Buriton, Hants., No. 278, Chazey Heath, Oxford, No. 313) there is a likelihood that the site bore woodland in the recent past. The pasture sites include a large proportion of examples of very poor growth. Although there are but few records from beech planted on arable land, there is an indication that early growth is much better on such ground than on pasture or heath: this is no doubt due to good surface rooting conditions and the absence of strong competition from established vegetation. Scrub represents an advance from pasture in the direction of woodland, but the competition from the roots and sometimes the shoots of common scrub plants like dogwood, thorn, privet, ash, spindle, rose, is often detrimental to the early growth of beech. The Crawley, Hants., records indicate, however, (when Nos. 287 and 293 are compared with 286 and 290) that, on shallow chalk soils, beech may derive benefit from the presence of scrub of moderate density.

Shelter

The first point to be noted is that shelter may vary widely in character and intensity. Many State plantations of beech (e.g., those at Collingbourne and Goodwood) were made under a thin crop of natural birch, etc., and further thinning or complete removal was effected within ten years. Such shelter tempers the force of the wind and the fierceness of the sun's rays, but probably has little influence on the light intensity and does not fully protect against frost. In other cases shelter consisted of rather dense lateral screens of hazel, etc., coppice, which modify the environmental factors differently. At the other extreme are underplantings of more or less full crops of oak or pine (or natural regeneration under beech) where shade may be the most important limiting factor. The second noteworthy point is that, on the old woodland sites, the presence of some overhead shelter does not generally appear to have resulted in improved growth of beech. Where other conditions were favourable, fast growth was recorded on clear felled woodland sites, as at West Dean, Sussex, (No. 312—54 feet at 35 years); Hardwick (No. 322—50 feet at 39 years); Powys, Montgomery, (No. 301—34 feet at 25 years); Abbotswood, Glos., (No. 314—54 feet at 37 years); Goggin (No. 331—69 feet at 48 years). It should be observed, however, that most of the recorded beech plantations on clear felled areas refer to small blocks in extensive standing woods, which often afford valuable shelter from the wind. In this respect many of the plantations on cleared woodland were more favourably situated than the plantations at, e.g., Collingbourne, Wilts., with only a light overwood screening them from full exposure to the prevalent winds.

On treeless sites, shelter may be provided by another species planted with the beech, but on difficult sites the beneficial effect is realised only if the associated tree happens to be much more tolerant than beech of the adverse conditions. Good examples of effective shelter of this kind are given by the Cirencester, Glos., stand (No. 327) where, on a fertile loam, larch grew vigorously and nursed the beech; and by the Thetford, Norfolk, stand (No. 288) where Corsican pine within a few years provided valuable shelter on a site which would doubtless be too dry and exposed for unprotected beech. The Crawley, Hants., data illustrate the failure of this system where the associated tree (larch) is no more tolerant of the environmental conditions (shallow dry soil and frost) than is beech. There are many unrecorded examples of the same ineffective shelter on difficult sites.

Topography

There are no records from over 1,000 feet: below this there is little evidence that altitude affects the growth of beech in the early stages. In Appendix VI A good growth is recorded at 600 feet or over, from Maiden Bradley, Wilts., (257), Brecon (258), Collingbourne (262, 263), Powys (295), Blubberhouses, Yorks., (305), Colesbourne, Glos., (309, 310), Stanage (329) and the Goggin (331). Aspect is important in relation to sun and wind and, probably frost. South and west aspects are unfavourable on sites liable to drought. An examination of 18 examples of outstandingly good growth showed that, in the great majority of cases, the aspect lay between north-north-east and south-south-east, and in no case was the aspect west or south-west. The topography is also of much importance in relation to the liability of a site to spring frost.

Latitude

There are only six records from Scotland, all from the South Conservancy. But there are 14 records from Northern England and, taken together, these 20 records indicate that, south of the Forth, the growth of beech in the early years is little affected by the latitude. The best of these northern stands showed an average rate of growth of well over a foot per year.

Soil

Most of the examples of very slow early growth relate to rendzina soils (e.g., Crawley, Buriton). On the deep sands and more retentive loams, whether acid or alkaline, early growth is, in otherwise favourable conditions, almost invariably good. The comparatively few records from the older limestones suggest that, in the areas of low rainfall, shallow freely drained soils result in slow early growth (e.g., Bramham, No. 250, Ledston, No. 281). On old woodland "rendzina" soils growth is often very good (e.g., West Dean, No. 312; Buriton, No. 376). But, apart from the effects of overhead or side shelter, which must usually be taken account of on old woodland sites, the forest rendzina is a much more favourable rooting medium than the rendzina of chalk pasture. The former is deeper, less chalky and without an obstinate grass mat.

A general inference from these data is that establishment and early growth are much better on old woodland sites, partly because of the shelter afforded by residual trees, or adjacent standing woods, partly because of the favourable woodland soil and the reduced root competition from grasses or shrubs. Heath and pasture soils are in general less favourable. Shallowness and dryness render chalk pasture soils specially unfavourable, and frost often aggravates the effects of soil conditions and exposure when beech is planted in the open. For England and southern Scotland a height of 50 feet at 40 years may be expected on old woodland sites, irrespective of soil, where the exposure is moderate: on the best sites beech will do better than this. On other sites, the height growth is much more closely dependent on soil conditions, frost, local relief, exposure and soil cultivation: in favourable circumstances the rate of growth would soon approach that on a corresponding old woodland site.

PART III. STUDIES BASED ON THE SURVEY OF BEECHWOODS, 1948-1950

Chapter 7
SILVICULTURAL NOTES

MIXTURES

ALTHOUGH MANY of the mature beechwoods seen were purely beech, in most cases there was evidence that the woods had at one time been mixed. The commonest associates of beech were Scots pine, larch, oak and ash: others were Norway spruce, sycamore, wych elm, chestnut and cherry. Interest in these mixtures touches on the relative height growth of beech and other trees on different soils, the nursing effect of the other tree on beech and the reciprocal influence of beech on its associate, and the effect of the mixture on humus decomposition.

Oak

Oak is very frequent in beechwoods on loams and clay loams, especially in the Chilterns, where it regenerates with some freedom and is an important element in the natural succession from grassland or scrub to beechwood. On the slightly acid loams (pH 5 to 6.5), the oak, although making good growth, is generally overtopped and suppressed by beech, thus forming at most only a small proportion of the mature wood. On more acid loams, the trees are fairly equally matched, and many mature woods on such soils contain a high, but locally variable, proportion of oak. In such mixtures the oaks were usually tall and of good form. Heights of 90 to 100 feet were occasionally recorded on favourable sites: heights of 80 to 90 feet were common. The influence of beech on the form of the oak boles is remarkable, and there are some very fine clean straight oaks of large diameter scattered through the Chiltern beechwoods.

Outwith the Chiltern area, oak was often seen in the planted beechwoods on loamy soils. An instructive example was seen on the Powys Castle estate near Welshpool, where, at 800 feet on an acid Silurian silt-loam, the 200-year-old beech and sessile oak were nearly equal in height (93 and 91 feet respectively). The good form of these oaks prompted the head forester to use the mixture on an adjacent site, as well as on other sites in the park. In these young plantations beech sometimes tends to outgrow and suppress oak: but on this 800 feet ridge site there was very little difference in height at 22 years.

On calcareous soils, oak is suppressed by beech, persisting only in gaps, where oaks of fair height and diameter are occasionally seen, although they are clearly inferior to the oaks grown on the deep loams.

Oak is an infrequent constituent of the beechwoods on sandy soils, and there is little information about the relative height growth. The most northerly wood recorded (Foulis Castle, No. 207) had, however, a considerable proportion of oak mixed with the beech. The beeches averaged 100 feet in height and several of the oaks were more than 90 feet tall; but they tended to be subdominant to the beech and the height of the sample was very variable, averaging 86 feet. Other evidence from beechwoods on sand suggested that oak would generally tend to be outgrown and suppressed.

Admixture of oak in beechwoods has an important influence on litter decomposition. This is partly a result of the somewhat greater facility with which oak leaves break down, owing to their lower carbon-nitrogen ratio; but mainly a consequence of the reduction in the density of canopy, as compared with the pure beechwood. More sunshine and rain are admitted during the summer, so that the biological processes of decomposition are accelerated.

Ash

Ash is, like oak, a common constituent of beechwoods in the southern counties, but occurs over a rather different range of soils. On the calcareous soils ash regenerates very freely; there is usually an ashwood stage in the succession from grassland or scrub to beechwood, and ash occurs with some frequency (as in Singleton Forest, Sussex, No. 4) in the developing beechwood. Except in gaps, ash becomes overtopped by beech, which finally attains a much greater height. Ash is accordingly a rare constituent of the mature beechwood on rendzina soils. On the limestones outside the natural range of beech—e.g., on the Carboniferous limestone of the Pennines, ash is the natural climax dominant; but the height growth of ash on such sites is inferior to that of beech, which would, on introduction, suppress the ash. Certain of the limestone formations of the Jurassic, notably the Forest Marble, contain thin beds of marl, on which ash grows very well, even if the soil is shallow and stony. Given a reasonable amount of space, occasional ashes will keep their place in the canopy in beechwoods on these soils and grow to large size. At Badminton, some fine examples were noted, several of them over 100 feet in height and 23 to 35 inches in diameter at breast height.

On the loam or clay-loam soils of good base status, ash is a frequent constituent of beechwoods. On these soils both the absolute height growth of the ash, and the competitive power *vis-a-vis* beech are better than on the rendzinas, so that ash is an occasional to frequent constituent of the mature wood. Several of the Chiltern beechwoods on the more fertile brown forest soils of heavy loam or clay-loam texture included some fine ashes reaching the height of the canopy. On the more acid clay-with-flints and plateau gravels of the Chilterns, ash is not at home; oak then increases in frequency and ash disappears. In young and old planted woods on loam in other parts of Britain, mixtures of ash and beech were occasionally seen. On the sub-neutral or slightly acid loams, particularly in the moister west, ash rapidly out-grows its rival, forming a pure crop unless help is given to the beech. On the loams which are less fertile and drier (whether because of lower rainfall or freer drainage), the balance is tipped in favour of beech, which eventually dominates the crop.

An interesting example of ecological selection was recorded in an extensive 25-year-old mixture of beech, ash and larch on a rather acid silty loam derived from Triassic drift at Leaton Knolls, Salop. In the moister dingles sheltered from the wind, ash was equal with beech or dominant; but the main part of the wood was on a well-drained slope exposed to the south-west, and on this site the ashes had failed, or were being suppressed by the beeches; the larch had all recently been removed. A soil reaction of pH 5.5 to 6.75 is a rough index to the optimum performance of ash in competition with beech. Occasional good ashes may be found in beechwoods on more acid loams and fine ashes will grow on the basic marly beds of the Jurassic. Ash was very rare in the beechwoods on sand, even in those of good base status.

The observations made about the effect of an admixture of oak in promoting litter breakdown in beechwoods apply with greater force to an admixture of ash, the leaves of which break down with much greater rapidity. In both cases the micro-climatic benefits may be lost by an admixture so great as to foster a rich ground flora. The reciprocal influence of beech on ash is probably not inconsiderable. The humid atmosphere of small gaps in the beech canopy are favourable to the moisture loving ash, height growth is stimulated by the slightly taller beech and clean boles often result: the dark beech canopy also restrains the rich ground vegetation which flourishes under pure ash crops.

European larch

European larch, always a popular tree on private estates, has been used in mixture with beech on many chalk and limestone sites in the south. This mixture, which often also includes Scots pine and occasionally spruce, has been used also in other parts and was encountered as far north as Moray. Most of the mature planted beechwoods on chalk, and many of those on the Cotswold limestone, showed unmistakeable evidence of a conifer nurse, of which larch was probably the most frequent. It is not known how these older plantations were established. Current plantations (for the practice persists) are nearly always row-about mixtures of beech and larch (or beech and pine, as the case may be), although other arrangements, due to the late Mr. Ray Bourne, have been seen in Cirencester Park, Glos. There is no evidence that the modern device of double or triple row alternations was used in the past. Larch and beech mixtures of various ages have been examined on calcareous soils, and it is possible to form a picture of their development.

On sites in any degree liable to frost the mixture is inappropriate. Canopy is slow in forming and both trees experience crippling injuries. On dry shallow chalky soils, also, larch makes poor growth and does not nurse the beech. On other calcareous soils larch usually makes fairly rapid early growth and soon functions as a useful nurse for the beech, which it will, before long, threaten to suppress unless thinned in good time. Procrastination in the thinning of larch and beech plantations is seen too often: but unless former generations of foresters were much more diligent, it seems that beech will tolerate a moderate amount of neglect, because some very fine beech crops have been raised with larch (and/or pine) nurses. The final result is that, unless the larch is allowed to exterminate the beech early on, the beech will ultimately outlive and suppress the larch, except in gaps caused by natural death or thinning of the beech. Much of the larch is cut out as valuable intermediate produce during the rotation, while the fungus *Fomes annosus*, always virulent on chalky soils, accounts for more. It is, therefore, rare to see big mature larch in beechwoods: survivors are tall, but usually thin in the top and spindly.

On non-calcareous soils, larch is infrequent in beechwoods, oak and other hardwoods being the usual associates on loamy soils. On sands, beech was commonly planted pure, or with oak, chestnut, or Scots pine. The help afforded to beech by associated larch has thus been mainly on the deeper calcareous soils, or thin loams over chalk, and has consisted in some protection from excess transpiration during early years and, in the economic sphere, in the value of the larch thinnings, which render the cultivation of high quality beech economically possible. An admixture of beech may benefit a larch plantation by allowing wider spacing of the larch and thus, perhaps, some reduction of the incidence of canker fungus. As regards the biological condition of the soil, larch needles have been found to be peculiarly resistant to decay, so that the composite litter is, other things being equal, slower in breaking down than beech leaves alone. On the other hand the larch-beech mixture admits of a more favourable microclimate at ground level, so that biological activity is fostered. Insofar as larch-beech mixtures occur on calcareous soils, where microbiological changes are promoted by the neutral reaction and earthworms are active, the decomposition of litter will never be unduly retarded.

Scots pine

Scots pine is, like larch, a much-used nurse for beech on chalk and limestone. Scots pine is to be preferred to larch on dry chalk soils and on sites where frost may be expected. In both these conditions it has, nevertheless, serious shortcomings as a nurse because, on the very shallow rendzinas, it may become chlorotic and grow very slowly. On frosty sites, moreover, the pine offers quite insufficient protection to the beech during the critical early years, although it undoubtedly makes eventual establishment more certain. Although Scots pine nearly always grows long enough to serve as a nurse for beech, there are some shallow rendzinas on which it experiences root troubles, which lead to early death before it has attained an economic size. On other calcareous sites, Scots pine in mixture with beech behaves very much like larch, threatening to suppress the beech in early life, but eventually ceding to the latter's superior height. In the mature wood the pine is usually found only near the margins or in gaps. Scots pine has also been used as a nurse for beech on thin loams over the chalk. Here, as on the deeper rendzinas and on sands, it gets away fast and affords the tender young beeches valuable protection.

In regard to litter decomposition, Scots pine in a beechwood brings about a worse litter and, unlike larch, also has an unfavourable microclimatic effect: the canopy is scarcely lighter in summer, whereas, in early spring, the pines tend to stand in the way of that advantageous warming of the soil surface which takes place under the bare beech, or larch and beech.

In the Goodwood area of Sussex, patches of sub-spontaneous Scots pine may be seen here and there on downland turf in the beechwood zone. Occasional beech seedlings may be seen among the pines; but it seems unlikely that this attempt by nature to copy artifice and do without the thorny scrub stage in the succession can prosper without the forester's rabbit-proof fence.

Norway spruce

In northern Europe, mixed beech-spruce woods are of frequent occurrence, both at certain altitudes in the mountains where natural beech forest gradually gives way to spruce forest and in those regions where, under the drive for higher production, spruce and beech have been planted in mixture. The mixture has been criticised in Germany, on the grounds that the biological advantages from the beech are trifling in comparison with the great sacrifice of production in the diluted spruce forest. A small proportion of Norway spruce is found in some British beechwoods on chalk, where pine and larch, or one of these, has been used to nurse the beech. On chalky soils, particularly in regions of low rainfall, spruce grows poorly and is very prone to *Fomes annosus* rot, so that there is rarely much trace of it in the mature beechwood. Its main value is as game cover in winter.

Sycamore

Sycamore is widely dispersed throughout England and Wales and Southern Scotland. In Yorkshire the tree has been planted on a variety of soils, including, in particular, the Magnesian limestone; planted, or sometimes sub-spontaneous, sycamore was seen in many of the Yorkshire beechwoods. In the South, sycamore does not seem to have been extensively planted pure, or in mixture with beech, but sub-spontaneous sycamore is frequent in gaps in mature beechwoods, or on clear-felled areas. The silvicultural requirements of sycamore appear to resemble those of ash, i.e., it does best on neutral or mildly acid loams and clay loams; but is less tolerant of imperfect drainage than ash. Sycamore also appears to thrive on immature glacial drift soils, as in the Skipton district of Yorkshire, even if these are somewhat coarse-textured and acid. The mature height, even on optimum sites, is inferior to that of ash or beech, so that sycamore is usually overtopped by beech, unless given preferential treatment. Sycamore on suitable sites grows very fast at first, and may outgrow and suppress beech in the first 30 or 40 years: a good example of this was seen on Carboniferous limestone drift at Ingleborough, Yorks. In this vigorous early growth on good soils sycamore resembles ash, with the advantage that, casting a heavier shade, sycamore is better fitted to oust its rivals.

In a number of southern beech forests, sycamore appears to be gaining ground at the expense of beech and ash. Winged fruits, produced in abundance most years, free regeneration on mull soils, rapid early growth, resistance to rabbit attack, and considerable tolerance of shade, all equip sycamore as a very aggressive colonist. In the Goodwood area and in Cirencester Park, Glos., and elsewhere, sycamore appears to be invading the beechwoods where openings offer suitable conditions. The future of these sycamore groups is obscure. Where beech regenerates freely, ultimate replacement by the taller beech appears inevitable; but, where rabbits abound, the sycamore is largely protected from competition and seems likely to advance, unless man intervenes. Growing in such gaps among older beech, sycamore produces some fine trees, occasionally of very good form. Good sycamores, about 100 feet in height and of large size, were recorded in these conditions in Duncombe Park, and in Bramham Park, both in Yorkshire.

Sycamore leaves decompose faster than beech leaves on the same soil; but the tree also casts a rather heavy shade and therefore no appreciable improvement in the rate of litter break-down can be expected to follow the mixing of sycamore with beech.

Other species of trees found in British beechwoods can be only briefly mentioned. In spring the wild cherry or gean (*Prunus avium*) adorns some of the Chiltern beechwoods. It appears to do best on the deeper loams, but also occurs on the chalk; occasional trees attain the height of the mature canopy. Wych elm occurs here and there in beechwoods in many parts of Britain. A more exacting tree, elm can compete successfully with beech only on the best soils, as on the deep calcareous boulder till of the East Midlands and Lincolnshire. Elsewhere elm is commonest in understocked, ornamental woods, where the ample room and its low commercial value favour the persistence of elm. Some sweet chestnut was noted in a few beechwoods on the lighter soils. The most interesting instance was at Hallyburton, in Angus, where a small proportion of chestnut occurred in a 130-year-old beech stand. The chestnuts were usually a little shorter than the 90 foot high beeches, and appeared in some parts of the wood to have been suppressed by the beech earlier in the rotation.

UNDERPLANTING

Mixtures of beech with other trees often owe their origin to an underplanting of some light-crowned tree with the shade-tolerant beech. Oak, Scots pine and larch are the species most commonly seen with a beech underplanting, and examples of all these were encountered.

There are also cases where severely-cankered larch has been very heavily thinned and underplanted with beech, with, or without, other species. In these cases the object is the elimination of the most affected larches, and the reduction of the risk of further infection, coupled with the provision of a stand-by crop should the larch fail to make a worthwhile crop.

In some cases Scots pine and birch have been used to nurse beech planted under them after thinning. This is one important method of establishing beech, and will be considered below when problems of beech establishment are reviewed.

PRUNING

For several reasons pruning is rarely practised in beech plantations. In close canopy the trees usually clean themselves satisfactorily without artificial help. Secondly the value of beech timber has hitherto hardly justified the cost of pruning. Thirdly, there is the risk that organisms of disease may gain entry through pruning wounds. On one estate in Gloucestershire, beech plantations were seen in which the pruning of side branches had lately been carried out. In one of these, an 18-year-old beech and larch plantation at 800 feet on the Cotswold limestone, cankers were frequent, usually in the angle of branch and main stem. Similar cankers (possibly of bacterial origin) were observed in some unpruned plantations, and it is not clear whether the wounds aided the spread of infection. In this plantation the branches had been shortened to a three or four inch stub. It is possible that small beech plantations could be improved by a treatment aimed at the singling of all double or triple leading shoots. Pruning in an older beech plantation was seen in the Eskdale Woods, Dumfriesshire, where a promising, carefully thinned, plantation of beech, 40 years old when examined, had been pruned in two stages about ten years previously. The trees remaining after four thinnings (about 440 per acre) had all been pruned close to the bole to a height of 15 to 20 feet. A few trees had been seriously affected by canker.

THINNING

The recorded beechwoods provided very little material for a comparison of the results of different thinning practices. In the older stands, which formed the bulk in most parts, it was difficult to find out when thinnings were begun, or with what regularity and intensity they had been repeated. No examples of high or crown thinning were seen, and the low-thinning appeared in most cases to have been unduly light, though there were exceptions to this. The mature beechwoods in the Goodwood area, where much of the finest beech was seen are (or were until quite recently) for the most part overstocked, and the diameter growth is disappointing for the age. It appeared that, once the associated conifers had been removed, little was done until the 1939 to 1945 war, and post-war reorganisation, provided a stimulus. Some woods in other parts of the country had evidently been left to thin themselves, whereas several had evidently been given very careful attention. As regards the younger crops, there were welcome indications that the importance of an early beginning and the regular prosecution of thinnings is now widely recognised. One of the advantages, for private estates at least, of a considerable admixture of conifers, especially larch, is that the growth of the beech is nearly sure to benefit by a certain measure of thinning at a vital stage.

ROTATIONS

The records from British beechwoods show that, at least on most of the sites where it is found, beech will remain alive and sound for 200 years or more. There is evidence that on poor sites, i.e., shallow dry rendzina soils and badly drained soils, the unfavourable soil/water relations cause root disease and an earlier onset of senescence and death; with this proviso, it can be said that the rotation may be determined on economic grounds by the time required, under appropriate thinning, for production of trees of the most profitable size. A beech tree of 18 in. diameter, or 56 in. girth, at breast height, has attained a valuable size, and it is interesting to know at about what age trees of this mean size will be produced on the different sites where beech is grown.

A glance at the tables forming Appendices I-V will reveal a most inconstant relation between age and mean girth of the trees. This is partly a result of site differences, partly a result of widely different intensities of thinning. Reliable information will only be given by sample plots established on a series of well defined sites, and thinned according to definite prescriptions. Meanwhile some indications are given by the best performances of fully stocked stands on some of the major site types. On good brown forest mull soils in England, the Glenthorne, Devon, stand (No. 83) with a mean girth of 75 inches at 105 years is noteworthy: several other stands showed the requisite mean girth of 56 inches at 120 years or less. In the Chilterns, trees of 56 inches girth appear to be infrequent in stands under 150 years old. This is, however, largely a result of the selective felling (intensified during the war) of the larger trees. On fertile sand with mull, the fully stocked Powderham B, Devon, stand, No. 174, (mean girth 84 in. at 140 years) again testifies to the fast growth in the south-west. On podsolised sands, mean girths of 56 and 62 inches respectively at age 100 were recorded at Nesscliffe (Salop) and Penridge (Wilts.). All the older (140 years and over) stands in the podsol group were of satisfactory dimensions. On the chalk soils of southern England, trees of 56 inches girth are infrequent in stands under 140 years old. For the shallow rendzina soils this result probably represents the poor potentialities of the site. On some of the deeper chalk soils, however, (e.g., West Dean and Goodwood, Sussex) the comparatively small size of the trees was partly due to very conservative thinning; the deep chalk soil at Latimer, Bucks., produced beech with a mean girth of 66 inches in 115 years. Large dimensions were attained in a shorter time on the deep calcareous loam at Barton Hall, Devon (82 inch girth at 110 years) and on deep chalky boulder-clay at Exton, Rutland (67 inches at 98 years). The Scottish data show that on moderately good sites as far north as Aberdeen, trees of 56 inches mean girth can be produced, without heavy thinnings, in 130 years.

In Hanover, under a system of low thinning, Quality II beech has a mean girth of about 56 inches at 140 years, which is accordingly the accepted length of the rotation. In the southern parts of Britain, beech makes faster growth, and the most economical rotation may prove to be a good deal less than 140 years. It is only on shallow rendzina soils, or on dry exposed hillsides, that it will be necessary to extend the rotation to 140 years, or to rest content with smaller trees. Until increment curves for beech, on a range of sites, are available, it will not be possible to fix the most economical rotations with any precision.

RESPONSE TO COPPICING

In view of the well-known fact that beech responds poorly, as compared with other broadleaved trees, to coppicing, it is of interest to record that some of the beech High Forest inspected during this survey had been derived from coppiced or pollarded trees. Many of the trees in the Frithsden Beeches (Ashridge Estate, Herts.) and at Stourhead, Wiltshire, had been pollarded, it seems to provide firewood for the mansion. Left to themselves, the Stourhead trees eventually attained a height of 110-120 feet, and some would surely have been magnificent timber trees but for the mutilation. High forest, derived partly from coppiced beech, was occasionally noted on sites which were probably at one period subject to common rights and used as sources of firewood.

Chapter 8

PROBLEMS OF ESTABLISHMENT

There are four ecologically distinct sets of conditions in which young crops of beech are ordinarily raised, and each of them merits special consideration. These are: clear-felled woodland; chalk downland; derelict woodlands; and mature beech or mixed forest suitable for natural regeneration. In all consideration of the successful establishment of beech, the environmental factors of soil, climate, animals, and plant life must be compared with the conditions obtaining in natural beech woodland where reproduction is present. It will make the discussion clearer if these conditions are first described. After that, the different systems of natural regeneration will be briefly reviewed in the light of this description of fundamentals. Then the artificial establishment of beech on cleared and derelict woodland and on pasture, heath and scrub, will be considered in turn.

NATURAL REGENERATION

In primeval beech forests, the close canopy suppresses any regeneration until the wood opens out with age. Beech rarely produces much fruit before the age of 50 years and, in close canopy, fruiting, except at the margins, is probably quite inconsiderable until the trees are much older. In any case such seedlings as do appear under full canopy survive for only a few years at the most under the deep shade. Regeneration is initiated when individual trees die here and there from old age or disease, and the gaps become colonised by seedlings derived from nuts which fall from the adjacent trees. The mother trees protect the tender seedlings from frost, and from excessive sun and wind; while the increased light and reduced root competition in the gap offer much better growing conditions than exist under full canopy. A further effect of the gap is that the access of sunshine and rain promotes humus decomposition and nitrification in the surface soil. Except on very acid soils, where a considerable thickness of mor may have formed, the soil and microclimate of these small gaps are favourable to the regeneration, which is mainly threatened by competition from animals or other plants. Deer and rodents are the important animals in relation to beech regeneration: much the most influential animal in British conditions is the rabbit. Blackberry (*Rubus*) is the most abundant of the serious plant competitors.

It is an interesting and suggestive point that rabbit and blackberry were both probably of little or no account in the primeval beech forests of central and north-west Europe. A native of south-west Europe, the rabbit had doubtless long been at home in the main beech forest areas of France, Germany, Denmark, and Switzerland: but rabbits do not travel very far from their burrows in search of food, and it is unlikely that they threaten regeneration in the heart of extensive beech forests. The bramble is an Atlantic species and its abundance in the beechwoods of the southern part of Britain, wherever the soil is sufficiently moist, is doubtless bound up with the evergreen habit there assumed. Normally restrained under canopy by competition with the trees for light and moisture, brambles often develop luxuriantly in gaps, so that beech regeneration, unless it has a good start, may be smothered. However, where rabbits abound, a moderate growth of brambles may offer valuable protection to the seedlings.

The essential conditions for the successful natural regeneration of beech may be summarised as:—

(1) Abundant mast.
(2) Good distribution of seed: therefore no large openings in the stand.
(3) A low population of deer and rodents, or adequate protection therefrom.
(4) Favourable surface soil conditions, affording concealment for the nuts and, on germination, moisture and a ready access to the mineral soil.
(5) Absence of smothering ground vegetation.
(6) Protection from frost.
(7) Adequate light.
(8) Absence of excessive root competition.
(9) The avoidance of damage by felling.

Each of these conditions requires some explanation.

Abundant mast

Beech produces plentiful seed at irregular intervals, which, in the climate of north-western Europe, may extend to a considerable number of years. The studies of Lindquist (1931), Watt (1923) and others have shown fairly conclusively that flower production is stimulated by a high summer temperature, full mast years being invariably preceded by years when summer sunshine and temperature were above average. In the Scandinavian beech forests, Lindquist found that two consecutive mast years never occurred, but that, given favourable weather, beech may produce two good masts in three years. The good 1948 and 1950 masts in Britain confirm this last point, besides illustrating the importance of summer warmth. Partial local masts break the runs of fruitless years, but Watt's work has proved that the hazards from various causes, particularly drought and animals, are so formidable that partial masts rarely have any practical result. Seed production in beechwoods is also partly governed by two other factors, one within and the other outside the forester's control. Severe spring frosts when the beech is in flower may destroy the potential mast: this appears to have happened in parts of North-east England in May, 1948. It is well known that small crowned trees in a close beech canopy bear much less heavily than trees with large crowns in a stand which has been thinned. It is customary to initiate regeneration by a preparatory heavy thinning designed to promote flowering.

Good distribution of seed

Good distribution of heavy seeds like beech nuts necessitates gaps of small size, unless, of course, there is a sufficient seedling cover on the ground before the gaps are made. Satisfactory distribution will follow a heavy general thinning, as in the large shelter-wood system of regeneration; or the clearance of narrow strips; or small openings caused by the felling of one or two mature trees. Larger openings, 20 metres (22 yards) or more in diameter, do not become adequately stocked in the middle. Furthermore, if brambles are present, the favourable light and moisture conditions in the centre of large gaps cause a luxuriant growth which will smother such seedlings as do appear. The centres of large gaps, may, however, become colonised by trees of other species, especially birch, ash, oak and cherry; the seeds of the former two being brought by wind, those of the latter two by birds. These four trees all appear to be less sensitive than beech to bramble competition. Under these conditions there often results a group of beech saplings with a few oak, birch, etc., in the centre.

Deer and Rodents

Rabbit control is essential to successful beech regeneration, especially in small woods adjacent to areas of scrub and neglected pasture and woodland, where the animals burrow and breed. Wood mice (mainly the long-tailed mouse, *Apodemus sylvaticus*) certainly cause much destruction of seed and damage to young seedlings of beech; yet, as agents in the formation of mull and in the incidental burial of nuts out of sight of pigeons and out of danger from drought, these rodents may, on balance, be advantageous in a beechwood.

Surface soil conditions

The condition of the surface soil profoundly affects the security of the nuts and successful germination. The best conditions are provided on calcareous sites, sheltered from strong wind, where litter break-down is fairly rapid and there is a good crumb under a general but thin cover of beech leaves. The nuts become covered by the leaves, which fall immediately after. Many lodge in crevices in the mull, or get buried by mice. Unless there is prolonged drought at germination, the seedling roots make early connection with the mineral soil, and tolerate the drying-out of the surface litter. On brown forest soils with mull, almost equally good conditions obtain, though there may be a thicker litter layer which delays the anchorage of the roots in the mineral soil. On acid soils where mor has formed, the soil environment is less favourable. During 1949, several promising crops of newly germinated beech seedlings were observed in Scottish beech-woods on mor and it appears that in favourable weather there may be many survivors. But the seedling roots are confined, or practically confined, to the mor, which may dry out in summer with fatal effects on the regeneration. Where, instead of mor, there is a thick layer of undecomposed leaves, the seedlings are equally vulnerable to drought. Beechwoods on sites where the wind sweeps the forest floor offer very unfavourable conditions for seedling establishment. On the extensive areas of bare ground or moss the nuts are deprived of the concealment normally afforded by leaves and herbs. Such as survive the attacks of birds and mice will rarely germinate successfully, because the wind keeps the surface soil inhospitably dry and at the same time increases transpiration. In the occasional depressions in these wind-swept stands, leaves accumulate to such a depth that the chances of successful establishment are almost equally small. Lastly, beechwoods which have been excessively opened-out present difficulty in regeneration. A dense growth of grasses, or in some cases of blackberry, may keep the nuts from reaching the soil at all. Competition for water, light and nutrients is also likely to result in unusually high death rates of seedlings.

The forester desiring natural regeneration of beech must pay careful attention to the condition of the forest floor and to the way in which this is affected by silvicultural practices. In several countries efforts have been made to improve the edaphic environment for beech regeneration by cultivation of the ground. On acid sands with mor formation in Germany, good results have been claimed for a surface cultivation, combined with the application of lime. Cultivation has also been tried in the Chiltern beechwoods, but there have been no controlled experiments.

Ground vegetation

In this country brambles are the most widespread source of danger to beech regeneration from competing ground vegetation. On some sites, the tufted hair-grass (*Deschampsia caespitosa*) forms large tussocks which exclude beech seedlings. On others bracken (*Pteridium*) may be present in sufficient force to invade any natural or artificial gaps, but bracken is usually absent from pure beech stands. Occasionally the wild raspberry (*Rubus idaeus*) replaces the bramble as the main colonist of gaps in beechwoods. In the Chiltern beechwoods, brambles are such a menace to regeneration on some estates that mechanical mutiliation of the large clumps has been tried experimentally. Grasses may invade understocked beechwoods and add to the difficulties of regeneration, both by forming an unreceptive mat of dead leaves and by competing with beech seedlings for water and nutrients. Some of the German beech forests were very heavily thinned during and immediately following the 1939-1945 war, and a strong growth of grasses has made the prospects for regeneration very uncertain. Beech seedlings have been found occasionally in a continuous grassy cover during the survey, but as a colonist of grassland beech is much inferior to oak.

Frost

Some protection from spring frost is automatically assured by any practical system of beech regeneration. Mother trees which are close enough to seed-up the whole ground will ordinarily provide enough shelter against spring frosts. Beechwoods do not occur in the worst frost hollows. Elsewhere the protection against radiation provided by the old stand is usually adequate. When, however, severe air frost occurs after the germination of nuts, or the flushing of established seedlings, damage may be caused even under canopy. This is particularly likely in small woods, or near the edges of larger woods, where there is much exchange of air with the open ground outside. Beech seedlings germinate early in the forest, usually beginning before the end of March in the south of England. Severe winter frost may be damaging to nuts lying exposed on the surface of the soil; recent mast autumns have been followed by mild winters, and no observations have been made on this possible source of loss.

Light

Contrary to current opinion, young beech seedlings appear to be no more tolerant of shade than seedlings of ash and sycamore. Under full beech canopy, seedlings appear in plenty: they persist for several years, but make negligible growth after the first year and then succumb. In small gaps caused by felling or natural death, or at the edge of a wood, or where a heavy general thinning has been made, the light conditions, though often falling short of the optimum, are adequate for survival and considerable growth of beech seedlings. In the course of years the crowns of the remaining mother trees tend to close up, so that, unless the canopy is further opened, shade will seriously limit growth. When this occurs, the leading shoots of the young trees bend towards the nearest break in the canopy.

Root competition

In woodland ecology it is notoriously difficult to distinguish the effects of shading from the effects of root competition for water or nutrients. Experiments now in hand are designed to indicate within what range of light intensities beech seedlings will grow satisfactorily when root competition is eliminated. In a mature beech stand, many of the fine roots are found near the surface and it may be presumed that the young seedlings will experience severe competition under canopy. In group regeneration, the pudding-shaped profile so frequently observed, with dense small trees at the edge of the group and taller, more widely spaced trees near the centre, is probably due more to the intensive root competition at the edge than to lack of light. Inasmuch as he can ameliorate both adverse factors in one operation, the practical forester is more concerned with the results than with the fundamental cause of this shade/root-competition effect.

Felling damage

Where natural regeneration is aimed at, the likelihood of damage to the young saplings by the removal of the mother trees has to be considered. Very serious damage to natural saplings 10 to 20 feet in height has been observed to follow the felling of large mother beeches. In some cases the risk of frost renders it desirable to retain the old wood for a good many years: in other cases patchy regeneration calls for the contribution of a second mast year, which may come only after a long interval.

Discussion of Methods followed in Britain

Some of the valuable environmental conditions (protection from frost, suppression of ground flora, even distribution of seed) suggest the retention of as much cover as possible; whereas adequate light and the removal of root competition of the mature trees are best achieved by somewhat drastic openings of the canopy. Success in the natural regeneration of beech depends on:

(*a*) The evolution of a compromise, adapted to the local conditions, between these conflicting desires.

(*b*) The control of rabbits, deer and pigeons.

(*c*) Judgment in the exploitation of mast years.

Various methods of regeneration in British beechwoods have been observed or recorded during the survey but, as a clearly prescribed plan has rarely been followed, it is only possible to give a general indication of what has occurred. The large shelter-wood regeneration, as standardised in the Hanover beech forests, does not appear to have been practised in Britain, though it appears to be finding favour on one of the larger Chiltern estates. Where, on good mull soils, reproduction occurs in plenty, the method is straightforward. On acid sands, where mor has formed, the regeneration may be quite inadequate, unless soil cultivation and liming are carried out. In some cases, unless thinnings are very light, seedlings appear in quantity long before they are wanted. It is then customary to suppress them by keeping the shade heavy: this may be one reason why crown thinning of beech, which permits heavier thinning without too much exposure of the soil, is in vogue in many European beech forests. The heavy general thinnings associated with the large shelter-wood system of regeneration occasionally result in wind-blow, unless they are initiated very gradually; and, on exposed sites in Britain, this consideration might render the system impracticable. Otherwise, this appears the best way of obtaining an even-aged crop by natural regeneration; but on sites where bramble tends to be luxuriant the regeneration would have to be initiated early, before bramble becomes rampant.

On some estates in the Chilterns, a selection system of management has been practised at least for a considerable time. The woods are gone through at regular intervals and a proportion of the larger trees are cut. Very few of the smaller trees are taken in most cases, and a rather dense canopy is maintained. This is especially true when prices are low and markets for the poorer quality trees are bad. The consequences are, first, that, even in mast years, the quantity of seed produced is often unsatisfactory: and, secondly, that the regeneration which does appear fails to survive. Many of these selection woods of the Chilterns are now practically even-aged high forest: a few malformed small saplings occur here and there, but, except in accidental gaps, trees of intermediate age are usually entirely wanting. During the recent war, unusually heavy thinnings were made in a few woods and regeneration has since appeared.

Regeneration in groups has been observed both in the Chilterns and in the Cotswolds. On the Hampden estate, near Princes Risborough, very successful regeneration followed small group fellings in Monkton Wood about thirty years ago. In this case there is no doubt that success was largely due to the coincidence of the operation with the exceptionally good beech mast of 1922. On the National Trust's Ashridge estate, there is some very good group regeneration in Frithsden Beeches, near Berkhamsted. The groups range in age from 30 years downwards, and can be traced to sporadic natural deaths and the felling of individual trees in the past 30 years. Many of the groups can be assigned to the 1922 mast. In Queen Wood, Watlington Forest, the group fellings made early in 1945 were too large (30 to 40 yards in average diameter) for successful colonisation by beech. In 1947 the gaps were occupied by a variety of low shrubs and tall herbs (bramble, raspberry, bracken, willow-herb, sedges, grasses and rushes) and few seedlings were to be seen.

In the Cotswolds, group regeneration was lately begun in a fine stand of 110 years old beech in Cirencester Park. There was a promising crop of seedlings in the small gaps in 1949, and more are expected as a result of the good mast in 1950. The regeneration observed in the eastern part of Kingscote Wood, near Nailsworth, is more like a shelterwood regeneration, following a general thinning about 1932. The regeneration occurs all over the thinned area, but with a marked tendency to form groups. The clearance of the parent trees was deferred until 1949, when some damage was caused to the young growth. Provided that regeneration is initiated while bramble growth is slight, that the groups are kept small, and that the fellings are timed to correspond with mast years, the group method may be counted on to give good results on all sites where there is no pronounced mor formation. The resulting crop, is, however, bound to be more or less uneven-aged.

Penn Wood, Bucks., was successfully regenerated nearly 100 years ago, following an almost clear-felling of a mature wood consisting mainly of beech. A mixed growth, predominantly of birch and bramble, occupied the ground for about 15 years; but before, during and subsequent to the felling of the old crop, the ground became sown with beech, oak and a few cherry seeds. In course of time these supplanted the inferior shrubs and trees, and there is now an extensive, nearly fully-stocked, 90 year-old stand of beech, with variable proportions of oak and an occasional cherry. This appears a hazardous method of obtaining beech regeneration.

A note may be added on some of the devices which are occasionally used by foresters to promote natural regeneration of beech. Methods of seedbed preparation by mechanical cultivation have already been referred to. These are specially important on mor soils. With these may be mentioned the soil disturbance caused by timber extraction, which, if it takes place in the winter following a mast, may increase the germination substantially. Bramble destruction is particularly important in the Chiltern beechwoods, and implements have been adapted to this purpose.

ESTABLISHMENT ON CLEAR-FELLED WOODLAND SITES

The aerial environment of clear-felled woods differs significantly from that under standing trees: the light intensity is equal to, or not far short of, full daylight; extremes of temperature are much greater, and atmospheric humidity, generally lower than in woodland, shows also much greater fluctuation. Young beech plants, are, therefore, much more seriously exposed to frost, to sun-scorch and to excessive transpiration; whereas the light intensity, more or less sub-optimal in woodland, becomes optimal, or supra-optimal. The edaphic environment, on the other hand, differs much less from that of woodland. In particular the deep penetration of the soil by tree roots and the good structure and humus content make the old woodland soil a more favourable medium for tree growth than the soil of pasture or heath. For a short time after the felling, the soil keeps its favourable characteristics; indeed the diminished root competition and intensified nitrification make it more favourable than under growing trees. Soon, however, biological activity becomes depressed by exposure to sun and wind. The sharp fluctuations in temperature and moisture and the local excessive wetness are inimical to soil life, so that fertility is affected. Simultaneously the increase of "weeds" (coppice shoots, bramble, willow-herb, and the like) bring about a degree of root competition, which, although less in total volume than that of the tree crop, may be more intense in the surface layers. The advantages of the old woodland soil are, therefore, most readily gained if reforestation takes place without delay.

To beech planted on clear-felled woodland, the risk of drought is greatly influenced by the soil characters, the topography, and the nature and density of the subsidiary vegetation. Losses are much more severe on dry sandy, or shallow chalky, soils, than on retentive loams. Slopes exposed to the sun, or to the prevailing winds, are notably less favourable than cool sheltered north and east slopes. The instances of serious losses observed have been on elevated ridges with southerly or all-round exposure.

The influence of the ground flora is more intricate. Coppice shoots, grasses, tall herbs like *Chamaenerion* (*Epilobium*) *angustifolium* and *Digitalis purpurea*, bracken, bramble and other rosaceous shrubs compete with young trees for water and nutrients as well as light; while at the same time they shield the plants from sun and wind and create a favourable micro-climate around them. The net result to the young beeches of these joint beneficial and harmful influences varies much with the conditions of climate and soil and with the life form of the associated plants. Grasses usually compete strongly for water and nutrients, but not for light; seldom having any sheltering effect, they are unwelcome associates. Scrambling shrubs are also undesirable if luxuriant, because of the mechanical smothering effect. Coppice shoots, if controlled, appear to have a very good nursing effect on beech. Examples of the successful reforestation, with beech, of old hazel coppice with oak standards, can be seen in many State forests in the southern counties. But for inadequate maintenance during the war, there would be few failures on this type of ground. Bracken and tall herbs like willow-herb seem capable of exercising a beneficial influence, but undoubtedly much depends on the way in which they are regulated.

Two interesting examples of the action of soil and associated vegetation were recorded during the survey of young beechwoods. On a high and somewhat exposed site in County Durham, beech and hybrid larch were planted in 1944 following a recently cleared immature crop of mixed conifers. The soil is an acid light loam over a silty sandy clay with rusty mottling. Over much of the ground bracken, about three feet tall, is dominant, with rare *Rubus*, willow-herb, wavy hair grass (*Deschampsia flexuosa*). On this ground survival and growth of larch and beech are satisfactory to very good: the beech averaged 60 inches in height at 7 years (current shoot 12 inches) and survival was 66 per cent. Part of the site is, however, dominated by wavy hair grass; bracken is absent and other plants are rare. The soil is covered with a thick mat of dead stems, etc., of the grass and was very dry when examined in July. Beech survival was only 24 per cent. and the mean height 29 inches (current shoot 5½ inches). The hybrid larch had also failed over much of the *Deschampsia* ground. The second example was of a very young 1948-49 beech plantation on Netley Heath on the North Downs, examined after a long drought in September, 1949. On one site, where the beech had nearly all died, the soil profile showed 60 to 65 cm. (24 to 25 in.) fine sand over a reddish-brown retentive sandy clay. The flora was dominated by *Agrostis tenuis*, with other species of *Agrostis*, *Holcus mollis*, *Rubus* and *Rumex acetosella*. Not far away, an area was dominated by bracken with *Holcus*, *Digitalis*, *Rumex acetosella*, *Chamaemerion*, *Rubus* species. The difference in flora was associated with a difference in soil; it was found that the retentive sandy clay layer began at 28 cm. (11 in.) from the surface. In this bracken area the beech had survived the drought, and made satisfactory growth.

Other cases were noted during the 1949 drought where beech showed good survival in bracken. Competition for water and light appears to be more than balanced by protection from strong sun and wind. The cutting of the bracken bears on the result and, at least in dry summers, it appears to be beneficial to cut the bracken in early summer when height increment of the beech is occurring, and to refrain in the late summer when atmospheric drought is critical. The bracken also screens the soil surface from direct evaporation. A cover of vegetation usually has a desiccating influence on the soil in spring, but is rather conservative of moisture in summer. Incidentally vegetation cut early in summer can furnish a valuable mulch to the soil during subsequent hot weather.

Frost is the other important danger to young beech planted on cleared woodland. Beech should not be used to reforest obviously frosty hollows and valleys, and on other sites the frost danger should be carefully assessed and the treatment fitted to the site. Apart from depressions where the pooling of cold air occurs, the most vulnerable sites appear to be:

(*a*) Easterly aspects, where the tender young beech shoots might experience in succession: a cold east or north-east wind maintaining a low soil and air temperature by day; intense radiation by night; and bright morning sun.

(*b*) Slopes where a standing wood, belt of trees, or tall hedge, below the plantation, blocks the free drainage of cold air.

(*c*) Flat crests of ridges and hills where, on clear still nights, radiation is intense and there may be little air circulation.

Unless a site is topographically favourable, the successful establishment of beech requires a pioneer shelter crop, which may be provided by hazel coppice or spontaneous birch, or by frost-resistant trees artificially introduced before the beech. On all but the worst frosty sites, beech can be raised with the help of frost-resistant trees (e.g., pines) planted simultaneously; but the advantages of the nurse tree are not felt during the early years when they are needed most. It is, however, worthy of note that the extent of frost damage is often dependent on the soil. If the soil is favourable to rapid growth, the young trees will soon outgrow the frost danger, and they may thrust their tips above the frost level before any damaging spring frosts have been experienced. On sites of similar topography, the frost danger is less on clear-felled woodland than on grasslands, partly because of the screening effect of the subordinate vegetation, partly because of soil conditions more favourable to early growth.

There is one other ecological factor which is of importance in relation to frost damage to beech, namely the phenological traits of the tree as expressed on different sites. Damage by spring frosts is bound up with the date of flushing of the tree, which is determined partly by local climate and the prevailing weather and partly by inherent tendencies in the tree. Holm (1939) found that beech of Swiss origin in Denmark came into leaf earlier than local beech, the differences persisting at least for a considerable number of years. It may be that southern English beech, or continental beech, when used in afforestation in northern England or Scotland, will come into leaf unseasonably early. Another phenological character related to frost damage is the production of lammas shoots, which may fail to harden off before the onset of autumn frosts and result in injured tips and malformed trees. Environment certainly, and heredity probably, are concerned in the initiation and the ripening of these lammas shoots, but as they are of more significance in relation to stem form, further consideration will be left to a later section.

ESTABLISHMENT ON CHALK DOWNLAND

Beech is not a natural colonist of pasture or heath. Although seedlings occasionally appear in chalk grassland, colonisation rarely follows. The development of beechwood on heath or grassland is preceded by a scrub stage, and the course of development on different kinds of soil has been followed on commons of southern England which have been relieved of grazing pressure. The components of the scrub vary greatly with the type of soil, but hawthorn is prominent, or at least present, in many cases. On shallow dry chalk soils, juniper is the most important element; on moist loamy soils, bramble, gorse, birch and roses accompany the hawthorn as early colonists; on sandy heaths, birch and then pine are the chief invaders of the ericaceous associatons. Elder, distasteful to rabbits, is often present on the better soils. Beech may colonise the scrub stage directly, but more often the first tree colonists are ash, whitebeam and yew in chalk scrub; birch, oak and ash on the moist loams; and pine, or oak, following birch, on the sandy heaths. An examination of the juniper-hawthorn scrub of certain areas of the Chiltern escarpment will clearly show the nursing effect of the scrub on the small beech saplings, which are, in practically every case, partly enveloped by thorny bushes. It is doubtful what part protection from rabbits plays in this distribution, because rabbits freely eat hawthorn and most of the other shrubs present. The most important factor seems to be the improvement in the physical environment near the bushes, where the beech seedlings are protected from summer sun and wind, and very much less exposed to frost, overheating and atmospheric drought. At the same time, there is an improvement in the soil. The shrub roots will have penetrated the soil to some depth, and the beech root-system can take early advantage of the better aeration and moisture supply. This factor is important, especially on shallow rendzina soils, where soil mosture is an important limiting factor, and the deep hawthorn roots do a valuable pioneer work.

Direct planting of beech on chalk grassland has sometimes entirely failed or often resulted in heavy losses. In such artificial plantings the biotic environment alone is improved, as compared with unenclosed grassland where beech is attempting to invade. Ploughing or screefing has a useful effect in reducing competition from the roots of grasses and herbs. On the other hand, there may be increased water loss from the bare soil in summer drought, and the net gain to the beech plants is generally small. It is understandable, therefore, that a good deal of attention has been devoted to methods by which the environment could be made more like a natural scrub, or birch-oak associes, which is being successfully invaded by beech. There are three obvious ways in which this can be attempted:

(*a*) By planting fast growing trees with the beech, to which they will very soon give shelter.

(*b*) By planting appropriate nurse trees some years before the beech, which is then introduced as an underplanting or inter-planting.

(*c*) By fencing the grassland against rabbits, and waiting until natural shrubs have appeared in sufficient amount to shelter the beech.

Chalk downland is used to illustrate the difficulties of afforestation with beech and the efficacy with which they can be circumvented in these three ways.

A great deal of the grass land or heath allotted to beech is chalk downland, and it is there that the difficulties have been felt most acutely. The problems are essentially similar on the chalky glacial drift of East Anglia (where frost risk is more widespread) and on dry sands (where, however, trees susceptible to chlorosis on chalk are available as "nurses").

The conditions of bare downland which may limit the survival and growth of planted beech and, therefore, call for amelioration are:

(1) The light intensity.
(2) Exposure to full sun.
(3) Exposure to frost.
(4) The low atmospheric humidity.
(5) Insufficient soil water.
(6) Carbon dioxide supply.

Light intensity

It has been shown (Harley, 1939) that a reduction to 60% of full daylight causes a slight reduction in the dry weight of beech seedlings, although height growth may be slightly increased. Investigations now in progress with small beech plants, under a range of light intensity from full daylight to about 6 per cent., indicate that a reduction to 20 to 25 per cent. may be made without significant reduction in height growth, and that the fall-off in height growth under full daylight is probably inconsiderable. There are doubtless complications due to weather and the interaction of other factors, and further research is needed on the light factor in relation to beech growth. But the inference appears justified that, other things being equal, full daylight causes at most a slight reduction in height growth, and is optimal for dry weight increase: it is thus not directly inimical to young beech trees. The indirect effect of light in regulating the opening and closing of stomata may have an important influence on water loss in drought.

Exposure to sun

The heating effect of the sun's rays is probably more important in relation to beech survival in the open. There do not appear to be any data about the temperature effect of insolation of beech, but remarkably high leaf temperatures have been recorded for some plants. High temperatures may be directly harmful, or they may cause wilting or die-back indirectly by increasing transpiration. The evaporation of water via the stomata is the plant's main safeguard against overheating. In hot dry weather excessive loss of water may be needed to keep the temperature below the lethal point.

Frost

There are few sites where beech can be planted in the open without any risk from spring frosts. In the severe frosts of mid-May, 1935, topography was of little account, and it was only in coastal districts that tender trees like beech were immune from damage. In years when no abnormally severe late frosts are experienced, beech is generally safe on slopes and hilltops, from which the cold air can drain freely downhill. On frosty flats and in valleys or other depressions, protection is essential, and this is a major reason for a nurse crop for beech. Frost damage is always more serious on sites where early growth is slow, so that the trees remain vulnerable for many years, and run a greater risk of experiencing a particularly severe May frost. The irregular incidence of these frosts from year to year introduces an element of chance, and accounts for some of the large differences in amount of frost damage in the plantings of different years.

Atmospheric humidity

The lower atmospheric humidity, in warm dry weather, of open ground as compared with scrub, results in a higher vapour tension gradient between the leaf tissues and the outside. Subject to stomatal control, transpiration is accelerated, and tends to exceed the absorption of water by the roots, especially in dry soil. Wind greatly aggravates this condition by removing water vapour from the vicinity of the plant, which is thus prevented from creating a relatively humid micro-climate in which transpiration would be reduced. The interaction of water loss and temperature of the leaf, as a result of the dual control exercised by the stomata, has been referred to under *Exposure to sun*, above.

Soil water

The water-supplying power of downland soils varies within wide limits, in dependence on the presence or absence of a drift cover, and its character and thickness if present. At one extreme are the shallow rendzina soils, derived directly from the chalk, on sites that have not carried forest within historic times. At the other extreme are deep, retentive, somewhat sticky clay-loams with, however, a layer of well-drained flinty loam covering them and providing a favourable rooting medium. In between these are found flinty loams, varying a good deal in texture and stoniness, and with or without chalk in the profile. Within each soil type, the topography profoundly affects the soil's ability to meet the plant's needs. The importance of topography has been discussed in a preceding section in relation to the performance of mature beech on calcareous soils. Escarpment slopes tend to be driest, and south and west aspects, exposed to sun and prevailing winds, are drier than north and east aspects. Rendzina soils are typical of steep escarpment slopes, which are, therefore, always more or less subject to drought—especially so where the aspect is south or west. The escarpments are not of great aggregate extent, but, being unsuitable for

Yearly Height Increment of Selected Trees showing Growth Check. Beech in Compartment 1, Crawley Forest, Hants. Planted 1928

TABLE 1 Inches

Tree No.	1	2	3	4	5	6	7	8	9	10	11
Year 1940	7	—	—	—	12	—	—	4	5	3	7
,, 1941	9	—	—	10	11	—	—	9	3	10	7
,, 1942	11	12	—	11	11	7	9	8	4	9	12
,, 1943	20	16	9	7	4	8	8	8	5	6	9
,, 1944	4	6	10	7	4	6	9	4	8	8	8
,, 1945	9	14	10	7	3	9	8	3	7	5	9
,, 1946	9	10	11	9	6	2	1	1	3	—	4
,, 1947	2	8	5	—	5	—	5	1	3	—	4
,, 1948	—	5	7	4	10	—	10	7	3	4	7
,, 1949	—	2	3	4	12	2	8	2	2	8	5
,, 1950	1	5	11	12	19	6	20	9	12	26	22
Actual height in 1950	110	115	104	102	143	64	110	86	86	114	136

tillage, they are of considerable importance for forestry. There is, in addition, a large area of chalk upland in the south-eastern counties, where the soil is a shallow rendzina very liable to summer drought. Rendzinas and deep brown earths may occur on the same down, and, when afforestation takes place, striking irregularities of growth are sometimes recorded.

An instance of wide variation in the early growth of beech on the same hill was investigated in Crawley Forest, near Winchester, Hants. Compartment 1, on Windmill Hill, was planted in 1928 with a row-about mixture of beech and larch; first beech and then Scots pine was used for replacement of the many failures. The slopes of the hill have a shallow rendzina soil, and the beech are very patchy, while the larch have failed over large areas. An assessment of 50 beech (random sample) on the north-east slope in February 1950, when the plantation was 22 years old, showed a mean total height of 66 inches, the mean height increment for 1949 and 1948 being 6.3 and 5.4 inches respectively. Many of the trees were still growing less than an inch yearly. About 150 yards from this site, on the summit of the hill, the beech and the larch were observed to have made moderately good growth, the mean height being about 21½ feet and blanks few. Examination of the soil showed about 60 cm. (24 in.) of flinty drift, consisting of a retentive clay-loam or clay, over the chalk. Frost seems to have been a contributory cause of the poor survival and growth of beech in this compartment, and it was clear that the good initial growth on the patch of clay-with-flints enabled the trees near the summit to clear the frost zone quickly. There can be no reasonable doubt that the severe frosts of mid-May 1935 struck the beech and larch on the rest of the area, as elsewhere in Crawley Forest. Some of the taller trees in the poor areas, now over 8 feet high had, after recovering from initial check and making yearly growths of 9 inches or more, slipped back into check, so that the recent increments were often only fractions of an inch. Some examples of this are recorded in the table above: when fuller data were collected in January, 1951, it appeared that the wet summer of 1950 had reacted favourably on the checked trees and produced a substantial improvement in height. This secondary check is independent of frost and may probably be ascribed to the low water capacity of the soil, and the increased transpiration when the trees grow a little above their fellows.

Compartment 4, Crawley Forest, showed a less pronounced range in beech growth, associated with a somewhat smaller difference in soil depth. A wide survey of beech plantations in other forests in the southern counties indicated that soil drought is important only on the shallow rendzina soils. On these it is of great significance, particularly on sites where the risk of frost makes rapid establishment necessary. It is very probable, however, that nutrient supply is closely bound up with the dryness of many shallow downland soils. Biological activity, in particular nitrification, is depressed when the soil surface is dry, plants indicative of free nitrification are usually absent from open downland sites. The stunted, impoverished look of beech on these sites may be in considerable degree a reflection of poor nitrogen supply.

Carbon dioxide

Estimates of the carbon dioxide content of the atmosphere at shrub and herb level in forests have shown relatively very high (though variable) amounts, as compared with adjoining open ground. These high values are due partly to the respiration of plants and animals near or in the ground, partly to the decomposition of organic litter, and they are greatly affected by air movement. In many circumstances the normal carbon dioxide content of the air has been proved to be far below the optimum for photosynthesis. It seems, therefore, probable, that, when other conditions (light, moisture, temperature) are favourable, beeches growing in a relatively sheltered environment among, or under, other trees or shrubs, may be able to make use of the relatively high carbon dioxide concentration of such sites, whereas beech on open downland may be limited in photosynthesis by this factor.

Methods of Nursing Beech

The three methods of nursing beech on open downland will now be considered in relation to the adverse factors which have been reviewed.

Nurses planted at Same Time as Beech

In the first method, whereby nurse trees are planted at the same time as the beeches, the choice of suitable trees presents some difficulty. On chalk downland the qualifications of a good nurse tree are chiefly: frost hardiness; ability to root vigorously and grow in dry chalky soil, without chlorosis or serious check, and an evergreen habit, or failing that, early foliation in spring, so that the beeches are given some shelter against frost and drought during May. It is desirable in addition that the nurse trees should not interfere mechanically with the tips of the beeches, and that they should produce material of some value before they are removed in thinning.

The most useful species appear to be the pines, although whitebeam (*Sorbus aria*), birches (*Thuja plicata*) and other trees have also proved satisfactory. Larch suffers from drought on rendzina soils, and is valueless on frosty areas; on the deeper loams of frost-free slopes and ridges it may serve the purpose.

The pines have vigorous tap roots and are resistant to drought; Scots pine often develops chlorosis on shallow chalk soils, where Corsican and especially Austrian pines are more at home. These two have the disadvantage that, unless carefully handled, they may make very slow growth in early years, and thus fail to do their duty. The heavy branches of Austrian pine are liable to chafe the tips of the beeches later on.

Sorbus aria is a small xerophytic tree characteristic of dry warm chalky sites, where it is an early colonist of scrub. Both *Sorbus aria* and the closely related *Sorbus intermedia* (less markedly calcicole) have been used experimentally to nurse beech on the downs at Buriton, Hants. They are drought- and frost-resistant, but show the serious disadvantages that they do not respond well to transplanting and, having a light canopy, they are slow to suppress the herbage.

Birch has proved a valuable nurse to beech on most soils, but it has been most commonly used as a pioneer crop into which beech was introduced subsequently. Frost-hardiness, fast early growth, and a very light canopy qualify birch as a good pioneer shelter tree for beech. Birch was used on a considerable scale in Denmark in the latter part of the nineteenth century (Bojesen, 1904), but mainly for the replanting of clear-felled woodland. It is less suitable for simultaneous planting with beech, partly because it is troublesome to transplant successfully, and partly because its light canopy is slow in suppressing the herbage, and affords but little shelter to the beech in early years. Birch is not found naturally on very shallow dry rendzina soils, where it may prove very difficult to introduce artificially.

There is another tree which may be of some value as a nurse of beech on chalk downland—*Thuja plicata*. Thuya grows well on basic soil, but it remains to be seen whether it will tolerate the driest sites well enough to be a useful general nurse on chalk ground.

Simultaneous planting of nurse tree and beech cannot be expected to give protection against frost, even where the nurse becomes established quickly, and it has been found that, in frosty situations, beech plantations so raised need many replacements and suffer considerable injury. Nor is there any useful protection against strong sun in the early years. Vigorous evergreen trees like the pines will soon give some protection from wind, increasing rapidly with the years, and this will allow of a higher humidity, and perhaps a higher concentration of carbon dioxide, around the beeches. In the early years, the nurse tree can have little influence on the amount of soil moisture available to the beech, either by suppression of the herbage, or by deep root penetration of the soil.

On shallow dry chalky soils, and on all sites where severe spring frosts may be expected, there will always be difficulty in establishing beech, except under a shelterwood previously established. Where soil moisture conditions are better, and frost is not greatly to be feared, beech can be safely planted with the nurse. In these circumstances a pure plantation of beech may succeed equally well, and the only advantage of the nursed plantation is that the beech may be subsequently educated into better shape.

Beech planted in Shelter of Older Trees

In this method a pioneer crop is first established, and the beeches are introduced later. The pioneer crop may consist, on chalk downland, of any of the trees mentioned in the preceding section: some difficulty in establishment may, of course, be experienced on the shallower soils. The manner of bringing in the beech may vary widely, and there is no space to discuss all the possibilities. It will be assumed that the introduction is not made until the pioneer crop is advanced enough to give a large measure of protection against sun-scorch, wind and atmospheric drought, and to check the vigour of the ground vegetation. The beech may then form an interplanting in rows or circular gaps, either origin-

FIG. 1. Fine mature beech on acid flinty loam of Quaternary period; height 110 feet, age about 220 years. Heavily thinned in 1944. Bramble, *Rubus*, dominant in ground flora, with birch, and willow-herb, *Chamaenerion angustifolium*. Slindon Park, Sussex. September, 1951.

Fig. 2. View from Goodwood Park, Sussex, looking south-west towards Chichester, showing mature beechwoods on the chalk of the South Downs. September, 1951.

FIG. 3. Mature beechwood on acid, leached, silty Quaternary gravel: 95 feet in height, about 220 years old. Exposure to the west wind has resulted in an impoverished soil surface decked with cushions of the moss, *Leucobryum glaucum*. Slindon Park, Sussex. September, 1951.

FIG. 4. Fine mature beech on acid flinty loam derived from Quaternary gravels: 115 feet in height at 220 years. Bramble, *Rubus fruticosus*, dominant in ground flora. Slindon Park, Sussex. September, 1951.

FIG. 5. Chalk beechwood on exposed spur slope of South Downs: 80 feet in height at 170 years. Shallow rendzina soil with mainly grassy flora (*Festuca*, *Poa*, *Brachypodium sylvaticum*) near the exposed west edge. Goodwood Park, Sussex. September, 1951.

FIG. 6. Mature beech, 100 feet in height at 170 years, on sheltered spur slope of South Downs. Rendzina soil over Upper Chalk. Dense canopy, floor bare apart from small patches of dog's mercury, *Mercurialis perennis*. Goodwood Park, Sussex. September, 1951.

FIG. 7. Mature beech, 110 feet in height at 130 years, on rendzina soil over Upper Chalk: altitude 400 feet, aspect north. Ground flora dominated by ivy, *Hedera helix*, with wood sanicle, *Sanicula europaea*, enchanter's nightshade, *Circaea lutetiana*, and sycamore saplings. West Dean Park, Sussex. September, 1951.

FIG. 8. Mature beech, 100 feet in height, 130 years old, on escarpment slope of South D
Altitude 600 feet, north aspect, steep (25°) slope. Rendzina soil over Lower Chalk. Yew under
and ground flora of dog's mercury, *Mercurialis perennis*, ivy, *Hedera helix*, wood spurge, *Eupl*
amygdaloides, and other herbs. Ashford Hanger, Petersfield, Hants. 1949.

FIG. 9. Fine mature beech, 100 feet in height, 140 years old, on Jurassic limestone in a Cotswold valley. Dense natural regeneration following thinning. Kingscote Wood, Nailsworth, Gloucestershire. 1949.

FIG. 10. Mature beech, 87 feet in height at 130 years, on leached sand derived from Lower Greensand. Scanty ground flora of bracken, *Pteridium aquilinum*, and mosses (*Dicranum* spp, *Mnium hornum*). Cognor Wood, Linchmere, Sussex. September, 1951.

FIG. 11. Mature beech, over 100 feet in height at about 120 years in sheltered dry chalk valley. Rendzina soil over Upper Chalk. Toward the left of the picture can be seen surviving oak and larch associates. Whitedown Wood, West Dean, Sussex. September, 1951.

FIG. 12. "Fagetum rubosum". Fine mature beechwood on acid flinty loam of Quaternary period, heavily thinned in 1944. Height over 110 feet, age about 220 years. Bramble, *Rubus fruticosus*, dominant, with some willow-herb, *Chamaenerion angustifolium*, millet grass, *Milium effusum*, and honeysuckle, *Lonicera periclymenum*. Slindon Park, Sussex. September, 1951.

FIG. 13. Chalk beechwood on exposed spur slope of South Downs. Wood sanicle, *Sanicula europaea*, dominant in ground flora, with the grass *Brachypodium sylvaticum*, violet, *Viola sylvatica*, and ivy, *Hedera helix*. Beech 80 feet in height at age of 170 years. Goodwood Park, Sussex. September, 1951.

FIG. 14. Group of ash poles in gap caused by felling, death, or wind-blow in mature beechwood on rendziniform forest soil over Upper Chalk. Selhurst Park, near Goodwood, Sussex. September, 1951.

FIG. 15. Mature beech, 90 feet in height at 170 years, on rendzina soil derived from Upper Chalk. Dense group of sycamore saplings up to 30 years old. Goodwood Park, Sussex. September, 1951.

FIG. 16. Beech and larch, ten years old, in patch of hawthorn, elder, and bramble scrub on otherwise bare chalk downland. The rod is 6 feet high. Buriton Forest, Hampshire, Compt. 34. July, 1938.

FIG. 17. Beech 42 years old, planted in 1908 under an oak crop planted in 1850, now 100 years old. Bere Forest, Hampshire, 1950.

FIG. 18. Beech planted about eight years previously under a thinned natural stand of ash and birch, 30 feet in height. Good growth under shelter on an old woodland site on Upper Chalk. Eartham Wood, Slindon Forest, Sussex. September, 1951.

FIG. 19. Damage by grey squirrels to 40-year-old beech planted in 1908 under oaks now 100 years old. Bere Forest, Hampshire. 1949.

FIG. 20. Fine mature beech ("Plus tree") on acid flinty loam of Quaternary period. Height about 115 feet, breast-height diameter 33 inches, age about 220 years. Slindon Park, Sussex. September, 1951.

Fig. 21. Damage by voles at base of 10-year-old beech, Buriton Forest, Hants. Compartment 23, 1950. × 1.

FIG. 22. Damage by Tortricid larva to tip of 12-year-old beech, West Dean, Sussex, November, 1950. End of late summer shoot extension recently girdled. × 10.

FIG. 23. Insect damage to tip of 12-year-old beech, West Dean, November, 1950. Hairy "Lammas" shoot invaded. × 10.

FIG. 24. Extensive insect damage to Lammas growths at tip of 12-year-old beech, West Dean, November, 1950. × 2.

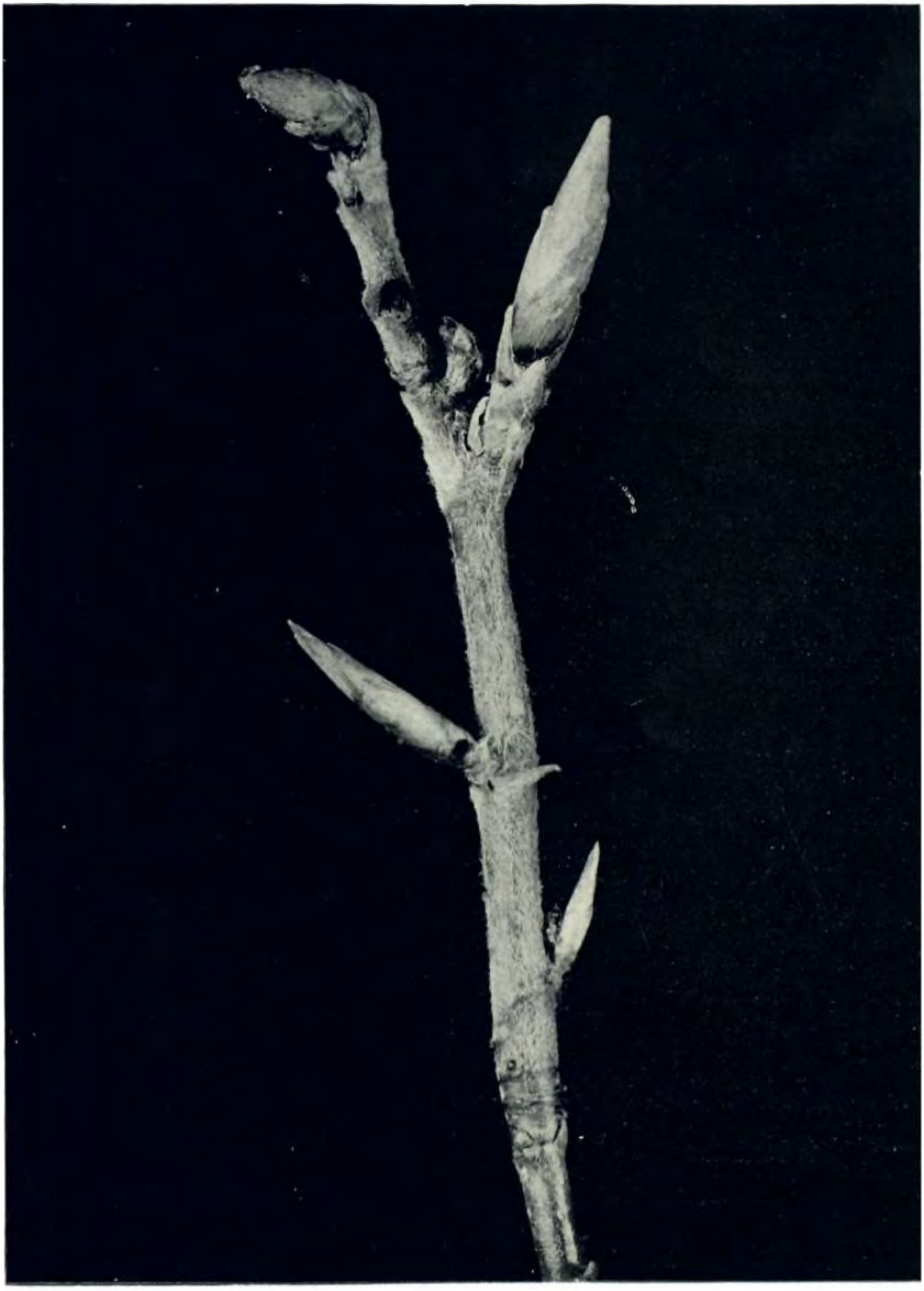

FIG. 25. Distorted bud as a result of damage by Tortricid larva to tip of 12-year-old beech, West Dean, November, 1950. × 4.

FIG. 26. Fan-like array of buds at tip of 12-year-old beech, as a result of insect damage to late summer shoot extension. A common appearance. West Dean, Whitedown, November, 1950. × 6.

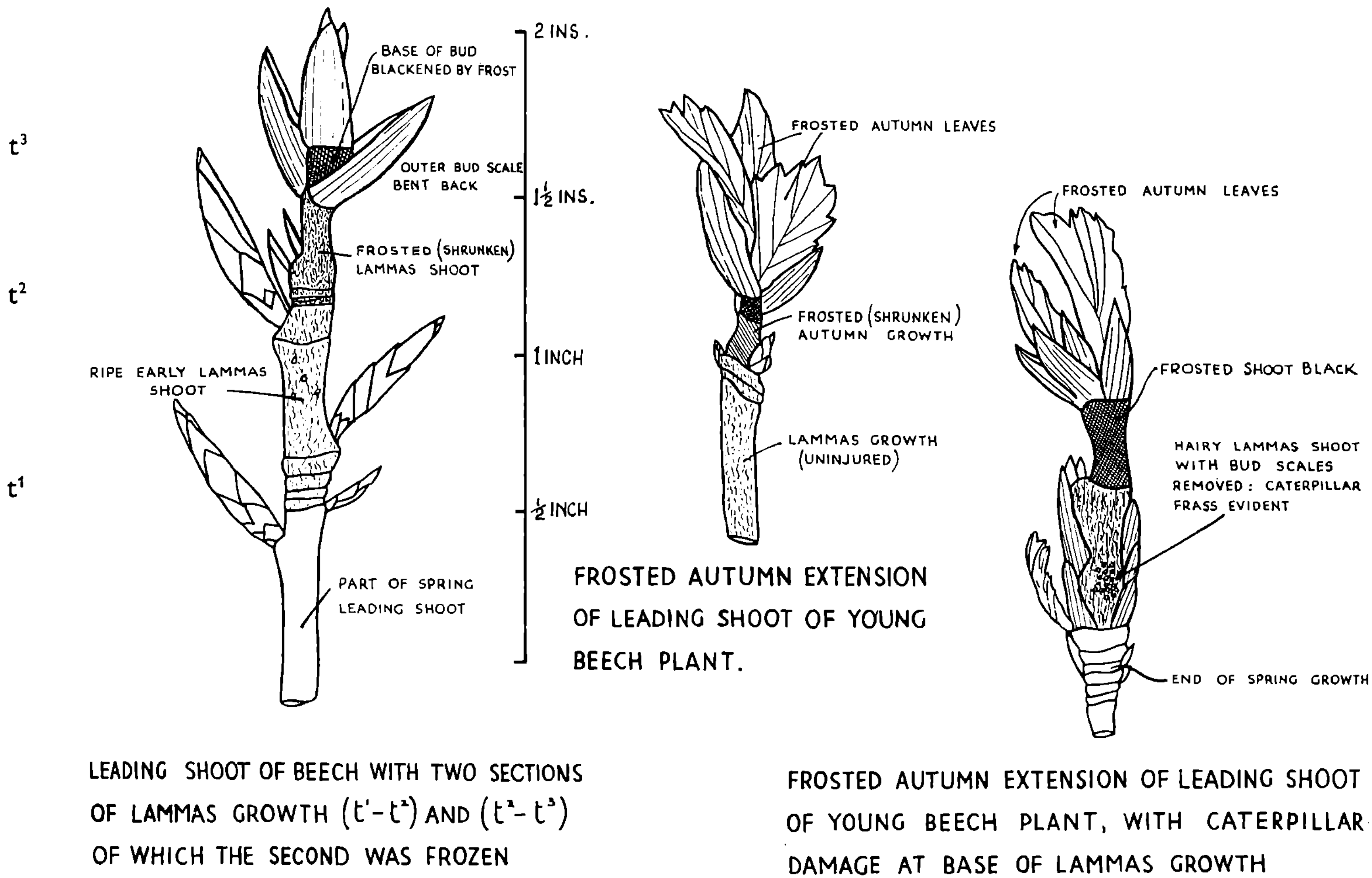

FIG. 27. Frost damage in autumn to six-year-old beech. Gardiner Forest, Wilts., 1950. All × 2½.

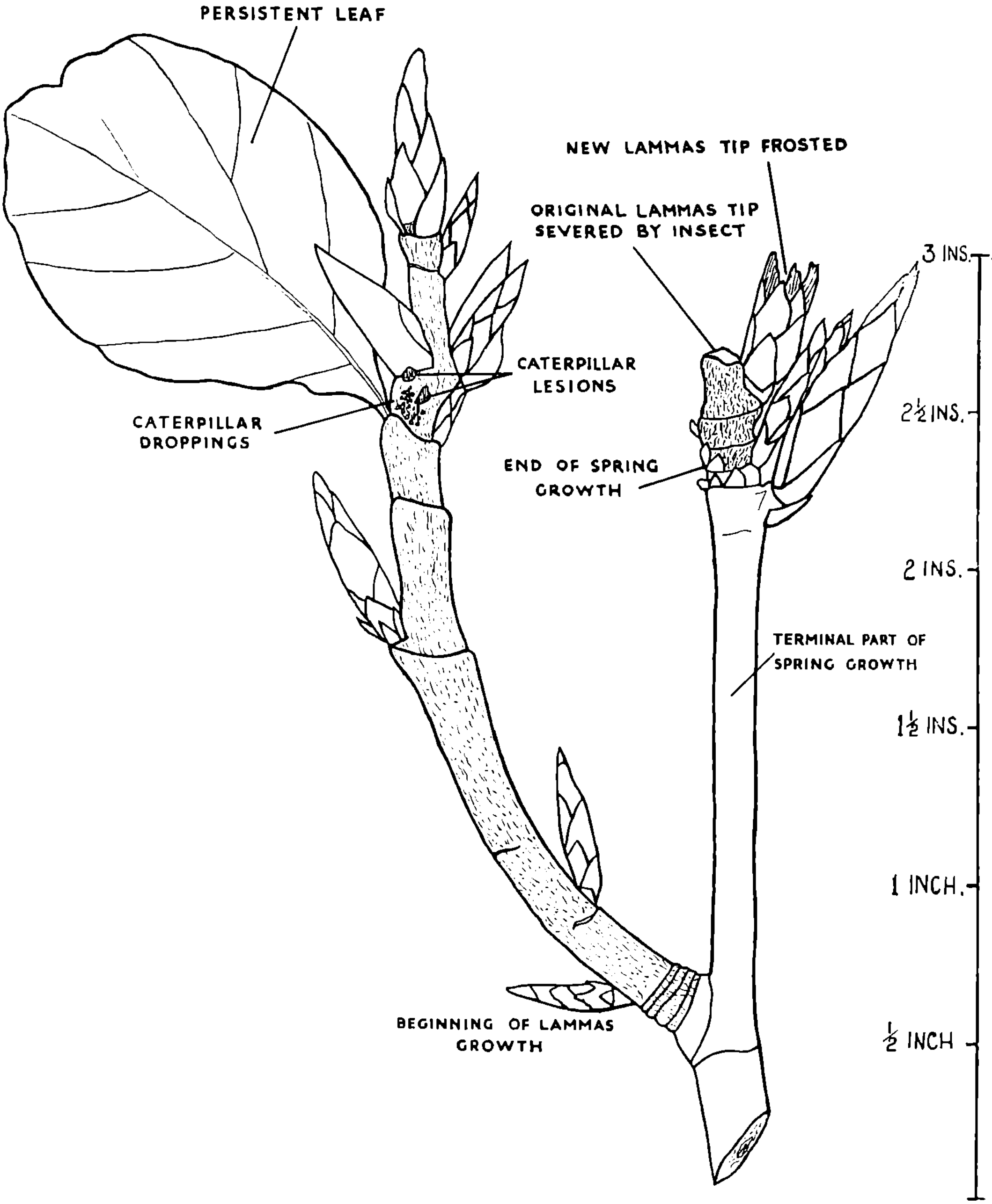

FIG. 28. Caterpillar damage to Lammas growth of beech, causing potential fork. New Lammas tip (on right) later affected by autumn frost. Micheldever Forest, Hants., Compartment 16. January, 1951.

ally left vacant, or specially cut. Or the beech may form an underplanting when the pioneer crop is about 20 feet high or more. In both cases there will be a considerable reduction in light intensity as compared with the open. Inter-planted beech will not suffer light hunger in the early stages, but may be severely checked when the nurse crop forms canopy, unless the density is carefully controlled. Under-planted beech will not grow vigorously unless the overwood is considerably thinned, although survival and a modest increment have often been found in quite low light intensities. A reduction to rather less than half daylight has no detrimental effect. Frost damage under this system is much less likely than when beech is planted in the open. An overwood in particular provides a good barrier to the radiation of heat; in this respect evergreen pines are superior to birch, which is, again, better than late-flushing trees like ash. Radiation is not so effectually prevented, although greatly reduced, by a side screen of nurse trees, which are chiefly beneficial as a barrier to cold winds. A light overhead canopy may not shield under-planted beech when the influx of cold air between the boles is sufficient to cause an air frost. This is an important consideration in small woods and near the edges of woods. The influence of a pioneer crop on soil moisture conditions is also complex, inasmuch as the reduction, or elimination, of competition from the surface vegetation is balanced by the competition from the roots of the trees. In this respect birch, with its spreading superficial root-system, is less favourable than the pines. The important point is that the deeper penetration of the soil by tree roots has begun before the beeches enter.

Examples of good growth of beech on chalk downland have been observed where the beeches were interplanted among pines 5 to 12 feet in height. The improvement in the environment, as compared with open downland, is mainly a micro-climatic effect (increase in humidity, reduced temperature range, increased carbon dioxide supply), but also concerns the moisture and biological conditions of the soil. The possible influence on the stem form of the beech will be discussed later.

Scrub Shelter

Natural scrub may have a valuable nursing effect on beech in certain circumstances. In Buriton, Hants., and Friston, Sussex, Forests there were, at the time of planting, some areas of chalk slope formerly tenanted by rabbits, where a sparse shrub growth, of elder mainly, had developed. On these patches, the growth of beech has been conspicuously better than on the bare surrounds. Improvement in the soil may partly account for this, but the main factor is probably the more favourable microclimate. Also at Buriton, on the top of War Down, there is a plantation of beech made in an area of gorse (*Ulex europaeus*) scrub which involved unpleasant and costly weeding for several years. The beeches have again made very good growth, being now about 24 feet tall at 20 years, and much superior to the beeches planted on downland turf at the same time. Adjoining this gorse area is an experimental plot where an artificial sowing of broom (*Sarothamnus scoparius*) was used to nurse beech planted at the same time. The broom made a patchy crop, but grew well enough in places to have a very beneficial influence on the beech. If, with modern methods of cultivation, a way can be found of establishing broom easily and cheaply on chalk downland, further trial of this method of raising beech seems warranted. Besides the micro-climatic effect, broom, with its deep and extensive root system and nitrogen-fixing bacteria, has a very beneficial effect on the soil. Furthermore, the young beeches do not later suffer from excessive shade or mechanical injury, as they may among pines, because the broom dies out after 10 or 12 years. For this reason, however, it may not give enough protection on very dry or exposed sites, where the beech needs shelter for a longer period.

The beneficial influence of patches of natural thorn scrub may be observed on a small scale in many parts of the chalk downs. These are common for example in Crawley Forest, Hants., where, in some compartments, the beeches have generally failed except in the small areas where thorn has colonised the grassland from the adjacent hedges.* Protection from frost, from atmospheric drought and from sun scorch, as well as the opening up of the soil, may account for the much better survival and growth of the beech. In such thorny patches, natural seedlings of oak, ash or beech are occasionally found and, where there are adjacent woods or hedgerow trees, it would doubtless be possible to secure in this way the natural colonisation by trees of small areas, where dry soil and exposure thwart attempts to establish beech artificially. Beech is, however, a slow invader of scrub and there is no doubt that human intervention at the scrub stage would enormously accelerate the process. Under favourable conditions, colonisation by scrub may be rapid once rabbits are kept out, so that beech might be brought in fairly soon with good prospects of success. The raising of an artificial shelter crop is probably a more easily controlled and more satisfactory way of establishing beech on very difficult sites.

* In Compartment 7, Crawley, an assessment in the open grassland showed a mean height of 4.3 ft. at 21 years for surviving beech, whereas in an area of sparse scrub the mean height of the much more numerous survivors was 10 ft.

The observations which have been made nearly all refer to chalk soils, where most of the difficulty in establishing beech in the open has been experienced. There is very little information about sandy heath soils, where several mature beech woods established by planting have been seen during the survey. In some of these woods beech was certainly associated with conifers, but there is nothing to show whether beech and conifers were planted at the same time, nor what replacements were called for and, in the absence of young plantations on similar sites, one can only acknowledge that beech has been successfully established on sandy heaths. The difficulties of sandy heaths are very like those of chalk downs, and it may be presumed that, on sites liable to frost, or to severe soil drought (because of low rainfall, or very pervious soil), beech could best be established under shelter. In general this appears to be the lesson of the afforestation of bare downland. Where the soil is moderately deep and retentive, and exposure to frost or wind not extreme, satisfactory survival and early growth of beech may be expected whatever the silvicultural conditions. Where frost, or wind, or soil drought are likely to be severe, beech will fail unless prior shelter of some kind is provided.

ESTABLISHMENT OF BEECH ON DERELICT WOODLAND AREAS

Derelict woodland comprises a wide range of ecological types, which have, however, certain features in common, and differ in one or more important respects from any of the kinds of site already considered. Derelict woodland differs from clear-felled woodland and grassland in bearing woody vegetation, which will profoundly influence the aerial environment of the young trees which may be introduced. From grassland it differs also in having a forest soil differing in depth, organic matter content, and biological conditions, from pasture soils derived from the same parent rock. In these features derelict woodland resembles a mature beechwood. But the light and humidity conditions differ more or less considerably from those of a mature beechwood, while the existing crop is rarely such that much useful natural regeneration of beech can be looked for. In relation to the planting of derelict woodland with beech, there are six ecological factors which need to be considered, three of them aerial and three edaphic. These are light, humidity, and carbon dioxide content of the air, and soil water, soil air and root competition.

Light

In the examples of derelict woodland examined, the dominant vegetation has usually been either birch poles, with an occasional ash, etc., or hazel coppice with occasional oak or ash. At Goodwood, Sussex, where much beech has been planted under birch poles, a heavy thinning has always been made before the planting, and it is clear that shade is not a limiting factor to beech growth, at least in the early years. Photo-electric measurements in one stand (Eartham Wood, Compt. 6), where the shade is rather greater than is customary, showed mean values of one quarter to one third of full daylight under the birch and ash poles: growth of the 12-year-old beeches was fully equal to growth on adjacent open ground, or under more heavily thinned birch. It is certain, however, that once the range of tolerance of beech is known, a comprehensive series of light measurements under birch shelter crops of different densities, repeated for the first 10 to 20 years of the plantation, would provide valuable information, both about the appropriate initial density and about the time and manner of removal of the shelterwood.

Although no data have yet been obtained in this particular environment, some records from beech planted under pine at Friston, Sussex, and under artificial screens at Alice Holt, Hants., will serve as pointers. At Friston, beech growing in 22 per cent. of daylight were erect, with current increments about equal to those growing in full daylight, whereas those growing under deep shade (7 to 10 per cent. of daylight) were flat topped with shorter, weaker current shoots. Preliminary data from the artificial shading experiment at Alice Holt suggest that withdrawal of 75 to 80 per cent. of the light causes no significant reduction in height growth. The degree of shade under hazel coppice is very variable and normally very dense. At Gardiner, Wilts., (Stonedown Wood) some rather patchy uncut hazel, with sporadic oak and ash, provided a set of readings in June, 1950. In percentages of full daylight the readings ranged from 5 to 14.5 per cent., with a mean of 7.4. As was expected, this degree of shading proved critical for the occasional natural beech plants growing under the hazel. The local variations in light intensity appeared to be closely paralleled by variations in the growth of these beeches. The plantations of 6-year-old beech at Gardiner were made in small rectangular gaps cut in the hazel coppice, or in long narrow strips about 4 metres (13 feet) wide, or again in clear-cut hazel. The hazel coppice is about 20 feet tall, and it was found that in the centre of the north-south beech strips the light intensity was practically 100 per cent. At the edges of these strips, close to the hazel hedges, there is an appreciable reduction: the lowest reading obtained was, however, nearly 70 per cent. of full daylight, and it may, therefore, be assumed that shade is not a limiting factor in this environment. It should, however, be pointed out that these measurements were confined to strips running north and south: on the south edge of east-west strips the reduction in light intensity might be much greater.

The light conditions in rectangular or elliptical gaps in hazel coppice are considerably more complex even than in narrow strips. Apart from the very important fluctuations due to the march of the seasons, the rising and setting of the sun, and the variations in the amount and character of the cloud, there are very large local variations within each group. Thus on overcast days the centre of the group will receive most light, whereas on sunny days the

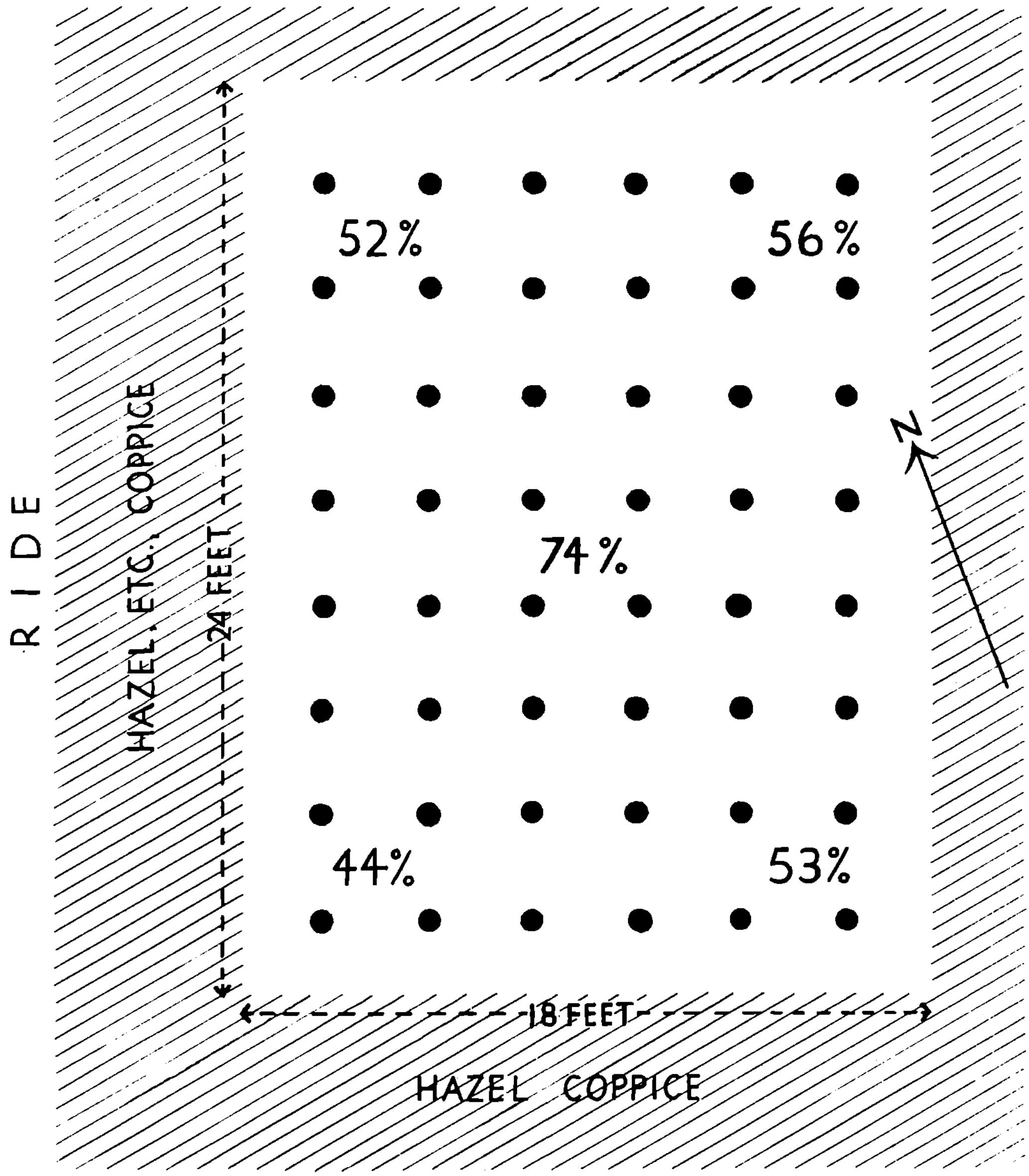

DIAGRAM OF GROUP OF 48 SIX-YEAR-OLD BEECHES SURROUNDED BY 15-20 FOOT TALL HAZEL COPPICE, C.23, GARDINER FOREST, WILTS. DISTRIBUTION OF RELATIVE LIGHT INTENSITY IN EARLY AFTERNOON 100% = LIGHT INTENSITY IN THE OPEN northern part of the group will receive more light, because it will be affected by the direct rays of the sun for a longer period. It may be noted, too, that, as the beeches grow, their tips will tend to come less under the influence of the lateral hazel screens. Therefore any measurements of light intensity taken in this environment can have no high degree of exactitude, but as pointers they may be valuable nevertheless. In June, 1950, a set of five readings, one in the centre and one near each corner, was taken under an overcast sky in each of ten planted gaps. These gaps are about 20 feet in diameter, the flanking hazel being about 16 feet tall, and the photo-electric cell was operated at breast-height, which was roughly the height of the base of the current shoots of the beech. Measurements in the centre of the gaps ranged from 50 to 84 per cent. of the light in the open, with a mean of 74 per cent. Near the corners the range of light intensity was from 28 to 78 per cent., with a mean of 51 per cent. The average reading for the five positions in one gap ranged from 41 to 68 per cent. of full daylight, only the one mean lying below 50 per cent. Of the five positions, the shadiest was the south-west corner (mean 44 per cent.); for north-west, north-east and south-east corners the mean readings were 52 per cent., 56 per cent. and 53 per cent. of full daylight. The readings were taken shortly after mid-day and the low reading in the south-west position is interesting in this connection. These light measurements are shown on the diagram overleaf. On theoretical grounds it was assumed that the height growth of beech in this environment would not be adversely affected by the reduced light, though there seemed a likelihood that there might be a very local effect at the southern edges of the gaps. Sample measurements showed very good total height and current increment, these being better than heights recorded in other environments at Gardiner, and some of the best that have been seen anywhere for beech of similar age. There was no clear evidence that the beeches in the shady corners were held back by too much shade. It is possible that height growth was stimulated by the reduction in light, but no valid comparison with beech in full daylight was possible in this area. The data indicate that the maximum reduction in light in such gaps in hazel coppice is of the order of 60 per cent., and that this does not adversely affect the height growth of beech.

Atmospheric humidity

One of the most marked effects of woody vegetation on the environment concerns the humidity of the air. The increased humidity under or among trees and tall shrubs is partly caused by the more profuse evaporation from the moist woodland soil and the vegetation it bears, as compared with pasture or heath; partly, perhaps chiefly, by the reduced air movement in the neighbourhood of the trees and shrubs. Adamson (1922) gives some data for relative humidity in beechwoods and in the open, and Miller (unpublished report) investigated the rate of water loss from a freely exposed surface on open downland and in the environment of derelict woodland with different degrees of shelter. In hot summer weather, the differences in the rate of evaporation between open downland and the sheltered gaps in hazel coppice were astonishing. This difference can be immediately sensed on a hot summer day as one moves from the warm but dry atmosphere of an open down, or clear-felled area, to the warm, very humid, atmosphere of the gap in the hazel. From the point of view of beech growth and health, the reduction in the evaporative power of the air is important in relation to water-loss from the leaves in dry periods. It should be noted that this factor is only one of several which govern water-loss from the plant: stomatal opening, protoplasmic permeability, and the temperature gradient between the leaf and the outside air are all of great significance. There is good reason to believe, however, that reduced evaporation is one of the most influential characteristics of the woodland environment, whereby the early growth of beech, given enough light, is greatly favoured. It may be added that the more uniform temperature in woodlands tends to reduce the temperature gradient between leaf and outside air, on which transpiration also depends.

Temperature

In hazel coppice, birch scrub, or other derelict woodland, the temperature of the air is less subject to fluctuations than in the open. Frosts are less frequent, and the risk of dangerously high leaf temperatures in summer are reduced. This more equable temperature is best provided by a light uniform overhead shade; but side screens may give sufficient protection from frost. No special observations have been made on the temperature factor in relation to beech growth in different environments.

Carbon Dioxide

No special attention has been given to the carbon dioxide content of the atmosphere as a factor in beech growth in different environments. There is, however, need to mention a factor which is believed to be sub-optimal for photosynthesis in many circumstances. The carbon dioxide in the air is being constantly replenished from the soil: therefore anything which checks air movement near ground level must improve the local supply of this gas.

Soil Moisture

Low-branching woody vegetation shields the soil from sun and wind, and therefore tends to conserve soil moisture. The net influence on the amount of moisture available for the growth of planted beech clearly depends also on the quantity of water abstracted by the associated herbs, shrubs and trees. Some observations on root competition in derelict woodland will be made in the next paragraph. Undergrowth and surface vegetation tend to make the soil drier than bare soil in spring, when growth is active and most of the water loss from the soil is due to transpiration by plants; whereas in summer drought, protection of the soil from sun and wind more than balances the water loss by transpiration from such vegetation, which may, therefore, conserve the moisture of the soil. On loamy garden soils, for example, bare fallow ground is as a rule distinctly moister in spring but drier in summer (unless there is excessive rain) than ground which is intensively cropped. Similarly, in the early summer of 1950, screefed patches on the summit of War Down, Buriton, Hants., showed a significantly higher soil moisture content than areas bearing the natural turf of fescues. No general statement can, however, be made when so much depends on the seasons, the weather, the properties of the soil, and the depth and intensity of roots of the herbs, shrubs and trees present. Other things being equal, a screen of low woody vegetation will, by intercepting wind and sun, greatly reduce direct evaporation from the soil.

Root Competition

In derelict woodland, the important competitors with planted beech for water and nutrients are, at least on downland sites: hazel, birch, ash, oak; privet, dogwood and other calcicolous shrubs, and the herbaceous plants, which are important only in gaps, or following clearance of the woody growth. These plants differ in their effects, in accordance with the different distributions of their roots. This distribution varies within certain limits with the soil, but each species has a characteristic root habit. Current observations appear to warrant a classification into four groups.

(*a*) Deep rooting species like oak and hazel.
(*b*) Species with wide-spreading, rather superficial roots: ash, birch.
(*c*) Species with close mats of fine surface roots: privet and dogwood.
(*d*) Mull plants, including most of the herbs.

For the early growth of beech, it would appear that plants in groups (*b*) and (*c*) are most dangerous. Very little is, however, known about the root distribution of common woodland plants, and it is only possible to make tentative general inferences. In Compartment 18, Gardiner Forest, Wilts., very poor growth of beech was noted on ground occupied by a rather close low shrubbery of privet and dogwood. An assessment was made in one of these privet-dogwood patches and in a nearby group of thriving beech in a gap in hazel coppice at the south-west corner of compartment 23. The data for mean annual increments in inches since the date of planting (1946) appear in the table below. It will be seen that the beech within the hazel gap had, since planting, made nearly thrice the height growth of the beech among privet and dogwood.

It is not clear how much of this difference may be ascribed to micro-climatic differences and now much to edaphic factors. Soil moisture determinations in hot dry weather in June, 1950, showed a small but definite difference in favour of the beech in compartment 23. The soil of the A horizon under the privet and dogwood felt much drier, and the intense mat of fine roots left no doubt that the small beech plants, the roots of which had not tapped the A/C horizon, and were in close competition with those of the shrubs, were being robbed of water and, perhaps, of mineral nutrients.

In this same Compartment 18, a few small ash trees proved instructive. An examination was made, on June 9th, 1950, of the root-range of one ash 28 feet tall and 37½ inches in breast-height girth, standing at the edge of one of the hazel hedges separating the strips of 5-year-old beech. Five pits were dug at a distance of 22 feet (6.7 metres) from the ash in south, south-west, west, north-west and north directions among the planted beech, there

Height Increment of Beech, Planted in 1946, at Stonedown Wood, Gardiner Forest—Wiltshire

TABLE 2 — Inches

Mean Increment in Year	1946	1947	1948	1949	1950	Aggregate	Initial Height, 1946	Total Height in 1950
C.18, Open	3	2	3	5	7	20	16	36
C.23, Gap in Hazel	4	7	13	14	15	53	15	68

being uncut hazel to east of the tree. In each pit fibrous ash roots were very abundant, there were also thicker roots up to 17 mm. ($\frac{3}{4}$ in.) in diameter, and it was clear that the fine feeding roots must extend very much farther than 22 feet. The behaviour of the beech within this segment of a circle was interesting and rather puzzling. None had been planted within 6 feet of the ash; at a distance of 6 to 15 feet the beeches had made fair growth, the mean height of 20 trees being 50 inches, and the main yearly increment since planting (1946) about 7 inches. Beyond 15 feet, as far as and beyond the inspection pits, growth of the beeches was very poor, the mean total height of a typical sample being 22½ inches and the mean yearly increment only 1½ inches. There is thus good evidence that the finer roots of ash, ramifying intensively in the surface 15 to 20 cm. (6 to 8 in.) of rendzina soils, and extending far beyond the crown spread of the tree, compete vigorously with young beeches for water and nutrients. The fine roots of a large mature ash have been traced, always near the surface, for 25 metres (80 ft.) from the bole on Jurassic limestone soils. In these cases, it appeared that, a short distance from the tree, the roots ran at a somewhat deeper level and were less finely branched. This may perhaps explain why, at Gardiner, the beeches planted 6 to 15 feet from the ash did not show the influence of severe root competition.

No detailed observations have been made on the rooting of birch, which appears to resemble ash in possessing an extensive superficial root-system which does not, however, exploit the soil as intensively as ash. The feeding roots of oak and hazel run deeper than those of ash, and probably do not extend so far from the tree. But no special assessments have been made, and further information is required about the range, depth and density of the root systems of the more important plants encountered in the afforestation of derelict woodland. Such are: birch, hazel, sycamore, ash, oak, yew; hawthorn, blackthorn, privet, dogwood; and, of course, the beech itself. Competition for water and nutrients (especially nitrates) may sum up the harmful effect of these associated plants on young beech trees, insofar as shade and mechanical injury are not involved.

Chapter 9

STEM—FORM OF BEECH WITH PARTICULAR REFERENCE TO ENVIRONMENT

There are three main ways of obtaining information about the effect of environmental factors on the forms of beech trees. First, to examine the forms of numerous mature beech crops, growing in a wide range of conditions, and attempt to find a relation between good and bad form and factors of the animate and inanimate environment. Second, to collect evidence from young planted and natural stands of beech, where different habits of growth are in process of becoming set, and where the early stages of forking can be observed and perhaps traced to a particular cause. Third, to subject young beeches experimentally to conditions similar to those which are suspected of affecting the forms in nature, and observe the result. Investigations are proceeding along all these lines, the second having been given special attention as likely to provide the best clues.

EXAMINATION OF MATURE BEECHWOODS

During the survey of mature beechwoods, notes were kept on the form of the trees. In the early work, regular appraisals were made of straightness, the frequency and distribution of forks, natural taper and cleaning, fluting at the base of the bole, as well as the occurrence of injury and disease. These detailed assessments showed the very large differences which exist between different stands, but gave little promise of producing definite evidence about the factors which influence form, and so were discontinued in favour of a wider extension of the survey. In every stand examined, an estimate was made of the "mean height of clean bole", in addition to estimates of total height and timber height. This figure, with some qualifying notes, proved a useful record of the forms of the trees. The appearance of mature stands is, in large measure, determined by the closeness of canopy during development, and by the intensity and character of the thinning applied. Although it was instructive to have the importance of these two factors emphasised, their operation tended to obscure the earlier influence of race, climate and soil. Some general inferences can, however, be based on the data collected, but at the present stage they should be regarded as tentative.

(*a*) The tallest stands generally showed rather good form and a very satisfactory mean length of clean bole. This is partly incidental to the height. In most samples there are some trees without a fork below the live crown, and in very tall stands these trees will pull up the average clean bole measurement. But the effect appears to be partly a direct result of the good water supply of the site, causing both good height growth and a relatively vigorous leading shoot.

(*b*) Some stands of moderately good height showed very poor form. In a few cases this conjunction was found on soils with impeded drainage in the subsoil; in other cases the cause was considered to be racial, the effect being often aggravated by neglect.

(*c*) In crops established by natural regeneration, forks were often relatively rare in the lower part of the bole, which occasionally showed a sinuous form. The absence of low forks is perhaps due to protection from frost, and the sinuous habit is undoubtedly caused by the impulse to grow towards any break in the canopy.

(*d*) Although the best-formed stands mostly grew in valleys, there was no clear evidence that beech in exposed situations habitually show poor form. In some cases beech growing in exposed positions were of pleasingly good form. On windy sites water supply is commonly a limiting factor, with the result that total height and clear height are both adversely affected. It does not, however, appear that, in moderation, wind causes a tendency to fork. On very exposed mountains, or near the coast, strong winds have a well-known stunting effect, and beech assumes a one-sided shrubby form.

STUDY OF DEVELOPING BEECHWOODS

Along the second line of approach, a study of developing beech crops has given much information about the environmental causes of bad form, but so far only limited information about their relative importance. Only when trees are small (up to 10 feet) is it possible to observe large numbers of them in detail. Such observations cover, however, the most valuable part of the stem and the part where forks and other blemishes are often most pronounced. Once the factors causing forks at this stage have been identified and evaluated, observations can be extended to their incidence in somewhat older crops. Of the factors recognised, but not nicely appreciated at the outset of the enquiry, may be mentioned: frost, shade, the rabbit, and the grey squirrel. Factors unknown or scarcely suspected, include: soil conditions; atmospheric drought; wind; snow and ice; competition; and Lammas growth.

EXPERIMENTS ON YOUNG BEECH

Fabricius (1929) essayed careful pruning of misshapen three-year-old beech plants, and simultaneous maltreatment (beheading) of shapely plants. The not very conclusive results obtained four years later indicated that heredity and environmental factors both play an important part in determining the form of beech at that early age.

Observations will now be offered on the factors considered significant in the forking of beech. The appearance of mature beech crops may be greatly influenced by whatever thinning has been carried out; but this discussion is concerned only with the agencies which fashion the raw material offered to the forester when thinnings begin.

INANIMATE FACTORS OF THE ENVIRONMENT

Soil Conditions

In a consideration of form in the ash, Møller (1941) ascribes the major influence to the water and nutrient conditions of the soil, and he suggests that the soil may affect the forms of other trees in a similar manner. On badly drained, or very dry, soils the leading shoot has, sooner or later, difficulty in maintaining its pre-eminence, and becomes outstripped by a side shoot, whereby a fork may be caused. Nutrient status is important, insofar as a high nitrogen/phosphorus ratio tends to prolong vegetative growth and thus expose the leading shoot to autumn frost. The present enquiry has produced conflicting evidence in regard to soil water; because plentiful soil moisture, while producing a vigorous leading shoot, stimulates also Lammas growths, which may be followed by various troubles detailed below. In one important respect, favourable soil conditions have a very beneficial, though indirect, influence on the form of beech, because rapid early growth carries the trees quickly past the stage when they are most vulnerable to frost and rabbits.

Frost

Spring frost is one of the most important factors affecting the survival, growth and form of beech in the young stages. On susceptible sites, unprotected trees, if they survive at all, become bushy; and although they may eventually produce a good strong leading shoot above the frost level there will be a high proportion of trees with blemishes in the basal four feet. Recent observations have shown that, in certain circumstances, the leading shoots of beech are susceptible also to freezing in autumn, and there is no doubt that forks are occasionally produced in this way. Autumn freezing is closely connected with "Lammas" extension, considered below.

Atmospheric Drought

Die-back of tips during the summer is of frequent occurrence in young beech plantations. In many cases this is associated with insect damage, but in others there is no evidence of insect or other attack, and drought is the most probable explanation. At present there is nothing to indicate whether lethal high temperature, or excessive water-loss, is the primary cause nor, in the latter case, how soil moisture is concerned.

Wind

Wind may break off young beech shoots, but there is no reason to think this an important source of deformation of the leading shoot. Wind has, however, a very marked desiccating action, and thus has an important influence on soil moisture and on atmospheric humidity. In Denmark there are some very badly formed stands of beech in the more exposed parts of Jutland and it has been argued that the Danish spreading beech (Vrange Bøge, or "wrongling beech") is a phenotype reflecting exposure to wind. Oppermann (1909), however, adduces evidence to show that the form is inherited. Within the range of conditions where mature beechwoods were examined in Britain, there appeared to be no linkage between poor forms on the one hand and elevation and exposure on the other.

Snow and Ice

In January, 1940, glazed frost caused considerable damage at Buriton Forest, Hants., and may partly account for the very frequent forking in the older plantations of beech there. It seems probable that injury was caused to young beech plantations in other parts of Britain at the same time, but no reports have come to notice. In winter, beech sheds snow rather easily, and instances of breakage are rare.

Shade

Moderate shade, cutting off up to perhaps 50 per cent. of the light, does not appear to have any measurable effect on the habit of growth of young beech, although the height growth may be mildly stimulated. Deep shade depresses height growth and vigour, and causes a tendency to horizontal branching, in which the leading shoot eventually becomes involved. A very good example of these table-topped beeches was seen at Stourhead, near Maiden Bradley, Wiltshire, where natural regeneration appeared about thirty years ago, probably in small gaps caused by felling or natural death, in a stand of pure beech. As the gaps closed in, the young beeches were increasingly affected in growth rate and form by the deep shade. They are now very markedly flat-topped and growing very slowly. No light measurements were taken in this stand, where a thinning had just been carried out: but some instructive records were obtained in Friston Forest, Sussex, and in Cirencester Park, Glos., where beech in shade had responded by flattening of the branches.

At Cirencester (Jubilee Plantation) beech and larch had been planted in alternate rows 15 years previously. In one plantation of beech and Japanese larch, the larches had far outgrown the beeches and were about 32 feet in height. The beeches were mostly 4 to 10 feet in height and all "table-topped". The larch had recently been thinned, and the actual relative light intensity (20 to 25 per cent.) bore no relation to the conditions ruling when the beeches assumed the flattened form. In the mixture of European larch and beech, the larches were about 28 feet tall and the beeches 6 to 11 feet: in this case the tips of the beeches were only slightly inclined away from the vertical. The larch had not yet been thinned, and readings of light intensity, taken at 4 feet in the crowns of the beeches, showed a mean of 17 per cent. of the full light in the adjoining open ground. Measurements of recent height increments of the beech failed to disclose any fall-off in the last year or two, and it appeared that the light intensity prevailing at the time the measurements were taken was near the critical point for good height growth and erect form.

Some rather more detailed measurements were taken in March, 1951, in Compartment 24, Friston Forest. This compartment had been planted with beech and pines (Scots and Corsican) 22 years before, but most of the existing beeches are much younger replacements. A small proportion of the beeches are practically level with the pines (20 to 25 feet tall), though somewhat hemmed in. These trees have remarkably horizontal lower branches under the canopy of pines. The remaining trees are much below the pines and all exhibit a somewhat horizontal branching habit. Many have an erect leading shoot, while in many this too is strongly inclined from the vertical; there are also some trees of intermediate form. In the very lightly thinned plot, where the mean light intensity at breast-height is about 13 per cent. of full daylight, table-topped beech preponderate; whereas in a more heavily thinned plot, where the mean light is about 29 per cent., there is a greater proportion of trees with erect leading shoots. There appears to be a good correlation between the habit of individual trees and the light reaching them: for 20 table-topped trees this ranged from 6.5 per cent. to 12.5 per cent. (mean 8.5 per cent.) and for eight trees with erect tips from 19.3 per cent. to 26 per cent. (mean 22 per cent.). One tree, in which the flattening of the leading shoot was hardly enough to justify inclusion with the table-topped trees, gave a light reading of 12.7 per cent.: another, slightly deviating from the vertical, gave a reading of 15.3 per cent. Measurements of current increments of 20 shaded beeches with erect leading shoots showed that the rate of growth was not greatly different from that in the open, where, on a rather dry site, 10 inches yearly, with a small gradual improvement, was recorded over the preceding five years. In the heavily shaded plots, the mean increment was also about 10 inches yearly, but with indications of a fall off: whereas the moderately shaded beeches (25 to 30 per cent. light) had been growing at a steady rate of 12 inches annually. There was, however, a significant difference between the angle of branching of shaded beeches and beeches in the open.

As a measure of branch-angle, the mean of the angles made by the main axis and the first five major branches from the tip downwards has been used. At Friston the beeches in the open showed a branch angle of 38 degrees and shaded beeches an angle of 61 degrees. There was little difference in this respect between the more heavily shaded plot and the thinned plot as the following summary shows:

Growth Rate, Angle of Branching, and Form of Beech under Various Relative Light Intensities at Friston Forest, Sussex

TABLE 3	PLOT A	PLOT B	OPEN
Approx. Mean Relative Light Intensity	13%	29%	100%
Angle of Branching of Beech....	62.3°	59.5°	37.7°
Mean Height Growth, 1946-1950	10 in.	12.2 in.	10 in.
Form of Beech	Mostly Table-Topped	Rarely Table-Topped	Erect; Sometimes Slightly Fastigiate

The measurements of increment and branch angle refer only to those beeches which showed erect leading shoots.

A horizontal tendency of the branches has been observed in many other stands of planted or natural beech growing under canopy. Some of the experimental plots on Holt Down, Buriton, are a good illustration. Following heavy thinning of the associated Austrian pines, beeches showing this tendency were receiving a little more than 40 per cent. of daylight when an assessment was made in one plot in October, 1949. It was assumed that the horizontal branching had been adopted when the shade was heavier before the recent thinning.

It may be concluded that shade and the branching habit of young beeches are interconnected, and there is some ground for the supposition that a light intensity of *about* 25 per cent. of full daylight will have a significant flattening influence on the branch angle, without reducing height increment, or causing the leading shoot to deviate. It is, however, impossible at the present stage to define with any precision the ranges of light intensity within which the different habits are assumed, while it should be clearly recognised that the range may be a function of the age of the tree, or may vary with soil conditions, or the quality of the light which penetrates the overhead canopy. It is not certainly known that light is the decisive factor at all, although this appears likely. From the practical point of view the most important points which need to be cleared up are:

(*a*) Does a wide branch angle lead to a reduction in forking?

(*b*) If so, can a desirable widening of the branch angle be induced by a degree of shade which will not cause the tip to go astray, nor seriously impair vigour?

(*c*) How does the response of beech to shade change with increasing age?

(*d*) Once a tip has inclined towards the horizontal, will it resume an erect habit on receipt of more light?

BIOTIC FACTORS OF THE ENVIRONMENT

The six factors already briefly discussed—soil, atmospheric drought, frost, wind, snow and ice and shade probably include all the factors of the inanimate environment which affect the form of beech. The important biotic factors are: rabbits and hares; the grey squirrel; insects; and the mutual influence of the beeches. Nothing need be put down here about the rodents named: their injuries are only too well known, and a few comments will be offered in the section dealing with pests and diseases. (Page 56.)

Insects

Beeches planted under, or near, other hardwoods are occasionally subject to defoliation by caterpillars of the Winter Moth, or Mottled Umber Moth. It sometimes happens that the tender leading shoot is bitten through or dies during these attacks, and forks may be caused in this way. There is, however, a much more important *Tortricid* moth, which has lately been discovered in autumn sheltering and feeding on the tips of young beeches in numerous plantations in the south of England. This creature has so far been seen only as a very small caterpillar in late autumn, either sheltering under a bud scale on the current shoot, or in a burrow which it had excavated in the late summer extension of the shoot. The accompanying photographs, Figs. 22 to 25, and sketch Fig. 28 give some indication of the appearance of affected shoots and of the nature of the damage caused. All beech tips harbouring the insect, or with signs of recent activity, show Lammas growth, which in many cases continues until a late date. In addition summer buds found dead with "frass" inside are probably to be debited to the same insect: in some instances the same tip includes a dead summer bud with old frass and a Lammas replacement shoot bearing the caterpillar, or signs of its recent activity. It appears to be more usual, however, for the insect attack to begin shortly after Lammas extension of the spring shoot. This Tortricid caterpillar, which has been provisionally identified as *Peronea ferrugana*, has been found at Goodwood (Slindon and Charlton Forests), Sussex, Micheldever and Buriton, Hants., and Gardiner, Wilts.: also on the West Dean Estate near Goodwood, Sussex, and on natural regeneration on Selborne Hanger, Hants. The life history is being worked out and the insect will be kept under close observation in view of its possible importance in relation to the forking of beech.

In 1950 and 1951, a brown discoloration and, in many cases, subsequent death, of the terminal buds, or Lammas sprouts, was observed in many young beech plantations during the summer months. Dissection often disclosed several larvae of a gall-midge (*Contarinia* sp), of which there are about three generations in the year. This creature appears to be widespread, and important in relation to beech forking.

Competition of other Trees

The mutual competition for light, which obtains in close stands of naturally regenerated beech, appears to favour the early natural cleaning of the stems and the suppression of potential forks. It is clear that, at the planting distances of current practice, the advantages of close spacing are unattainable in the early stages, and accordingly no detailed observations have been made on the forms of dense crops of regeneration.

GENETIC FACTORS AFFECTING TREE FORM

The third set of factors which influence the forms of beech includes those inherent in the trees themselves. There should be no sharp segregation of genetical from environmental factors, when the development of beech form is considered. Every response which a tree makes to environmental conditions is partly determined by that tree's inherent tendencies. For example the responses to shade, which were discussed in a preceding section (height growth, survival, branch angles and so on) might, other things being equal, be appreciably different for beech samples of different provenances. On the other hand, the expression of all innate tendencies is modified in an important way by the environment. The ecologist and the geneticist are concerned with two aspects of the same problem. The question whether environment or race is the more important is irrelevant, and probably insoluble. What is wanted is the best race in the best environment, or, failing them, the best available in the particular circumstances. The inter-locking of genetics and environment is nowhere more evident than in the two phenomena which remain to be reviewed in relation to beech forms—namely flushing date and Lammas growth.

Date of Flushing

The date of flushing of beech trees is dependent on the local climate and the prevailing weather, but within any one community, under identical conditions of microclimate and weather, the date of flushing varies much from tree to tree. Burger (1933) states that parental tendencies influence the offspring for some time, irrespective of climate; i.e., seed from southern beech will produce offspring which come into leaf earlier than the offspring of northern beech: this trait tends to disappear in course of years. The date of flushing of beech affects the length of the vegetative period and the susceptibility to spring frosts. The latter is the more important effect and the only one relevant to this discussion. Late flushing beech are less susceptible to frost damage in spring than early flushing beech and, insofar as frost is a vital factor on the site in question, length of growing season may well be sacrificed in favour of firm and easy establishment. But late-flushing beech are by no means immune to frost. Some of the most damaging frosts, (e.g., that of May, 1935) have been at a time when all beech would have broken bud, and early trees would have hardened off a little and so, perhaps, become more resistant to cold. Doubtless chronic frost damage is more noticeable on early flushing trees.

Lammas Growth

The term "Lammas shoot" has been conveniently used to denote what seem to be two distinct kinds of secondary extension in beech.

(*a*) Midsummer shoots, following a short but definite suspension of growth. These shoots are often of considerable length and they normally ripen well.

(*b*) Autumn shoots, which appear very late in the season and are always short with many close buds. Typically they are thick, fleshy and very hairy, and frost damage to leaf or shoot is of common occurrence. Späth, distinguishing this kind of extension as "proleptic", maintained that it is an anticipation of the following year's shoot.

It is possible that these two kinds of shoot are bridged by intermediates and that there is no hard and fast distinction between them. But an individual beech may show three clear phases of shoot elongation in one season. The chronology of these phenomena is not clear and more information is needed. Their practical importance depends on:

(*a*) the danger of frost, which is, perhaps, important only for the late (early autumn) shoots.

(*b*) Susceptibility to insect damage: the autumn shoots often harbour the caterpillar of a moth, which appears also to kill or injure midsummer buds and shoots.

(*c*) The possibility that the closely set buds may make forking more likely in the following year.

The causes of Lammas growth are obscure, but there is doubtless some direct or indirect dependence on the shoot/root balance, probably acting through the supply of water and nutrients. Oakwoods severely defoliated by *Tortrix viridana* produce Lammas shoots earlier and in much greater profusion than oakwoods not defoliated. Until the Lammas shoots appear, there is an acute want of balance between shoot and root. Much the same seems to hold for beech, and observations point to a more generous Lammas shoot production where root absorption is vigorous in relation to the development of the aerial parts of the young tree. Thus the wet late summer of 1950 appears to have been associated with an unusual frequency of Lammas shoots of beech. On the dry rendzina soil at Crawley, Hants., however, there was very little Lammas growth, whereas these shoots were very noticeable on moist loams in the adjacent forest of Micheldever. The influence of shelter is probably important. Insofar as shelter conserves soil moisture and reduces water loss by the trees, it appears to foster Lammas growth (as at Gardiner, Wilts., in 1950). On the other hand the beeches growing under pines at Friston, Sussex, showed remarkably little Lammas growth: this may result from the known depressing influence of shade on the root/shoot ratio, or it may be only a reflection of the dry soil at Friston aggravated by root competition of the pines. Then there is the question of the balance of nutrients, of the influence of which we know nothing in this particular case. It has been found that autumn extension in ash is correlated with a high Nitrogen/Phosphorus ratio, and it is well-known that plentiful nitrates promote the growth of leafy tissues.

More information is needed about the complications associated with late shoot extension, and their effects on stem form of beech. Meantime we must draw the inference that Lammas growth is an occurrence of considerable importance, which we should try to control. Before we can hope to control it, we must understand it; the explanations in the technical literature are somewhat vague and contradictory, so that some accurate, direct observation seems to be required. The environmental factors which favour beech (plentiful soil moisture, shelter from wind) appear also to favour Lammas growth; but, if moderate shading depresses Lammas growth, there may be a way out of the dilemma.

A provisional conclusion is that the stem form of beech is affected by a great number of environmental factors, not all of which are important at any one stage. In early life, spring frost and rodent attack appear to be the most frequent causes of bushy forms and forking. A little later, when the tips of the trees are beyond the reach of rabbits and May frosts, the incidence of "Lammas" growth, and the light environment, are probably the most influential factors, though, on warm dry sites, die back caused by atmospheric drought may be important. From the thicket stage on, it seems likely that shade and Lammas growth (with the dependent autumn frost and caterpillar damage) recede in importance, and then the closeness of canopy and the abundance of grey squirrels may be decisive. In the older stand, fresh forking is probably insignificant and the gain or loss in the quality of the stems is mainly decided by the skill exercised by the forester in thinning. Of the factors which mar the form of the mature stems, rabbits, hares and squirrels, frost, excessive shade, incomplete stocking and neglect of thinning will, as far as possible, be eliminated on general silvicultural grounds. Chief interest, therefore, attaches to the influence of moderate shading, and to the causes and consequences of secondary shoot extension, upon which so much appears to depend in the important period when the trees are five to twenty years old.

Chapter 10

INSECTS AND FUNGI ASSOCIATED WITH BEECH

INSECTS

In Britain the beech offers food and shelter to many fewer species of insects than does the oak. This report is concerned only with those insects which affect the growth and vigour, or the form, of beech; some notes follow on the species encountered during the investigations. First may be mentioned a widespread and important Lepidopterous seed-borer, of which Ardö and Lindquist (1947) give a full account. This is *Laspeyresia grossana*, a near relative of the apple codlin moth, which was observed to be very plentiful in the Thetford district of East Anglia in 1948 and common in many South Down forests in 1950. The larva feeds inside the nut and makes its exit by a circular hole. In some circumstances the prospects for regeneration may be impaired.

In the forest, young beech seedlings are often severely affected by *Phyllaphis fagi* L., an Aphis which lives amidst a woolly exudation on the under side of the leaf and sucks the sap. In July, 1949, enormous numbers of these insects were seen at Countesswells, Aberdeenshire, on first-year natural seedlings suffering from the prolonged drought. *Phyllaphis* was common also on first-year beech seedlings in some other forests that year and noted also on second-year seedlings in 1950 on Ashford Hanger, nr. Petersfield, Hants. Another small sucking insect which attacks beech regeneration in the early years is the Jassid bug *Typhlocyba douglasii* (Homoptera), which, unlike the aphis, hops about freely. Some account of the prevalence and importance of these two leaf-suckers is given by Watt (1923), who regarded them as serious adversaries of beech seedlings growing in shade, where the rate of photosynthesis is slow and the seedlings have little reserve with which to withstand the constant drainage of nutriment. *Lachnus exsiccator* L., which sucks the sap of young beeches and may do serious damage, was not observed during the survey, but a rather severe attack has lately been reported from the Forest of Dean, Gloucestershire.

Phyllaphis fagi is met with also on somewhat older beech, planted and natural. In the early summer of 1948 the aphis was very abundant in some beech plantations, for example in an area of fifteen year-old beech at West Harling, Thetford, Norfolk. It does not appear to be a very serious pest. In plantations beech receives attention from several other insects, and mention has already been made of the Winter Moth *Operophthera brumata* L., the Mottled Umber Moth, *Erannis defoliaria* Cl., and an unnamed Tortricid caterpillar, which does considerable damage to the leading buds and shoots of beech five years old and upwards. Exceptionally, other caterpillars are found defoliating young beeches and Purser (1948) describes the depredations caused in 1947 on recently planted beech in Collingbourne Forest. Various caterpillars were identified, the four commonest being: *Himera pennaria* L., *Phigalia piloseria* L. (Geometridae), and *Taeniocampa gothica* L. and *T. miniosa* Fabr. (Noctuidae). These all feed on various broadleaved woody species, principally oak.

Young beech trees are frequently found with the bark of the tips gnawed by weevils, giving them a pock-marked look. The injury is done in summer, and probably at night, and the agents have not been discovered. It seems likely, however, that a species of *Strophosomus* or *Bareipithes* is concerned. A severe attack may cause the die-back of the tip, but it is not considered that these insects are formidable enemies of beech. Gall midges of the genus *Contarinia*, already referred to in Chapter 9, are more important at this stage.

Adult beech trees have a rather limited insect fauna and, apart from the Geometrid defoliators already named, which may be found on beech of all ages, though much less abundantly than on oak, the two most noteworthy are the little black weevil, *Orchestes fagi* L., and the Felted Beech Coccus, *Cryptococcus fagi* L. *Orchestes fagi* feeds in both adult and larval stages on beech, the weevil eating small holes in the leaves and the grub burrowing inside the leaf and causing red-brown blotches. The insect is very plentiful in some summers, but of no considerable importance: few were seen in the beechwoods examined in 1949 and 1950. *Cryptococcus fagi* occurs on beech of all ages, but is not common on very young trees. In affected stands the distribution of trees bearing the white woolly secretion is very irregular, and both attacked and clean trees may continue living side by side for many years. The young cocci settle in crevices where the bark is thin, and they can probe with their probosces to the sap below. There is a good deal of evidence that a colony of long-standing will deepen and enlarge the crevice where it shelters, and it is believed by some that the rough bark of many mature beeches is sometimes due to former severe and prolonged attack by the coccus. There is considerable evidence that this insect is associated with unfavourable soil conditions. Some of the worst attacks have been recorded on soils with defective drainage, or, on the other hand, on very freely drained soils liable to summer drought. It is at least probable that, where a beech affected by coccus dies, root disease and/or inadequate water supply have contributed to the weakening of the tree. A case of this kind was examined at Thornthwaite Forest, Cumberland, where a number of beeches, some mature, some middle-aged, were dying in 1950 with more or less severe infestation by coccus. It was considered that the 1949 summer drought, on a rather dry site, and the insect were jointly responsible for the deaths. There is a noteworthy example of *Coccus* attack on the twenty-five-year-old plot of copper beech at Alice Holt Forest, Hants.

The Wood Leopard Moth *Zeuzera pyrina* L., was observed to have tunnelled several young beeches in Gardiner Forest in 1950. The Ghost Swift Moth, *Hepialus humuli* L., has a larva which is common in grassland and woodland soils; beech is sometimes severely damaged by the *Hepialus* in the nursery, and the larvae have occasionally been found gnawing the roots of planted beech (and other broadleaved trees).

FUNGI

A few notes are given on the fungi that are of widespread importance in beechwoods, especially those encountered during the survey.

In very damp seasons, beech seedlings are sometimes decimated by the damping-off fungus *Phytopthora omnivora*, which has been cited as a factor in the unsuccessful regeneration of beechwoods.

The most important fungus enemy of young beechwoods is probably *Nectria ditissima* Tul., which is associated with many of the cankers found on beech in plantations and natural regeneration. These appear on the stem typically as irregularly rounded sunken sores, with some broken bark, often of a bluish or purplish colour, and callus formation at the edges. Sometimes the cankers are more elongate, and there is some confusion about the cause, because the three *Nectria* species—*ditissima* Tul., *galligena* Bres and *coccinea* Fr.—have been clearly distinguished only recently, and fructifications are rarely found in the cankers. It has been suggested that these may in some cases be of bacterial origin. A canker of the kind described, which was collected at Goodwood, Sussex, bore a fructification identified as that of *N.coccinea*, which is not universally regarded as a pathogen. Cankers of *Nectria* type were recorded in beech plantations in various parts of the country, most frequently in the southern part of the Cotswold Hills. The development of these cankers is commonly preceded by some injury to the bark caused by pruning, insect or rodent attack, frost or gunshot. Two badly affected stands in the Stroud district, Glos., each fifteen to twenty years old, had been extensively pruned not long before. Cankers may cause the death or malformation of the young tree; but the sporadic occurrence seems to indicate that, unless there is some widespread predisposing cause of injury, severe outbreaks do not occur. In this connection the activity of the insects *Lachnus exsiccator* and *Cryptococcus fagi* are worth attention. Cankers are also frequently met with on the stems of older beeches, but their origin is not always clear. These most often take the form of longitudinal fissures, but annular swellings are occasionally seen. The Felted Beech Coccus appears, in some cases, to be a prior cause of the cankers on middle-aged and older beeches. Some of the affected stands are on shallow chalk soils.

Beech is relatively resistant to honey fungus, *Armillaria mellea* Quel., and red root rot, *Fomes annosus* Fr. *Fomes* was, however, recorded on young beeches in Denmark seventy years ago, and has recently been observed on some young beeches, associated with severely affected pines in Thetford Chase, Norfolk. Inspection of the 1932 beech planting in somewhat older pines at Wangford, part of Thetford Forest, showed that the disease was present on some of the smaller trees, but not to any alarming extent. Older beeches are said to be much more resistant, and there was little butt rot of any kind in felled beeches examined during the 1939/45 war.

Polyporus adustus Fr. is another fungus of questionable status, which often affects standing beeches as well as other broadleaved trees. It is generally regarded as a harmless saprophyte, but Ferdinandsen and Jørgensen (1938) record it as occasionally infecting the wood of beeches damaged by sun scorch; and Ehrlich (1934) considered it as a final stage in the death of trees affected successively by *Coccus* and *Nectria*. Writing of it as the "beech snap disease", Ray Bourne (unpublished notes) considered *Polyporus adustus* an important contributor to the failure of beech on dry chalk escarpments and ravines. Affected trees are often snapped off by wind several feet above the base: such broken trees were noted particularly on Selborne Hanger, Hants.

Mention may also be made of "black heart", although nothing appears to be certainly known about its origin, fungal or otherwise. Black heart affects the heart-wood at various vertical levels and, while not lessening the strength of the timber, makes it unsuitable for certain special purposes. Black heart is generally restricted to stands which are rather over-mature, and appears to be specially associated with shallow calcareous soils. There is no external indication of the presence of the disease, so that little information was collected about its distribution in a survey of standing woods.

Chapter 11

SOME VERTEBRATES OF IMPORTANCE IN BEECHWOODS

Wood Pigeons

Wood pigeons devour enormous quantities of beech nuts, and probably have a significant effect on the success of regeneration. Mr. Workman, the owner of the fine Kingscote Wood in Gloucestershire, believes that pigeons were largely responsible for the failure of regeneration in 1949, following an exceptionally good mast in 1948. On October 31st, 1950, pigeons were observed raiding a small beechwood near Haslemere, Surrey, where nuts were very plentiful: in March, 1951, a considerable search yielded only one sound nut. Hard winter weather drives many pigeons to Britain from the Continent, and acorns and beech nuts are an important part of their food.

Mice

Mice may occur in beechwoods of any age, and their activities are interesting in several ways. The forester is primarily concerned with their habit of gnawing the bark at the base of young trees of many species in plantations, and thus weakening or killing them. A few instances of beech plantations severely attacked were recorded during the survey. On old woodland sites the long-tailed wood mouse, *Apodemus sylvaticus* L., is probably always the species concerned, though the bank-vole, *Evotomys glareolus* L. (which sometimes climbs trees), may also be important. Open ground, on the other hand, sometimes teems with the little short-tailed vole *Microtus agrestis*, which has often been recorded as injurious in virgin plantations.

The wood-mouse is a regular denizen of mature beechwoods, but appears to be restricted to mull soils. In some cases soils where, under the deep beech shade, mor is gradually forming, are found with many old tunnels, but no other signs of mouse activity. The conditions of acidity and deep shade in which mor develops appear to be unfavourable in some way to these animals, which are equally rare on sites exposed to the wind, where the firm, dry soil surface, draughtiness and exposure to their enemies are doubtless uncongenial. In beechwoods on mull mice eat, and accidentally bury, many nuts; they also bury, incidentally, fallen leaves, and occasionally damage seedlings. The destruction of nuts may be more than offset by the advantage of having many nuts deliberately or accidentally protected from pigeons and placed in a good bed for germination. The damage to young seedlings is difficult to assess, but may well be considerable. In mixing the fallen leaves with the surface mineral soil, burrowing mice perform a useful service in the maintenance of mull.

Hares and Rabbits

The damage caused by hares and rabbits is so well known that a brief notice only is needed. The hare is important mainly on open ground, as when new beech plantations follow grass or arable cultivation. Hares are particularly fond of young beech shoots; they occasionally leap over rabbit fences and, as one hare can nip off many tips, the damage in young plantations is often considerable. Rabbits are, however, more generally important, because they feed much in woodland and the beech is, consequently, vulnerable at all ages, from seedling to maturity. In hard winters, a great deal of damage may be caused to the bases of big beeches by rabbits gnawing the bark, though the trees do not often seem to be killed. Many Scottish beechwoods suffered thus in 1947. Rabbits appear to be less important in dense pole-woods. Their worst damage is in any case in young plantations, or natural regeneration, where they crop the tips if within reach and also gnaw the bark at the base. Rabbits are the most widespread major cause of failure of the regeneration of beech in Britain.

The influence of old rabbit warrens on the establishment of beech is also of ecological interest. On downland it has more than once been found that, on the sites of old warrens—often constructed in the softer Middle Chalk—the establishment and early growth of beech are much faster than elsewhere, whereas in a zone immediately beyond the warren growth is sometimes particularly disappointing. The good growth in the warrens is due to a combination of three favourable circumstances:

(*a*) the improvement of soil depth, structure and aeration caused by the tunnelling;
(*b*) the partial elimination of competing grasses;
(*c*) the shelter afforded by the shrubs which establish themselves on the old warrens—especially elder, which rabbits dislike.

Squirrels

Hardly less important than the rabbit, the grey squirrel has now become established in most of the English beechwoods; beech and sycamore are the trees most commonly damaged.

Unlike the rabbit, the grey squirrel does no damage (so far as is known) to beeches until they are about twenty feet in height. From this time on the bases are gnawed and sometimes fatally girdled: but the commonest and most serious damage is done to the main stem in the region of the crown. The bark is ringed a few feet back from the tip, which quickly dies: the tree is distorted, or may be killed outright. Natural regeneration and planted beech are equally affected and, even if the crop is not ruined, the prospects for choice of good stems for the final crop are gravely impaired. Squirrels are dainty movers and feeders, and it has been observed that young beeches with waste from thinning or brashing around them are less prone to damage than beech standing on a clean floor. This delicacy may also perhaps account for the impression one often receives that the straightest tall trees in a plantation are maliciously chosen for feeding. While making their dreys in crooked trees, squirrels may prefer to manoeuvre and feed in vigorous trees with a relatively straight clean stem.

Squirrels in older beechwoods do much damage by gnawing the bases of trees. Like rabbits in a hard winter, squirrels are impelled to this in dry weather in early summer when the sap is flowing, and nuts and fruits are scarce. A feast is also made of the young shoots and flowers when they appear in early May; the ground beneath roadside beeches is sometimes strewn with the waste from the squirrel's breakfast. Beech nuts are also eaten in autumn. Owners are now well aware of the damage caused by the grey squirrels in woodlands and especially in beech plantations.

Deer

The last mammalian enemy of beech to be mentioned is the roe-deer, which is plentiful in many of the remoter forests. Considerable damage was done in beech plantations in Thetford Chase, Norfolk, until the most promising areas were enclosed by a deer-proof fence. There has also been damage at Buriton, Hants., Goodwood, Sussex, and elsewhere. In some cases fallow deer which have escaped from parks are present with roe-deer in beechwoods, but the roe is the species commonly destructive.

Chapter 12

THE FLORA OF BEECHWOODS

In all the beechwoods recorded the plant associations were noted. In dense stands records of the scanty flora under the full beech canopy were supplemented by notes on the flora of gaps, or adjoining stands, where the light favoured the development of a richer flora. These lists have not been included in the summarised records in the appendices for several reasons. Many of the woods were examined in the winter, and in no case was it possible to make a series of visits at different seasons and thus ensure a complete inventory of plants. Secondly the flora of a fully stocked beechwood is commonly scanty, and must be interpreted in the light of all the local conditions, if it is to yield useful information about the site. Primarily dependent on the soil, the beechwood flora is greatly modified on the one hand by the density of the canopy and, on the other hand, by the west wind. This results in a multiplicity of site types. In Britain the artificial character of very many beechwoods further complicates the issue; the present flora of planted beechwoods, on sites where beech did not grow before, is probably not that characteristic of long-established beechwood on that site. This particularly affects certain plants which show in their distribution a high loyalty to the beechwood association—e.g., *Sanicula europaea*, *Viola reichenbachiana*, *Asperula odorata*, *Hedera helix*—more especially if they have feeble powers of dispersal.

The overriding influence of shade was observed in Sweden by Lindquist (1931), who distinguished sharply between the dense primeval beech forests, with very scanty flora until disease and death or wind-blow caused gaps in the canopy, and the regularly thinned beechwoods of well-managed estates, where the characteristic flora was well developed from middle age. Bornebusch (1931) stressed the importance of the westerly winds in Denmark, and observed that, for each basic type of plant association, there is a derivative type, often strikingly different, which is characteristic of exposed sites.

First, the general poverty of the flora of beechwoods, as compared with ash or oak woods, may be noted. None the less, in well thinned stands, there should, from early middle age, be a moderate development of plants appropriate to the soil. Except for scramblers like *Rubus fruticosus* agg., *Hedera helix*, and *Lonicera periclymenum*, shrubs are generally restricted to wood margins and gaps, or to the occasional planted rhododendrons and other ornamental, or berry-bearing shrubs. Herbs include a considerable number of hemicryptophytes and several geophytes; therophytes (annuals) are very rare. Mosses do not grow on the deep, rather persistent, beech litter, and are usually restricted to places where wind has scattered the leaves and left bare soil, or to the boles of the trees themselves. There are two main reasons why the characteristic flora fails to develop:

(*a*) Dense shade brings about a scattered and impoverished flora on calcareous soils, and usually suppresses the flora entirely on other kinds of soil.

(*b*) Exposure to the prevalent winds may make conditions intolerable for *Rubus* and herbs and, by exposing the soil, pave the way for mosses.

In the north and west of Britain the absence of many characteristic plants is doubtless to be ascribed in many cases to the fact that beechwoods are comparatively recent in the locality.

The floral associations observed may be grouped in three basic types: the limestone beechwood type: the acid mull type; and the heath beechwood type. These correspond with the *Fagetum calcicolum*, *Fagetum rubosum* and *Fagetum ericetosum* described by Tansley (1939).

Limestone Beechwood Association

The limestone beechwood association is found on calcareous soils and, rarely, on base-rich sands or light loams, which are warm, well-drained and freely nitrifying. It has been shown (de Silva, 1934) that many so-called "calcicole" plants depend, not on free lime in the soil, but on a sufficiency of exchangeable calcium, which may be provided by many brown forest soils and at a reaction considerably on the acid side of neutrality. Thus many calcicole plants are occasionally found on non-calcareous soils, and there were several records during the survey of such characteristic plants as *Mercurialis* and *Sanicula* being recorded from loamy brown forest soils of low pH. It is, however, true that in British beechwoods many plants are mainly associated with soils derived from chalk and limestone. *Mercurialis perennis* and *Sanicula europaea* are the most widespread and frequent: others are *Arum maculatum*, *Allium ursinum*, *Brachypodium sylvaticum*, *Cephalanthera damasonium*, *Daphne laureola*, *Hordelymus europaeus*, *Viola reichenbachiana*.

The limestone beechwood association does not readily suffer degradation under deep shade, or exposure to the west winds. A number of the common plants (*Sanicula*, *Viola*, *Asperula odorata*, *Hedera helix*, *Ranunculus ficaria*) can exist in rather deep shade: many underthinned chalk beechwoods have been seen with a close carpet of ivy, which appears to be valuable in keeping the soil surface moist and preventing the scattering of the leaves by the wind. The ground becomes quite bare only when the shade is so deep that biological decomposition is arrested and somewhat acid litter accumulates. Under the influence of the wind, the surface soil is drier and poorer in organic matter, tending also to become firm and to lose the porous crumb structure. *Mercurialis* cedes to *Sanicula*, with which may be associated *Brachypodium*, *Viola reichenbachiana*, *Hedera*, *Festuca ovina*. It appears that exposure to wind, rather than depth of soil (as suggested by Watt, 1934) determines the relative frequency of Dog's mercury and Sanicle and accounts for the conspicuously better average height of the "mercury beechwood". This is shown most clearly where mercury and sanicle types occur in different parts of the same stand, as at Mellersh Copse (Nos. 7, 8*) and Goodwood, Sussex (Nos. 39-42). At Mellersh, where the sanicle wood was only moderately exposed, its height was only nine feet less than that of the mercury beechwood. At Goodwood, where the two sanicle woods were more severely exposed, the mature height of the beech was 75 to 80 feet, a compared with 100 to 105 feet in the sheltered mercury woods. It happens occasionally that local shelter at ground level is sufficient for the development of a *Mercurialis* society on a site where considerable general exposure may result in only moderate height growth of beech. Commonly, however, the mercury beechwood is a quality-class higher than the sanicle beechwood.

Of the other calcicole plants named, and of the many which occur not only on limestones but with equal frequency on slightly acid mull soils, there is need to notice only garlic, *Allium ursinum*, which occasionally forms pure societies in beechwoods, and points to a deep retentive basic soil capable of growing good ash.

Acid-mull Beechwood Association

The acid-mull type of beechwood association occurs on loams without free calcium carbonate. There are many variants, but *Rubus fruticosus* is commonly dominant in the mature wood in the south, and there characterises the association.

(*a*) On loams of good base status and a reaction of pH 5-6.5, an *Asperula* type may be distinguished. This is associated with very good growth of beech, a mature height of 100 feet or more being usual except on exposed sites. *Rubus* is frequent and often luxuriant and, in favourable conditions of light, there may be a wealth of the more exacting herbs—*Anemone nemorosa*, *Asperula odorata*, *Circaea lutetiana*, *Epilobium montanum*, *Euphorbia amygdaloides*, *Ranunculus ficaria*, *Fragaria vesca*, *Geum urbanum*, *Glechoma hederacea*, *Galeobdolon luteum*, *Oxalis acetosella*, *Veronica chamaedrys*, *Viola riviniana*. *Mercurialis perennis* and *Brachypodium silvaticum* are occasionally present. This type is

* See Appendices, pages 78–79

found on brown forest soils derived by leaching of the chalk, as well as on fertile non-calcareous loams. Under the influence of wind, *Rubus* and the herbs become reduced in frequency, or disappear, and grasses tend to become dominant. *Milium effusum*, *Melica uniflora* and *Poa* spp., are the most frequent grasses and, in the Chilterns, a *Melica* sub-association can be recognised on soils of good base status pervaded by wind, where the canopy is not too dense. An important practical point is that the abundance of *Rubus* in the mature beechwood leads to difficulties in regeneration.

(*b*) On more acid loams (pH 4.5-5) a *Rubus-Oxalis* association is frequent in the Chiltern beechwoods, and has occasionally been identified elsewhere. The flora is very much poorer, including, as the most frequent associates of the two characteristic plants: *Agrostis tenuis*, *Deschampsia caespitosa*, *Digitalis purpurea*, *Dryopteris austriaca*, *Holcus mollis*, *Lonicera periclymenum*, *Luzula pilosa*, *Milium effusum*, *Endymion non-scriptus*. *Chamaenerion angustifolium* and *Rubus idaeus* colonise gaps formed by felling or death of trees, and bracken (*Pteridium aquilinum*) often dominates under-stocked areas. Mosses, especially *Polytrichum formosum* and *Mnium hornum*, are common on the bare ground near the bases of the beeches. In deep shade, as in the young unthinned wood, the ground is usually bare. *Oxalis*, a sensitive indicator of conditions favourable to litter decomposition in this type, is usually the first plant to appear. *Rubus* comes in only later, when the stand has opened out more and light is favourable at ground level. Watt (1925) has, however, shown the probability that the more favourable soil moisture conditions of the older, less densely stocked, wood, rather than the increase in light, foster brambles. The *Rubus-Oxalis* association on acid loams and sandy-loams is very sensitive to exposure. The dry impoverished surface soil supports a more or less scanty flora of unexacting grasses (*Agrostis tenuis*, *Anthoxanthum odoratum*, *Deschampsia flexuosa*, *Festuca ovina*, *Poa* spp.) and calcifuge mosses (*Dicranella heteromalla*, *Hypnum cupressiforme*, *Mnium hornum*, *Polytrichum formosum*, mainly): *Luzula pilosa* and *Veronica officinalis* are often also seen.

On the normal type, beech growth is not much inferior to that on the more basic soil of type (2a). Mature heights of 100 feet are sometimes recorded. Careful management is needed if mor is to be avoided; but, given the necessary attention, the wood may regenerate more freely because of the diminished frequency and luxuriance of *Rubus*.

(*c*) On fertile loams and loamy sands in Scotland a different flora was noted in the beechwoods examined. *Rubus fruticosus* was wholly absent; *Asperula* and some other of the herbs characteristic of southern beechwoods on acid mull soils were very rare. Several woods, particularly those on Old Red Sandstone drift, or river alluvium, were characterised by the frequency (sometimes dominance) of the great hairy wood rush, *Luzula sylvatica*. *Dryopteris austriaca* is frequent in many woods and *D. filix-mas* and *Blechnum spicant* were also often recorded. Of the grasses and the herbs may be mentioned: *Ajuga reptans* *Anemone nemorosa*, *Anthoxanthum odoratum*, *Digitalis purpurea*, *Ranunculus ficaria*, *Holcus mollis*, *H. lanatus*, *Lysimachia nemorum*, *Melandrium rubrum*, *Oxalis acetosella*, *Endymion non-scriptus*, *Teucrium scorodonia*, *Veronica chamaedrys*, *V. officinalis*, *Viola riviniana*. The absence of *Deschampsia caespitosa* is noteworthy. *Mnium undulatum* and *Catharinea undulata* were recorded from a few of the better sites.

Under the influence of the wind, the herbs usually disappear, with the exception of *Veronica officinalis*. Mosses occupy the ground swept bare by the wind and, where the light is adequate, or near the wood edge, a thin sward of grasses (*Agrostis*, *Anthoxanthum*, *Holcus* spp., *Poa* spp.) will be found.

Many of the Scottish and northern English beechwoods seen were on the site of former oakwood, and this fact was often mirrored in the flora, e.g. by the occurrence of *Digitalis*, *Luzula sylvatica*, *Teucrium* and *Veronica chamaedrys*.

Heath Beechwood Association

A marked paucity of species characterises the heath beechwoods on sands and gravels, with a degraded brown earth, or podsol, profile (pH under 4.5). The more or less thick layers of undecomposed litter and mor exclude practically all herbs, while the moisture and nutrient conditions are also generally unfavourable to plant life. *Deschampsia flexuosa*, *Vaccinium myrtillus* and calcifuge mosses are the most constant constituents, and two subtypes may tentatively be distinguished.

(*a*) The degraded brown forest soil type, with *Agrostis tenuis*, *Anthoxanthum odoratum*, *Deschampsia flexuosa*, *Galium hercynicum*, *Holcus mollis*, *Luzula pilosa*, *Teucrium scorodonia* and a few other unexacting species.

(*b*) On podsolised sands and gravels, the genuine heath beechwood association, with *Vaccinium myrtillus* and *Calluna vulgaris*. *Vaccinium* is, however, frequent only in the northern beechwoods on sandy soils, while *Calluna* is found only in well-lighted gaps and wood margins. *Deschampsia* is very frequent in north and south: *Galium hercynicum* is occasionally noted.

The plants of the heath beechwood are generally less tolerant of shade than those of other associations; consequently the densely stocked beechwood has usually a bare floor. *Calluna* and *Erica cinerea* are particularly intolerant of shade, while the growth of *Deschampsia* is much restricted: the evergreen *Vaccinium* is rather more tolerant than other ericaceous species. Under the influence of the wind both these types degenerate to a moss beech-wood, with or without *Deschampsia flexuosa.*

The calcifuge Bryophytes most frequently recorded during the survey of beechwoods on sand were:

(1) Campylopus flexuosus
(2) Dicranella heteromalla
(3) Dicranum majus
(4) D. scoparium
(5) Eurhynchium { myurum & myosuroides }
(6) Hylocomium loreum
(7) H. splendens
(8) H. triquetrum
(9) Hypnum cupressiforme
(10) H. schreberi
(11) Lepidozia reptans
(12) Leucobryum glaucum
(13) Mnium hornum
(14) Plagiothecium undulatum
(15) Polytrichum formosum
(16) Thuidium tamariscinum.

Of these sixteen species Nos. (7), (8) and (14) were rarely found in southern beechwoods, while Nos. (2) and (12) were not recorded from northern beechwoods. *Dicranum majus, Hypnum schreberi* and *Leucobryum glaucum* were found only on soils which were distinctly leached.

This exposed moss, or *Deschampsia*-moss, type of beechwood is generally distinguished by moderate or poor growth of beech (Quality III or lower) and by some slow impoverishment of the soil. On sheltered sites beech appears to grow well on sandy podsols, or degraded brown earths, provided there is no iron pan, or compacted B horizon.

Discussion of the flora

It will appear from the observations made that there is no close correspondence between the quality of beech and the basic plant associations recognised; the influence of topography is too great. By means of a synthesis of the factors of soil, climate and topography, it may be practicable to define a number of site types for beech, related to the four quality-classes, and to correlate these not only with the plant associations of the beechwood, but with other natural and semi-natural plant communities. This cannot be attempted until the data have been further analysed, compared with data from other sources, and supplemented by more information about the past history of the sites investigated. In the meantime it is possible to single out the *Sanicle* type and the *Deschampsia flexuosa*-moss type from the central *Rubus*-herb types, where the high quality beech is found. The *Rubus* and herb associations are developed on sheltered, or moderately exposed, sites on chalk and limestone and on fertile sands, as well as on non-calcareous loams. On the loams and clay loams, *Rubus fruticosus* is characteristic of southern beechwoods; but wanting, probably for climatic reasons, from Scottish beechwoods. Many mesophile herbs occur with greater or less frequency, according to the light intensity and the fertility of the soil. Oak and ash are the subsidiary associates of beech in the tree layer, oak especially on the more acid loams, ash on the sub-neutral loams. On the chalk soils, *Mercurialis* is the characteristic plant in the field layer, but many other exacting herbs are present. *Rubus* occurs with some frequency, especially in the mature wood, wherever light and moisture are favourable. On the more fertile sand, various herbs (mostly unexacting species) characterise the beechwood flora: *Rubus* occurs only in sheltered moist places. Beech of Quality II may be expected on all these three site-types; but, where shelter is good, Quality I.

The sanicle beechwood is characteristic of rendziniform soils with south or west exposure. This beechwood is nearly always artificial, inasmuch as the conditions for colonisation of exposed chalky and limestone slopes are very adverse. But it is possible for beech to advance slowly up a slope with southwest aspect from established beechwood at the foot of the slope, in such a way that the colonists are ever sheltered by older trees. The beech is of third quality or, in very exposed positions, fourth quality. Regeneration is very improbable on these dry windy sites: left to nature, the sanicle beechwood of exposed sites would in many cases degenerate to ash-yewwood, or perhaps to chalk scrub. Under successive crops of planted beech, a progressive increase in soil depth, with correlated slight improvement in beech growth and in the prospects for regeneration, may be looked for. The sanicle beechwood is related to chalk and limestone grassland, often dominated by *Festuca ovina, Zerna erecta,* or *Brachypodium pinnatum.*

The mossy type of beechwood on leached sands and gravels in exposed positions is also impermanent, inasmuch as the acid mor layer is unsuitable for the germination of the nuts. The exposure of the nuts on the bare, or moss-covered, soil surface, where pigeons can easily find them, and the drying action of the wind, are further barriers to regeneration. Most beechwoods on this site-type are planted, but the course of natural succession from grass-heath, or *Calluna*-heath, via an oak-birch heath, has been traced in the Burnham Beeches district, Bucks., (Tansley, 1939). Third quality beech is usual on this type also; fourth quality is found only in exposed positions, or in open-grown stands.

Non-calcareous loams in positions fully exposed to the wind will, under beech, undergo some degradation, with the formation of mor. The ground flora is then hardly different from that of the beechwood on leached sands, with *Deschampsia flexuosa* more or less frequent, and calcifuge mosses occupying the ground swept bare by the wind. On the more fertile loams, a slightly open canopy will allow the development of a moderate herb and grass flora, even on windy sites. The quality of the beech is then rather better (III/II); but the evidence from relatively few examples indicates that, on the moss type, the beech is of quality III or IV, as on the leached sands.

The only other type of beechwood which may be identified is a very local *Deschampsia caespitosa* type on flat ground, with a compact loamy or silty soil showing slight impedance of drainage. Local areas dominated by *Deschampsia caespitosa* have been noted in a few planted beechwoods. In natural woods oak is more suited to the conditions, and has a rather better height growth. In one instance, the water table was permanently high and the beeches were dying.

Apart from information about the soil, the plant associations of beechwoods (or their absence) give information about the silvicultural conditions of the stand. Thus a floor without any plants, and thickly covered with beech leaves, indicates the need for thinning, and the appearance and increase of the herbs after thinning (especially the appearance of nitratatophilous plants like *Chamaenerion* (*Epilobium*) *angustifolium*, *Urtica*, *Geranium robertianum*, *Mercurialis*) that humus decomposition is proceeding favourably. On the other hand a strong increase of grasses witnesses to an unduly wide opening of the canopy, which is wasteful of the soil capital and unfavourable for regeneration of beech. The development of extensive patches of moss under beech is a sure indication that wind is pervading the stand, scattering the leaves, impoverishing the soil, and creating conditions unsuitable for regeneration. In a state of nature this may be remedied when a tree is overthrown by wind: the branches will then intercept the leaves and break the force of the wind, while the increase of light and shelter in the lee of the fallen tree will foster the growth of *Rubus* and grasses.

Chapter 13

ACTION OF BEECH ON THE SOIL

This is a vexed question, but recent years have seen considerable progress towards an answer. The problem is of much theoretical and practical interest, and merits treatment in some detail, although special experimental work on it has not formed a part of the present investigations. There are those who deny that the plant associations have much influence on the soil, which is, so it is alleged, fashioned by the macro-climate acting on a specific mother rock. On the other hand, many ecologists claim that plants do much to make the soil in which they grow, the dynamic equilibrium between plants and the edaphic environment being as much a result of the reaction of the plants on the soil, as of the natural selection of those plants only which are fully equipped for life in that soil. On the other hand, there is evidence that trees sometimes create conditions in the surface soil which are unfavourable to their own regeneration; beech on very acid soils may be a case in point. The succession which would then take place naturally would be something different from the succession to climax beechwood, but none the less consistent with dynamic concepts of ecology.

CHARACTER OF BEECH LITTER

The slow break-down of beech leaves, as compared with many other leaves of British trees, is due to a number of properties, of which their relatively high lignin content and high carbon nitrogen ratio are perhaps the most important. The total ash content is also lower than that of oak, ash, elm, alder, hazel, maple leaves and some of the conifers (Hesselmann, 1926). The calcium content of beech leaves varies widely in accordance with the calcium content of the soil, as was clearly demonstrated by Krauss (1926) and subsequently by Chodzicki (1934). This is generally the case with trees, but beech appears to be especially prone to absorb calcium in quantity when this element is freely available in the soil. The calcium content of the litter determines the reaction in which the decomposition occurs. This largely explains the observed fact that beech leaves break down much more slowly on base-deficient soils than on calcareous soils.

A fourth factor is the action of earthworms. Some laboratory trials at Alice Holt showed that, while ash and sycamore leaves were readily drawn by earthworms into their burrows and devoured, beech and oak were attacked much more slowly. The experiment was set up on November 15th, 1950, with *Lumbricus* in two sets of jars and the little rosy worm, *Eisenia rosea*, in the third; each jar contained 5 grams of air-dry leaves on top of the soil, which was occasionally watered. In the jars containing *Lumbricus*, the ash and sycamore leaves had almost all disappeared by January 16th, 1951, whereas most of the beech and oak leaves remained on the soil surface. On 7th March the jars were cleared out, and it was confirmed that not a trace of ash or sycamore leaves remained, except in the jars containing the rosy worm, where 1.3 and 2.0 grams, respectively, remained untouched. On the other hand, nearly one half of the original oak leaves and one third of the original beech leaves remained on the soil surface in the *Lumbricus* jars, as well as in those with *Eisenia rosea*. Wittich (1947) states that, in contrast to conifer needles, the litter of leaf-trees does not need to be buried as a prelude to effective decomposition, but there can be no doubt that decomposition is greatly accelerated by the action of earthworms, which devour many leaves and use others for lining their burrows, where they are kept moist and more favourably situated for bacterial action than when exposed on the surface.

Information about the relative rates of decomposition of different sorts of leaves was given by an experiment set up on November, 24th, 1950. Small lots of leaves of ash, birch, hornbeam, lime, sallow, sweet chestnut, sycamore, Turkey oak, red oak and pedunculate oak were disposed in a young beechwood, on thin acid gravel overlying Gault clay. By early spring the ash leaves had practically all disappeared; those of lime, sycamore, hornbeam, and birch were much reduced; those of sallow and pedunculate oak rather less so and those of chestnut, red and Turkey oaks, like those of the indigenous beech, very little reduced.

ENVIRONMENTAL FACTORS GOVERNING THE DECOMPOSITION OF BEECH LEAVES

Edaphic Factors

The calcium content of the soil determines the calcium content and the reaction of the leaves, with the result that beech litter on calcareous soils provides a more favourable milieu for the agents of decomposition. The reaction of the surface soil is also important, biological activity being depressed when the reaction is very acid or very alkaline. Satisfactory drainage is beneficial in two ways: if the soil is excessively drained, leaching is promoted, with the result that, on non-calcareous soils, podsolisation ensues; on the other hand abundant calcium in the lower horizons is of little use if a high water table, or compaction and poor aeration, prevent the beech from sending roots into these horizons. The aeration of the surface soil is specially important, because certain stages in the decomposition process depend on oxidation. Much depends also on the action of the macro-fauna, which is linked with the reaction, calcium content and moistness of the surface soil. Earthworms are generally more abundant on calcareous soils, and the plentiful and valuable turgid worm (*Allolobophora turgida* Eisen.) appears to be specially characteristic of calcareous soils, though widely distributed in woodland mull soils. There are, however, species which inhabit somewhat acid woodland soils; of these the most important is the ruby worm, *Lumbricus rubellus* Hoff., which is common in a wide variety of soils, woodland and other. Leached sands are usually without worms; there is a little worm occasionally found working in the mor, *Dendrobaena octoedra* Sav., but it is hardly of much consequence in the decomposition of humus. Mention may also be made of the rosy worm, *Eisenia rosea* Sav., which is valuable in heavy loam soils. Apart from the soil reaction, moisture and food mainly govern the numbers of earthworms in forest soil. They are, therefore, generally absent from wind-swept forest floors, where food and moisture are insufficient, and they are rarer in acid, than in sub-neutral or alkaline, soils.

Next to earthworms, the small mammals (mice, voles and moles) are probably the most useful animal agents in mull formation. The activities of wood mice have already been considered. There are also innumerable insects, Arachnida and Myriapoda which live in the litter and mor layers and promote the decomposition of forest litter.

Climatic Factors

Rainfall, wind, temperature and light all affect the decomposition of beech litter, directly or indirectly. Rainfall is concerned in the leaching process, upon which depends the base status of the surface soil. Rain, especially the summer rain, also maintains favourable moisture conditions in the litter at a time when biological activity is greatest.

The baneful influence of wind is exercised in three ways. In the first place the leaves are blown away in autumn and winter, so that large areas may be impoverished, while local depressions receive a larger leaf fall than can break down in good time. Secondly, wind dries the surface soil and lowers the atmospheric humidity at soil level; in summer, when the temperature is favourable, biological activity must often be depressed by lack of moisture. Thirdly, the current of air on the soil surface, and the evaporation caused by it, lower the temperature of the litter and humus. This factor is perhaps important mainly in northern districts and in spring and autumn, when moisture is favourable and temperature is the limiting factor.

Temperature is unquestionably of great importance in all circumstances in Britain: it is conditioned by several factors, of which the most important are latitude, aspect, canopy density, season of year, and exposure to wind. The influence of the seasons on litter temperature is rather complex, and it is proper to distinguish between the summer temperature, when there is a full leaf-canopy, and the temperature at seasons when the trees are bare. The relative light intensity is some indication of the proportion of the solar radiation striking the beechwood floor: whereas, in summer, measurements have ranged from less than 2 per cent. to about 5 per cent., some readings taken in a beech wood in March showed a light intensity of 60 to 70 per cent. of full daylight. (These data from a thirty years old wood at Alice Holt are somewhat higher than those obtained by Adamson (1922) in mature beechwoods in April). It is thus clear that the stronger radiation in summer is more than offset by the greater transmission in spring and early autumn. A temperature of 16°C. (65°F.) under the litter was recorded on 19th February, 1951, in the beechwood referred to: subsequently the weather was exceptionally wet, with cold winds and little sunshine, so that it was not until April that this temperature was exceeded (18°C., 70°F. on the 17th; 28°C., 82°F. on the 25th). It is certain however, that in the warm sunny spells which are frequently experienced in March and April, the warmth in the litter may stimulate biological activity to a considerable degree. In Germany litter temperatures of 30°C. (86°F.) have been recorded in spring in various broadleaved woods (Wittich, 1947). The salient facts are that, in the oceanic climate of Britain, the usually very dense beech canopy has a significant effect in slowing down biochemical processes in the litter, whereas in spring, before leaf break, and in autumn, after leaf fall, conditions are often favourable to these processes. It is evident that the spring and autumn warming effect are greatly influenced by latitude and aspect, and must be practically nullified when evergreen trees are mixed with the beech. It is unlikely that light affects the decomposition of the litter directly, but, in controlling the ground flora, the light intensity may indirectly modify the microclimate and to some extent the composition of the total litter.

Topography

Little need be said about topography, of which the influence is expressed mainly through the microclimate. The surface temperature, particularly in spring and autumn when the sun is low, is greatly influenced by aspect and slope. Exposure to the prevailing winds is also largely determined by aspect. Thus aspects between south and east are favourable, while west and north aspects are unfavourable to the decomposition of beech litter.

Associated Trees and Ground Flora

These are important in a number of ways, but their effects are complex and greatly dependent on local conditions. In the first place the associated trees, shrubs and herbs contribute to the litter, which may thus be rendered biologically more or less favourable than pure beech litter. Broadly, therefore, other leaf trees tend to improve the quality of the litter, while conifers make it worse. Secondly, the associated trees have some influence on the soil. Beech roots go only moderately deep, but penetrate the upper horizons intensively and widely. The admixture of deep-rooted trees like oak or pine, may, therefore, provide for improved drainage of gleyed soils and for better use of the bases in the C horizon. The main effect of the associated vegetation is, however, on the microclimate in which the breakdown of litter goes forward. Trees with light crowns, like oak, ash, larch and birch, are valuable in increasing the warmth of the litter in summer, but this advantage may be lost if the light is increased so much that a dense shrub or grass layer forms. On the contrary, the influence of evergreens is wholly bad; apart from the poor contribution to the litter, these lower the temperature in spring and autumn.

The ground flora affects the temperature and the moisture of the litter. Acting as a wind-break, the shrubs, herbs and grasses protect the litter from evaporation. The soil and litter under clumps of *Rubus* are often noticeably moister in summer than on adjacent bare areas. The effect on the temperature is more complex. Both gain and loss of heat are reduced, so that the microclimate is more equable. A dense ground flora of any kind is probably bad (apart from its influence on the production of timber), because it both dries the surface soil and lowers the summer temperature. But a light ground flora, especially of mull herbs or *Rubus*, generally improves the conditions for the breakdown of beech litter. The action of the wind in scattering the leaves and drying the surface is controlled, while the temperature and humidity conditions are more favourable. In a mature beechwood on acid gravel in Slindon Park, Sussex, it was noted that the only places with mull were under a moderately dense growth of *Rubus*. *Rubus* and herbs will not tolerate the combination of low light intensity and wind which the beechwood floor offers in exposed positions. In these circumstances the admixture of light crowned trees has a beneficial influence in fostering a ground flora which will hold the leaves and protect the soil. The same result might perhaps be gained by crown thinning and the maintenance of suppressed trees.

DISCUSSION OF THE ACTION OF BEECH ON THE SOIL

P. E. Muller's classic studies of mull and mor (1887) directed attention to some of the important factors concerned in the breakdown of forest litter and in the maintenance of a healthy soil. With particular regard to beech litter, Krauss (1926) demonstrated the important relation between the calcium contents of the leaves and of the soil nourishing them, and he investigated the distribution of available calcium at different depths in different soils. Hesselmann (1926) carried out a comprehensive examination of the reaction, buffer capacity, and ash content of different leaves, and conifer needles: in more recent years his researches have been extended in various directions by Wittich (1936, 1943, 1947) and Boudru (1947) and others. These investigations have resulted in a general alignment of the leaves of trees according to total ash and calcium contents, pH, buffer capacity and carbon/nitrogen ratio. It has been shown that the site often has an overriding influence on the absolute values (as Krauss found with beech in particular); but the relative values are little affected.

Attention has also been directed by these same investigators and by Bornebusch (1943) to the rate of litter decomposition in the forest. In general, the order in which these investigations placed the various leaves runs very close to the order based on calcium content, carbon/nitrogen ratio and so on; but there are considerable divergencies due to microclimatic factors. For example, oak and beech leaves are similar in composition and, other things being equal, decompose at nearly the same rate. Nevertheless, adjoining stands of oak and beech on equivalent soils may have mull and mor respectively; the more favourable microclimate under oak may be decisive.

Although it is a general rule that beech leaves on limestone soils are richer and decompose faster than beech leaves on acid sands or loams, one sometimes finds beech mull on an acid loam and a tendency to mor formation on chalk. In these cases, canopy density and the influence of the prevalent winds will probably explain the unexpected result.

When comparing the rate of decomposition of different kinds of forest litter in the field, one must also bear in mind the great influence of the soil. Beech litter, for example, breaks down much faster than pine litter partly (and only partly) because beech soils are, on the average, appreciably richer than pine soils.

There is the further general question of the effect of beech on soil fertility and on production. Chodzicki's (1934) important study was concerned with the influence of an admixture of beech in pine stands on brown earth and podsol. The results, based on a comparison of the nutrient status of the surface soils, showed the decisive importance of the calcium content of the C horizon. Only in soils where an impoverished A horizon overlay a C rich in lime, which the roots of beech could absorb, was there a demonstrable improvement of the surface soil and hence, presumably, of fertility and production. On podsols beech has no power to effect an improvement and acid mor continues to accumulate. In such circumstances, Chodzicki suggests that beech may ultimately make the soil too poor for its own survival. The question of successful regeneration of beech on acid soils where mor is forming is also discussed by Watt (1931). The action of beech on soil health and fertility is also reviewed in a general way in publications by Etter (1943), Boudru (1947), "G.P." (1948) and Duchafour (1947). Duchafour's (1950) investigation of the manner in which the evolution of the soil from rendzina to brown forest soil proceeds *pari passu* with the floral succession from chalk grassland to beech forest has been alluded to previously (page 8).

CONCLUSION

In the warm climate of central Europe, under good forest management, beech litter breaks down well even on base-deficient soils. Beech produces a big yearly leaf-fall, and shields the ground from desiccation by sun and from the development of herbage. For these reasons, beech has been called the "mother of the forest". This term spread to Northern Europe and to Britain, where it appears often to be justified by the thick layers of litter often found in beechwoods; these the uninstructed forester kicks and appraises as a perfect source of nutriment for his trees. It has been shown that the rate of breakdown and the end-product depend on the composition of the leaves, which varies with the soil, and on the conditions in which they break down, which is largely determined by the microclimate of the beechwood. On calcareous soils the conditions are such that, in ordinary circumstances, the decomposition is complete and not unduly slow (i.e. within two years) so that good mull is formed. But under the influence of the wind, or of very dense canopy (especially on north slopes) decomposition may be so retarded that, in spite of the favourable reaction, litter accumulates and there may even be a trace of mor. On acid soils, the litter is poorer and the reaction less favourable, so that mor readily forms unless the stand is carefully managed. This involves (*a*) regular thinnings and the avoidance of a very dense canopy; and (*b*) protection from the wind on the more exposed sites by an evergreen belt or in some such way.

It is probable that, once mor formation has begun, it proceeds at an accelerating pace. Good breakdown demands moisture, warmth, oxygen and a neutral or only feebly acid reaction. A mor layer may exclude both oxygen and the warm rays of the sun from the vital zone where humus and mineral soil are in contact, while acidity is increased by the humic acids freed when break-down is incomplete. Thus biological activity is depressed on all sides. The thickness of the mor is by no means an accurate index of the biological condition. Where leaves are scattered by the wind, the mor layer may be very thin, often hardly perceptible; yet the surface may be highly acid and conditions distinctly worse than under thicker layers of leaves and mor. Fortunately mor formation under beech is usually remediable. A heavy thinning will greatly improve the microclimate and also, by the disturbance of the soil, cause some mixture of humus and mineral soil. The health of basic soils is quickly restored in this way, especially where the fauna has not been impoverished. Soils very poor in bases will respond much more slowly and may need more drastic treatment, e.g., by liming. In this case prevention, that is to say, management adapted to the characteristics of the site, is better than cure.

As a "soil improver", beech is sometimes planted with other trees, sometimes planted under existing stands. It has been shown that, on basic soils, beech fetches up the calcium and this, when mixed with trees producing a very poor litter, may improve the overall quality of the litter. Provided the associated tree is light-crowned, decomposition will be favoured. On soils poor in bases, the acid beech litter will bring about no improvement in this direction, and the advantages of the mixture then consist in the control of the ground vegetation and the more effective cleaning of the stems of the associated trees. These benefits are substantial, but they are not concerned with the soil.

Lastly the importance of climate should again be stressed. Britain extends through nine degrees of latitude and the mean annual rainfall ranges, even only through the beechwoods examined, from 23 to 50 inches. Beech litter may break down readily and form good mull in Kent on a soil where, under identical treatment, mor would form in Galloway or Moray. In this respect temperature, especially the summer temperature, is doubtless the decisive factor: for example, mull appeared to be general in the Devon beechwoods on rather acid soils, even where the rainfall amounted to 40 inches.

Chapter 14

THE FUTURE OF BEECH IN BRITAIN

The future of beech in Britain is connected with its use:

(1) As a major timber crop, pure or mixed with other trees.
(2) As an underwood.
(3) For shelter belts.
(4) In ornamental woods.

AS A MAJOR TIMBER CROP

The conditions for beech are rather different as between Britain south of the Cleveland Hills (latitude 54°) on the one hand, and Scotland and the most northerly counties of England on the other hand. Except for western coastal districts, the southern half of Britain (latitude 50° to 54°) is climatically not far from the optimum for beech: there are, furthermore, extensive outcrops of limestones, on which the soils are warm and well-drained. The northern half is, on the other hand, well outside the climatic optimum—though beech grows well and regenerates freely—while the soils are mostly siliceous and commonly more or less leached. Five broad sets of conditions can accordingly be distinguished on the basis of climate and soil, viz., limestones, loams and sands in the southern half; and loams and sands in the northern half of Britain.

Chalk and Limestone Soils

On chalk and limestone soils, beech is the natural dominant, and most other trees fail in competition with beech. As is well known ash dominates, or formerly dominated, considerable areas of the

Carboniferous limestone outcrops of Derbyshire and West Yorkshire. This is, however, only because the ash was free from competition with beech, of which the height growth would be rather better in these conditions. On all the chalk and limestone soils, pure stands of beech are fully justified ecologically. A progressive improvement in the soil, with correlative improvement in the quality of the beech, and in the conditions for establishment, may be expected. On steep chalky slopes, especially those with south or south-west aspect, only poor growth of beech can, however, be looked for, while there may be a serious mortality of young trees following dry summers. Some form of natural regeneration would obviate the difficulty attending the planting-up of sites liable to frost or drought: but the data show that these are much eased on the sites of former woodland, particularly where lateral shelter from standing woods, or a suitable nurse, is provided. A relatively rich beech litter, and the neutral or alkaline soil reaction will, with good management and protection from excessive wind, ensure against litter accumulation and soil deterioration.

Loams in the South

On loamy soils, slightly to moderately acid, in the South and Midlands of England, beechwood, or a mixed oak-beechwood, is probably the natural climax on most sites. There, in the South at any rate, beech finds its optimum, but many other trees can compete more successfully with beech and the silvicultural possibilities are more varied. From many points of view, there is a strong case for an oak-beechwood, wherever this appears to accord with the ecological character of the site. The production of taller, cleaner oaks, some improvement in the micro-climate and in depth of root penetration, the increased value of the crop and, possibly, better conditions for regeneration, are advantages which can all be gained on soils where beech and oak grow about equally well. Broadly, this would apply to much of the clay-with-flints and loam over the chalk, to the mixed boulder-clay of the Midlands and to the Palaeozoic loams of the West, where some good mixed stands of sessile oak and beech have been noted. There are, however, many loamy sites where an oak-beech mixture is inappropriate. The drier downland sites may be too dry for oak, while on the wet gleyed silty loams and clay-loams beech should be used sparingly if at all. On the richer sub-neutral loams ash, or, in certain circumstances, other exacting species like elm, sycamore, or poplar, will be preferred to beech. On sites which appear suitable for ash a mixture of beech and ash, with or without other trees, may be a safe choice. Ash on a really good site will quickly outgrow the beech, which will then make a useful underwood, cleaning the ash stems and suppressing the ground vegetation. If, on the other hand, the ash does not everywhere succeed, the beech will complete the main crop.

On acid loams, careful management is needed if mor formation is to be avoided. Natural regeneration of beech is also a problem on the many sites where *Rubus* dominates the ground flora of the mature wood, and regeneration, if desired, may have to be initiated early before the *Rubus* is well established. Natural regeneration, by small groups or otherwise, supplemented by planting in shelter, will doubtless be adapted in the light of experience to beechwoods on loam. The Chiltern beechwoods now offer instructive examples of successful and unsuccessful regeneration.

Sands in the South

Sands vary greatly in depth and fertility. Good quality beech can be grown on all but the poorest gravels and strongly leached soils. On these the somewhat inferior growth, tendency to mor accumulation and failure of regeneration, do not recommend beech. On the deeper and moderately fertile sands, beechwood can doubtless, under careful management, be successfully maintained for several rotations. This applies chiefly to the sands of the south-eastern and eastern counties, a special case being the somewhat chalky sands of Breckland, East Anglia. In the high rainfall areas of the west of Britain, the greater production under conifers will generally decide against beech, although some high quality beech woods on sand were recorded in the West Country.

Loams in the North

On good sites in northern Britain, Quality II and III beech may be found as far north as Inverness, and there is unquestionably a place for beech as a major timber crop in the lower rainfall areas of the east, where there is in fact much mature beech at present. Although an introduced tree, beech in east Scotland and north-east England, at the lower elevations, exceeds all other native trees in height, and is in fact now naturally invading and supplanting woods of pine, oak or birch in some localities. On the heavy loams it is probable that, as in England, an oak-beech mixture could be successfully grown. The seed origin of the widely planted Scottish beech is presumably southern in most cases, since the fashion for planting beech took root in Scotland only in the eighteenth century. This fact may partly explain the good height growth often noted, because southern beech provenances would tend in a northerly environment to retain the long vegetative period to which they are wont, and to grow faster than northern provenances on the same site. There is for this reason a risk that beech from seed ripened in the South of England may be relatively more sensitive to spring frost in Scotland. It seems that a beech provenance trial, embracing good strains from southern England, Scotland, Scandinavia and perhaps Central Europe, would give interesting results in East Scotland and be a valuable prelude to any extensive reforestation with beech. Scottish beech sample plots are equally desirable.

Regeneration of Scottish beechwoods is, in some degree, favoured by the scarcity of brambles, but is at present generally threatened by the rabbit. In some of the mature woods the poor forms cast doubt on the advisability of any attempt at natural regeneration.

Sands in the North

The remarks about beech on sandy soils in southern Britain apply *a fortiori* to Scottish sands, where some Old Red Sandstone soils in sheltered situations need alone be considered as fully suitable for beech. In the Lothians and Border Counties, there are many small outcrops of basic igneous rocks where beech seems to have a special place.

UNDERWOOD

In several European countries it has been a common practice to grow beech as an underwood beneath light-crowned major timber trees such as oak and Scots pine. The shade of the underwood aids the natural cleaning of the oak or pine boles and may in this way enhance the value of their timber: the beech itself yields little but firewood and it is possible that the practice originated when beech was still in great demand for fuel. Observations made during the recent survey suggest that, on good sites for oak, a level mixture of beech and oak may be successfully raised and the desired clean oak boles obtained in this way, without the need for underplanting.

A second advantage claimed for a beech underwood in crops of light-crowned trees is the suppression of the ground vegetation and the fuller exploitation of the soil. As regards the latter point, much depends on the value of the beech produce, which may well be negligible. The net effect of a beech underwood on soil conditions and litter breakdown will be governed by the various factors of topography, soil and climate as well as the composition of the ground flora which would develop in the absence of an underwood. Some of the considerations have been discussed in the preceding section: proofs of the ecological effects of a beech underwood are, however, lacking. Where natural regeneration of the overwood is desired, an underwood of beech may enable the forester to forestall the development, towards the end of the rotation, of a tangle of weeds which would compete strongly with seedling trees.

The practice current in several State forests of planting beech under natural birch poles, or planted or natural pines, is, of course, in a different category: this aims at the establishment, in a relatively short time, of a pure stand of beech.

SHELTERBELTS

Beech shelterbelts are now widely used in southern Scotland, the Cotswolds and elsewhere. In spite of the greater difficulty of establishment and reduced height on exposed sites, these belts have proved successful, and they will doubtless find favour in other districts, especially where amenity counts for much. In smoky districts and, perhaps, coastal areas, sycamore may be more suitable for leafy shelter belts.

AMENITY WOODS

Gilbert White (1789, letter 1) was not the first to praise the beauty of the beech at all seasons. New uses for beech timber, and a revival of interest in broadleaved trees generally, promise that, instead of losing ground in Britain, beech is likely to gain in the future. Apart from the commercial beechwoods, beech will fill many places where beauty is the main, or an important, consideration. Such are:

(*a*) Places of public access and recreation.

(*b*) Shelter belts and clumps, which are by their nature more or less exposed to view.

(*c*) Edgings to plantations and roadside strips in all districts, but particularly where conifers have been planted near populated districts.

Beech can be considered as eminently suited for all these situations, on account of its wide tolerance in respect of soil and climate.

SUMMARY

1. The present distribution of British beechwoods can be traced in most localities to extensive planting between 1720 and 1850, after which a decline in popularity occurred. It is only in the southern counties of England and possibly south-east Wales that beech can be accepted as a native tree. Even in these districts most existing woods were probably planted, although the tree sets seed very freely and reproduction, as well as fresh colonisation, can be commonly observed. There is no sure evidence of beech in Britain until Sub-Boreal times, when beech pollen occurs sparingly in peats in East Anglia, but has not been identified in southern England. The possible implications of this distribution are considered.

2. In brief notes on the life cycle of beech, the close dependence of flowering and fruiting on summer warmth (and in some degree on spring frosts) is discussed. Foliation in spring and "Lammas" shoot extension are important in relation to injuries to the tips. Beeches of 250 years and over were rarely seen during the survey, but there are many stands over 200 years old.

3. The European distribution of beech is discussed, and various authorities are quoted as concerns the relative weight of climate and soil. The application of these findings in British conditions is considered.

4. About 200 mature beechwoods, well distributed through Britain, were examined and recorded. Soil is made the basis of classification of these woods, of which the records have been summarised in Appendices I-V.

5. On calcareous soils the climax association is considered to be pure (or practically pure) beechwood on a shallow brown forest soil, from which all the calcium carbonate has been leached. *Rubus* is then typically dominant in the mature beechwood, which closely resembles the beechwood on fertile non-calcareous loam. Soils from calcareous parent materials showed all gradations between the climax brown forest soil and a rendzina under first crops of beech. These last are characterised by a ground flora of calcicoles, of which *Mercurialis* and *Sanicula* are the most frequent, mercury tending to dominate the more sheltered, moister places and sanicle the drier, more exposed places. Under deep shade ivy may be the sole phanerogam. While the height growth of beech improves with the development from rendzina to brown forest soil, there is no close correspondence, owing to the major influence of topography and microclimate, which may temper the rendzina's aridity. Heights at maturity of 65 to 95 (rarely 100) feet on the forest rendzina compare with heights of 80 to 115 feet on the brown forest soil derived from chalk or limestone. Chalk beechwoods are best developed on the Sussex and Hampshire Downs and on the oolitic limestones of Gloucestershire, but occur sporadically on other formations and in other districts.

6. On fertile non-calcareous loams beechwood reaches a fine development, fully equal to the beechwood on shallow loam over the chalk. Heights of over 100 feet at maturity are frequent in all parts of England and East Wales and occasional in Scotland. On soils showing incipient podsolisation, height growth falls off a little, as also on soils with impeded drainage, but, as with the calcareous soils, local climate more than offsets soil differences. In the higher rainfall areas of the West, however, there is evidence that beech on loamy soils is less sensitive to exposure, provided salt-laden winds have no access: good height growth was recorded on several rather exposed sites in Wales and north-west England. Many Chiltern beechwoods were inferior because of early suppression in shade, as indicated by extremely close early rings and a marked improvement in quality from middle life to maturity. Bramble is characteristic of English, but not of Scottish, beechwoods on loam. Under close canopy, or exposure to the west winds, litter decomposition is arrested, mor forms, and brambles and herbs are replaced by bare ground or mosses.

Beechwoods on non-calcareous loam occur widely on the clay-with-flints and plateau gravel of the Chiltern Hills, on the extensive deposits overlying the southern chalk downs and throughout Britain as plantations, mainly on old broadleaved woodland sites. Oak is a frequent constituent of the beechwood, especially on the more acid loams and on moist sites, while on the more basic loams ash may find a place in the canopy.

7. For beechwoods on sandy soils, mature heights, girths and volumes equal to those on the best loams and chalk soils were occasionally recorded in south and north. Many of the woods examined showed a brown forest soil, with mull and a herbaceous flora, but mor humus was usual and some degree of podsolisation was frequently observed. Well-developed podsols were found under beech only on heathy sites, where there was presumptive evid-

ence of a pre-existing podsol. Provided a compacted B horizon does not restrict the roots, beech on slightly podsolised soils is little inferior to beech on brown forest soils. Acid litter tends, however, to accumulate and regeneration fails.

The best beechwoods on sandy soils were seen on the Upper Greensand of West Wiltshire, on the Permian in Devon and on river alluvium in several localities. Fine beech may also be seen on Devonian sandstone in sheltered Scottish valleys. Heath beechwoods were recorded on coarse-textured boulder till in Scotland, and on Triassic, Cretaceous and Tertiary sands in England. These woods commonly show a ground flora of calcifuge mosses, with, or without, *Deschampsia flexuosa;* where the canopy is open, *Vaccinium myrtillus* and often *Calluna* are observed.

8. In relation to the rate of growth of beech, climate is of greater significance than soil: in particular, exposure to the prevailing winds appears to have a strong influence on the trend of the age-height curve and on the final height. The development of the subordinate vegetation, and the maintenance of a healthy soil surface (i.e., mull, not mor) are primarily determined by the base status of the soil, but, here also, the microclimate, as controlled by density of canopy and exposure to the westerly winds, may have an over-riding influence.

9. Early growth of beech in Britain is determined partly by soil, partly by other factors. As a general rule good early growth was recorded only on woodland sites where some shelter—either from adjacent standing woods, or from residual trees on the ground—is provided against strong sun and wind. An important exception is provided by deep, retentive, adequately drained loams where, especially under a rainfall of 35 inches or more, good establishment and satisfactory early growth are commonly observed. On frosty sites, and on shallow chalky, or dry sandy, soils, shelter is imperative. A height of 20 to 30 feet at 20 years is regarded as satisfactory, but on favourable sites beech may do better. Comparison with Danish and German yield tables is hardly appropriate, because, under the shelterwood system of regeneration, the early growth is more or less depressed by shade, and often by mutual competition.

10. Mixtures of beech and other trees were noted wherever there was opportunity, and observations made on relative height growth and other matters of silvicultural interest. Oak is a common and successful associate of beech on acid loams, where individual trees often equal the beech in stature and show remarkably clean straight boles. It seems likely that beech would dominate the canopy on freely drained loams, but on moist clays and clay loams, especially where there is drainage impedance, oak may be the natural climax dominant, with, on soils of intermediate character, an oak-beech association. On the drier calcareous loams, especially shallow soils over chalk, beech is clearly the dominant.

Some examples of beech and ash, and beech and sycamore, were recorded. On first-class ash sites, ash will easily outgrow beech in the early years. As single trees, fine ashes, scarcely inferior to beech in height, are sometimes seen in beechwoods on soils which would not be regarded as first-quality ash soils. Sycamore freely invades gaps in beechwoods, profiting by fast early growth and some immunity from rabbit attack; but the final height of beech is probably superior on every class of soil.

Mixtures of beech and conifers, principally larch and Scots pine, are of interest as the forerunners of most of the mature beechwoods seen today. This is particularly so on chalk and limestone soils, where beech, unless suppressed at the outset, outgrows and outlives its coniferous associates, forming a nearly pure beechwood.

11. Notes are recorded on pruning and thinning practices, and on the probable length of rotation of beech crops in Britain. It was difficult to draw conclusions, because of varying thinning practices (or none), and the scarcity of records. Assuming that a tree of 18 inches diameter has attained a profitable size, we may expect that British beech crops will be marketed in appreciably less than the 140 years fixed in Germany. This is partly due to the faster early growth of most planted beech here.

12. Consideration is given to the ecological problems involved in the establishment of beech crops naturally and artificially. The usual process of reproduction in primeval beech forest is first described, and the various factors (climatic, edaphic and biotic) which make or mar its successful outcome are reviewed. Some practical systems of natural regeneration are discussed in relation to these factors, and examples of successful and unsuccessful regeneration of beech in Britain are briefly described. Group regeneration has yielded good results where the groups were small and full masts were exploited. The large shelterwood system favoured in Danish and German beech forests has hardly been tried in Britain, and the Selection System, as practised in the Chilterns, has generally proved inadequate from the point of view of regeneration. While a few instances of haphazard regeneration have been recorded, it cannot be doubted that success in the natural regeneration of beech is normally dependent on attention being given to many interacting environmental factors, most of which are, in some measure, within the forester's control.

13. The establishment of beech by planting is

considered in relation to clear-felled woodland, derelict woodland and chalk downland. The important ecological factors of light, humidity, temperature, carbon dioxide, soil water and nutrients are considerably influenced by these different environments. Data from Crawley Forest, Hants., are quoted to show the importance of soil, and how this may influence susceptibility to frost damage. Light measurements in a variety of woodland environments show that overhead or side shelter, adequate to cut out much of the unwanted fluctuation in temperature and humidity, may be retained without causing light-hunger. The records of early growth of beech, summarised in Appendix VI, show a marked superiority of crops raised on woodland sites, whether clear-felled or not. On the cleared woodland, however, there was often, besides the better soil environment, some side shelter from adjacent stands; where there was none such, early growth was not so good. On deep retentive loams, first crops of beech have often been established without shelter, especially on cultivated ground. On dry chalk pasture, establishment is always troublesome; the special characters of these sites are described. Such sites, and also frosty sites, call for special treatment, and some of the ways in which this has been attempted are indicated.

14. Evidence was collected about the environmental factors which influence the forms of beech. Appraisal of the mature woods was not very instructive, because of—

(*a*) The influence of thinnings.
(*b*) Lack of information about the early environment.
(*c*) The wide differences in provenance.

There was less forking in beech stands raised under shelter, and this could not readily be ascribed to protection from wind, because stands in exposed positions had not a bad record as regards form. The generally good form of most of the tallest stands suggested that water supply may be influential, but the effect may with equal probability be ascribed to the close canopy in which these stands matured.

In early years, frost and rodents are important causes of forking and shrubby growth. Good forms were occasionally noted in beech under pines, as compared with beech in the open, and investigation confirmed a suspected marked widening of the branch angles. The angle of branching, and the erect or horizontal direction of the leading shoot, appear to be closely linked with the light intensity, and it is suggested that an erect leading shoot and flat branches are found when the relative light intensity is about 20 to 30 per cent.

It was found that the likelihood of forking is much greater when secondary extension of the shoot occurs, especially when this takes place at the end of the season. Frost and insect damage are often rife in these late summer shoots. The factors determining Lammas growth in its various manifestations are shortly considered. It is suggested that the light intensity and the occurrence of Lammas growth are the most important factors in relation to the forking of beech saplings 5 to 20 feet in height. Later, other influences are important; in the pole stage squirrels and the closeness of canopy are probably decisive.

15. Some insects and fungi observed in the young and old beechwoods are recorded. Many of these are important silviculturally, but the only interesting original record of an insect which seems to be important concerns a small Tortricid (tentatively identified as *Peronea ferrugana*), which was found gnawing and mining the tips of small beeches.

16. Several rodents are of great importance in beech woods. Notes were made on the status and activities of these, and of the roe deer and wood-pigeon.

17. Observations on the beechwood flora make plain the close dependence on the soil, in particular on lime content and condition of humus, but stress the way in which shade and the prevalent winds modify the development of the plant associations. These are, accordingly, valuable as indicators of over- or under-stocking, of the action of the wind and of conditions for regeneration. The overriding influence of topography limits their value as indicators of site-quality, but it is justifiable to separate a *Sanicula* type on exposed chalk slopes and a *Deschampsia flexuosa*—moss type on sands and gravels, or leached loams, as indicative of inferior quality beech.

18. The action of beech on the soil was studied on account of its theoretical and practical importance, and the conflicting statements which have been made. Possessing a good deal of lignin and a rather high carbon/nitrogen ratio, beech litter compares unfavourably with the leaves of most other British broadleaved trees, but may be better than the litter of conifers. The composition of beech litter depends on the soil, the calcium content being much higher on calcareous soils. Observations have been made at Alice Holt on the relative rates of break-down of leaves. The rate of break-down is largely conditioned by the soil: on basic soils the litter is richer and the medium is more favourable for biological activity. The important part played by earthworms on different soils is indicated, and experiments showing the reaction of worms to different sorts of leaves are described.

The microclimate within the beechwood has a profound influence on the decomposition of the litter. The dense beech canopy in summer intercepts much rain and nearly all the sun's rays, while the very scanty ground flora gives free passage to the wind on exposed sites. Wind, which scatters the leaves and dries and chills the surface soil, and the temperature of the humus layer, are probably the most significant microclimatic factors. The low summer temperatures are, however, partly compensated by warmth in spring and autumn when the trees are bare. Under a stand of young beech at Alice Holt Forest, Hants., 61°F. was recorded in February and 82°F. in April under the dead leaves. The microclimate and, to some extent, the quality of the litter, are influenced by the associated trees and ground flora. The manner in which evergreens, deciduous leaf trees, and the ground flora affect the conditions for litter decomposition in a beechwood are briefly indicated. Decomposition is thus dependent on climate and soil, on the composition of the stand, and on the treatment. On chalk soils in the south conditions are naturally favourable, and good mull is found, except under a deep shade or severe exposure. In the north, or on acid soils, a tendency to mor can often be guarded against by timely thinnings, or dilution with light-demanding trees, especially those producing a richer litter.

19. The future of beech as a forest tree in Britain is linked with the extended use of the timber; with the suitability of beech for underplanting and for shelter-belts, and with the universal desire to preserve a native tree of great ornamental value. Recent investigations have shown the tree's wide tolerance in respect of soil in most parts of Britain, and there is every likelihood of a revival of beech popularity in all districts except the extreme north and west. Extensive forests of beech will, however, doubtless be restricted to the southern counties, where the combination of climate and soil is peculiarly favourable, and where alone beechwood was an important element in British vegetation in the past.

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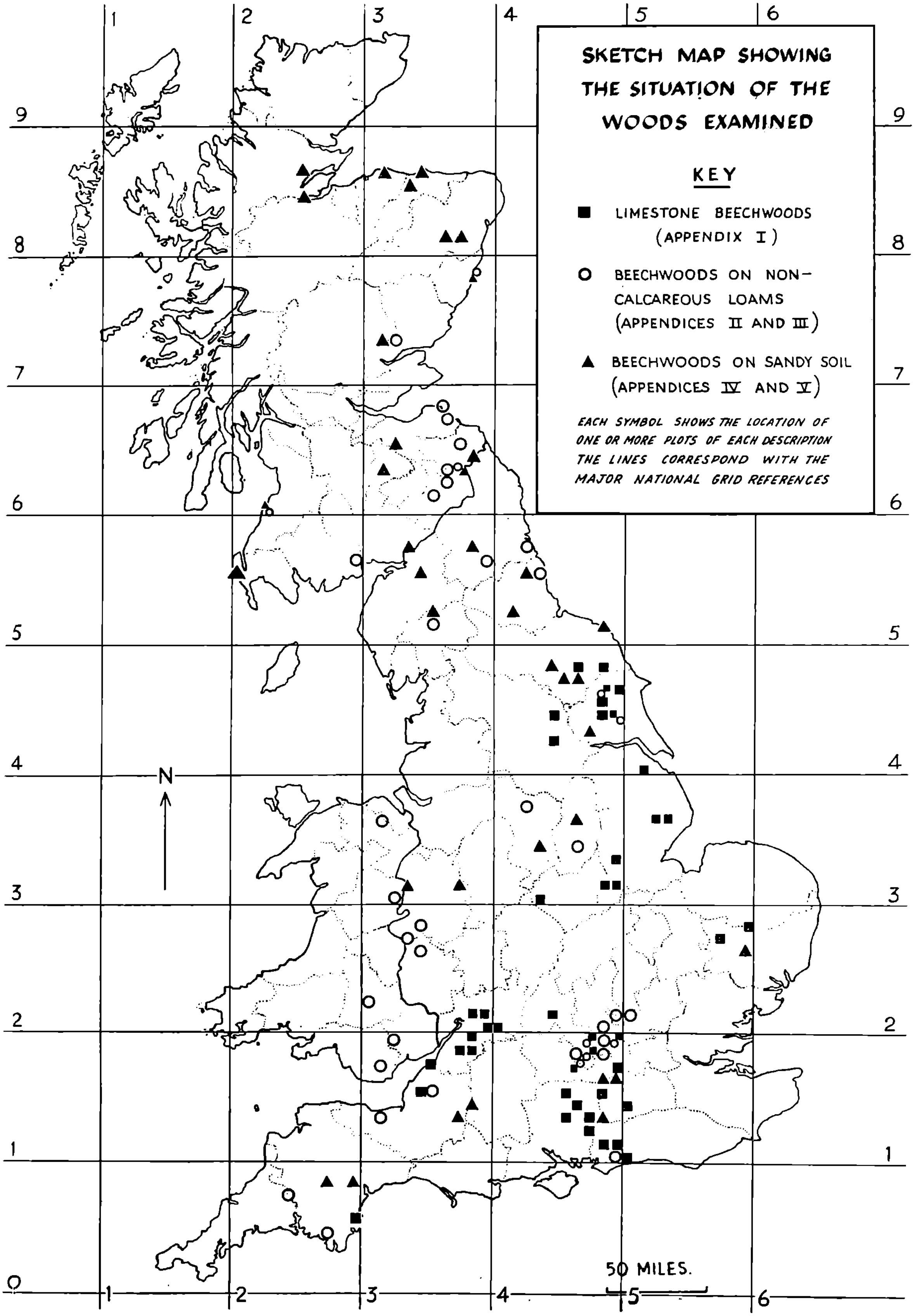
SKETCH MAP SHOWING THE SITUATION OF THE WOODS EXAMINED
KEY
LIMESTONE BEECHWOODS (APPENDIX I)
BEECHWOODS ON NON-CALCAREOUS LOAMS (APPENDICES II AND III)
BEECHWOODS ON SANDY SOIL (APPENDICES IV AND V)
EACH SYMBOL SHOWS THE LOCATION OF ONE OR MORE PLOTS OF EACH DESCRIPTION
THE LINES CORRESPOND WITH THE MAJOR NATIONAL GRID REFERENCES
N
50 MILES.
0
1
2
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APPENDICES

RECORDS OF STANDS EXAMINED IN SURVEYS OF BRITISH BEECHWOODS

KEY TO SYMBOLS AND ABBREVIATIONS USED

Appendices I to V

Column 1. Serial number as occasionally referred to in text.

2. Reference to filing system of field records in recent survey.
5. Brief characterisation of topography.
6. Altitude in feet.
7. Slope in degrees.
8. Aspect on 32 point compass.
9. Exposure on 0—4 scale.
   - 0—fully sheltered.
   - 1—considerable shelter from relief.
   - 2—moderate exposure.
   - 3—considerable exposure to prevailing winds.
   - 4—severe exposure.
11. Depth, in centimetres, of friable soil over parent rock, or compacted, impervious, or predominantly stony horizons. For the calcareous soils (App. I), this datum gives the total depth of the A horizon only.
12. Texture of main rooting zone of soil.
    - Sa: Coarse sand or gravel.
    - Sb: Fine sand.
    - La: Sandy loam.
    - Lm: Medium loam.
    - Lb: Heavy loam.
    - C: Clay.
    - Z: Predominantly silty.
13. In the case of calcareous soils only (Appendix I) this column records the presence (+) or absence (—) or sometimes the approximate percentage, of calcium carbonate in the A horizon (++ denotes abundant chalk, tr. a trace only). Otherwise this column is reserved for a figure denoting the drainage of the soil profile.
    - 1—excessive.
    - 2—satisfactory percolation and retention.
    - 3—imperfect, some gleying.
    - 4—water-logged.
14. pH measurement on A horizon by indicator solution, or electrometer, where available.
15. In Appendix I, depth of A/C (or, in certain cases, B) horizons: otherwise occurrence of mull or mor humus: (mull) indicates a local tendency to mor formation.
16. In Appendix I, Beechwoods on Chalk and Limestone, the symbols indicate the probable stage of development of the soil profile from rendzina (R0) to brown forest soil derived by leaching of chalk (R3) through the forest rendzina type (R1) and the intermediate rendziniform forest soil (R2).

    In Appendices IV and V, B., D., P. and PP. denote, respectively, brown forest soil, degraded brown forest soil, and weakly and strongly podsolised soils. The loam and clay soils were all brown forest soils, or degraded brown forest soils.
17. Rainfall in inches, as approx. average yearly fall.
18. Average height in feet of beech, exclusive of any suppressed trees: data from much understocked stands are in brackets.
19. Approximate age in years from ring counts or local records (c=circa; + = older than).
20. Average girth in inches at breast height, over bark.
21. Volume, where data available, in cubic feet per acre (Hoppus measure, over bark), computed according to beech volume tables.
22. Quality-class according to Møller's Danish yield tables, in which five classes are recognised. Where a figure in brackets is also given, this refers to an intermediate height measurement on felled trees. III+ and III— denote that the stand is well above or below the mean of Quality III. No quality-class rating is given for the stands over 150 years.
23. Full National Grid reference to the site.

Appendix VI

Corresponding references apply, as appropriate. "Cons." in third column = Forestry Commission Conservancy.

Note. The main survey was carried out from 1948 to 1950, but records made by the author between 1943 and 1948 are also included.

APPENDIX I. BEECHWOODS ON CHALK AND LIMESTONE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
										"A" Horizon							Beech Statistics					
No.	Ref.	Name of Wood	Date	Topography	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Depth cm.	Text.	Chalk	pH	"A/C" Depth cm.	Soil Type	Rain-fall in.	Height	Age	Girth	Vol. p. Acre. h. ft.	Quality	Map Ref. Nat. Grid.
	A. CHALK																					
1		Sledmere—Cherry Wood, Yorks.	9/43	Wold Top	475	5	S.W./W.	3	Middle Chalk	25	Lb	+		10	R1-2	31	53	50	29		II/III (II)	44/943652
2		Middleton on Wolds, Yorks.	9/43	Plateau	200	3	N.W.	2	Middle Chalk	17	Lb	++		8	R1	27	59	60	43		III+(II)	44/946487
3		Burwell, Catchacre, Lincs.	3/44	Easy Valley Slope	170	4	S.W.	2	Middle Chalk	30	Lb	++		8	R1	28	68	86			III/IV (II/III)	53/377796
4	C/8	Singleton, Sus.	1/50	Easy Dip Slope	550	4	S.S.W.	2	Upper Chalk	38	Lm	—	6/5.5	10B	R3	37	93	90	38.6	5,629	II/I	41/891156
5	D/41	Northington, Hants.	3/50	Easy Ridge Slope	400	8	N.W./N.	2	Upper Chalk	32	Lb	tr.		—	R2-3	33	85	108	42	1,882	III+	41/552374
6	D/6	Crowell Hill, Oxon.,	4/49	Scarp Slope	650	c15	N.W.	3	Upper Chalk	30	Lb	++		7	R2	31	65 D	110	35		IV—	41/753985
7	D/75	Mellersh Copse, Sus.	2/50	Spur on	450	12	N.N.E.	2	Middle Chalk	23	Lm	++	7	60	R2	35	94.5	115	48	3,511	II	41/907169
8	D/76	Mellersh, Sus.	4/50	Escarpment	340	12	N.E.	1	Lower Chalk	18	Lm	++	7	20+	R2	35	103	115	52	4,606	I—	41/909171
9	D/65	Settrington, Yorks.	6/50	Crest of Scarp	525	4	S.W.	4	Thin drift on chalk	20	Lm	++		25	R1	30	70	115	49.5	3,661	IV	44/862694
10	D/64	Garrowby, Yorks.	6/50	Escarpment	550	20/35	N.W./N.	2	Middle Chalk	12	Lb	++		48	R1	30	82	115	59		III	44/803570
11		Warter Priory, Yorks.	9/43	Valley Slope	375	15	S.	2	Middle Chalk	17	Lb	++		10	R1	27	86½	115	50		III (III)	44/849500
12		Londesborough, Yorks.	9/43	Spur on Scarp Slope	330	10	S.S.W.	3	Thin drift on middle chalk	40	Lb	+		10+	R2	28	79	115	56		III— (III)	44/884459
13		Brocklesby-Pillar, Lincs.	1/44	Ridge, Easy Slope	375	3	N./E.	2	Thin drift on middle chalk	48	Lm	+		10+	R3	28	78	115	71		III—	54/129042
14		Latimer-Lane Wood, Bucks.	3/45	Valley Slope	375	7	N.E.	1	Upper Chalk	24	Lb	—		24B	R3	29	99	115	66		II+ (II)	41/993985
15	D/63	Sledmere-Life Hill, Yorks.	6/50	Wold top	500	0	—	4	Thin drift on chalk	48	Lb	+		—	R2	31	76	120	84		III/IV	44/928620
16	D/20	Tunworth Board, Hants.	8/49	Easy Ridge Slope	470	6	N.W.	2	Upper Chalk	38	Lb	8%	8.0	14	R2	30	95	120	53	2,870	II	41/678475
17	D/21	Tunworth Board, Hants.	9/49	Easy Ridge Slope	480	8	N.W.	2	Upper Chalk	26	Lm	27%	8.0	20	R1	30	90	120	51	3,536	II/III	41/677474
18	D/23	Tunworth Hummock, Hants.	9/49	Easy Ridge Slope	480	2	E.S.E.	2	Upper Chalk	28	Lm	28%	8.1	8	R1	30	87½	120	43.5	3,151	II/III	41/672477
19	D/11	West Dean Park, Sus.	5/49	Easy Ridge Slope	460	6	N.E./E.	2	Chalk (? Upper)	25	Lm	0.66	7/8.3	20	R2	35	93	125	50	4,775	II—	41/873118
20	D/11	West Dean Park, Sus.	5/49	Easy Ridge Slope	380	8	E.N.E.	1	Chalk (? Upper)	—	—	—	—	—	R2	35	101	125	47	4,825	I/II	41/873119
21	D/33	West Dean Park, Sus.	10/49	Easy Ridge Slope	410	7	N./W.	1	Chalk (? Upper)	23	Lm	4.2	8.2	12	R2	35	114	125	53	7,664	I+	41/871122
22	D/79	West Dean, Warren Hanger, Sus.	10/50	Easy Spur Slope	300	8	S.	2	Upper Chalk	28	Lm	tr.		20	R2	35	101	125	61	5,554	II+	41/853133
23	D/81	West Dean, Warren Hanger, Sus.	10/50	Steep Spur Slope	325	16	W.S.W.	3	Upper Chalk	22	Lm	—		28	R2	35	91	125	51	4,942	II—	41/855132
24	D/80	West Dean, White-down, Sus.	10/50	Ravine Slope	300	21	E.N.E.	0	Talus on Chalk	M.25	Lm	++		28	R1-2	35	110	125	54	6,787	I	41/851132
25		Latimer-West Wood, Bucks.	3/45	Valley Slope	350	11	N.	1	Upper Chalk	23	Lb	—		12B	R3	29	105	127	68		I/II (II)	41/997983
26		Stonor Doyley Wood, Oxon.	4/45	Valley Slope	425	12	N.W./N.	2	Upper Chalk	20	Lb	—		18	R2	30	88	128	44		III+ (IV)	41/723893

(See also Graph 1, page 97, and Map, page 76.)

APPENDIX I (*contd.*). BEECHWOODS ON CHALK AND LIMESTONE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
										"A" Horizon							Beech Statistics					
No.	Ref.	Name of Wood	Date	Topography	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Depth cm.	Text.	Chalk	pH	A/C Depth cm.	Soil Type	Rain-fall in.	Height	Age	Girth	Vol. p. acre h. ft.	Quality	Map Ref. Nat. Grid.
27		Allwick Dell, Hants.	3/45	Easy Ridge Slope	430	10	N.N.W.	2	Upper Chalk	22	Lb	++		9	R1	30	85	130	40		III (III)	41/553578
28		Bentworth Lodge, Hants.	2/43	Valley Slope	475	13	N.W.	1	Upper Chalk	20	Lb	++		15	R1	34	102	135	69		II+ (II)	41/682405
29	D/82	Ashford Hanger, Hants.	10/49	Scarp Slope	650	25	N.E./N.	2	Thin drift on lower chalk	20	Lb	tr.	8.3	55	R3	36	98	135	63.7	4,257	II	41/733263
30	D/82	Ashford Hanger, Hants.	10/49	Scarp Slope	600	28	N.E./N.	1	Lower Chalk	20	Lm	3%	7.8	45	R2	36	101	135			II+	41/733264
31	D/10	Netley Park, Surrey	5/49	Scarp Slope	430	13	S./E.	2	Upper Chalk	30	Lm	++		16	R1-2	33	93	135	53	4,506	II	51/076489
32	D/25	Netley Park, Surrey	9/49	Scarp Slope	600	12	S.	2	Upper Chalk	33	Lm	16%	8.5	20	R1-2	33	90	140	48	4,280	II/III	51/079489
33		Hailey Wood, Hants.	4/45	Easy Ridge Slope	700	10	E.	2	Upper Chalk	23	Lm	++		10	R1	31	75	149	47		IV (IV)	41/737963
34	E/15	Selborne Hanger, Hants.	9/49	Scarp Slope	600	24	N.E./N.	2	? Upper Chalk	16	Lb	35%	8.3	16	R1	35	90	150	50	4,243	II/III	41/740334
35		Wormsley, Bowleys, Bucks.	4/45	Ravine	650	20	W.	3	Upper Chalk	40	Lb	+			R2	31	77	152	53		—(IV)	41/746948
36		Wormsley, Bowleys, Bucks.	4/45	Ravine	550	10	W.	1-2	Thin drift on chalk	65	Lb	tr.		—	R3	31	87	160	54		—(IV—)	41/744948
37		Hardwick, Oxon.	3/45	Valley side	320	12	N.E./N.	2	Upper Chalk	20	Lm	—			R2	26	83	165	58		—(IV—)	41/664781
38		Bottom Wood, Oxon.	3/45	Valley Floor	240	3	S.E.	1	Alluvium on Upper Chalk	70	Lm	—		—	R3	26	91	165	60		—(IV—)	41/664783
39	E/16	Goodwood Plantation, Sus.	10/49	Easy Spur Slope	430	9	W.S.W.	3	Upper Chalk	25	Lm	17%	7.6	9	R1-2	34	80	170	45	3,967	—	41/887104
40	E/18	,, ,,	1/50	,, ,,	470	6	E./N.	1	Upper Chalk	20	Lm	12%	8.0	30	,,	34	100	170	54.3	6,339	—	41/889105
41	E/19	,, ,,	1/50	,, ,,	425	10	E.N.E.	1	Upper Chalk	23	Lm	11%	7.1	22	,,	34	105	170	62.1	6,356	—	41/890104
42	E/20	,, ,,	1/50	,, ,,	440	6	W.S.W.	3	Upper Chalk	20	Lm	13%	7.7	25	,,	34	75½	170	46.3	3,847	—	41/887102
43	E/4	Arundel—The Bank, Sus.	5/49	Easy valley Slope	120	7	E.S.E.	1	Upper Chalk	30	Lb/C	7%	7.1	18	R2	30	111	170	69	6,160	—	51/011077
44		Halton Wood, Bucks.	3/45	Steep Scarp Slope	750	24	W.N.W.	3-4	Upper Chalk	20	Lm	++		8	R1	31	65	170	46		— (<IV)	42/995086
45		Latimer-West Wood, Bucks.	3/45	Valley Slope	350	12	N.	1	Upper Chalk	23	Lb	—		10	R2-3	29	107	176	79		— (IV+)	41/997983
	B: JURASSIC LIMESTONES																					
46	D/27	Cirencester Park, Glos	9/49	Easy Ridge Slope	440	3	S.	2	Great Oolite	18	Lb	19%	8.5	22+	R1	31	101	106	49	4,815	I/II	32/993019
47	D/26	Whiteway Belt, Glos.	9/49	Plateau	600	2	S.W.	3	Great Oolite	22	Lb	++	8.4	35	R1	32	78	106	48.5	—	III	42/030072
48	D/31	Sapperton Tunnel, Glos.	11/49	Plateau	600	5	N.E.	2	Great Oolite	33	Lb	.3%	6.7	17+	R2-3	32	96	110	52	4,990	II+	32/938025
49		Pope's Wood, Glos.	1/47	Steep Scarp Slope	720	25	N./E.	2	Oolite	35	Lm	—		60		30	100	120	50.2		II+	32/878130
50		Peascliff Tunnel, Lincs.	12/43	Ridge Crest	300	2	E.	2	Mid. lias marlst.	30	Lb	++		30+		25	104	133	105		I/II (II)	43/913394
51		Kingscote, Glos.	11/48	Valley Slope	450	20	N./E.	2	Great Oolite	15	Lm	++		45+	R2	32	83	135	58		III	31/832971
52	D/4	Kingscote, Glos.	11/48	Valley Slope	380	27	N./E.	0	Inf. Oolite	17	Lm	+		45+	R2	32	102	135	66		I/II	31/832972
53	D/29	Kingscote, Glos.	9/49	Valley Slope	500	25	S./W.	2	? Great Oolite	60	Lb/C	+	4.5	8	R3	32	99	135	56	3,756	II	31/828973
54	D/30	Kingscote, Glos.	9/49	Valley Slope	430	23	S.	1	? Great Oolite	14	Lb	30%	8.4	30+	R1	32	97	135	53	3,140	II	31/828973
55		Kingthorpe, Yorks.	7/43	Valley Slope	320	15	S.	2	Inf. Oolite	40	Lb	++		12	R2	28	87	140	68		III+ (III)	44/838853
56	D/38	Badminton—Bath Verge, Glos.	3/50	Plateau	450	2	E.N.E.	2	Forest Marble	12	Lm	10%	7.4	35	R1	34	106	140	70		I—	31/797827

APPENDIX I (*contd.*). BEECHWOODS ON CHALK AND LIMESTONE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
										"A" Horizon							Beech Statistics					
No.	Ref.	Name of Wood	Date	Topography	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Depth cm.	Text.	Chalk	pH	A/C Depth cm.	Soil Type	Rain-fall in.	Height	Age	Girth	Vol. p. acre h. ft.	Quality	Map Ref. Nat. Grid
57	E/25	Bath 7 mile, Belt, Glos.	3/50	Plateau	490	3	S.	3	Great Oolite	25	Lb	.5%	6.7	30+	R2	34	105	155	69	4,974	—	31/788821
58	E/26	Bath 7 mile Belt, Glos.	3/50	Plateau	510	—	—	3	Great Oolite (Hinton Sands)	37	La	65%	8.8	10	R1	33	103	155	65.4	6,749	—	31/809872
59	E/24	Ebworth Park, Glos.	3/50	Ravine	620	18	S.S.E.	2	Oolite	13	Lb	11%	8.0	50+	R2	32	100	155	45	3,987	—	32/902109
60		Warleigh, Som.	5/43	Valley Slope	320	15	W.S.W.	2	Great Oolite	20	Lb	+		16	R2	32	106	175	78		—III	31/795647
61	E/3	Blenheim Park, Oxon.	4/49	Plateau	370	2	S.	2	Great Oolite	18	Lm	++		30+	R1	27	105	175	85		—	42/425184
62	E/36	Duncombe Park, Yorks.	5/50	Plateau	350	1	N.	2	Corallian	20	Lb	tr.	6.6	14+	R2	30	106	200+	131	—	—	44/605828
63	E/37	Duncombe Park, Yorks.	6/50	Plateau	300	10	S.E.	3	Drift on Corallian	30	Lm	+	6.5	30	R3	30	95	200	92		—	44/603826
64	E/17	Cirencester Park, Glos	11/49	Plateau	460	1	S.	2	Great Oolite	20	Lb	+	7.5	28	R2	31	110	215	91.4		—	42/000024
	C. PERMIAN																					
65	D/49	Barton Hall, Devon	4/50	Easy Ridge Slope	370	3	W./S.	3–	Permian Marl	60	Lm	tr.	7.2	—	R3	35	104	110	82.5		I—	20/900672
66	D/54	Ledston-Sheldon Hill Yorks.	5/50	Scarp Slope	180	17	S.S.W.	3	Magnesian-	15	Lm	40%	7.1	17	R1	24	82	110	49	5,345	III	44/428291
67	D/54	„ „	5/50	Ridge Crest	200	1	E.	2	Limestone	25	Lm	++		20	R1	24	96	110	51	6,565	II+	44/428292
68	D/56	Bramham, Well Hill, Yorks.	5/50	Ridge Slope	150	10	W.N.W.	3–	„	29	Lm	—	5.4	20+	R3	26	91	c130	59.4	5,250	II—	44/416421
69	E/30	„ „ Drives	5/50	Plateau	260	2	E.	2	„	35	Lm	+	7.0	15	R2	26	118	200+	105.3		—	44/406415
70	E/31	Parlington, Wilderness, Yorks.	5/50	Plateau	200	2	S.S.E.	1-2		12	Lm	+	7.9	27	R1-2	26	111	200+	100		—	44/422263
	D. MOUNTAIN LIMESTONE																					
71		Belmont Hill, Som.	6/43	Easy Ridge Slope	450	4	S.W.	3	Carb. limestone	50	Lb/C	—		—	R3	35	48	37	22		I (I)	31/523710
72		Charterhouse, Som.	5/43	Shallow Valley Slope	750	9	S.S.W.	3	„ „	38	Lb	—		10	R3	44	64	60	33		II—	31/496553
73	D/60	Threshfield, Yorks.	5/50	Ridge Slope	600	15	N.W.	3	Drift on „	20	La	++	7.4	6	R1	45	73½	130	86		IV+	34/996632
74	D/61	Skipton Castle, Yorks.	5/50	Steep Spur Slope	425	20±	S.W.	2-3	Carb limestone	40	Lb	tr.	6.6	15+	R2	35	83	130	37		III	34/993523
75	E. CALCAREOUS GLACIAL DRIFT																					
		Sturton Six Acres, Lincs.	1/44	Plain	200	3	S.W.	2	Chalky drift on Kimmeridge	50	La	+				25	71	69	48		I!— (I—)	53/210758
76		Sturton Big Wood, Lincs.	3/44	Plain	200	3	W.S.W.	2		75	Lm	+				25	74	69	55		II (II+)	53/217753
77		Gopsall, Orange, Leic.	5/44	Plain	350	2	W.S.W.	2	Drift on Keuper	76	Lm	+				27	65	69	41		III (II)	43/380063
78		Exton, Oakham Road, Rutland	4/44	Plateau	375	3	S.E.	2	Chalky drift on Oolite	53	Lb	+				26	88	98	67		II— (III/II)	43/914111
79		Eriswell, Dale Hole, Suffolk	6/45	Plain	50	4	S.S.W.	2	Chalk drift	45	La	++				23	67	100	38		IV+	52/729771
80		Laxton's Covert, Leic.	4/44	Easy Ridge Slope	400	4	S.S.E.	2	Chalky drift on Lias	45	Lb/C	+				26	95	115	82		II	43 /808166
81		Harling Belt, Worc.	7/47	Plain	100	—	—	2	Chalk drift	23	Sb	+		8		23	78	120	50		III—	52/952835

APPENDIX II—BEECHWOODS ON NON-CALCAREOUS LOAMS—ENGLAND AND WALES

1 No.	2 Ref.	3 Name of Wood	4 Date	5 Topographic Type	6 Alt. Feet	7 Slope Deg.	8 Aspect	9 Exp.	10 Geology	11 Soil Depth cm.	12 Text.	13 Drainage	14 pH	15 Humus	16 Soil Type	17 Rainfall in.	18 Beech Statistics: Height	19 Beech Statistics: Age	20 Beech Statistics: Girth	21 Volume p. acre h. ft.	22 Quality	23 Map Ref. Nat. Grid
		ENGLAND—SOUTH WEST																				
82		Luscombe Down, Dev.	4/43	Spur on Valley Slope	400	5	S./W.	3	Devonian	50+	Lm	2		Mull		50	81	80	47		II+	20/437716
83		Glenthorne, Dev.	4/43	Ravine (Near sea)	550	30	E.	1	Devonian	70+	Lm	2		Mull		50	85	105	75		III+	20/794495
84	D/32	Chewton Mendip, Som.	11/49	Limestone Upland	820	2½	N.E.	3	? Lias on Carbons.	96	Lb	2	6-7	Mull		45	90	115	57		II—	31/585511
85	D/48	Cothelstone, Som.	4/50	Escarpment Slope	930	20	S.S.W.	3	Devonian	60	Lm	2		Mor		35	88	130	83		II/III	31/191324
86	D/46	Cothelstone, Som.	4/50	,, ,,	720	22	S.	2	Devonian	60	Lb	2	4.3	Mor		35	99	140	101		II+	31/187323
87	D/47	Cothelstone, Som.	4/50	,, ,,	630	20	S.W./S.	2	Devonian	55	Lb	2	—	Mull		35	100	140	118		II+	31/184323
		ENGLAND—SOUTH EAST																				
88	D/24	Winchester, Hants.	8/49	Upland	570	3	S.E.	2	Flinty-Drift	60+	Lb	3	4.4	Mull		37	105	120	60	3,696	I—	41/680321
89	E/21	Slindon Park, Sus.	1/50	Plain	100		None	2	Flinty-Drift	80+	Lm	2	4-5	Mull		29	115	200—230	100	6,007	—	41/954074
90	E/22	Slindon Park, Sus.	1/50	Plain	100	4-8	W./N.	3	Flinty-Drift	40+	Lm	2	4.5	Mor		29	97	,,	75	3,543	—	41/953076
91	E/23	Slindon Park, Sus.	1/50	Plain	110	2	W./N.	3	Flinty Drift	50+	Lm	2	4.5	Mor		29	92	,,	71.4	3,997	—	41/953077
		ENGLAND—EAST																				
92	C/2	Penn Wood, Bucks.	5/49	Upland	525	2	S.S.W.	2	Flinty-Drift	70	Lb	2-3	3.8	Mull		30	82	90	43.5	3,900	II/III	41/910957
93		Great Chalk Wood, Oxon.	3/45	Easy Valley Slope	375	10	N.W.	1	Flinty-Drift	76+	Lm	2		Mull		27	86	96	50		II— (II/III)	41/624802
94		Crowell Hill, Oxon.	4/45	Escarpment	750	8	N.W.	3/4	Flinty-Drift	53+	Lb	2		Mor		31	69	106	47.5		IV (III/IV)	41/754984
95		Queen, Watlington, Oxon.	3/45	Upland	730	3	N.E.	3	Flinty-Drift	60	Lb	2		Mull		31	70	105	41		IV+ (IV)	41/718924
																	71	120	43		IV <(IV)	
96		,, ,,	7/45	Valley Slope	640	16	S.W./S.	1	Flinty-Drift	70+	Lb	2		Mull		30	84	106	46		III+ (III—)	41/723924
																	85	145	51		III (IV—)	
97		,, ,,	8/45	Valley Slope	690	10	W.	2	Flinty-Drift	45+	Lb	2		Mull		30	72	110	41		IV+ (IV)	41/724924
98	D/5	Nettlebed—Hatch Copse, Oxon.	4/49	Valley Slope	400	10	S.E./S.	1	Flinty-Drift	80+	Lm	2		Mull		30	84	100—120	46		III+	41/723853
99		Nettlebed, Oxon.	8/45	Upland	525	1	S.E.	3	Flinty-Drift	60+	Lb	2		Mull		31	74	120	51		IV+ (IV)	41/704857
100		Lackmore, Oxon.	8/45	Upland	460	2	E.	2	Flinty-Drift	70+	Lm	2		Mor		29	70	120	42		IV (IV—)	41/663812
101		Hale Wood, Bucks.	3/45	Escarpment Slope	730	10	W.N.W.	3	Flinty-Drift on chalk	60	Lb	2		Mull		31	63	122	50		IV— (IV—)	42/890067
102		Nuffield Grove Wood, Oxon.	4/45	Upland	550	4	N.E.	2	Flinty-Drift	60+	Lb	2		Mull		31	82	126	50.5		III (IV)	41/691872
103		,, ,,	4/45	Upland	600	1	N.E.	2	Flinty-Drift	60+	Lb	2		Mull		31	80½	122	46		III (IV)	41/688873
104		Stonor Doyley, Oxon.	4/45	Valley Slope	450	10	S.E.	1	Flinty-Drift	60+	Lb	2		Mull		30	87½	126	50		III+ (IV)	41/723894
105	D/8	West Wycombe--High Wood, Bucks.	5/49	Valley Slope	420	10	N.N.W.	2	Drift on Chalk	60+	Lb/C	2	5.0	Mull		30	100	135	51.7	4,713	II+	41/825940
106		Crowell Hill, Oxon.	4/45	Escarpment Slope	750	8	N.W.	3/4	Flinty-Drift	53+	Lb	2		Mor		31	71½	136	50		IV (<IV)	41/754984
107		Green Dean, Oxon.	4/45	Upland	300	7	N.	2	Flinty-Drift	50+	Lb/C	2		Mull		27	90	140	55.4		II/III (IV+)	41/687786
108		Thirds Wood, Bucks.	4/45	Upland	600	2-3	S.	2	Flinty-Drift	60+	Lb	2		Mull		30	75	140	48		IV/III (III)	41/792949
109		Lodge Wood, Bucks.	12/46	Valley Slope	530	5	N.N.E.	2	Flinty-Drift	40+	Lb	2		Mor		29	87½	140	?36		III+	42/866021

APPENDIX II (*contd.* BEECHWOODS). ON NON-CALCAREOUS LOAMS—ENGLAND AND WALES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drainage	pH	Humus	Soil Type	Rainfall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid
110		Littleboys Heath, Bucks.	3/45	Valley Floor	560	1	N.N.E.	1	Flinty-Drift	45+	Lb/C	3		Mull		29	82	146	54		III (III)	42/844037
111		Hailey, Oxon.	5/47	Upland	810	1	E.S.E.	3	Flinty-Drift	70+	Lb	2		Mull		32	89	150	47.5		III+	41/735966
112		Oakengrove, Bucks.	12/46	Valley Slope	625	10	N.N.E.	2	Flinty-Drift	45+	Lb	2-3		Mull		29	100	150	58.5		II	42/857022
113		Wycombe Court, Bucks.	3/45	Upland	550	7	S.E.	2	London Clay	25	C	3		Mor		29	83½	150	50		III (IV—)	41/820916
114		Woodend-Holme, Bucks.	4/45	Valley Slope	380	10	E.	1	Flinty-Drift	60	Lb	2-3		Mull		27	75	150	52.5		IV/III (<IV)	41/816887
115		Nethercote, Cowleaze, Oxon.	7/45	Upland	750	10	S.E.	2	Flinty-Drift	70+	Lb	2		Mull		31	85	155	57		—(IV/III)	41/730955
116		,, ,,	4/45	Upland	820	2	W.	3	Flinty-Drift	70+	Lb	2		Mull		32	81	160	60		—(IV)	41/728958
117		Hardwick, Oxon.	5/47	Upland	380	2	N.E.	2	Flinty-Drift	50+	Lb/C	2		Mull		28	89	150—60	53		—	41/664789
118		Hardwick—Hoare Hill, Oxon.	4/45	Upland	380	6	W.N.W.	2	Flinty-Drift	76+	Lb	2		Mull		28	84	158	(45)		— (IV—)	41/664798
119	E/3	Frithsden Beeches, Herts.	5/49	Upland	530	2	E.S.E.	2	Flinty-Drift	65+	Lb/C	2		Mull		31	109	170	76		—	42/999105
120	E/28	,, ,,	5/50	Upland	550	2	S.E.	2-3	Flinty-Drift	70+	Lb/C	2		Mor		31	101	c170	66	4,102	—	42/997104
121	E/29	,, ,,	5/50	Valley Slope	500	7	S.S.E.	1	Thin drift/chalk	70+	Lb/C	2		Mull		31	116	c170	81.5	5,133	—	52/000104
122		Fugsdon, Bucks.	3/45	Upland	740	3	S.E.	2-3	Flinty-Drift	60+	C	3		Mull		31	70	c175	51		— (<IV)	42/858055
123		Nuney Green, Oxon.	3/45	Upland	350	1	S.E.	2	Flinty-Drift	60+	Lb	2		Mull		27	81	180	55		— (<IV)	41/672789
	MIDLANDS																					
124	C/20	Croft Castle, Herefordshire	9/50	Valley Slope	600	20	W.	2-3	Silurian Drift	60+	Lm	2	4.3	Mor		31	76½	75	45.4	6,336	II—	32/452663
125	C/21	,, ,,	9/50	Valley Slope	650	20	N.W.	2-3	Silurian Drift	60+	Lm	2	4.3	Mor		31	79	75	49	4,477	II	32/453665
126		Longville, Wart Hill, Salop.	11/44	Ridge Slope	770	11	N.N.E.	2	Ordovician	76+	Lm	2		Mor		32	83	89	(85)		II—	32/405847
127		Gedling Wood, Notts.	12/43	Upland	200	7	S./W.	2	Keuper Drift	30	C	3		Mull	B	24	93	132	69		II— (III+)	43/626427
128	D/74	Gatley Clump, Herefordshire	9/50	Hillcrest	1,050	3	W.	4	Silurian Drift	60+	Lm	2	5.5	Mull		34	82	c140	83			32/441691
129		Hassop, Derbyshire	2/44	Upland	660	2	S.S.E.	2	Carb. Drift	50+	Lb	2		Mull		37	77	160	64		(IV)	43/213716
	WALES																					
130	B/56	Stanage, Radnor	9/50	Hillslope	750	14	N.	2	Silurian Drift	60+	Lm	2	5.2	Mull		35	52	45	26		II	32/331726
131	D/72	Llanover, Mon.	9/50	Steep Valley Slope	450	27	W./N.	2	Coal Measures	55+	Lm	2		Mor		50	72	c100	63		III/IV	31/215983
132	D/73	Brecon Groves, Brecknock.	9/50	Valley Slope	540	18	E./S.	1-2	O.R. Sandstone	65+	Lm	2		Mull		42	108	130—40	64	5,444	I—	32/047296
133	D/71	Coedarhydyglyn, Glam.	9/50	Ridge Slope	375	4	N.E.	2-3	Mixed Drift	50+	Lb	2	6-7	Mull		45	106	140	102		I—	31/107747
134	E/87	Stanage, Radnor	9/50	Hillslope	800	15	N.W.	2	O.R. Sandstone	60+	Lm	2		Mull		35	91	180	100		—	32/338717
135	E/82	Powys Avenue, Mont.	8/50	Ridge Crest	800	0–15	Gen.	4	Silurian	40	Lb	3	4.3	Mor		40	83	c200	74.5	5,475	—	33/205062
136	E/84	Powys Avenue, Mont.	8/50	Ridge Crest	800	7	N.W./N.	3	Silurian	50	Lb	3	4.5	Mor		40	93	c200	91.5		—	33/203061

APPENDIX II (*contd.*). BEECHWOODS ON NON-CALCAREOUS LOAMS—ENGLAND AND WALES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drain-age	pH	Hu-mus	Soil Type	Rain-fall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid
137	E/79	Penbedw, Flint.	8/50	Valley Slope	570	25	E.	1	Silurian, Carb. Limestone	80+	Lm	2	4.2	Mull		35	110	c200	108		—	33/168687
138	E/80	Penbedw, Flint.	8/50	Valley Slope	610	2	S.E.	2	Silurian	50	Lm	2		Mor		35	97	c200	106		—	33/167686
139	E/81	Penbedw, Flint.	8/50	Hillside	1,020	12	E./S.	3	Silurian	25	Lm	2		Mor		36	80	c200	91		—	33/156679
	NORTH-WEST																					
140	E/77	Lowther—Whale Moor, Westmorland	8/50	Upland	1,100	3	N.	4	Carboniferous limest. drift	42+	Lb	2	4.7	Mull	B	50	85	200	83		—	35/533193
	NORTH-EAST																					
141	D/59	Rylstone Clump, Yorks.	5/50	Side of Wide Valley	700	5-15	N.W.	3	Glacial drift over carb. lime.	23+	Lb	3	4.8	Mull		38	79	120	70		III—	34/970577
142	E/39	Birdsall Park, Yorks.	6/50	Valley Slope	300	8-15	E.S.E.	2	Sandy fluvia glacial over Jurassic.	80+	Lm	2	4.2	Mull		27	93	150	92		II—	44/814650
143	E/51	Beaufront Keepers' Lodge, Northumberland	7/50	Hill Slope	560	7	W.S.W.	3	Glacial drift over carb.	40+	Lb	3		Mor		28	91	175	74		—	35/962667 /8
144	E/52	„ „ Hill Head, „	7/50	Hill Crest	680	4	W.S.W.	4	„ „	40+	Lb	3		Mull		28	82	175	61		—	35/964670
145	E/38	Dalton Park, Yorks.	6/50	Plain	150	—	—	1	Esturial Drift over chalk	50+	Lb	2		Mor		27	96	200	102		—	44/954450
146	E/46	Blagdon Garden, Northumberland.	7/50	Sides of Gulley	180	15	S.S.E.	1	Glacial drift over coal measures	50+	Lb	2	4.8	Mull		24	96	214	118		—	45/213772
147	E/47	„ Drive „	7/50	Plain	230	2	W.S.W.	3	„ „	28	Lb	3	4.3	Mor		24	85	214	115		—	45/218773
148	E/53	Lambton Biddick, Durham.	7/50	Shallow Valley	120	2-7	N.W.	2	„ „	22	Lb	3		Mull		24	(86)	200+	118		—	45/315528

(See also Graph 2, page 98, and Map, page 76.)

APPENDIX III. BEECHWOODS ON NON-CALCAREOUS LOAMS—SCOTLAND

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drainage	pH	Humus	Soil Type	Rainfall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid
149	D/67	Duns Castle Wood, Berwickshire	8/50	Steep Valley Slope	450	24	W.N.W.	2	Quartz-Dolerite Dyke and thin drift.	60	Lm	2	4.6	Mor		30	86	120	72	7,229	III	36/782558
150	D/70	RutherfordWindBelt, Roxburgh.	8/50	Low Ridge Top	270	2—3	W.S.W.	3	O.R.S. drift	60	Lm	2	—	Mor		27	76	130	54	4,224	III/IV	36/668307
151		Sundry Record (a), East Lothian, 4		Plain	70	0	—	2	Drift on l'r. carb.	60+	C/Sb sb	2		Mull		25	83½	125	95		III (III/IV)	
152		„ „ 2		Valley Slope	600	30	E.	1	Drift on O.R.S.	50+	Lb	2		Mull		30/35	89	142	100		III/II (III)	
153	E/69	Monteviot Grumphies Scar, Roxburgh.	8/50	Steep sided Spur	300	9	S.W.	3	O.R.S. (Shales)	35	Lm	2	—	Mor		30	66	150+	66	3,450	IV—	36/657215
154	E/71	Cavers Policies, Roxburgh.	8/50	Easy Valley . Slope	630	2—6	W.N.W.	3	Silurian Shales	50	Lm	2	4.8	Mull		33	80	170	71	5,220	—	36/537151
155	E/72	Wells Meadsgrove, Roxburgh.	8/50	Rounded Ridge Top	450	—	—	2	O.R.S. and Sil. drifts	70	Lm	2	—	Mor		33	85	190	64	6,142	—	36/593174
156	E/68	Mellerstain Wind Belt, Berwick	8/50	Side of shallow valley	500	5	N.W.	2	O.R.S. (+Igneous) drift.	50	Lm	2	—	Mull		30	90	190	75	7,597	—	36/653397
157	E/65	Biel Buchlaw, East Lothian	8/50	Slope of outlier	390	11	N.W.	3	O.R.S. (+Igneous) drift.	55	Lm	2	4.1	Mull		27	74	190	71	5,328	—	36/615738
158	E/70	Monteviot Natives, Roxburgh.	8/50	Medium Valley Slope	550	12	S.E.	3	Dolerite	60	Lm	2	4.9	Mull		30	82	200	79	3,919	—	36/654256
159	E/67	Floors Castle, Roxburgh.	8/50	River Terrace	170	13	S.E.	2	River Drift	50	Lm	2		Mull		27	98	240	115		—	36/700346
160		Sundry Record (b), East Lothian		Plain	70	0	—	2	Drift volcanic tuff.	70+	C/Sb	2		Mor		25	91	240	124		—	
161		Sundry Record (c), Wigtown 1			200	12	E.		Drift Silurian	80	Lb	2		Mull		42	74	73	60		II— (II)	
162	E/56	Bargany North Lodge, Ayrshire	7/50	Upper Valley Slope	220	14	S.S.E.	2	Drift over coal measures.	22	Z Lm	3	5.2	Mull		45	92	150+	81	3,014	—	26/240014
163	E/80	Shambellie, Dumfries	7/50	Lower Valley Slope	100	5	E.S.E.	1	Granite	60	Lm	2	—	Mor		44	93	173	67	4,333	—	25/961667
164	D/18 (a)	Hallyburton, Angus	7/49	Area of low relief	210	—2	S.E.	3	Glacial Drift (O.R.S.)	40	Z	3	—	Mor		30	87½	120—130	66	2,632	III+	37/232389
165	„ (b)	„ „	7/49	Plain	210	—	—	3	„ „	40	Z	3	—	Mor		30	90	120—130	58	2,999	II/III	37/232389
166	„ (c)	„ „	7/49	Shallow depression	200	—	—	2	„ „	45	Z	4	—	Mor		30	87	120—130	79		III+	37/232389
167	E/10	Dunottar, Kincardine	7/49	Hillslope near foot.	210	4	N.N.W.	2	Devonian conglom. + sandstone (drift)	75	Lm	2	—	Mull		31	92	155	70	4,944	—	37/863848
168	E/11	Dunottar, Kincardine	7/49	Sheltered Valley	140	2	E.N.E.	0	O.R.S. conglom. river drift.	50	Lm	2	—	Mull		31	106	155	100		—	37/863848

(See also Graph 2, page 98, and Map, page 76.)

APPENDIX IV. BEECHWOODS ON SANDY SOILS—ENGLAND

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drain-age	pH	Hu-mus	Soil Type	Rain-fall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid
169		Foggathorpe, Yorks.	9/43	Plain	25	—	—		Glacial drift on Keuper marl.	50+	La	2		Mull	BFS	25	57	55	31	+		44/769369
170	C/14	Upsall Beckside, Yorks.	7/50	Plain	225	—	—	2	Fluvio-glacial drift over Triassic	40	Sb	2	5-6	Mull	B.	25	76	80—90	68		III+	44/454853
171	D/41	Chagford A, Devon	4/50	Easy spur slope	670	5	W.N.W.	2	Granite	80+	La	2	5.2	Mull	B.	45	(77)	100+	86		III	20/703874
172	D/42	Chagford B, Devon	4/50	Steep spur slope	775	15	W.N.W.	3	Granite	80+	La	2	5.2	Mull	B.	45	73	100+	71		III/IV	20/704872
173	D/43	Chagford D, Devon	4/50	Uneven slope	600	5–15	N.	1	Granite	80+	La	2	5.2	Mull	B.	45	101	100+	—		I/II	20/704876
174	D/44	Powderham B, Devon	4/50	Ridge Slope	90	14	S.S.W.	2	Permian	90+	Sb	2	—	Mull	B.	33	107	140	84	6,808	I—	20/955846
175	D/45	Powderham A, Devon	4/50	Ridge Slope	110	6	N.W.	2	Permian	70+	Sb	2	—	Mull	B.	33	107	140	106		I—	20/954847
176	E/40	Mulgrave Castle A, Yorks.	7/50	Ridge Slope	420	6	S.E.	4	Glacial drift over Jurassic.	70	La	2	6	Mull	B.	30	63	150	57		IV—	45/851130
177	E/41	„ „ „ B.	7/50	Hill Slope	400	6	W.S.W.	3	„ „	55	La	2	6	Mull	B.	30	83	200	—		—	45/846126
178		Kedleston Park, Derby.	2/44	Shallow Valley Slope	380	6	S.W.	2	Keuper Sand	76+	La	2		Mull	B.	29	105	190	110		—(III)	43/313414
179	E/43	Raby Bath Wood A, Durham	7/50	Slight hollow	400	6	S.S.W.	1	Drift over carboniferous.	75+	La	2	6	Mull	B.	26	120	200+	99		—	45/122214
180	E/27	Stourhead Millridge, Wilts.	3/50	Spur Slope	580	5–10	S.E.	0	Upper Greensand	85+	Sb	2	4.2	Mull	B.	37	121	200—/220	113		—	31/770342
181	E/76	Lowther, Mitchell, Westmorland	8/50	River Plain	500	—	—	0	Alluvium on carboniferous.	62+	La	2	—	Mull	B.	47	120	200—/220	72	9,674	—	35/522255
182		Haughley Park, Suff.	7/45	Ridge Crest	240	2	E.	2—3	Glac. sand and gravel.	100+	Sa	1		—	D.	24	83½	115	53			52/998623
183	D/42	Chagford C, Devon	4/50	Spur Slope	825	9	W.N.W.	4	Granite	80+	La	2	—	—	D.	45	63	100+	73		IV	20/704871
184	D/62	Warren House, Yorks.	6/50	Ridge Slope	500	8	S.	3	Sandy drift over Jurassic.	75+	Sb	2	4.4	Mor	D.	28	80	100+	82		III	44/601732
185	D/37	Witham Park, Som.	3/50	Spur Slope	600	20	W.S.W.	3	Upper Greensand	83+	Sb	2	4	—	D.	40	95	140	58	9,813	II	31/773398
186		Longleat-Swancombe Wilts.	5/43	Valley	600	7	S.S.E.	1	Upper Greensand	60+	Sb	2	—	Mor	D.	36	94	160	67		— (III—)	31/839429
187		Rufford, Notts.	11/43	Easy Ridge Slope	230	3	W.	2-3	Bunter	60+	Sa	2	—	Mor	D.	25	98	170	80.4		—	43/640647
188	E/89	Silwood Park, B, Surrey.	10/50	Valley Slope	200	11	N.W.	2	Bagshot Sands	70+	Sb	2	—	Mor	D.	26	97	170 ±	109		—	41/943686
189	E/42(a)	Raby Middle Ridge (A), Durham	7/50	Ridge Slope	620	15	S.W.	3	Millstone Grit	85+	Sb	2	—	—	D.	26	80	170	71	4,393	—	45/110223
190	„ (b)	„ „ (B), „	7/50	Ridge Slope	620	14	S.S.W.	3	Millstone Grit	64+	Sb	2	—	Mor	D.	26	86	170	71	6,285	—	45/107224
191	E/33	New Burgh Priory, Yorks.	5/50	Plain	400	2-3	N.W.	3	Glacial drift over Jurassic.	40+	Sb	2	—	—	D.	27	97	200+	92		—	44/545758
192	E/44	Raby Bathwood B, Durham.	7/50	Valley Floor	400	—	—	1	Glacial drift over millstone grit.	50	La	3	—	Mor	D.	26	114	200+	89		—	45/125213
193	E/49	Nunwick Park A, Northumberland.	7/50	Irreg. Plain	330	5	N.N.E.	2	Glacial drift over carboniferous.	50	Sb	2	4.4	Mor	D.	32	100	200+	84	10,599	—	35/878742
194	E/50	Nunwick Park B, Northumberland.	7/50	Irreg. Plain	320	2	S.S.E.	2	Glacial drift over carboniferous.	45+	La	2	—	Mor	D.	32	110	200+	134		—	35/878740
195	C/18	Nescliffe Hill, Salop.	9/50	Dipslope Plain	500	7	E.	2	Keuper sand	80+	Sb	2	3.8	Mor	P.	27	85	95-100	56	7,021	II/III	33/386198
196	D/40	Stourhead Penridge, Wilts.	3/50	Ridge Crest	650	7	N.E.	2	Upper Greensand	68+	Sb	2	4.0	Mor	P.	37	92	100	62	5,425	II	31/756324
197	D/22	Bagshot Pennyhill, Surrey.	11/49	Shallow Valley	300	4-6	N.	1	Bagshot Sand	80+	Sb	2	4.0	Mor	P.	27	101	100+	64		I/II	41/897628

APPENDIX IV (*contd.*). BEECHWOODS ON SANDY SOILS—ENGLAND

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drainage	pH	Humus	Soil Type	Rainfall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid
198	D/77	Cowdray Cognor, Sus.	10/50	Spur Slope	470	17	S.	3	Lower Greensand.	50+	Sb	2	—	Mor	P.	36	87	140	58	5,784	III+	41/876307
199	E/85	Bradford Mound, Staffs.	9/50	Knoll Top	400	—	—	3—4	Triassic drift over Trias.	70+	Sb	2	—	Mor	P.	28	80	170	91	5,776	—	33/797113
200	E/32	Bolton Strid, Yorks.	5/50	Steep Gulley	470	28	E.N.E.	1	Mixed carboniferous drift.	75	Sa	2	3.6	Mor	P.	35	89	170	71		—	44/073557
201	E/48	Lumley Park, Durham	7/50	Gulley Floor	60	0–4	—	0	Alluvium over coal measures.	65+	La	2	3.8	Mor	P.	26	113	200	123		—	45/290508
202	D/36	Witham Park, Som.	3/50	Spur Slope	625	8	N.N.W.	2	Upper Greensand	88	Sb	2	3.5	Mor	P.P.	40	99	140	69	9,528	II	31/774398
203	E/88	Silwood Park A, Berks.	10/50	Plain	230	—	—	2	Bracklesham Tertiaries.	70	Sa	2	4.0	Mor	P.P.	26	89	150	99		II/III	41/946684
204	E/73	Edmond Castle, Cumberland.	7/50	Plain	100	1	W.	2	St. Bees Sands	46	Sb	2	—	Mor	P.P.	32	97	170	84		—	35/495588

(See also Graph 3, page 99, and Map, page 76.)

APPENDIX V. BEECHWOODS ON SANDY SOILS—SCOTLAND

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
No.	Ref.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Text.	Drainage	pH	Humus	Soil Type	Rainfall in.	Beech Statistics Height	Age	Girth	Volume p. acre h. ft.	Quality	Map Ref. Nat. Grid.
205	D/78	Moniack Castle, Inverness.	6/49	Steep Valley Slope	200	20—25	W.	1-2	O.R.S. drift over Moine Schists	60	Sb	2	—	(Mull)	B.	34	85	120—140	79		III	28/558428
206	E/55	Culzean Nat. Trust, Ayrshire.	7/50	Easy Valley Slope	120	5	S.	2	Lower local O.R.S. + basic Igneous.	64	Sb	2	—	(Mull)	B.	38	100	150	82	6,757	II	26/231095
207	E/7-8	Foulis Castle Drive, Ross & Cromarty.	6/49	Even slope to loch.	140	3 ±	E.S.E.	1	O.R.S. Drift	60	La	3		(Mull)	B.	29	101	160	85		—	28/594636
208		Sundry Record (*d*), Dumfries.			420	2½	S.E.	1	Fluvio-glacial on Silurian.	45	La	2		(Mull)	D.	45	75	100	68		III— (III+)	—
209		Sundry Record (*e*), Kincardine.		Valley slope	310	20	W.	1	—	75+	La	2	—	Mor	D.		70	112	54		IV (III—)	—
210	D/12	Westfield, Moray.	6/49	Plain	40	1—2	S.E.	2	Marine Sand over Permo-Trias.	40	Sb	2	—	Mor	D.	26	79	113	42	4,094	III—	38/155655
211	D/17	Urie House, Kincardine.	7/49	Steep Valley Slope.	170	35—40	N.E.	1	O.R.S. drift over O.R.S.	180	Sb	1	—	Mor	D.	33	85	120—130	66	4,928	III	37/858882
212	D/15	Cluny. Netherglenton, Aberdeen.	7/49	Near foot of valley slope.	330	5	N.	1	Mixed granite + schist drifts.	60	Sb	2	—	Mor	D.	31	86	135	54	4,277	III+	38/667126
213	D/16 (*a*)	Cluny Cunningar, Aberdeen.	7/49	Short Steep Slope	300	18±	N.	2	Aberdeen Granite	45	Sb	1	—	Mor	D.	29	81	136	56	3,854	III	38/699128
214	,, (*b*)	,, ,,	7/49	Low Hill	360	8	W.S.W.	3	,, ,,	80	Sb	2	—	Mor	D.	29	71	136	52	3,037	IV	38/697127
215	D/66	Penicuik Ravensnuik, Midlothian.	7/50	Low upland ridge.	750	2—3	S.E.	4	Drift over carb.	60	La	2	4.2	Mor	D.	32	73	120—150	62		IV+	36/231587
216	E/12	Urie House/Policies, Kincardine.	7/49	Crest of Valley Slope	175	10±	S.E.	2	O.R.S. drift over O.R.S.	40	Sb	2	—	Mor	D.	33	91	c150	79	5,510	II/III	37/859881
217	E/6	Foulis Castle Hill, Ross & Cromarty.	6/49	Steep hill slope	575	15	E.S.E.	2	O.R.S. drift	60	Sb	3	—	Mor	D.	31	78	150—160	90		—	28/581645
218	E/9	Dunottar, Kincardine	7/49	Hill Slope	210	4	N.N.E.	2	O.R.S. conglom. + sandstones.	75	La	2	—	Mor	D.	31	87	155	69		—	37/863844
219	E/14	Dunsinnan, Perth	8/49	Flat Knoll	400	2—3	S.	2	O.R.S. drift	40	La	2	—	Mor	D.	33	105	150—160	77		—	37/171327
220		Sundry Record (*f*), Angus.			600	17	E.	2	O.R.S. drift	76	Sb	2	—	Mor	D.	30	85	175	68		— (IV)	
221	E/57	Bargany Policies, Ayrshire.	7/50	Edge of Low terrace.	150	0—5	W.	2	Drift over carboniferous.	55	Sb	2	4.9	Mor	D.	45	94	180—190	85		—	26/243002
222	E/63	Dawyck Policies, Peebles.	7/50	Medium hill slope.	630	14	N.W.	3	Thin drift over Silurian shales.	60	La	2	—	Mor	D.	37	78	200 ±	94		—	36/170352
223	E/58	Castle Kennedy, Wigtown.	7/50	Uneven low ground.	80	1—3	W.	2	Glacial drift over Permian.	30	Sb	1	4.5	Mor	D.	41	86	200+	93		—	25/090597
224	E/59	,, ,, Gallahill ,,	7/50	Morainic Knoll	110	5 ±	S.W.	4	,, ,,	50	Sb	2	—	Mor	D.	42	62	200+	76		—	25/092595
225	E/61	Eskdale, Dumfries	7/50	Spur on valley slope.	160	15	S.W.	2	Drift over lower carboniferous.	55	La	2	—	Mor	D.	44	(90)	200+	95		—	35/395773
226	E/62	Penicuik, Policies, Midlothian.	7/50	Upland Shelf slope.	750	—	—	2	Glacial drift over carboniferous.	60	Sb	2	4.5	Mor	D.	35	85	220+	88		—	36/217593
227	E/66	Hirsel Policies, Berwickshire.	8/50	Steep Valley Slope.	100	22	S.W.	2	Deep drift over O.R.S.	50	La	2	—	Mor	D.	26	91	200—250	98	6,134	—	36/827412
228	D/14	Castle Fraser, Aberdeen.	7/49	Low Relief Plain.	300	3	N.E./N.	2	Granite drift over granite.	21	Sb(2)	3	—	Mor	P.	29	87	120—130	60	3,041—5,370	III+	38/726132
229	D/69	Jockscairn, Roxburgh.	8/50	Upland Ridge	550	1—2	N.W.	4	O.R.S. Drift over old red sandstone.	50	La	2	4.2	Mor	P.	27	61	130	38	2,926	IV—	36/783343
230	D/13	Gordon Castle, Moray	6/49	Steep Valley Slope.	200	30 ±	S.S.W.	2	O.R.S. drift	80	Sb	2	—	Mor	P.	30	(63)	145—150	60		IV—	38/357592
231	E/64	Tyninghame Binning, East Lothian.	7/50	Littoral Plain	15	—	—	3	Sand-marine ? over O.R.S.	90	Sb	2	4.2	Mor	P.	25	88	200—250	75	7,085	—	36/629803
232	C/6(*a*)	Letterfourie Drive, Banff.	6/49	Easy Ridge Slope.	440	2	W.	3	Drift over O.R.S.	40	Sb	3	—	Mor	P.P.	31	61	76	40	2,294—3,477	III/IV	38/443626

(See also Graph 3, page 99, and Map, page 76.)

APPENDIX VI(A). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
233	A.77	S.(S)	Mellerstain Hill, Berwickshire.	8/50	Gentle hill slope	600	10	S.E.	1	O.R.S. drift over O.R.S.	45	Lm	2	Mor	33	3.5	3	—	Formerly open woodland—Beech, etc., cleared. Pure beech 3 x 1½ ft.	36/644396
234	A.49	N.E.(E)	Parlington Hollins, Yorks.	5/50	Uneven Hollow	175	—	—	1	Coal Measures	50	Lm on C.	2-3	Mor	26	5.7	4	—	Former woodland—oak etc., cleared beech, syc., ash, larch, pine. Smoky.	44/414354
235	A.56	N.E.(E)	Hovingham Brown Pltn. Yorks.	6/50	Spur of low ridge	300	5-8	S.	3	Sandy drift over Jurassic	50	La	2	Mull	30	3.0	4	—	Former oakwood—cleared beech, oak, syc., larch, pine and spruces.	44/642747
236	A.58	S.W.(E)	Gardiner Forest, C.18, Wilts.	6/50	Chalk uplands	550	4	S.S.E.	2	Thin loam + flints over chalk.	40	Lm	2	Mull	33	2.9	5	—	Former scrub of privet, dogwood, etc., pure beech now coming out of check	41/993202
237	(b)	,,	,, ,, C.23	6/50	,, ,,	570	3	S.E.	2	,, ,,	38	Lm	2	Mull	33	5.6	5	—	Former woodland, oak, hazel, etc. Beech in gaps cut in hazel coppice.	41/994204
238	A.82	N.W.(E)	Coxalls, The Knoll, Salop.	9/50	Slope of outlier	600	12	S.S.W.	3	Talus over Ludlow shales.	60+	Lm	2	Mull	33	6.9	5	—	Former scrubby oak wood, cleared. Pure beech. Some side shelter.	32/365733
239	A.83	,,	,, ,, ,,	9/50	,, ,,	650	12	W.N.W.	3	,, ,,	60+	Lm	2	Mull	33	4.1	5	—	As above but more exposed.	32/363736
240	A.63	N.E.(E)	Kilnwick Percy, Firkin, Yorks.	6/50	Slope of shallow valley.	300	17	N.N.W.	2	Loamy drift + rare chalk (deep) over chalk.	50+	Lm	2	Mull	30	3.9	6	—	Old woodland (oak, ash, larch)—cleared pure beech.	44/829504
241	A.22	S.E.(E)	Micheldever Forest, C.12, Hants.	2/50	Chalk downland	300	—	—	2	Loamy drift on chalk.	52+	Lm	2	Mull	23	5.0	6	—	Former oakwood with copp., hazel, etc., Beech under light birch cover + side shelter.	41/530376
242	A.61	N.E.(E)	Sledmere Hanging Fall, Yorks.	6/50	Chalk wold	430	2-10	N.N.W.	2	Very flinty lm on chalk.	65	Lm	2	Mull	30	5.0	7	—	Former mixed woodland—cleared. Beech, larch, pine, spruce.	44/921630
243	A.68	N.E.(E)	Raby Castle, The Folly, Durham.	7/50	Low Hill, Crest	770	1	E.	3	Deep sandy lm drift over millstone grit.	35+	Lm	2-3	Mor	26	2.4 5.0	7 7	—	Former conifer wood, cleared 1942. Beech and hybrid larch in *flexuosa* and bracken	45/125233
244	A.69	N.E.(E)	Lambton Biddick Wood, Durham.	7/50	Plain	130	—	—	1	Glacial drift over coal measures.	36	Lm	3	Mull	26	7.8	7	—	Former woodland—oak, ash, syc., elm—cleared. Beech, ash, sycamore.	45/315525

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
245	A.10	S.E.(E)	Slindon Forest, C.10, Sus.	1/50	Gentle slope	350	3	S.E.	1	Loamy drift on chalk.	60	Lm	2	Mull	32	4.8	7	—	Former woodland—mostly cleared. Rare oak, etc., to shelter beech in equal mixture with pine.	41/946113
246	A.11	S.E.(E)	„ „ „	1/50	„ „	360	3	S.E.	1	„ „	40	Lm	2	Mull	32	5.2	7	—	Former beechwood. Planted P/43 under light OH shelter birch, ash, etc., since thinned.	41/945114
247	A.76	S.(S)	Dalkeith Newtonside, Midlothian.	7/50	Top of low ridge	150	2	E.S.E.	2	Drift over coal measures.	55+	La	2	Mull	25	8.3	7	—	Formerly oak—syc., wood—cleared rich site. Pure Beech.	36/330687
248	A.32	S.W.(E)	Collingbourne Forest, C.9, Wilts.	3/50	Chalk downland	670	—	—	3	Loamy drift on chalk.	80+	Lm	2	Mull	33	4.2	8	—	Hazel coppice with oak standards cut over in both wars. Beech planted under birch.	41/272542
249	A.33	S.W.(E)	Collingbourne Forest, C.8, Wilts.	3/50	Chalk Downland	680	—	—	3	Loamy drift on chalk.	63+	Lm	2	Mull	33	5.0	8	—	As above; all shelter now gone in both.	41/274543
250	A.45	N.E.(E)	Bramham New Black Fen, Yorks.	5/50	Slight trough	225	4	W.	2	Loamy drift on magnesian limestone.	50+	Lm	2	Mull	26	6.0	9	—	Former woodland—beech, oak, ash—cleared ash, beech, larches, pine, spruce	44/424405
251	A.13	S.E.(E)	Slindon Forest, C.6, Sus.	1/50	Gentle slope	430	4	S.S.E.	2	Thin loam on chalk.	25	Lm	2	Mull	32	6.5	9	—	Former beechwood. Full overhead shelter from 30 ft. birch, etc.	41/948119
252	A.12	S.E.(E)	Slindon Forest, C.6, Sus.	1/50	Gentle slope	450	5	S.W.	3	Thin loam on chalk	50	Lb	2	Mull	32	7.1	9	—	As above, but shelter all cleared 1947-8.	41/947120
253	A.14	S.E.(E)	Charlton Forest, C.17, Sus.	1/50	Even slope	660	5	S.S.W.	3	Thin loam on chalk.	60	Lm	2	Mull	30	4.7	9	—	Former woodland—mainly beech, followed by birch under which beech planted.	41/908160
254	A.5	S.E.(E)	Buriton Forest, C.23, Hants.	1/50	Steep concave slope.	500	20—25	S.E.	0—1	Talus on chalk	50	Lm	2	Mull	35	6.7	9	—	Former open wood, beech, yew, ash, partly cleared for planting pure beech in shelter.	41/730183
255	A.6	S.E.(E)	„ „ „	1/50	„ „	400	12—15	S.E.	0—1	„ „	63	Lm	2	Mull	35	8.3	9	—	As above. Bad mouse damage.	41/731183
256		S.W.(E)	Haldon Forest, Devon	5/47	Base of Escarpment.	550	10—15	N.N.E.	1	? Permian Marl.	40+	Lm	2	Mull	37	14.0	10	—	Planted underthinned larch 60ft. tall.	20/893847 6
257	A.24	S.W.(E)	Maiden Bradley, C.72, Wilts.	3/50	Top of (flat) ridge.	800	2	W.	3	Upper greensand.	70+	La	2	Mull	37	9.7	10	—	Spruce following mature oak wind blown 1937; replaced after clearance by beech.	31/769383

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
258	A.88	S.(W)	Brecon Forest, C.26, Brecon.	9/50	Steep Hillside	980	19	S.E.	2	Silurian shales	60	Lb	2	Mull	45	9.0	10	—	Former scrubby hardwood (hazel, ash, oak, etc.) cleared and planted pure beech.	32/061387
259	A.34	S.W.(E)	Collingbourne Forest, C.7, Wilts.	3/50	Down top	700	2	S.W.	3	Thin loam on chalk.	60+	Lb	2	Mull	30	9.6	10	—	Oak standards & hazel coppice cut 1914-18. Beech planted under cover since thinned.	41/276547
260	A.86	N.W.(E)	Walcot Forest, Red Wood, Salop.	9/50	Uneven Hill Side	600	12	N.W.	2	Silurian drift over Silurian Shale.	60+	Lm	2	Mor	35	8.1	11	—	Formerly oakwood—cleared 1914-18, leaving coppice & birch in which beech and larch grouped.	32/309841
261	A.3	S.E.(E)	Buriton Forest, War Down, Hants.	1/50	Top of Convex Hill.	750	5–10	N.W.	3	Chalky loam on chalk.	42	Lm	2	Mull	35	6.2	11	—	Former chalk pasture local scrub beech 75 Pine 25 (After beech/Alnus incana).	41/724194
262	A.21	S.E.(E)	Micheldever Forest, C.16, Hants.	2/50	Chalk downland	300	—	—	2	Loam on chalk	60	Lm	2	Mull	33	8.1	11	—	Former oakwood with hazel coppice, etc., beech put in among hazel under light birch.	41/528382
263	A.36	S.E.(E)	,, ,, C.16 ,,	3/50	,, ,,	300	4	W./N.	2	Loamy drift on chalk.	50+	Lm	2	Mull	33	8.6	11	—	As above but shelter now all gone.	41/527381
264	A.37	S.E.(E)	,, ,, C.13 ,,	3/50	,, ,,	310	—	—	2	Loamy drift on chalk.	50+	Lm	2	Mull	33	10.5	11	—	Former oak standards in hazel coppice, beech under light overhead shelter of birch, oak.	41/527379
265	A.79	N.W.(E)	Thornthwaite Forest, C.22, Cumb.	8/50	Lower Hill slope	400	5–10	S.S.W.	2	Drift on Ordovician.	50+	Lb	2	Mull	55	9.4	12	—	Probably former open woodland–oak, etc., beech and ash, lately filled up with spruce.	35/206333
266	A.87	S.E.(E)	West Dean, Sussex	11/50	Valley side	300	10—15	E.S.E.	1	Chalky loam on chalk.	60+	Lm	2	Mull	35	13.3	12	—	Former beech wood. V. good site. V. frequent lammas & bud injury.	41/853136
267	A.28	S.W.(E)	West Woods Forest, C.24, Wilts.	3/50	Downland	675	—	—	2	Loam over chalk.	117+	Lm	2	Mull	32	7.9	12	—	Old woodland. Frost and weed competition.	31/156664
268	A.30	S.W.(E)	Collingbourne Forest, C.5, Wilts.	3/50	Downland	620	5	W.	2	Loam over chalk.	48+	Lm	2	Mull	33	16.8	13	—	Former oakwood—scattered standards left as shelter for pure beech until 1944-48. Birch and Hazel cut before planting.	41/272548
269	A.31	S.W.(E)	,, ,, ,,	3/50	Downland	640	5	S.W.	2	,, ,,	40+	Lm	2	Mull	33	16.5	13	—		41/273548

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
270		S.E.(E)	Buriton Forest, C.6, Hants.	1/47	Downland	550	2	S.	2	Chalk	45	Lb	2	Mull	36	17.0	14	—	Planted in remnants of old woods.	41/746178
271	A.35	S.E.(E)	Micheldever Forest, C.21, Hants.	3/50	Downland	300	2	S.W.	2	Loam over chalk.	55+	Lm	2	Mull	30	6.8	14	—	Former woodland. Shelter from birch, oak, hazel. Grave injury by Pteris, lonicera.	41/536386
272	A.15	S.E.(E)	Charlton Forest, C.6, Sus.	1/50	Chalk dip slope	475	5	S.W.	2	Chalk	30	Lm	2	Mull	36	8.6	15	—	Former wood of beech etc., light shelter from ash, etc., at planting—now gone	41/897152
273	(*b*)	S.E.(E)	,, ,, ,,	1/50	Chalk dip slope	450	7	W.S.W.	2	Chalk	40	Lm	2	Mull	36	16.0	15	—	Poor growth in 15(*a*) due probably to competition of scrub—cornus, fraxinus, rosa, rubus.	41/897152
274	A.7	S.E.(E)	Buriton Forest, Hants.	1/50	Side of deep valley.	500	14	N.W.	3	Chalk	60+	Lm	2	Mull	36	8.7	15	—	Old open mixed woodland and scrub light OH shelter. Neglected weeding.	41/734184
275	A.8	S.E.(E)	,, ,, ,,	1/50	,, ,,	450	20—25	W.	2	Chalk	40+	Lm	2	Mull	36	13.0	15	—	Shelter now all cleared	41/734184
276		S.E.(E)	,, ,, C.4 ,,	1/47	Downland	500	3	S.	2	Chalk	26	Lb	2	Mull	36	25.0	16	—	Overhead shelter of ash poles, etc.	41/745176
277	A.20	S.E.(E)	Micheldever Forest C.17, Hants.	2/50	Chalk down	300	—	—	2	Chalk	63+	Lm	2	Mull	33	7.2	16	—	Old woodland. Light OH shelter birch as hazel coppice. Frost and weed competition.	41/528383
278		S.E.(E)	Buriton Forest, C.26, Hants.	1/47	Chalk down	550	4	E.	2	Chalk	25	Lb	2	Mull	36	25.0	17	—	Alternate rows larch, beech same height.	41/729184
279	A.41	S.E.(E)	Micheldever Forest, Stratton, C.27, Hants.	3/50	Chalk down	400	—	E.S.E.	2	Chalk	40	Lm	2	Mull	33	11.2	17	—	Alternate rows beech, larch on chalk down with some scrub. Hardwood shelter belt to W.S.W.	41/533427
280	A.23	S.W.(E)	Ebworth/Salteridge, Glos.	3/50	High on Hill Crest.	800	9	W.S.W.	3	Oolitic lime jurassic.	35	Lm	2	Mull	32	9.0	18	—	Beech with 33% larch on grassland. Peg pruned. Canker bad on beech and larch.	32/891111
281	A.43	N.E.(E)	Ledston Hill, Yorks.	5/50	Dip slope	130	12	S.W.	3	Magnesian limestone permian.	40+	Lm	2	Mull	26	12.1	19	—	Alternate rows beech and birch on grassland with some thorn giving much side shelter.	44/436287

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics Height	Age	Girth	Remarks	Map Ref. Nat. Grid
282	A.25	S.W.(E)	Kingscote, Glos.	3/50	Steep valley side	430	23	S.E.	1	Oolitic lime jurassic.	50+	Lb	2	Mull	30(*a*) (*b*)	12.2 15.6	15 to 20	—	Natural beech under mother trees cleared (somewhat late) in 1949. Rodents and canker.	32/833973
283	A.26	S.W.(E)	Kingscote, Glos.	3/50	Steep valley side	425	23	S.S.E.	1	Oolitic lime jurassic.	60+	Lm	2	Mull	30	16.0	20?	—	Similar but more light here at edge of wood	32/833974
284	A.27	S.W.(E)	Kingscote, Glos.	3/50	Steep valley side	450	20	S.S.E.	1	Oolitic lime jurassic.	60+	Lm	2	Mull	30	6.5	12 to 20?	—	Similar but beech rather heavily suppressed.	32/833974
285	A.4	S.E.(E)	Buriton Forest, Hants.	1/50	Valley side	500	12—15	E.S.E.	1	Loam over chalk.	56	Lm	2	Mull	36	10.3	20	—	Grassland scrub with alternate rows beech and larch. Severe frost on both.	41/730194
286	A.39	S.E.(E)	Crawley Forest C.7, Hants.	3/50	Downland	360	2	S.S.W.	3	Loam over chalk.	50	Lm	2	Mull	31	10.0	21	—	Chalk Pasture, some thorn scrub. Alternate rows beech and larch. Frost.	41/423358
287	A.40	S.E.(E)	Crawley Forest C.7, Hants.	3/50	Downland	370	2	S.S.W.	2	Loam over chalk.	35	Lm	2	Mull	31	4.3	21	—	Beech and larch on chalk pasture. Severe frost and drought.	41/423359
288		E.(E)	Thetford Forest. High Lodge, C.205, Norfolk.	3/47	Flat Heath	125	0	—	2	Chalky drift	35	Sb	2	Mull	23	30(D)	21	—	2 rows CP x 2 rows beech; pine thinned	52/835835
289		S.E.(E)	Westdean Winden, Sussex	1/47	Chalk dip slope	550	4	S.	2/3	Chalk	20	Lb	2	Mull	36	23.0	21	—	Equal mixture beech/larch.	41/835167
290	A.38	S.E.(E)	Crawley Forest C.1, Hants.	3/50	Downland	425	3	N.E.	3	Loam over chalk.	35	Lm	2	Mull	31	13.6	22	—	Ploughed 1914-18. Pasture with occl shrubs when planted beech and larch. Frost bad.	41/410347
291	A.16	S.E.(E)	Crawley Forest C.4, Hants.	2/50	Downland	330	—	—	1	Loam over chalk.	25+	Lm	2	Mull	31	6.1	22	—	As above. The two samples show the great influence of soil depth and water retention.	41/406356
292	A.17	S.E.(E)	Crawley Forest C.4, Hants.	2/50	Downland	340	—	—	2	Loam over chalk.	45+	Lm	2	Mull	31	17.1	22	—		41/408356
293	A.18	S.E.(E)	Crawley Forest C.1, Hants.	2/50	Downland	400	5	N.N.E.	2	Loam over chalk.	22	Lm	2	Mull	31	5.5	22	—	As above. A/18 on shallow rendzina. A/19 on retentive loam over chalk.	41/410349
294	A.19	S.E.(E)	Crawley Forest C.1, Hants.	2/50	Downland	440	—	—	4	Loam over chalk.	48+	Lm	2	Mull	31	21.5	22	—		41/409347
295	B.42	N.(W)	Powis Castle, Montgomery	8/50	Valley slope	800	10	S.S.E.	3	Silurian shales	40+	Lb	2	Mull	40	29.0	22	—	Former woodland—beech, oak: cleared oak 50%, beech 25%, larch now gone.	33/202059

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics Height	Age	Girth	Remarks	Map Ref. Nat. Grid
296	A.80	N.W.(E)	Thornthwaite Forest C.6, Cumb.	8/50	Steep slope	300	18	W.S.W.	1	Ordovician shales.	60+	Lb	2	Mull	55	21.5	23	9.3	Former woodland—cleared. Pure beech amenity strip.	35/236273
297	B.31	S.(S)	Duns Castle, Berwick.	8/50	Gentle slope	500	5	S.S.E.	2	O.R.S. and dolerite drift on O.R.S.	60+	Lm	2	Mull	(D 31	ominan 39	ts) 23	20.0	Former oak and pine wood. Pure beech some shelter from adjoining woods.	36/778554
298		S.E.(E)	Alice Holt Forest, Hants. (Copper Beech.)	1/47	Plain	410	0	—	2	Thin drift on gault clay.	30	Lb C	3	(Mull)	30	43	24	10.5	Plot copper beech after old oak (coccus).	41/799428
299			West Dean, Winden, Sus.	1/47	Chalk dip slope	500	3	E.S.E.	2	Chalk	26	Lb	2	Mull	36	29	24	—	Intimate mixture 66% beech and larch.	41/836165
300			Alice Holt Forest, Hants. (Green Beech.)	1/47	Plain	380	1	N.W.	2	Thin drift on gault clay.	30	Lb	3	Mor	30	30	25	—	Patch of pure beech after old oak.	41/802432
301	B.41	N.(W)	Powis Castle, Montgomery	8/50	Steep valley side	580	15	S.E.	1	Silurian shales	55+	Lb	2	Mull	40	34	25	12½	Pure beech after clearance of former wood (oak, etc.).	33/208061
302	B.33	S.(S)	Bowhill, Selkirk	8/50	Gentle slope	550	5	E.N.E.	1	Drift over silurian shales.	50+	Lm	2	Mull	(D 35	ominan 28.8	ts) 25	15½	Former oak and pine woodland—a few old oak left when pure beech planted 7ft. x 7ft.	36/427276
303	B.59	N.W.(E)	Leaton Knolls, Salop.	9/50	Medium slope	250	10	S.W.	3	Lacustrine over bunter sand.	60+	Lm	2	Mull	25	32.7	25	21	Former oak woodland—cleared ash 25% beech 25% and larch all gone.	33/463171
304		E.(E)	Hardwick, Oxon.	7/47	Chalk ridge	300	5	S.	3	Thin drift on chalk.	40+	La	2	Mull	25	35	26	14	Former woodland—cleared equal mixture beech/larch; larch now out.	41/657780
305	B.10	N.E.(E)	Blubberhouses, Yorks.	5/50	Valley slope	600	8	W.	3	Mixed carboniferous drift on millstone grit.	75+	Lm	2	Mull	28	40	29	20½	Former tillage, oak and beech 3 rows each beech rough with coccus.	44/176552
306	B.48	S.(W)	Penhow, Glam.	9/50	High on valley slope.	500	10	S.S.E.	3	Carboniferous limestone.	45	Lm	2	Mull	45	45	30 to 35	15½	Former woodland—cleared. Beech and few ash planted without shelter.	31/204867
307		Dean Forest.	Highmeadow C.56, Glos.	1/47	Plateau	630	5	N.E./N.	2	Pennant Grit	45	La	2	Mull	38	46	31	—	? Former woodland. Squirrels serious. Equal mixture larch/beech. Bad forms.	
308		Dean Forest.	Blakeney Hill C.424, Glos.	1/47	Hillcrest	550	2	S.	2	Pennant Grit	60+	La	2	Mor	35	50	32	20	Former woodland. Pure beech ex Dean. Bad forms.	

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
309		S.W.(E)	Colesbourne SP.229, Glos.	7/48	Easy ridge slope	700	5	S.W.	3/4	Inf. Oolite	30	Lm	2	Mull	32	38	33	11¼	Larch thinned and underplanted now pure beech.	42/008144
310		S.W.(E)	Colesbourne SP.228, Glos.	7/48	Valley Slope	700	5	N.W.	2	Inf. Oolite	25	Lm	2	Mull	32	45.5	34	15¼	Alternate rows beech and larch following beech/birch.	32/991153
311		Dean Forest.	Abbotswood C.383, Glos.	1/47	Valley slope	480	10	E.S.	1	O.R.S. Conglomerate	76+	Lm	2	Mull	34	54	34	17	Former woodland—cleared nearly pure beech thinned 1945.	32/659116
312		S.E.(E)	West Dean, Sussex	1/47	Chalk ridge	460	25	E.	1	Chalk	16	Lb	2	Mull	36	54	35	20	Former woodland—cleared row about beech / conifers. (C.P., E.L.)	41/814166
313		E.(E)	Chazey Heath, Oxon.	5/47	Plateau	300	4	S.E.	2	Reading Sand	50	Sb	2	Mor	25	49	36	19	Beech / oak / larch on former heath.	41/694773
314		Dean Forest.	Abbots Wood SP.E.189, Glos.	5/50	Valley slope	480	7	S.E.	1	Carb. limestone.	45	Lm	2	Mull	34	54	37	20	Old woodland	32/658113
315		Dean Forest.	Middle Ridge C.243, Glos.	1/47	Crest of Ridge	540	7	W.	3	Coal measures	53	Lb	3	Mor	35	49	37	18	Oak shelter wood, now cleared.	32/639114
316		Dean Forest.	Middle Ridge C.244, Glos.	1/47	Crest of Ridge	550	2	E.	3	Coal measures	30	Clay	3	Mor	35	46	37	19	Pure beech—bad forms. Gleyed soil.	32/642114
317	B.19	N.E.(E)	Raby Castle, Durham	7/50	Top of convex ridge.	620	5	S.W.	3	Millstone Grit	45+	Sa	2	Mor	26	42	37	—	Probably former woodland—beech and larch, etc., now pure beech, sheltering woods to S.W.	45/107225
318	B.26	S.(S)	Dalkeith Lugton, Midlothian.	7/50	Plain	200	3—4	N.	1	Drift on coal measures.	40	Sb	3	Mor	25	45.7	38	30.4	Former damp oakwood—cleared beech 50%, larch 50% (now gone).	36/318676
319	B.27	S.(S)	,, ,, ,,	7/50	Plain	200	4—5	N.E.	2	,, ,,	40	Sb(z)	3	Mor	25	30	38	24	Beech planted under oak (now 130 years and soon to go).	36/313677
320	B.23	S.(S)	Eskdale, Dumfries.	7/50	Steep valley side	180	17	S.W.	1	Drift on lower carboniferous calciferous sandstone.	66	Lm	2	Mor	46	46.5	39	21.4	Former scrubby oakwood—cleared. Pure beech 3½ x 3½ ft.	35/377797
321	B.24	S.(S)	,, ,,	7/50	Top of steep slope.	225	6–13	W.S.W.	2	,, ,,	55	Sb	2	Mor	46	46.2	39	19.7	As above.	35/378797
322		E.(E)	Hardwick, Oxon.	7/47	Chalk ridge	300	5	S.W.	3	Chalk	35	Lm	2	Mull	25	50	39	19	Former woodland—beech, larch + few ash, oak—close spaced.	41/653780

APPENDIX VI(A) (*contd.*). HEIGHT GROWTH TABLE FOR YOUNG BEECH CROPS

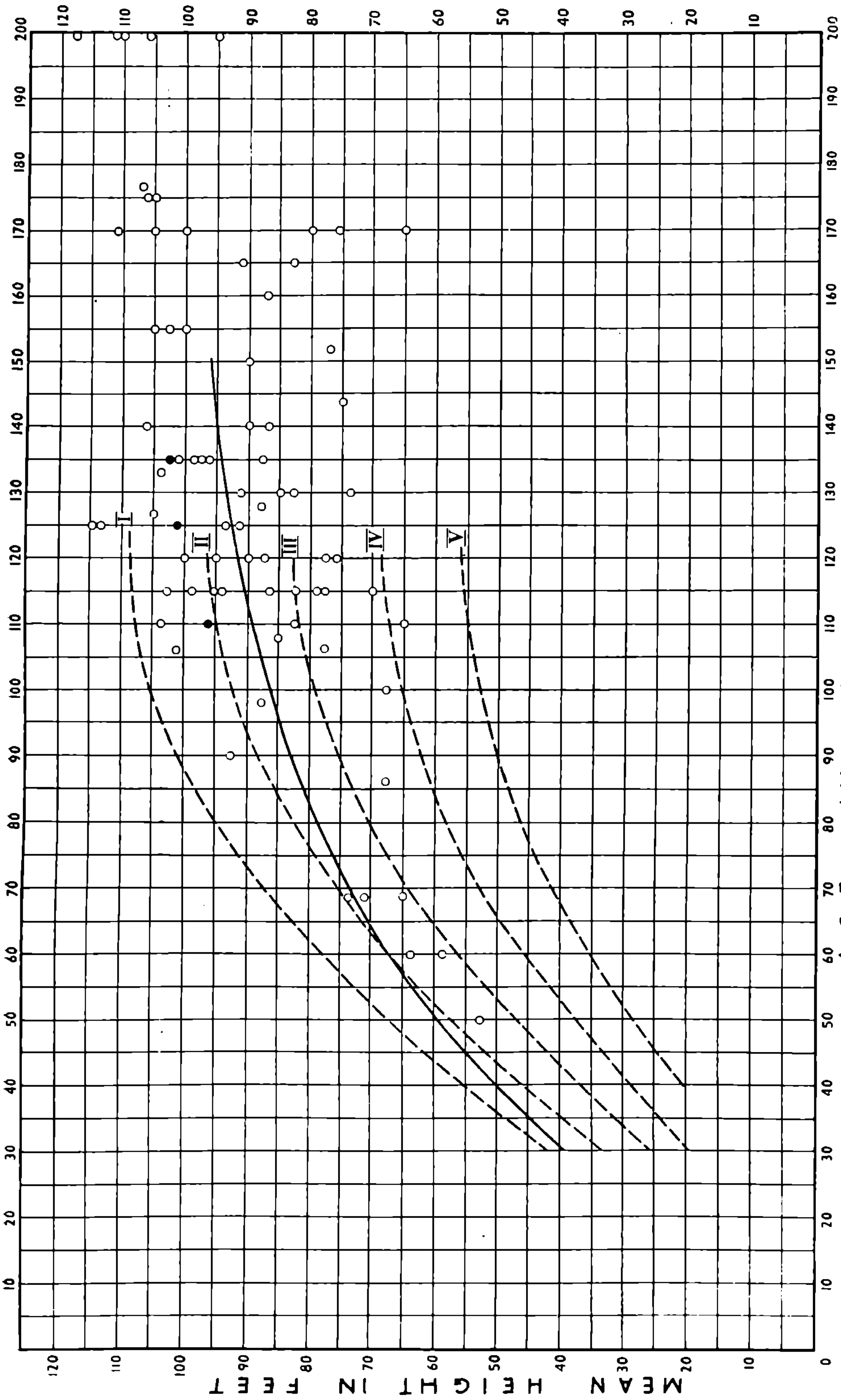
No.	Ref.	Cons.	Name of Wood	Date	Topographic Type	Alt. Feet	Slope Deg.	Aspect	Exp.	Geology	Soil Depth cm.	Texture	Drainage	Humus Type	Rainfall in.	Beech Statistics			Remarks	Map Ref. Nat. Grid
																Height	Age	Girth		
323	B.11	N.E.(E)	Hovingham, Yorks.	5/50	Valley floor	180	—	—	1	Alluvium on jurassics.	55+	Sb	2	Mull	29	(Dominants) 60.8	39	23.9	Former ornamental garden. 50% beech + 50% J. larch—now gone.	44/665758
324		S.E.(E)	Hackwood Park, Hants.	4/47	Chalk upland	590	2	W.N.W.	2	Thin drift on chalk.	50+	Lb	2	Mull	30	64	40	29	Pure beech 6 x 6 ft. on arable field.	41/656470
325	B.21	N.E.(E)	Lambton, Dawsons, Durham.	7/50	Scarp slope	280	8	N.W.	3	Magnesian linestone.	35	Lm	2	Mull	24	37	40	17	Ground formerly worked for limestone. Beech and ash. Thinning overdue.	45/336547
326	B.32	S.(S)	Eildon Hall, Roxburgh.	8/50	Hill slope.	700	10	S.E.	2	O.R.S. marl	40+	Lb	2	Mor	30	40	40	16	Beech planted under pine (now 90 ft. at 120 years)—formerly oakwood.	36/557323
327		S.W.(E)	Cirencester Park, Glos.	1/47	Plain	500	0	—	2	Jurassic limestone.	30	Lb	2	Mull	31	56	42	22	Dominants only: equal mixture beech larch.	32/979021
328	B.3	S.W.(E)	Cirencester Park, New, Glos.	11/49	Plain	480	—	—	1	Oolites on jurassics.	50+	Lb	2	Mull	32	39	43	14.7	Formerly grazing and tillage. Beech and larch alternate rows. Larch cut 1947 rather too late.	32/979021
329	B.56	N.(W)	Stanage Park, Radnor.	9/50	Steep slope to river bottom.	750	12—15	N.	1	Talus on Silurian shales.	60+	Lm	2	Mull	35	52.2	45	26	Former woodland (oak, etc.) equal mixture beech and larch (now gone).	32/331726
330	B.7	S.W.(E)	Blandford Bonsley, Dorset	5/50	Downland top	610	2	E.	3	Thick cl. flints on chalk.	95+	Lb	2	Mull	40	59	47	37	Formerly tilled. Pure beech spaced 8 x 7 ft., bad forms.	31/827084
331	B.55	N.W.(E)	Goggin, Salop.	9/50	Convex valley top	800	12—30	E.N.E.	2	Talus on Ludlow shales (Silurian).	60+	Lm	2	Mull	33	69.2	48	54.3	Former oak woodland (?)—good site pure beech.	32/462659

(See also Graph 4, page 100, and Map, page 76.)

APPENDIX VI(B). YOUNG BEECH SITES CLASSIFIED ACCORDING TO SOIL AND FORMER VEGETATION

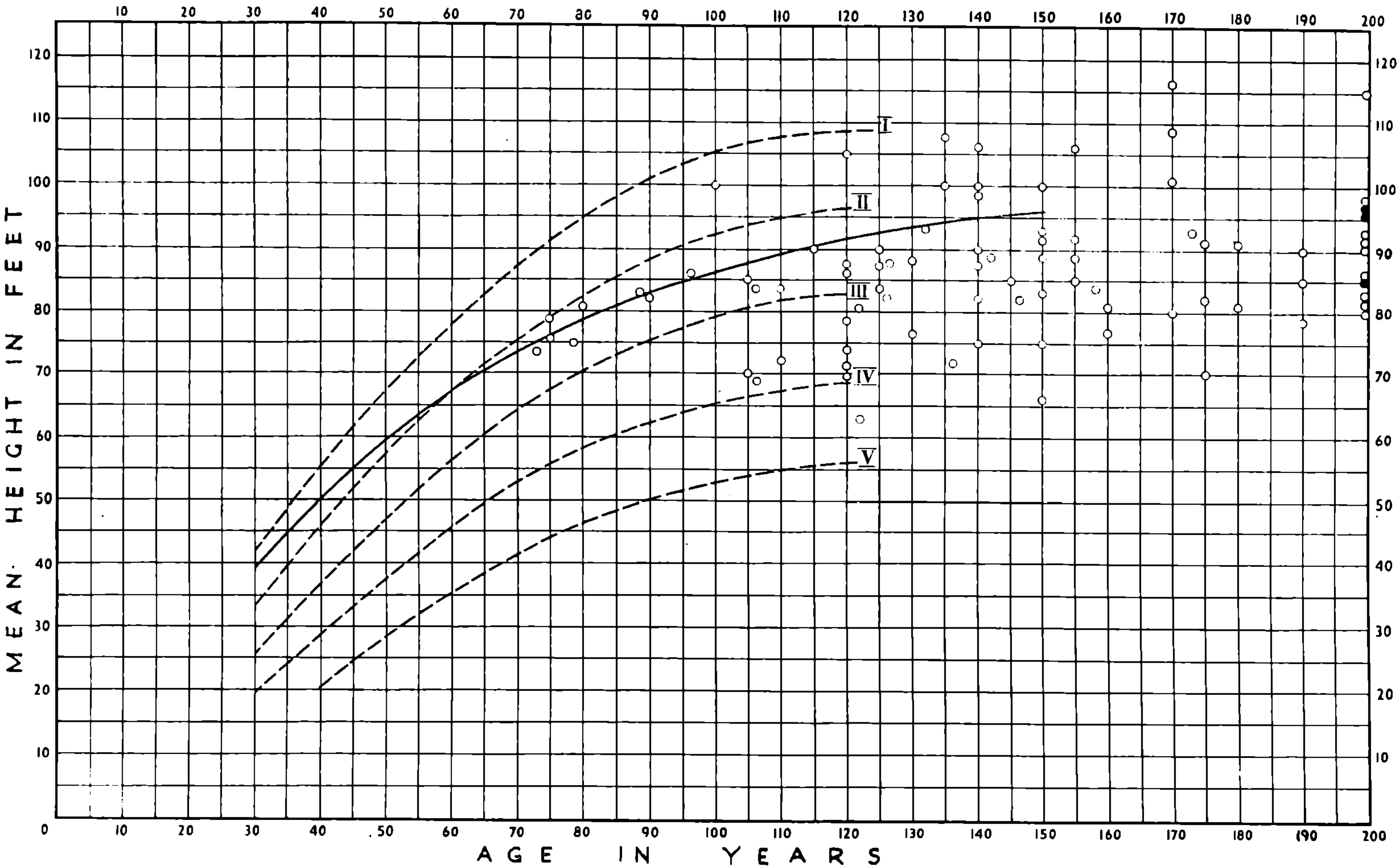
	RENDZINAS				SHALLOW LOAMS ON CHALK				OTHER LIMESTONES				ACID LOAMS								SANDS			
	No.	Forest	Height	Age	No.	Forest	Height	Age	No.	Forest	Height	Age	No.	Forest	Height	Age	No.	Forest	Height	Age	No.	Forest	Height	Age
Pasture or Heath (A)	261	Buriton	6.2	11	292	Crawley	21.5	22	280	Ebworth	9.0	18									288	Thetford	30	21
	285	Buriton	10.3	20					325	Lambton	37	40												
	287	Crawley	4.3	21					327	Cirencester	56	42												
	293	Crawley	5.5	22					328	Cirencester	39	43												
Scrub (B)	236	Gardiner	2.9	5					281	Ledston	12.1	19	267	West Woods	7.9	12					313	Chazey Heath	49	36
	279	Micheldever	11.2	17																				
	286	Crawley	10.0	21																				
	290	Crawley	13.6	22																				
Cleared Former Woodland (C_1)	242	Sledmere	5.0	7	240	Kilnwick Percy	3.9	6	250	Bramham	6.0	9	233	Mellerstain	3.5	3	300	Alice Holt	30	25	235	Hovingham	3.0	4
																	301	Powys	34	25				
	289	West Dean	23.0	21	245	Slindon	4.8	7	306	Penhow	45	33	234	Parlington	5.7	4	303	Leaton	32.7	25	247	Dalkeith	8.3	7
	299	West Dean	29.0	24	266	West Dean	13.3	12	310	Colesbourne	45.5	34	238–	Coxalls	{4.1	5	308	Blakeney	50	32	257	Maiden Brad-	9.7	10
													239		6.9		311	Abbotswood	54	34		ley.		
	312	West Dean	54	35	304	Hardwick	35	26					243	Raby	{2.4	7	314	Abbotswood	54	37	307	High Meadow	46	31
															5.0		316	Middle Ridge	46	37				
					322	Hardwick	50	39					244	Lambton	7.8	7	320	Eskdale	46.5	39	317	Raby	42	37
													258	Brecon	9.0	10	329	Stanage	52.2	45	318	Dalkeith	45.7	38
													260	Walcot	8.1	11	331	Goggin	69.2	48	321	Eskdale	46.2	39
													261	Thornthwaite	9.4	12					323	Hovingham	60	39
													295	Powys	29	22								
													296	Thornthwaite	21.5	23								
													297	Duns Castle	39	23								
Woodland Some shelter left temporarily (C_2)	237	Gardiner	5.6	5	246	Slindon	5.2	7	283	Kingscote	16.0	20	241	Micheldever	5	6	298	Alice Holt	43	24	319	Dalkeith	30	38
	254	Buriton }	6.7	9	251	Slindon	7.0	9	309	Colesbourne	38	33	248	Collingbourne	4.2	8	302	Bowhill	28.8	25				
	255		8.3																					
	272	Charlton	8.6	15	253	Charlton	4.7	9					249	Collingbourne	5	8	315	Middle Ridge	49	37				
	275	Buriton	13.0	15	259	Collingbourne	9.6	10					256	Haldon	14	10	326	Eildon Hall	40	40				
	276	Buriton	25.0	16	268	} Collingbourne	16.6	13					262	Micheldever	8.1	11								
					269																			
					270	Buriton	17.0	14					263	Micheldever	8.6	11								
					273	Charlton	16.0	15					264	Micheldever	10-5	11								
Formerly Cultivated (D)	278a	Buriton	25.0	17	324	Hackwood	64	40					305	Blubberhouses	40	29								
	278b	Buriton	29	21									330	Blandford	59	47								
	278b	Buriton	29	21																				

(See also Graph 4, page 100.)



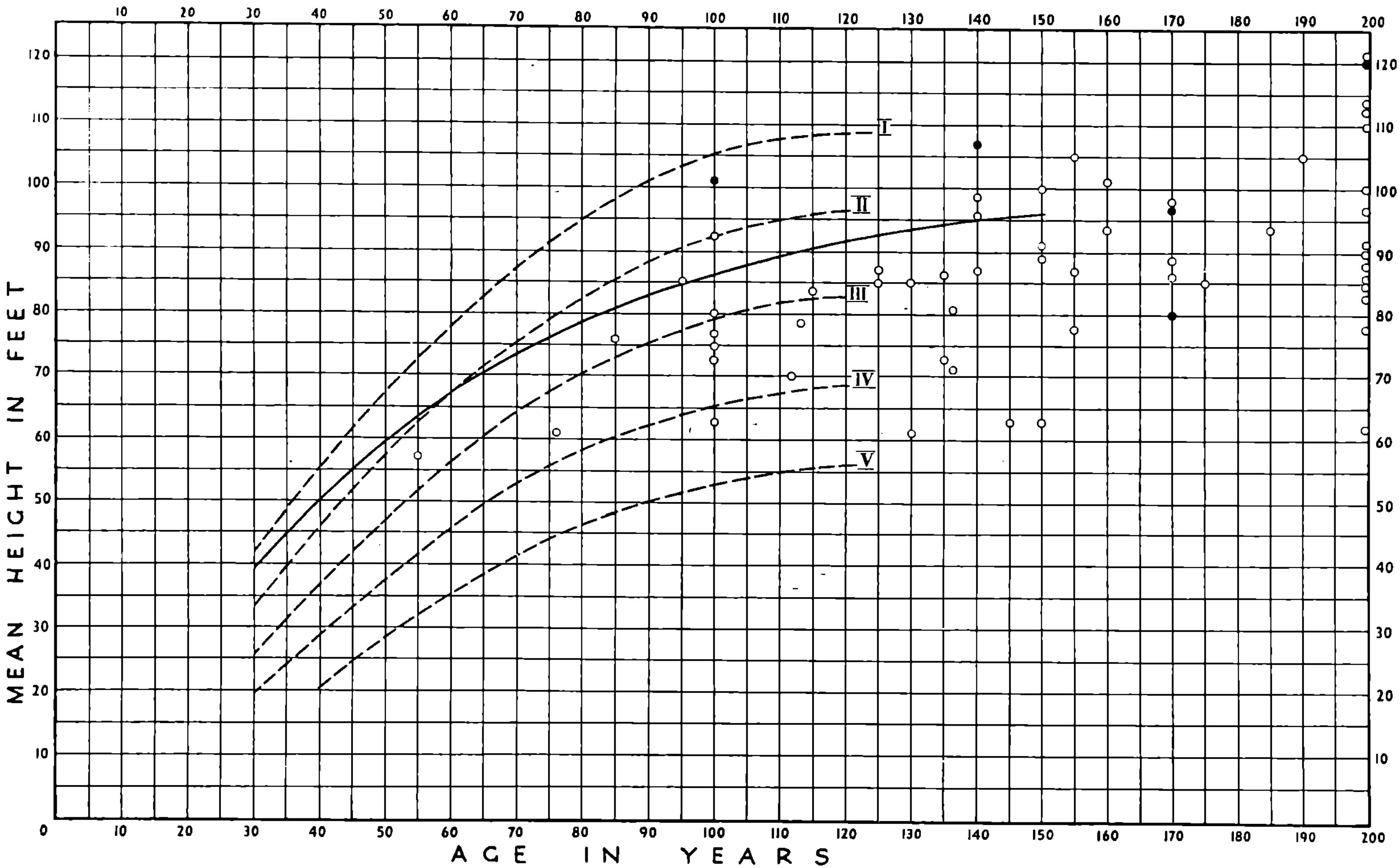
GRAPH I. Beech height growth in Britain: 50—200 years. Chalk and Limestone soils. Each sign ○ stands for one record, ● two records. (*Data from Appendix I*)

Dotted curves are from Møller's Danish yield tables, Quality Classes I to V. The full curve is a mean of earlier records from English temporary sample plots, none of which was on a greatly exposed site.



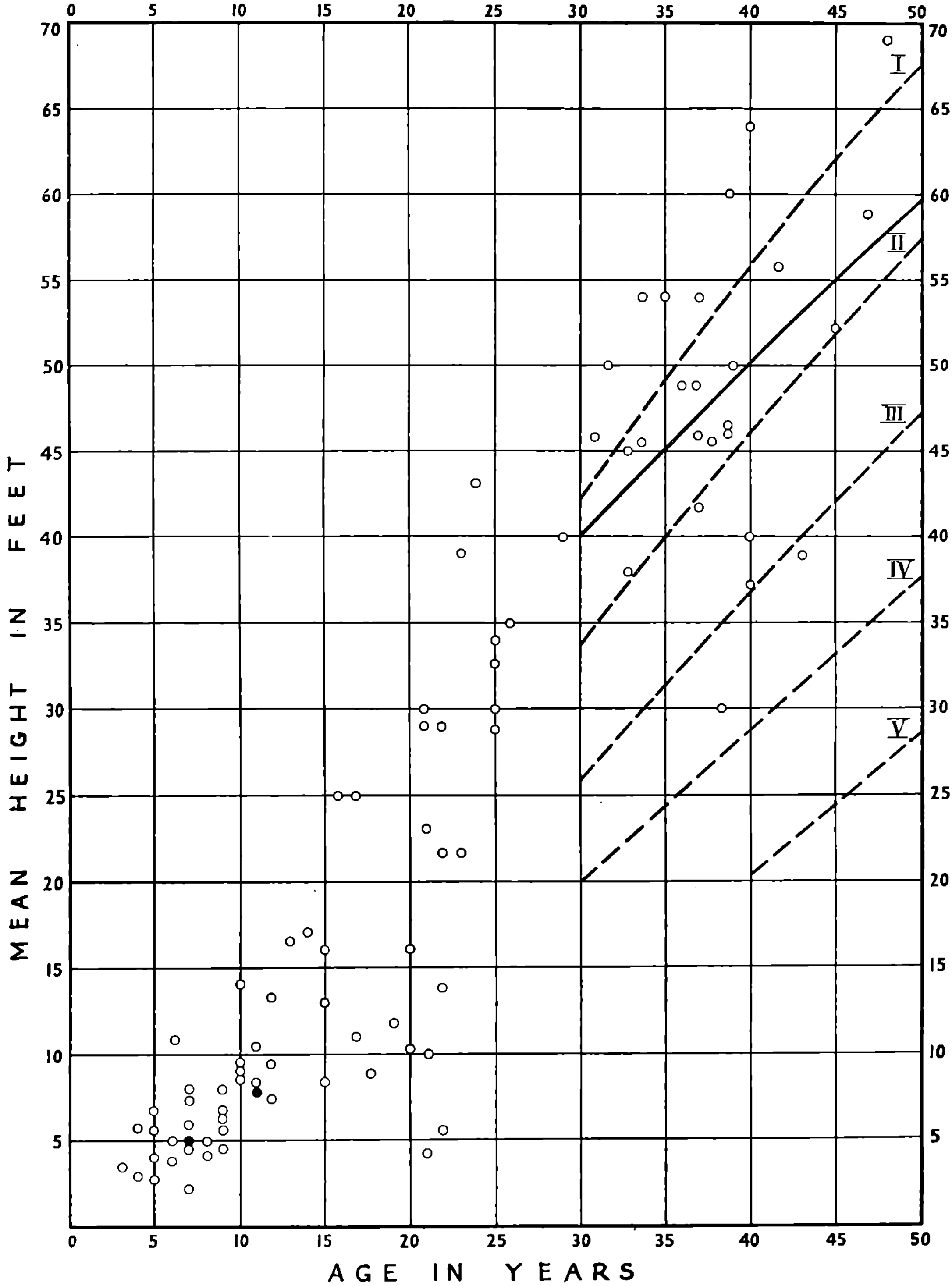
GRAPH II. Beech height growth in Britain: 50-200 years. Non-calcareous loams. Each sign O stands for one record, ● two records. (*Data from Appendices II and III*)

Dotted curves are from Møller's Danish yield tables, Quality Classes I to V. The full curve is a mean of earlier records from English temporary sample plots, none of which was on a greatly exposed site.



GRAPH III. Beech height growth in Britain: 50-200 years. Sandy soils. Each sign O stands for one record, ● two records. (*Data from Appendices IV and V*)

Dotted curves are from Møller's Danish yield tables, Quality Classes I to V. The full curve is a mean of earlier records from English temporary sample plots, none of which was on a greatly exposed site.



GRAPH IV. Beech height growth in Britain 3-48 years. Each sign ○ stands for one record, ● two records. (*Data from Appendix VI*)

Dotted curves are from Møller's Danish yield tables, Quality Classes I to V. The full curve is a mean of some earlier records from English temporary sample plots.

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