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FORESTRY COMMISSION.

BULLETIN No. 3.

Rate

OF

Growth of Conifers

IN THE

British Isles.

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NOTE.

THIS bulletin has been prepared by Mr. W. H. Guillebaud in collaboration with Mr. H. M. Steven and Mr. R. E. Marsden. All three officers have had charge of field parties, for longer or shorter periods—Mr. Guillebaud and Mr. Marsden in England and Wales and Mr. Steven in Scotland—and have therefore an intimate knowledge of the data upon which the bulletin is based.

The first three Chapters of the bulletin deal with the general methods employed in the field and the working up of the collected data into Yield Tables for the principal species. In order to confine the bulletin within reasonable limits, the methods by which the Yield Tables were prepared have not been described in detail. It is hoped to deal with this in subsequent publications.

In Chapters IV. to VIII. the data are submitted to statistical analysis with a view to investigating the effect of locality upon the growth of Larch, Scots pine and Spruce. Care has been taken to avoid as far as possible giving advice on silvicultural problems or stating mere personal impressions.

In one sense the data are fairly exhaustive, for they refer to a large proportion of the pure coniferous woods in the British Isles, and they are based on approximately 300,000 actual measurements. On the other hand the variants such as soil, exposure, elevation and rainfall, which affect timber production are so numerous and alter so greatly in different localities, also the distribution of data in respect of the variants is so irregular, that final results on many of the problems dealt with are not to be expected.

Finally, in Chapter IX. the evidence from the data as to the prevalence of canker in Larch, crown damage in Scots pine and heart-rot in Larch, Scots pine, and Spruce is briefly discussed.

The statement now put forward for publication may prove of use to owners of private forests in indicating the broad limits within which timber production is possible, in urging the necessity of collecting local data and in providing a common standard by which those data may be assessed.

It is desired to thank woodland owners for the many facilities which they have afforded to the field parties which carried out the survey, and for their readiness in permitting sample trees to be felled in their woods.

R. L. ROBINSON
Commissioner.

FORESTRY COMMISSION,
22, GROSVENOR GARDENS,
LONDON, S.W.1.

June, 1920.

Bulletin No 3.

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IN THE

BRITISH ISLES.

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RATE OF GROWTH OF CONIFERS IN THE BRITISH ISLES.

CHAPTER I.

The Survey.

A survey for the collection of statistics as to the rate of growth and production of timber was begun in the summer of 1917, at a time when the large demands for timber required for military purposes and the mining industry were being met mainly from British woods. Extensive fellings were in progress in all parts of the country, and negotiations were proceeding on all sides for the sale of standing timber.

These abnormal conditions offered a unique opportunity for the collection of forest statistics. In order to obtain results which should be generally applicable throughout the country, data had to be collected from woods growing under all conditions. Emergency fellings were so widespread, and landowners were so generous in allowing sample trees to be felled in standing woods, that there was no lack of material. That a great proportion of the middle-aged and old coniferous crops in the country were being swept away was an additional reason for action.

It will be generally admitted that hitherto there has been an almost complete lack of accurate information with regard to the rate of timber production in this country. Larch, for instance, is very widely grown throughout the British Isles, but its growth has not been studied in detail; thus it has not been possible for the owner of a young Larch plantation to form any reasonable estimate of its probable future production in terms of volume or money; or for an intending planter to compare its future yield with that of several alternative species. Again, very little is known as to the effect of the various factors of locality, such as elevation or soil, on the growth of the various species of trees. It was felt that a comprehensive survey carried out on uniform lines should throw light on these and similar problems.

Owing partly to the rapid disappearance of our coniferous plantations and partly to the somewhat different nature of the problems involved in measuring broad-leaved woods, it was decided to confine the investigation to the coniferous species.

Objects of the Survey.

The principal objects kept in view were as follows :—

1. To study the development of coniferous trees grown under silvicultural conditions in the British Isles.

2. To construct tables of production (Yield Tables) for the principal species. In such tables it is possible to trace the

relation between the different factors (height, basal area, etc.) as exhibited by woods with varying rates of growth.

3. To obtain material by collecting data from widely distributed woods for studying the influence of soil and environment upon the growth of the different species.

4. To construct Volume Tables, *i.e.*, tables showing for a given species the average volume of trees for a given height and girth, for use in estimating the volumes of standing crops.

5. An additional object of the investigation was to provide information on methods of measuring felled and standing trees, and on the thickness of bark, degree of taper, etc., in the different species.

Date of Commencement and Organisation of Survey Work.

The collection of data was begun in England in August, 1917, under the Forestry Branch of the Board of Agriculture. Careful instructions as to method were issued to the officer in charge of the field work, and though certain modifications became necessary in course of time, by the end of the first year the final lines had been established. These instructions are embodied in Bulletin No. 1 of the Forestry Commission.

In December, 1917, a survey on the same lines was begun in Scotland under the Board of Trade, Timber Supply Department (Scotland). The same methods were used, and the officer in charge of the unit was previously attached for a time to the original party in order to ensure uniformity. The work was extended to Ireland in February, 1919, where it was carried out under the Department of Agriculture and Technical Instruction for Ireland. Uniformity in the various countries was further secured by conferences between the officers concerned.

The work was carried out by women assistants under the supervision of trained forest officers. The women received their training in the field. The inspection of woods, selection and survey of sample plots, marking of thinnings, etc., were made by the officer in charge; the actual measurement of the trees and the working up of field data being in the hands of the women assistants.

As a rule each officer worked with two sub-parties of three women each, one of the women in each sub-party acting as forewoman.

For the greater part of the time two parties worked in England and two in Scotland, operations being continued all the year round.

It is difficult to speak too highly of the services of the women assistants; the accuracy of their work and their conscientiousness have been beyond praise. In the face of many discomforts, due to working in all weathers and to incessant changes from place to place, they have been invariably cheerful and willing to do more than was asked of them.

Methods of Survey.

The measurement of uniform, well-stocked sample plots in pure coniferous woods has formed the basis of the survey. By "well-stocked" is meant that the leafy canopy is reasonably complete for the species and age under consideration. The reason for insisting upon the measurement only of well-stocked woods is that the *average* stocking in any one wood of a given species and age may differ very greatly from that of a similar wood in another locality, while it may be possible to find well-stocked areas in both woods which are comparable. Moreover, the development of incompletely stocked woods will differ from that of fully stocked crops, and it is impossible to adjust the data without introducing the personal factor, which should be avoided as far as possible in an investigation of this kind.

For a detailed description of the methods used in measuring sample plots the reader should consult Bulletin No. 1 referred to above. A sample plot comprises a small demarcated block of forest, the area of which is accurately determined. The size of the majority of the sample plots ranged from 0.2 to 0.5 acre; it was considered better to have a large number of small plots than a few plots of, say, half an acre and over. The plots were made as large as possible, but great difficulty was explained in finding pure, uniform, well-stocked areas of any size.

The procedure within the sample plots was briefly as follows:— A thinning was marked to remove only dying, suppressed trees and whips, together with any stems whose crowns were badly hemmed in. This was done with the object of indicating the maximum main crop which the soil had produced. A light thinning of this kind had also the practical advantage of enabling the instructions to be made so explicit as almost to eliminate the personal factor, an important consideration when the work had to be carried on by several officers working in different districts.

The trees of the main crop were numbered, girthed at breast-height (4 ft. 3 ins. above the soil), and classified on paper according to Hartig's method* into five groups containing equal basal areas. The mean sample tree was then calculated for each group, and two sample trees in each group (*i.e.*, ten trees in all) of mean girth at breast height and typical form were selected in the sample plot, felled, and measured on the ground. From the volumes of these felled sample trees the volume of the plot was calculated in the usual way. The area of the sample plot being known, the corresponding figures per acre were readily obtainable.

If an appreciable number of trees were marked for removal as thinnings, sample trees from these also were felled.

A detailed description of the plot, giving elevation, aspect, soil, etc., was made on the spot by the officer in charge.

In addition to these plots a certain number of smaller areas about 0.1 acre in size were measured, chiefly in young woods. These have been called sub-plots. They have been treated in the same way as the plots, but the volume determination has been made usually from the measurements of three sample trees selected as the mean of all the trees in the sub-plot.

Sub-plots were taken in woods where larger plots were unobtainable; the data from them have not the same degree of accuracy as those from the plots.

During the course of the survey many woods were found where the timber had been felled but not removed. In order to make use

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* Details as regards the different methods of measuring the volumes of standing crops are given in Schlich's Manual of Forestry, Vol. III., pp. 43-70.

of the opportunity presented for measuring trees on the ground, groups of about twenty average stems were measured by the field parties, and the usual descriptions of locality recorded. A total of 9,750 trees in 405 woods was measured in felled groups in England.

Where large tracts were covered with mixed forest and suitable sample plots could not be found, material for studying the relative development of different species was obtained by means of measurements in pure clumps. The procedure followed was to girth thirty to fifty trees of the main crop and to calculate the mean girth; trees having a girth corresponding to this mean were then selected, felled, measured, and crosscut into sections for height analysis. One hundred and twenty groups were taken in Scotland and twenty in England.

The data from felled areas and groups are not included in this publication except in connection with heart-rot (see pp. 62-63).

Degree of Accuracy of Sample Plot Measurements.

Eleven Larch plots were measured by the methods described above and then clear-felled, all the trees being measured on the ground. A comparison between calculated and felled volume showed that the limits of error were + 5.2 per cent. and – 2.7 per cent., the mean error being + 0.2 per cent.

For Scots pine, 5 plots similarly treated showed the following limits of error: + 4.4 per cent. and – 1.6 per cent., the mean error being + 2.3 per cent.

The quarter-girth system of measurement has been used throughout the survey. This system was adopted in preference to that employed on the Continent, in which the diameters are measured by callipers, for the following reasons:—

(1) The quarter-girth system is always used in practice in this country.

(2) The tape is the simplest method of measurement, and requires less physical effort than the callipers, an important point when the measurements were carried out by women.

(3) A comparative series of measurements were made with tape and callipers on about 2,000 trees. The test was complicated by the difficulty of obtaining reliable callipers, but the conclusion reached was that where both methods of measurement are accurately carried out the difference in result is negligible.

In this connection it may be said that the cubic foot "quarter-girth measure" is as absolute a unit of measurement as the cubic foot "true measure." The relation between the two standards is represented by the ratio 1 : 1.273, *i.e.*, cubic feet quarter-girth x 1.273 = cubic feet true girth.

Sample trees were measured over bark and under bark at half the length of the stem measured down to three inches diameter. For comparative purposes many of the trees were measured also in ten-foot sections.

Distribution of Plots and Sub-Plots.

The following table summarises the distribution of the sample plots measured in England, Scotland and Ireland to December 31, 1919.

Species.	England & Wales.		Scotland.		Ireland.		Totals.	
	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.
European Larch ...	221	82	135	9	28	6	384	97
Scots Pine	130	22	170	2	8	2	308	26
Norway Spruce ...	53	28	59	9	5	3	117	40
Japanese Larch ...	14	5	20	8	—	—	34	13
Douglas Fir ...	20	7	10	6	—	—	30	13
Corsican Pine ...	12	4	3	1	—	—	15	5
Other Conifers ...	6	3	4	5	—	—	10	8
Totals	456	151	401	40	41	11	898	202
Total Plots& Sub-Plots	607		441		52		1100	

It will be seen that a grand total of 1,100 sample plots and sub-plots was measured in the three countries. Of these 481 were European larch, 334 Scots pine and 157 Norway spruce.

A detailed classification by counties will be found in Appendix C, pp. 78-80.

CHAPTER II.

Yield Tables for Larch, Scots Pine and Spruce.

Classification into Quality Classes.

The rate of growth of woods of the same species varies greatly in different localities. Local conditions, such as type of soil, amount of rainfall and degree of shelter, all exert a marked influence upon the growth. Moreover, the development of a wood is a complex process; thus the rate at which it grows affects, among other factors, its mean height and girth, number of stems and volume per unit area. When, too, the facts are realised that every gradation exists between woods of the fastest and slowest growth and that every variation in age is met with, it becomes clear that little is to be learned as to the course of development of a species as a whole from the study of individual woods unless these are first classified in some simple manner according to rate of growth. If, for a given species, a limited number of classes are formed which cover the range of rate of growth found, then it will be possible to refer to its class a wood of any age and subsequently to forecast its probable development with some degree of certainty.

These standard classes are known as Quality Classes, and the methods employed in determining them are of first importance. Generally speaking the chief object aimed at in commercial forestry is to produce in the shortest time the largest possible volume of timber of sufficiently good quality for the object in view. It would seem natural then to adopt volume production as the basis of classification into Quality Classes, in which case the sample plots would be divided into a series of classes graded according to the volumes produced for their respective ages. Thus the first or best class would contain those plots which had produced most timber for their age, and so on in more or less equal proportion down to the last class, which would contain the slowest growing plots producing the least volume for their age. Examination of the plots within each class would follow, resulting in the construction of mean curves for height growth, girth increment, etc., from which a Yield Table would be built up embodying these mean values.

This method gives reliable results if the woods in which the sample plots are taken be uniformly stocked and have been systematically treated in the past. Continental Yield Tables which have been constructed mainly in State-owned forests under continuous management are compiled more or less on these lines. In Britain, however, it was recognised that we were dealing with woods which had been subjected to widely differing methods of treatment. Thus some of the woods had been left for many years unthinned, others had been thinned at irregular intervals, while the intensity of thinning had varied from wood to wood. Hence localities really equal in yield capacity, owing to diversity in past treatment, may appear to belong to distinct Quality Classes when classified according to volume produced at a given age.

There remains, fortunately, another means of classification, namely, *height*. Height is so closely related to volume that wherever Yield Tables are in use height is employed as the index to quality. Using height as an index it is not necessary when assessing the quality of a given wood to determine its volume and to compare it with the volume at a corresponding age from the Yield Table, but merely to estimate the mean height of the crop and so by reference to the Tables to ascertain its Quality Class. Further, investigations on the Continent show that height is relatively little affected by different methods of treatment, and is certainly far less sensitive to disturbing influences than volume. In view of this last consideration it was decided to base the classification of woods upon height rather than upon volume, and the following system was adopted :—

The sample plots were classified according to the heights reached at a standard age. An age of 50 years was selected for the following reasons :—

(a) By the time a coniferous wood is 50 years old all the factors of locality should have found decisive expression in the growth of the crop, and the height growth at that age should be a reliable index to the quality of the wood. Exceptions occur, but are not likely to be numerous.

(b) It was desirable to take the lowest age at which these factors had produced decisive effect, as the lower the standard age, the fewer sample plots need be excluded from the preliminary classification and the more data will be available for constructing the height curves upon which the final classification depends.

Ten feet of height at 50 years formed the range of growth for each Quality Class, and the mean height was fixed at a multiple of ten feet. This mean height gives its name to the class. For example, the best Quality Class of Larch found in Britain is the 80-ft. class, by which is meant that the mean wood of that class attains the height of 80 ft. at 50 years, the upper and lower limits being 85 ft. and 75 ft. respectively. Similarly the 50-ft. or third class has a range of from 55 ft. to 45 ft. at 50 years, with a mean of 50 feet.

The sample plots of 50 years of age and over were temporarily allotted to their respective classes by means of mean age-height curves; these have been prepared for each sample plot from the sectional analysis of three of the sample trees. The height of each sample plot at 50 years was read off the curve and the plot assigned to its appropriate height class. The next process was to construct a mean age-height curve for each class by averaging the age-height curves of all the plots falling into that class. The trend being thus obtained, the mean Quality Class curves were drawn to pass through the heights of 80, 70, 60 feet, etc., at 50 years. The combined graphs were completed by interpolating a limiting curve between each pair of means; the limiting curves pass through the heights of 85, 75, 65 feet, etc., at 50 years. Curves constructed in this way for Larch, Spruce and Scots pine are shown in Appendix B.

The range of height class in Larch and Spruce is from 80 ft. to 40 ft. and in Scots pine from 60 ft. to 40 ft. In the first two species the Quality Classes are numbered from I. to V., Quality I. being the 80-ft. class and Quality V. the 40-ft. class. In the case of Scots pine the Quality Classes are numbered from I. to III., Quality I. being the 60-ft. class and Quality III. the 40-ft. class. Sample plots belonging to poorer qualities than the 40-ft. class were measured in all three species, but there were not sufficient data from which to construct curves or tabular statements.

All plots of each species were finally classified according to the height attained at the time of measurement; for example, a Spruce plot 70 years old and 60 feet in height falls on the Spruce graph between the 45 ft. and 55 ft. limiting lines, and belongs accordingly to the 50-ft. height class.

The younger plots below 50 years of age, which, owing to the nature of the classification, could not be used for constructing the Quality Class curves, were also assigned to the classes to which they belonged. For example, a Spruce plot 30 years of age and 45 ft. in height falls on the graph between the 75 ft. and 85 ft. limiting lines, and thus belongs to the 80-ft. class.

Construction of Yield Tables.

The classification of all plots of a species into Quality Classes enables the development of the remaining factors, *e.g.*, mean girth, number of stems per acre, volume per acre, etc., to be traced and tabulated in the form of a Yield Table.

A Yield Table for any species presents in tabular form the continuous development of average crops of each Quality Class into which the Yield Table is divided. It expresses further the average method of treatment of the woods from which it has been built up, and is strictly applicable only to woods which have received this average method of treatment.

It is proposed to describe more fully in subsequent publications the methods employed for tracing the development of the growth factors other than height. Briefly the process was as follows:—Graphs were constructed for each species and Quality Class, whereon the separate factors were plotted against height. Thus, in the case of Larch, the volumes of all sample plots in the 80-ft. class were plotted against their corresponding heights and a curve drawn which expressed the mean relationship between height and volume for that class. Graphs were similarly constructed for each of the remaining classes.

The other factors, quarter-girth, number of stems per acre and basal area per acre were treated in the same way. Finally, in each Quality Class the age was tabulated at five-year intervals (*i.e.*, at 5, 10, 15 years, etc.) to the end of the period given in the Yield Table; the heights corresponding to those ages were read off the height curves and entered in the next vertical column of the Table. Then for these heights the corresponding quarter-girth, number of stems, basal area and volume were obtained from the graphs of those factors and entered in the succeeding columns. The form factors were derived by calculation from height, basal area and volume at each five-year period.

Owing to the lack of any periodic measurements there are no direct data available for thinnings, and the values given in the last columns of the Yield Tables have been derived by indirect methods. The figures for thinnings should be accepted with caution, not as representing what has actually been removed in the past, but merely as reasonable estimates.

Yield Tables have been constructed on the above lines for Larch and Spruce in the British Isles and separately for Scots pine in England and Scotland. The division of the Scots pine was rendered necessary by the following considerations:—Although the height growth is so similar in both countries that the same height curves could be derived, it was found when the sample plots in each Quality Class were examined that the data from the two countries could not be combined. In Scotland the number of trees, basal areas, and volumes per acre were consistently higher than in England, though the remarkable fact appeared that the relationship between quarter-girth and height was not affected by this difference in stocking. No certain explanation can be given as to the cause of this difference.

The political boundary between the two countries has been adopted as forming a convenient division, but in point of fact there is no well-marked line of demarcation separating one type of growth from the other.

Yield Tables for European larch, Scots pine and Norway spruce will be found on pages 65 to 74 in Appendix A. Factors are given for converting the figures into the metric system and also a table showing the proportion of bark in the three species.

The final ages given in these Yield Tables are respectively 80, 100, and 70 years, the periods being limited solely by the data available. Individual sample plots up to 141 years of age have been measured in Scots pine and up to 120 years in Larch, but the number of these older plots was not sufficient to justify the prolongation of the curves.

Application of Yield Tables.

The figures in a Yield Table are averages compiled from a large number of woods situated in varying localities. The variations among individual woods from the mean figures are considerable, and this fact has to be borne in mind when the tables are applied to a single wood. It follows that the direct application of Yield Tables is limited to such cases where average figures suffice, and that they will prove most reliable, not for any particular wood, but for comprehensive estimates dealing with a series of woods spread over a large area. They cannot, for example, be used accurately to determine the sale or purchase value of a single wood.

The application of a Yield Table to a given wood depends first and foremost upon the assessment of the Quality Class of the component stands, and, as already remarked, this may be done by determining the mean age and height of each stand. For example, if a Larch wood 40 years old has a mean height of 58 ft., reference to the height curves for Larch shows that this wood falls within the 70-ft. class. By assessing in the same way the Quality Class of every stand in the forest it may be ascertained what proportion of the whole area falls in each class, thus securing a basis for determining the economic treatment. Caution is needed in determining the Quality Class of young woods. A severe check in early life may cause a 20-year old wood of, say, Scots pine to appear to belong to the 40-ft., or even the 30-ft. Quality Class, while the same wood in 30 years time may have developed so rapidly as to bring it into the 50-ft. class.

It seems likely that in Britain the greatest practical utility of Yield Tables at the present time is in connection with problems of replanting and afforestation. On large areas suitable for planting operations there are generally to be found a few scattered plantations of one or more species, and by comparing their mean heights with the height graphs some indication may be obtained as to the Quality Class of the area for these species. When the quality of the locality has been determined the tables can be applied in order to assess the probable production, the rotation, and so on. As, however, they are prepared for fully-stocked areas it is necessary to employ a reducing factor to allow for land not actually planted, such as rides, etc., for possible damage by wind, fire, insects and fungi. The actual factor will depend upon the nature of the area to which the figures are applied.

The tables of thinnings are intended to apply to fully-stocked woods under steady, continuous management. Irregularity in the intervals between thinnings, and especially deficient or excessive stocking, would involve considerable modification in an estimate of intermediate returns.

A special warning is needed as to using the Yield Tables as a guide to treatment. These tables are calculated from figures collected in woods managed on different lines all over the United Kingdom, and represent a mean of the growth which has been obtained under the various methods of treatment adopted. They cannot be relied upon to show more than this.

Comparative Rate of Growth of Larch, Scots pine and Spruce.

The Yield Tables enable a comparison to be made of the rate at which average woods of Larch, Spruce and Scots pine develop in Britain. In the following extract from the tables the 60-ft. Classes of Larch and Spruce are compared with the 50-ft. Class of Scots pine. These classes are taken as representing an average rate of growth for the respective species.

	Larch, 60-ft. class.	Scots pine, England, 50-ft. class.	Scots pine, Scotland, 50-ft. class.	Spruce, 60-ft. class.
		AGE 10 YEARS.		
Height in feet ...	11	10	10	9
		AGE 30 YEARS.		
Height in feet	39½	31	31	36½
Mean quarter-girth (inches) ...	4¼	3¾	3¾	4
Number of stems per acre ...	800	1040	1230	1310
Basal area per acre (sq. ft.) ...	100	93	116	146
Volume per acre (cu. ft.)... ...	1460	1130	1300	2140
		AGE 70 YEARS.		
Height in feet	74	62½	62½	75
Mean quarter-girth (inches) ...	9¾	9½	9½	11¾
Number of stems per acre ...	220	270	325	230
Basal area per acre (sq. ft.) ...	147	169	199	224
Volume per acre (cu. ft.) ...	3910	4060	4880	6730

It will be seen that in early youth Larch grows fastest and Spruce slowest. This "hanging back" of Spruce is typical of the species, and is found in all qualities. In volume development, however, Spruce takes the lead at an early stage and maintains it throughout life. As shown in the above table Spruce yields at thirty years of age 50 per cent. more volume of timber per acre than Larch, and nearly double the volume of Scots pine. At seventy years of age the average Spruce wood contains one and three-quarter times the volume of the average Larch wood and one and a-half times the volume of the average Scots pine wood. Moreover, at this age every quality of Spruce except the poorest carries a higher volume per acre than even the best qualities of Larch or Scots pine.

At thirty years of age the average Quality Class of Larch produces a greater volume than the average Quality Class of Scots pine, but in later life the position is reversed.

While the Yield Tables present strictly average figures, a few examples of woods showing exceptional production may be of interest. The characteristic feature of Scots pine in Scotland is the heavy stocking carried throughout life, and especially in old woods. Instances of this are found at Orton and other places on Speyside, also in the Border country at Mellerstain and Jedburgh, where volumes of eight to ten thousand cubic feet per acre were measured in sample plots 120 to 130 years old. For the same age, height and quarter-girth the number of stems and volume per acre in Scotland is greater than in England by fifteen or twenty per cent. The heaviest volume for Scots pine in England was found on the Waverley Estate, in Surrey, where a plot 141 years old produced nine thousand three hundred cubic feet per acre. In the case of Spruce a plot on the Stevenstone Estate, in Devonshire, 51 years old, measured over eight thousand cubic feet, and in Glengarry, Inverness-shire, a plot 56 years old had a volume of ten thousand cubic feet per acre. In High Ashes Wood, Surrey, a plot of Larch on the Lower Greensand produced over eight thousand cubic feet per acre in 88 years.

Comparison of British with Continental Yield Tables.

Comparison with foreign tables is rendered difficult by the absence of a common standard. "Quality I." means a different thing in every table. In the British tables the method of classification adopts the same criterion for all kinds of trees—namely, a standard height for each Quality Class at 50 years of age, and in the statement below there have been selected from the Continental tables those classes whose mean heights at 50 years most nearly approximate to the corresponding British classes.

SCOTS PINE.

Name of Yield Table.			Age in Years.	Mean Ht. ft.	Mean Q.G. Ins.	No of stems per ac.	Volume cu. ft. per ac.
British Tables	1920	England 50-ft. class	30	31	3½	1040	1130
British Tables	1920	Scotland 50-ft. class	30	31	3½	1230	1300
Schwappach	1907	Prussia Quality II.	30	33½	3	1595	1165
Weise	1880	S. Germany Quality II. ...	30	31	2¾	1900	920
British Tables	1920	England 50-ft. class	80	67	10½	224	4470
British Tables	1920	Scotland 50-ft. class	80	67	10½	270	5400
Schwappach	1907	Prussia Quality II.	80	71	8	243	3620
Weise	1880	S. Germany Quality II. ...	80	73	8¾	264	4490

SPRUCE.

British Tables	1920	60-ft. class	30	36½	4	1310	2140
Schwappach	1902	Prussia Quality I.	30	38	3	1500	1400
Flury	1907	Swiss Foot-hills Quality III.	30	36½	3	1800	1860
Von Guttenberg	1915	Tyrolese Alps Quality I. ...	30	33	4¼	970	1960
British Tables	1920	60-ft. class	70	75	12	230	6730
Schwappach	1902	Prussia Quality I.	70	90	8½	312	6850
Flury	1907	Swiss Foothills Quality III. ...	70	80½	7¼	474	7310
Von Guttenberg	1915	Tyrolese Alps Quality I. ...	70	85½	9½	321	8000

LARCH.

British Tables	1920	60-ft. class	30	39½	4¼	800	1460
Gunnar Schotte	1917	Sweden Quality III. ...	30	39½	3¾	790	1460
British Tables	1920	60-ft, class	80	79½	11	185	4300
Gunnar Schotte	1917	Sweden Quality III.... ...	80	80½	10½	127	3700

Some interesting and well-defined points of difference emerge; age for age the numbers of trees per acre are fewer and the mean quarter-girth and basal areas per acre greater in our tables. In some of the Continental tables no class was found which could compare with our better qualities, and the best class in such tables had to be compared with our middle quality. The conclusion is unavoidable that special Yield Tables are necessary for the British Isles.

The growth in height of Scots pine in Britain is fairly similar to that on the Continent. Up to middle age the number of stems per acre is less in Britain than on the Continent, but in later life the figures are much the same, except in Scotland, where the stocking is somewhat heavier. At about 40 years of age the volume production per acre in Britain is approximately the same as that on the Continent, but increases with advancing age until at 100 years old our woods contain 25 to 50 per cent. more.

Spruce develops more rapidly here in early life than on the Continent, but after about 50 years the height growth falls off considerably. Similarly in volume production British woods are heavier up to about 40 years, but in later life lighter by about 20 per cent.

Comparing the British figures for Larch with those of Gunnar Schotte for Sweden,* the rate of growth in height and girth is remarkably similar; up to 30 years of age both countries carry much the same number of stems and volumes per acre, but after this stage the British figures show relatively an increasing number of stems and a heavier volume, until at 80 years the British woods contain half as many stems again and 16 per cent. more volume.

CHAPTER III.

Preliminary Tables for Douglas Fir, Corsican Pine and Japanese Larch, with Notes on Other Species.

In addition to Larch, Spruce and Scots Pine, there are certain conifers which now play an important part in British Forestry.

The most notable of these, Douglas fir, Corsican pine, Japanese larch and Sitka spruce, have been planted in the British Isles fairly extensively during the last twenty or thirty years. At first they were tried as a rule only on a small scale and were generally mixed with other trees. In consequence there are comparatively few pure woods of these species to be found in the older age classes, and it has not been possible to construct full Yield Tables on the same basis as for Scots pine, Larch and Spruce. Sufficient data, however, were available in the case of Douglas fir, Japanese larch and Corsican pine to construct curves for height and volume, and tables have been prepared giving the height and the volume produced for the Quality Classes into which each species has been divided.

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* Report of the Swedish Institute of Experimental Forestry, Vol. II., 1916-17.

Douglas Fir (Pseudotsuga Douglasii).

The statistics obtained refer only to the Oregon (green) variety of this species. In all forty-three sample plots were measured.

Quality Classes were constructed for this species on lines similar to those employed for Larch, Scots pine, etc. The data were found to fall into the following Quality Classes, 110-ft., 100-ft., 90-ft., and 80-ft. (For curves see Appendix B.)

The following table gives the mean height and volume production up to 50 years of age :—

DOUGLAS FIR.

Age in Years.	Quality Class I. (110-ft.)		Quality Class II. (100-ft.)		Quality Class III. (90-ft.)		Quality Class IV. (80-ft.)	
	Mean Height in feet.	Volume cu. ft. under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.
10	24	—	19	—	13½	—	9	—
15	37½	1440	31	840	24½	—	17½	—
20	53	2840	44	2030	37	1360	29	660
25	66½	4060	57	3200	49	2450	41	1740
30	78	5100	68½	4240	59	3380	51	2630
35	87	5910	78	5080	68	4220	59½	3420
40	95	6630	86	5800	76½	4950	67½	4150
45	103	7350	93	6460	83½	5600	74	4750
50	110	8000	100	7090	90	6170	80	5265

The table illustrates clearly the very rapid development of Douglas fir both in height and volume. The trees, however, especially in the older plantations, taper to a marked degree and thus have a low form factor. This may possibly be explained by the previous history of many Douglas fir plantations in this country. Most of them were either mixed with other species which have been suppressed, or they were planted at wide distances, namely, 10-15 feet apart. Some of the younger plantations, which were planted pure and from 4-6 feet apart, show a higher form-factor, but to what extent the form-factor and volume production can be improved in this way has still to be determined.

In the past Douglas fir has been grown principally in localities which produce Larch of the better Quality Classes. For this reason Larch has been selected as a standard for comparison.

Douglas fir was found growing under similar conditions to Larch in several districts, for instance, near Dunster and Luccombe, Somerset; at Warminster, Wiltshire; Llandovery, Carmarthenshire; near Loch Ryan, Wigtownshire; and at several places on Deeside, Aberdeenshire. The statistics from these areas indicate that land capable of growing Larch of Quality Class I. (80-ft.) will also produce Douglas fir of Quality I. (110-ft.), and similarly with the remaining Quality Classes. This, however, can be more definitely determined when Douglas fir is planted on a larger scale. The much faster height growth of Douglas fir has also been shown in other localities, where it has completely suppressed Larch when in mixture with it, notably at Llandinam, Montgomeryshire, and at Taymount, Perthshire.

The Yield Tables show that the volume produced at 50 years by the 110-ft. Quality Class of Douglas fir exceeds that of the 80-ft. Quality Class Larch by about 75 per cent., and a comparison between the other pairs of Quality Classes shows an even greater difference. The evidence, from the limited number of districts where the species could be compared, corroborates these figures.

It should be noted that hitherto Douglas fir has been planted chiefly under favourable conditions; generally at low elevations, in sheltered places and on fertile soils, and its growth indicates that for such conditions Douglas fir is eminently suitable.

In a few instances, however, this species was found to be growing well under relatively unsuitable conditions, for example, at Wimborne, Dorset, where a height of 85 feet and a volume of 4,400 cu. ft. per acre was attained in 43 years on a sandy soil, with a pan near the surface.

It may be of interest to compare with our figures the following abstract from a Yield Table prepared by E. J. Hanslik for Douglas fir in Western Washington and Oregon. (See American Forestry Quarterly, Vol. XII., pp. 440-452.)

DOUGLAS FIR IN WESTERN WASHINGTON AND OREGON.

Age in years.	Quality Class I.		Quality Class II.		Quality Class III.	
	Mean Height in feet.	Volume Quarter Girth cu. ft. per acre.	Mean Height in feet.	Volume Quarter Girth cu. ft. per acre.	Mean Height in feet.	Volume Quarter Girth cu. ft. per acre.
20	36	1650	31	1360	—	1040
30	61	3140	55	2540	44	1960
40	84	5300	76	4280	59	3300
50	102	7100	90	5790	70	4440
60	117	8480	100	6950	79	5260
70	129	9810	108	7850	86	6010
80	139	11150	114	8750	93	6730
90	147	12480	120	9620	99	7470
100	155	13820	126	10520	105	8120
110	163	15070	132	11380	111	8710
120	170	16250	138	12290	117	9220
130	177	17350	143	13070	122	9620
140	184	18370	148	13740	127	9970

With heights of 102 feet and 90 feet respectively at 50 years, the U.S.A. Quality Classes I. and II. correspond closely with our Classes II. and III. The U.S.A. Quality III. (70 feet at 50 years) is below anything we have found in this country as yet, though doubtless in the future, when the tree is planted more extensively, poorer growth will be obtained in some localities.

Comparing the height growth in U.S.A. Quality I. with that of Quality II. in Britain, the trend of the two curves is found to be very different. The American trees grow comparatively slowly at first, attaining a height of 36 feet at 20 years compared with 44 feet in this country. Between 20 and 30 years the growth is virtually the same, an increase of 25 feet of height being given by both curves;

in the next decade, however, there is a marked difference in favour of the American trees, which put on 23 feet of height against the 17½ feet shown in our tables, and in the following ten years 18 feet against 14 feet in the British tables.

When the volumes of the equivalent Quality Classes are compared, the American woods are seen to have a lower volume for a given age and height than in this country for the first 40 years. At 50 years U.S.A. Quality I. and our Quality II. both show a volume of 7,100 cubic feet per acre.

The American tables are interesting in that they show the very high yield obtained in the older age-classes on that Continent.

The low form factors noted in this country appear to be equally characteristic of the American woods.

Corsican Pine (Pinus Laricio var. Corsicana).

Twenty sample plots of Corsican pine were measured. Quality Classes were constructed as for other species. The plots were found to fall into three Quality Classes—namely, 70-ft., 60-ft., and 50-ft. at 50 years. (For curves see Appendix B.)

A table giving the mean height and volume for ages up to 50 years follows :—

Age in Years.	Quality Class I. (70-ft.)		Quality Class II. (60-ft.)		Quality Class III. (50-ft.)	
	Mean Height in feet.	Volume cu. ft under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.
10	12	—	—	—	—	—
15	20½	620	16	—	—	—
20	29	1,440	23½	920	18½	—
25	37½	2,240	31	1,620	25	1,050
30	45	2,940	38	2,260	31	1,600
35	52	3,600	44	2,840	36	2,110
40	58½	4,200	49½	3,370	41	2,570
45	64½	4,760	55	3,880	46	3,020
50	70	5,280	60	4,340	50	3,410

Fourteen out of the twenty sample plots measured fall into the 70-ft. Class, but the majority of these were found in the South of England. The plots indicate that the most rapid growth of the Corsican pine has been obtained in the warmer parts of the country, and it seems probable that the 70-ft. Class will be practically confined to the Southern and Western districts, but as the species has not been extensively planted in the North there is not sufficient evidence to allow definite conclusions to be drawn.

The comparison of the growth of Corsican pine and Scots pine is of interest. Sample plots of the two species growing under similar conditions were obtained near Dunster, Somerset; on the Southwick Estate, N.E. of Fareham, and in the New Forest, Hants; on the Endsleigh Estate, Devon; near Northallerton, Yorkshire; and at Ballogie, Aberdeenshire. In general the rate of growth of the

Corsican pine was faster than that of the indigenous species; thus, where a 70-ft. Quality Class of Corsican pine was found, the Quality Class of the adjacent Scots pine was 60-ft., and so on. This, however, was not the case in Aberdeenshire, where both species belonged to the 50-ft. class. As regards the South of England, the Yield Tables of Scots pine and Corsican pine show that the volume of the latter at 50 years is 50 per cent. greater than that of the Scots pine.

Practically no data are available for ages beyond 50 years, but at Highclere, Hants, a sample plot was obtained with a mean height of 104 ft. and a volume of 9,900 cu. ft. per acre at an age of 80 years.

The under-noted measurements of two sample plots of Corsican pine were recently obtained in Corsica and are given as an example of the rate of growth of the species in its native habitat :—

Locality.	Elevation. Feet.	Aspect.	Exposure.	Soil.	Age. Years.	Height. Feet.	Mean Quarter-girth, Inches.	Vol, under bark. Per acre
Forest of Aïtone, in the North West of Corsica	3,500	N.	Sheltered	Deep loam on weathered granite.	100	123	13¾	9,130
Forest of Valdoniello, 10 miles to the East of Aïtone.	3,500	E.	Sheltered	Stony loam on granite.	70	62	6¼	4,900

The analysis of the sample trees showed a remarkable correspondence in rate of height growth with the Corsican pine in this country, except that the native trees exhibited slower growth for the first ten years, a fact which may be explained by the Selection System of regeneration practised in Corsica.

The sample plots in the Forests of Aïtone and Valdoniello belong respectively to the 70-ft. and 50-ft. height classes. The former was selected on the ground that it appeared to indicate first-class growth conditions in Corsica, and the latter average conditions. The assessments of the best and average conditions, however, were made by eye and on scanty data, and it is possible that they are wide of the mark.

Japanese Larch (*Larix leptolepis*).

Forty-seven sample plots of Japanese larch were measured, all with one exception being under 25 years of age.

In view of the importance of this species and the wide range in its rate of growth, it was, nevertheless, decided to attempt a preliminary division into Quality Classes. For this purpose 15 years was adopted as the standard age. It was found that the division into two height classes, namely, a 35-ft. and a 25-ft. class at 15 years, covered satisfactorily the range of growth. Accordingly two Quality Classes were constructed, the limits for the first class being 40 ft. to 30 ft. and for the second class 30 ft. to 20 ft. at 15 years. (For curves see Appendix B.)

The statistics show that, for a given age and height, the volume production is heavier in Scotland than in England. This difference is due partly to heavier stocking and partly to higher form factor. A considerable number of the sample plots in England were measured in woods originally mixed, the other species having been suppressed by the more rapid growth of the Japanese larch, and where the latter were planted pure the plantation had, in many cases, been thinned before the sample plot was taken. On the other hand, in Scotland pure unthinned woods were the rule. This may explain the difference in volume.

A table showing mean height and volume at ages up to 25 years is given below :—

Age in Years.	Quality Class I. (35-ft.)		Quality Class II. (25-ft.)	
	Mean Height in feet.	Volume cu. ft. under bark per acre.	Mean Height in feet.	Volume cu. ft. under bark per acre.
5	9½	—	5½	—
10	23½	—	16	—
15	35	1095	25	470
20	44½	1930	33	1205
25	52	2580	39½	1820

The above table shows the rapid growth of this species in early life, especially in the better Quality Class.

It is a matter of everyday observation that Japanese larch grows much faster than the European species to begin with. Sample plots in certain woods near Thornhill, Dumfriesshire, Kilkerran. Ayrshire, and between Hay and Builth, Breconshire, where the two species were growing under similar conditions, enabled comparisons to be made. On the average, at twenty years of age the mean height of Japanese larch was 20 per cent. greater than that of the European species. It would appear from the localities investigated that where Quality Class II. of European larch is found Quality Class I. Japanese larch may be obtained, and that the third and second classes of the respective species are associated with each other. Additional evidence of the markedly faster height growth of the Japanese species is afforded by the fact that it almost invariably suppresses ordinary Larch when in mixture with it. This was shown in widely separated regions—*e.g.*, at Glendye, Kincardineshire, and Llanidloes, Montgomeryshire.

The evidence available does not permit the question whether there is a fall off in the height growth of this species to be definitely decided, for, unfortunately, few sample plots over 20 years of age were obtained. In some sample plots, where the age was less than 20 years, there was a marked decline, while in others, including several of the older sample plots, the trees were growing steadily. The fall off was more evident in the better than in the poorer Quality Class.

Reference to the Yield Tables shows that at ages of 20-25 years the volume production of Japanese larch in the two Quality Classes exceeds that of the European larch in the 70-ft. and 60-ft. classes respectively by 60-100 per cent. This is supported by the limited evidence available in the localities quoted above, where the species are growing under similar conditions.

Generally speaking, as with Douglas fir, Japanese larch has been planted under more favourable conditions than the European species as regards elevation, shelter and soil. An interesting plantation, however, near Llanidloes (Montgomeryshire), at an elevation of 1,500 feet, shows that this species can be grown successfully at a high altitude in some districts. In this situation a mean height of 23 feet was attained in 15 years.

The following table, obtained from information supplied by the Bureau of Forestry, Tokyo, shows the rate of growth and production in Japan, where the tree occurs in the mountains at about 5,000 to 6,000 feet above sea-level :—

Age in Years.	Quality Class I.		Quality Class II.		Quality Class III.	
	Mean Height in feet.	Volume Quarter Girth cu. ft.	Mean Height in feet.	Volume Quarter Girth cu. ft.	Mean Height in feet.	Volume Quarter Girth cu. ft.
		per acre.		per acre.		per acre.
20	45	2,605	36	1,855	29	1,701
30	64	4,445	55	3,550	47	2,605
40	76	5,840	68	4,290	60	3,910
50	84	6,870	77	5,975	70	4,975
60	90	7,660	83	6,810	77	5,840
70	95	8,255	89	7,480	83	6,560
80	98	8,740	93	8,030	88	7,150
90	101	9,130	96	8,470	92	7,640
100	104	9,480	99	8,850	94	8,065

At 20 years of age the mean height of Quality Class I. is the same as in our preliminary table, but the volume in Japan is markedly greater. The volumes at the later ages are also surprisingly high, and it is presumed, in absence of evidence to the contrary, that the Japanese figures include bark, which the British figures do not.

It is interesting to compare the rate of height growth, as stated in the Japanese tables, with that of European larch in this country. The curve for Quality III. in Japan corresponds almost precisely with our 70-ft. class curve for the European species. The curve for the Japanese Quality I. is well above our 80-ft. class curve until the 50th year (6 ft. above at 30 years, 6 ft. at 40 years and 4 ft. at 50 years), when these two curves begin to converge, and they coincide at 96 ft. about the 74th year. Thereafter the European larch goes ahead of the Japanese. It would appear, therefore, that if Japanese larch in this country grows at the same rate as in Japan, the frequently stated theory that it fails to keep pace with the European larch after early growth will require revision.

Sitka Spruce (Picea sitchensis).

There are unfortunately very few plantations of Sitka Spruce in this country which have reached measurable size, consequently it was impossible to prepare a table of production for this species. Four sample plots were obtained at Drumlanrig, Dumfriesshire, one sample plot at Durris, Kincardineshire, and one near Newbury, Hants. The age of the Durris wood was 43 years, the others being about 20 years old.

A fairly reliable comparison between Sitka and Norway spruce was possible at Drumlanrig. At 20 years the height of the former was, on the average, 50 per cent. greater than that of the latter, the actual heights being about 40 ft. and 25 ft. respectively. The Durris wood of Sitka spruce has special features of interest. It is growing on 2-3 ft. of peat at an altitude of 800 ft. above sea level (a high relative elevation for Lower Deeside). The same wood contains groups of Scots pine, Larch, and Silver fir, while a portion consists of a mixture of Norway spruce and Sitka spruce. The Norway spruce are living, but most are suppressed. The Scots pine, Larch and Silver fir show very poor growth. At the age of 43 years the Sitka spruce reached a mean height of 60 feet and produced a volume of 5,700 cubic feet per acre. The trees were still growing vigorously in height; some of the sample trees felled had leading shoots two to three feet in length.

Silver Fir, Maritime Pine, etc.

In addition to the conifers already referred to in this chapter there were measured five sample plots of Silver fir (*Abies pectinata*), three of Maritime pine (*Pinus Pinaster*), two of Austrian pine (*P. Laricio var Austriaca*), and one each of Weymouth pine (*P. Strobus*) and *Thuya plicata*. The sample plots of the last three species were in young woods and are of no particular interest.

Silver Fir.

This species has been seldom planted as pure plantations in the United Kingdom: the danger from frost in early youth and later from the *Chermes* has discouraged most foresters from the attempt to establish it in solid blocks.

On the Continent, Silver fir gives very high yields surpassing even Spruce in production; the sample plots measured in this country also are remarkable for the large volumes obtained. The following particulars indicate the growth in Great Britain.

Situation.	Elevation above Sea-level.	Aspect.	Exposure.	Geology and Soil.	Age.	Height.	Volume u.b. per acre.
	Ft.					Ft.	Cu. ft.
Stevenstone Park, Devonshire.	520	S.W.	Exposed	Culm measures 12—18in. light loam.	42	56	4,900
Endsleigh Estate, Cornwall.	500	S.W.	Fully exposed	Culm measures 2 ft. light loam.	48	69	5,700
Dunskey Estate, Port-Patrick, Wigtownshire.	300	S.	Moderately exposed	Glacial 12 in. clay loam on boulder clay.	55	54	6,300

It will be seen that the mean annual increments of the first two woods are well over one hundred cubic feet per acre per annum, and only just under one hundred cubic feet in the case of the third sample plot. The volumes are much greater than those given in the Yield Table for Quality I. Silver fir in Schlich's Manual of Forestry, Vol. III. It appears to be a fact that the growth of Silver fir in this country, and especially under West Coast conditions, is very much more rapid than on the Continent, and, moreover, it stands wind well. It would, therefore, be a very valuable species were it not for the way in which it suffers from *Chermes* attack.

In addition to the sample plots, 138 trees were measured in 25 woods in different parts of England and Wales. These woods consisted usually of a mixture of conifers, either alone or with hardwoods. Fourteen out of the twenty-five woods were in Norfolk, and the good growth of Silver fir on the light sandy soils is especially noteworthy.

Two examples are given below showing in the one case the relative growth of Silver fir and Larch, and in the other the relative growth of Silver fir and Scots pine.

Situation.	Species.	Elevation.	Exposure.	Soil.	Age.	Height.	Average volume per tree cub. ft. over bark.
Great Skates Hill, near Cromer.	Silver fir	Ft. 175	Moderately sheltered	Deep brown sand	75	Ft. 77	54
	Larch	175	Moderately sheltered	Deep brown sand	75	71	27
Earlham Plantation, nr. Cromer.	Silver fir	200	Well sheltered	Deep moist sand	73	72	42
	Scots pine	200	Well sheltered	Deep moist sand	73	53	23

The average volume per tree of the Silver fir is twice that of the Larch, and almost twice that of the Scots pine. An additional merit of this tree is that it appears to be less subject to heart-rot than Larch or Spruce when grown on sand. In the first of the above woods 80 per cent. of the Silver fir were sound at the butt compared with only 40 per cent. of the Larch, in the second case all the trees of both species were sound.

Maritime Pine.

Three Sample plots of *Pinus Pinaster* were measured on sandy soils in the counties of Dorset, Hants and Norfolk. The woods were mature, the youngest being 86 and the oldest 115 years old. The height growth was slow and the volume production little better than that of the surrounding Scots pine, with the exception of the sample plot on St. Catherine's Hill, Hants, where the Maritime pine gave 5,200 cubic feet per acre in 106 years and the Scots pine 3,600 cubic feet per acre in 102 years. The curvature of the stems which is so characteristic a feature of the Maritime pine was very evident in the above sample plots.

CHAPTER IV.

General Discussion: Larch, Scots Pine and Spruce in Relation to the Main Factors of Locality.

The development of a wood is dependent on a number of factors which are termed the "factors of locality." Some of these factors, such as climate and soil, are clearly of great importance, but there are others of which we know very little and can merely guess at the influence which they may exert. The analysis and assessment of the separate factors, therefore, is obviously a formidable undertaking. In agriculture, where final results are obtained in the course of a year or two, the factors which limit growth can often be readily ascertained and in many cases any defects made good. It is far otherwise in forestry, where many years elapse before all the factors of locality have found expression in the growth of the crop and where initial mistakes are not easily remedied. A study, then, of the factors which appear to be most important in forestry is one of the first duties of the forester. Much has already been done as a result of careful and painstaking observations on the part of generations of foresters in this country. These observations are of necessity confined to relatively restricted areas, for the conditions vary so widely that no one man could acquire an exhaustive knowledge of more than a limited range of country. Hence it is not surprising to find widely differing opinions as to the effect of various factors upon the rate of growth of trees. The statistical survey afforded an opportunity of reviewing the problem in a more comprehensive way. While on the one hand the chief use of the data collected is in their local application, on the other it seemed reasonable to suppose that by combining the data collected throughout the whole country general principles might come to light which would be of value.

The discussion which follows is confined to Larch, Scots pine and Spruce, and the data from sample plots of 35 years of age and over have been used. The younger sample plots have been excluded on the ground that in such woods the effect of the locality may not have made itself fully felt.

The discussion has been divided into four parts. In the first a brief description of the more important features of the climate of the British Isles is given, and then for each species the distribution of the sample plots in respect of geological formation, soil, exposure, aspect and slope is shown. The average elevation of the sample plots in each quality class is also given. The information regarding these factors was taken from the detailed descriptions which were made when each sample plot was measured. The second, third and fourth parts (Chapters V., VI. and VII.) are devoted to a separate and more detailed study of Larch, Scots pine and Spruce respectively.

Climate of the British Isles.

The climate of the British Isles is mainly determined by its position relative to the North Atlantic Ocean and by the influence of the Gulf Stream, which spreads a surface of warm water over the North-Eastern part of the Ocean.

The prevailing winds are south-westerly to westerly, though local configuration of the ground may cause variations to the N.W. or S. The effect of these prevailing winds on tree-growth is very noticeable, and the question is referred to again under the heading *Exposure* (p. 33).

The effect of the prevailing wind and of the Gulf Stream is to produce a comparatively mild, equable climate. The mean January temperature over the British Isles is as much as 30° F. higher than the mean temperature of the same latitude in the Northern Hemisphere. None the less the range, both in temperature and rainfall, is sufficiently large to effect powerfully forest conditions in this country.

It is difficult to give briefly any adequate idea of the climatic conditions of this country, because the questions of temperature, rainfall, etc., are intimately bound up with that of elevation above sea-level, and in a given district large variations may occur. In forestry we are more interested, as a rule, in conditions in the hills, where the climate in many respects is different to that at sea-level. For example, at 1,200 ft. elevation snow may cover the land for a large part of the winter, while the plain below may be practically free. Winter temperatures are much lower at high elevations, the growing season shorter and the rainfall higher. Wind pressure, also, is always greater on the upper slopes.

Cornwall and the S.W. of Ireland have the warmest winter climate, with a January mean daily minimum of 39° to 40° F., and a mean temperature for the month of 43°. The coldest winter climate is that of the Eastern Counties of England and the North-East of Scotland. The January daily minimums are 31° and 32° respectively, and the mean January temperature 32°. The climate of the mountainous districts of central and East Scotland is the most severe in the British Isles. Winter temperatures of Zero Fahrenheit are not uncommon and many species of exotic trees which flourish in the South of England are unable to withstand the severe winter cold of the North. The highest temperature in the British Isles has been recorded round London, and this area has the greatest mean annual range of temperature (namely, twenty-four degrees Fahrenheit). The mean daily maximum in the lower Thames Valley for the month of July is 71° compared with 63° round the West and North Coast of the British Isles.

A detailed study of the rainfall of the British Isles lies outside the scope of this Bulletin, but the following table, taken from "The

Weather of the British Coasts" (published by H.M. Stationery Office), will indicate the general range :—

RAINFALL OF THE BRITISH ISLES.

England. Eastern Counties.	England. Midland Counties.	Wales and Western Counties of England.	East of Scotland.	West and North of Scotland.	North of Ireland.	South of Ireland.
	Mean annual rainfall (1881-1915). Inches.					
24	27	38	31·5	50	39	41
	Average rainfall from April to August inclusive (1881-1915).					
10	12·5	13·5	12·5	17	15	15

The rainfall is seen to be lowest in the Eastern Counties of England and to increase steadily towards the West and North. There is a range of annual rainfall from 24 inches in the Eastern Counties of England to 50 inches in the North and West of Scotland, and for the same districts a range from 10 to 17 inches during the growing period from April to August. In Wales and the Western Counties of England the rainfall is somewhat heavier than in the East of Scotland. Ireland has a more evenly distributed rainfall than Great Britain; the minimum of just under 30 inches falls round Dublin, the maximum of over 50 inches being found in the South-West of the island. The highest rainfall in the British Isles is that of 200 inches round Snowdon. A good illustration of the influence of elevation and topography on rainfall can be found in the two stations of Ben Nevis and Fort William, distant less than five miles from each other. The rainfall on the summit of Ben Nevis is just over 160 inches per annum and at Fort William just under 80 inches.

Unseasonable frosts do great harm to forest growth; they are the result of excessive radiation on clear cloudless nights and are common in April and the early part of May and not rare even in June, they are frequent also in the early Autumn. The intensity of the frost depends largely upon the configuration of the ground; low-lying areas, especially when surrounded by slightly higher ground, are the most subject to damage. These frosts are curiously local, and are much more severe and dangerous in some localities than in others.

It is often a matter of great difficulty to plant a "frost hole," the young trees suffer year after year until their leading shoots get above the frost-level. Of the important conifers, Silver fir, Sitka spruce and Larch suffer most and Scots pine and Common spruce least from Spring or Autumn frosts.

It is difficult to assess the effect of climate upon tree growth in different parts of the United Kingdom, owing to the interaction of other factors, such as soil, exposure and elevation, which tend to obscure any purely climatic influences.

Of the two main components of climate, namely, temperature and rainfall, the range of the former is greatest from South to North, and its most marked effect is upon the growth of exotic trees, such as *Cupressus macrocarpa* and *Pinus insignis*, which grow well in the South and West of England, but do not survive the winter climate of the greater part of Scotland. Corsican pine also does better in the South. The hardier conifers are little affected except by early or late frosts. The distribution of rainfall, on the other hand, is from East to West, and the general opinion is that the greater rainfall and more equable climate of the West Country produces much faster growth, especially of Larch, than the East. It is not easy to prove this in England, because the West of the country is mountainous, the hills being composed of old rocks, yielding usually deep loamy soils; while the East is relatively flat, and the younger rocks yield very different types of soil from those on the West. Hence any difference in rate of growth may be due more to varying conditions of soil and topography than to climate alone. In Scotland, where the conditions are much more uniform, it should be easier to form a conclusion, but, unfortunately, a disproportionate number of the sample plots were measured in the eastern half of the country owing to lack of woods in the West, and further data are required before the question can be decided definitely. So far as our information goes, there does not appear to be the great difference in the rate of growth which was anticipated. Given the same elevation above sea-level and the same type of soil, it is doubtful if the West of Scotland produces appreciably faster growth of Larch than the East.

The outstanding examples of fast growth of Larch in the West of Scotland are, in some cases at least, *e.g.*, Braemore, due to unusually favourable conditions of a purely local character.

Geology.

Tables will be found on pages 81-83, in Appendix C, showing the distribution of the sample plots of Larch, Scots pine and Spruce on the different geological formations in England, Scotland and Ireland.

England and Wales.—The sample plots in England and Wales are spread over a much wider range of geological formation than is the case in the other two countries.

Taking first the distribution of the Larch plots in England and Wales, these are seen to occur mainly on the old rocks, and especially on the Cambrian, Ordovician and Silurian Shales and Devonian Sandstones. These formations are confined to the western counties, and form the most hilly part of the country; they yield deep fertile loams and sandy loams, usually well drained and free from peat, and when the elevation and exposure are not too great the conditions are excellent for the growth of Larch. Eight out of the seventeen sample plots in Quality Class I. were obtained on the rich sandy loams of the Old Red Sandstone and Devonian rocks.

The highest Quality Class was not found on the loams yielded by the Cambrian, Ordovician, and Silurian Shales.

A considerable number of sample plots of Larch were obtained on the Culm-measures of Devon, nearly half of which belong to the first and second Quality Classes. On the other hand, very little Larch was seen on the Millstone Grit and other rocks of the Carboniferous series in the Pennine Range. The conditions in this part of England are less suited to Larch than in the West Country, owing to the fact that most of the land up to 1,000 feet above sea-level is under cultivation or consists of improved pasture, while the higher land is often badly drained and peaty.

The Oolitic limestones and sandstones are well developed in the Yorkshire Moors, where several sample plots of Larch were measured. The soils are usually sandy and poor in lime, but generally of good depth. Larch of the better Quality Classes is practically confined to the lower slopes.

Twelve sample plots were measured on the chalk formations in the South of England. The soils are usually heavy, clay-loams and clays predominating. The depth of soil varies from a few inches to many feet. Of the twelve sample plots, nine belonged to the Quality Classes I. and II., and all were on deep soil; the only sample plot of Quality V. had been planted on shallow loam which contained a large proportion of chalk.

The Tertiary rocks and Glacial deposits of the East of England yielded only six sample plots of larch. The light soils and low rainfall of this area lead to heart-rot at an early age, although it will be seen from table No. 4 in Appendix C that exceptionally rapid growth is produced.

A different distribution is seen in the case of Scots pine, which has been mainly planted on those formations producing sandy soils, chief of which are the Millstone Grit, Permian and Trias among the older rocks, and the Lower Greensand, Bagshot Sands and Glacial Deposits among the more recent strata. Seventy-five per cent. of the sample plots occurred on these formations, the majority belonging to the first and second Quality Classes.

It is exceptional to find Scots pine planted except as shelter belts in the hill country of Wales and the Lake District, but it has been more widely used on the Carboniferous rocks of the Northern Pennines, where the soil is often sandy and the conditions unfavourable for Larch.

Nearly ninety per cent. of the Spruce sample plots were obtained on rocks of the older formations, pure Spruce being only occasionally met with among the newer rocks of the South and East of England. The Culm-measures of Devonshire and the Yoredale shales and limestones of the Pennine Range furnished nearly half of the sample plots. The soils are usually heavy, badly drained, and often peaty.

Scotland.—The geological structure of Scotland differs widely from that of England, the outstanding feature being the predominance of igneous and metamorphic rocks. So far as the forest regions investigated are concerned, the country may be divided as follows :—

1. The Highland Area. It consists largely of metamorphic rocks, such as schists and gneisses, although many of the mountain ranges, especially in the Eastern Highlands, *e.g.*, the Cairngorms, are formed of masses of granite. A sandy loam is the soil generally derived from these rocks. It varies in fertility, depending on its origin. The granites probably give the poorest soil and the Mica schist the richest, the Quartzite schists being intermediate. Larch and Spruce were often found on the soils derived from the metamorphic rocks, and Scots Pine on the granite soils. Glacial deposits overlie the rocks in many of the

valleys, and frequently extend into the hills. These deposits consist usually of sands and gravels, as in the moraines found all over the Highlands. These sands are rarely fertile, and are covered usually with Scots Pine, much of which is of natural origin.

2. The Southern Uplands. This region consists largely of rocks of the Silurian and Ordovician Series. These strata generally give sandy loams and loams, and Larch is here the principal species. Glacial deposits cover large areas, but in this part of the country they consist mainly of "boulder clay," yielding loams or clay loams. A good deal of Spruce has been planted on these soils.

Ireland.—The Irish sample plots are confined to an area in the South-West of the country, including the Counties of Kerry, Limerick, Tipperary and Waterford. The majority of the plots lie on the Old Red Sandstone of the Galtee, Knockmealdown and Comeragh Mountains, the remainder are on the Carboniferous Limestone and Silurian Shales.

Soil.

Tables illustrating the distribution of the sample plots of each species on the various types of soil will be found on page 84 of Appendix C. Diagrams based on these tables are shown on the adjoining page, from which it appears that Larch predominates on the sandy loams and loams, Scots pine on the sands and sandy loams, while Spruce occurs more frequently on the heavier soils and peats.

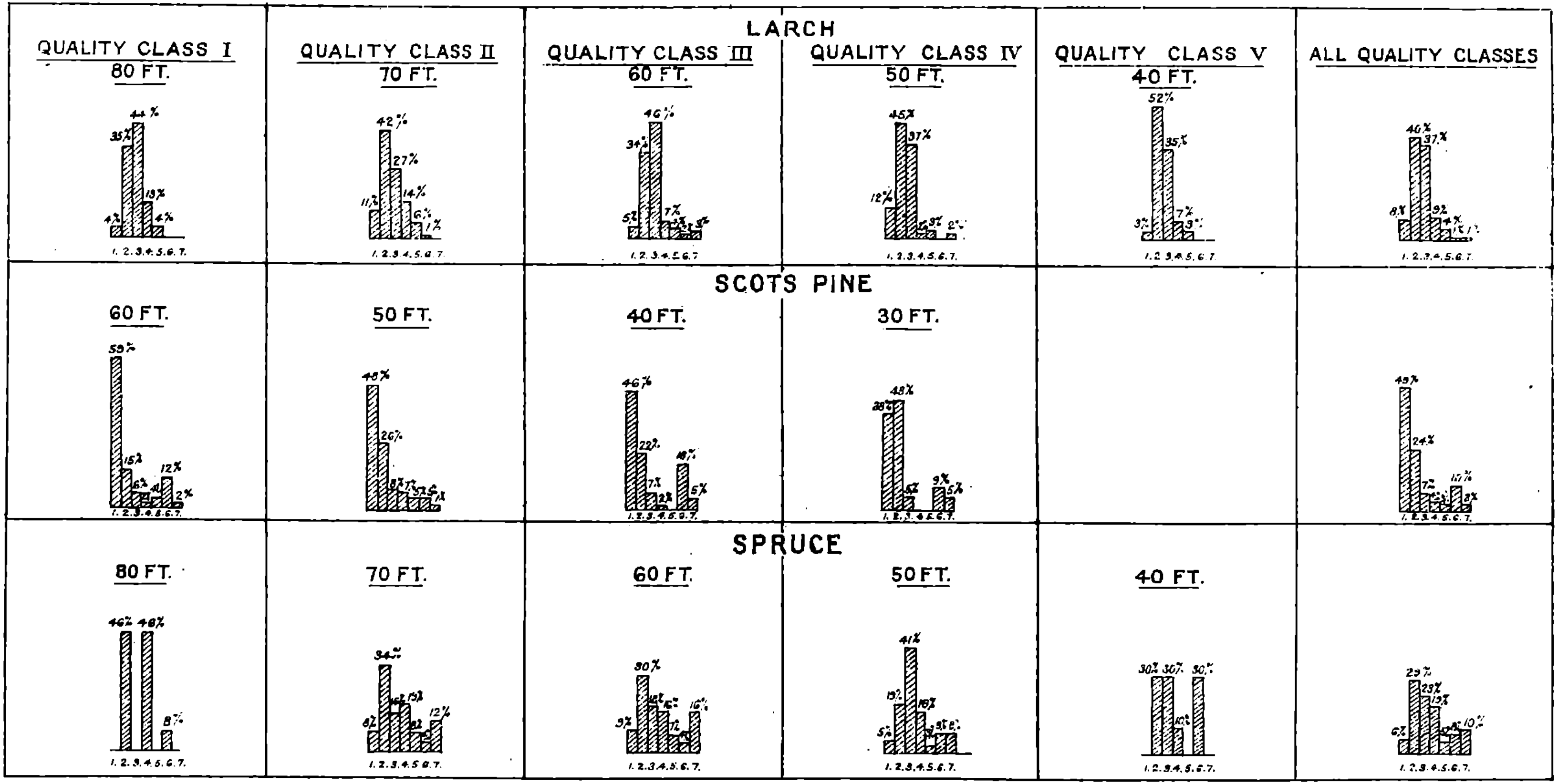
When the Larch tables and diagrams are considered, the most striking feature is the absence of any clear indications as to the effect of soil alone upon Quality Class. A rather larger proportion of the sample plots on clay loam and clay belong to the better Quality Classes. This is remarkable, in view of the general opinion that these soils are not so well suited to the growth of Larch as are the sandy loams and loams. The four sample plots on peat were found in Devon, and will be referred to again in Chapter V.

The sandy loams and loams on which the majority of the sample plots occur are represented in much the same proportion in each Quality Class.

In the Scots pine diagrams the proportion of sand is seen to fall and of sandy loam to rise in the poorer Quality Classes. It would be unwise, however, to assume that sand produces faster growth than sandy loam; other factors, chief among which are elevation and exposure, have more influence on the rate of growth, and the chief reason why there is such a large proportion of Quality Class I. Scots pine on sand is that these plots were all obtained at low elevations. As a rule the more loamy and richer soils at low elevations are put to agricultural uses, and thus are not available for forest crops.

The Spruce diagrams indicate an increase, in the poorer Quality Classes, of plots on the heavier and peaty soils, but here again elevation and exposure tend to outweigh any influence due to texture of soil.

In general, the nature of the soil, potent though it may be in individual cases, is not sufficient to determine the quality of growth over a wide range of country, where other and more powerful factors come in to obscure the issue.



KEY TO SOIL TYPES.

1. Sand. 2. Sandy Loam.
3. Loam. 4. Clay Loam.
5. Clay. 6. Peat & Peaty Loam (6"-12").
7. Peat & Peaty Loam (over 12").

Diagrams showing the proportion of the sample plots in each quality class on the different types of soil.

Elevation.

The tables below show the average elevation above sea-level of the sample plots in each Quality Class of Larch, Scots pine and Spruce, together with the maximum and minimum elevation in each class—*i.e.*, the highest and lowest elevations at which sample plots were measured in that class :—

LARCH.

(All sample plots over 35 years of age.)

Quality Class.	I. (80-ft. Class.)	II. (70-ft. Class.)	III. (60-ft. Class.)	IV. (50-ft.Class.)	V. (40-ft.Class.)
Maximum elevation ...	700	1,200	1,450	1,480	1,700
Mean elevation	420	570	700	820	1,100
Minimum elevation ...	50	80	120	200	350

SCOTS PINE.

(All sample plots over 35 years of age.)

Quality Class.	I. (60-ft. Class.)	II. (50-ft. Class.)	III. (40-ft. Class.)	IV. (30-ft.Class.)
Maximum elevation ...	700	1,050	1,300	1,350
Mean elevation	260	440	540	790
Minimum elevation ...	30	30	30	40

SPRUCE.

(All sample plots over 35 years of age.)

Quality Class.	I. (80-ft. Class.)	II. (70-ft. Class.)	III. (60-ft. Class.)	IV. (50-ft.Class.)	V. (40-ft.Class.)
Maximum elevation ...	450	1,300	1,500	1,700	1,880
Mean elevation	300	460	720	910	1,360
Minimum elevation ...	100	50	200	100	150

Both maximum and mean elevation show a progressive rise in all species with falling quality class.

The highest elevation at which an 80-ft. class Larch wood was obtained is 700 ft. above sea level, compared with a maximum elevation of 1,700 ft. for the 40-ft. class; the corresponding mean elevations are 400 ft. and 1,100 ft. Spruce, with maximum elevations of 450 ft. and 1,880 ft. for the best and the poorer Quality Classes and mean elevations of 300 ft. and 1,360 ft., exhibits similar behaviour to Larch, but with a considerably greater range. The mean elevation of the Quality Classes of Scots pine are lower than those of Larch and Spruce. Even the 30-ft. class, which does not represent an economic production, and includes only 12 sample plots, was found at a mean elevation of less than 800 ft. above sea level. The great proportion of the Scots pine has been obtained in the valleys and at low elevations—the tree does not thrive on the upper slopes of the hills. The best Quality Classes of Larch and Spruce also are only found on the average at low elevations.

It is interesting to find Larch with a higher mean elevation for its better Quality Classes than Spruce—400 ft. against 300 ft. for the 80-ft. class and 570 ft. against 470 ft. for the 70-ft. class. The mean elevation is practically the same for the middle class of each species, but the poorer Quality Classes go to a greater altitude than the Larch, the mean elevations of the fifth Quality Classes being 1,360 ft. and 1,100 ft. respectively.

The wide range between the maximum and minimum elevations indicate that absolute height above sea-level is far from being the most important factor involved in determining the quality of growth. Thus, when a 60-ft class Larch crop can be grown between elevations of 120 ft. and 1,450 ft., a 40-ft. class Scots pine crop between 30 ft. and 1,300 ft., and a 50-ft. Spruce crop between 100 ft. and 1,700 ft., it is clear that there are other factors to be considered besides elevation. At the same time the fall in Quality Class following the steady rise in both mean and maximum elevation is most apparent. The slower growth is presumably due to the influence of various adverse factors which accompany increased elevation such as shallower soil, lower temperature, and, above all, exposure to wind. It is the cumulative effect of all such factors which produces the results often ascribed to elevation alone.

Relation of Mean Elevation to Production.—The figures for the mean elevation of each Quality Class of Larch, Scots pine and Spruce will have a more practical significance if we can interpret them in terms of production. The difficulty arises, however, that the three species have been planted, to a large extent, in different localities and on somewhat different types of soil. This may be overcome to some extent by considering only the sample plots over, say, 500 ft. in elevation and regarding them as fairly typical of upland conditions in general, where soil and climate are likely to be more uniform than in the lowlands and plains. The following table shows the mean elevation of these sample plots for each species and Quality Class :—

SAMPLE PLOTS OVER 500 FEET ELEVATION.

LARCH		SCOTS PINE.		SPRUCE.	
Quality Class.	Mean Elevation.	Quality Class.	Mean Elevation.	Quality Class	Mean Elevation.
	ft.		ft.		ft.
I. (80-ft.)	600	I. (60-ft.)	550	I. (80-ft.)	—
II. (70-ft.)	610	II. (50-ft.)	660	II. (70-ft.)	750
III. (60-ft.)	870	III. (40-ft.)	760	III. (60-ft.)	820
IV. (50-ft.)	950	IV. (30-ft.)	1,000	IV. (50-ft.)	1,010
V. (40-ft.)	1,120	—	—	V. (40-ft.)	1,480

In order to relate these figures to production the final mean annual increment at an arbitrarily chosen age of 60 years was calculated for each species and Quality Class from the figures given in the Yield Tables (by dividing the volume of the Main Crop by 60). These increments were then plotted against the mean elevations in the preceding table, and a smooth curve drawn as the mean of each set of points. The curves obtained are reproduced on the adjoining page. The position of each Quality Class is entered on the different curves. It will be noted that there is no 80-ft. class for Spruce—this Quality Class has only been found at elevations below 500 ft. above sea-level.

The graph shows that for a mean elevation of 750 ft. above sea level in the hills Scots pine in England produces a mean annual increment, exclusive of thinnings, of 48 cubic feet per acre per annum, Scots pine in Scotland produces 55 cubic feet, Larch in Great Britain produces 68 cubic feet, and Spruce in Great Britain 116 cubic feet per acre per annum. Scots pine drops out at the higher elevations, leaving Larch and Spruce as the principal crops. At 1,000 ft. above sea level Larch produces a little over 40 cubic feet and Spruce over 82 cubic feet per acre per annum. These figures are averages, and have purely general significance; in any given locality the ratios between the production of the different species for a known elevation may be very different. They serve, however, to emphasise the vastly higher production of Spruce compared with Larch or Scots pine in the hills of this country.

Exposure.

The south-westerly winds which prevail throughout this country are perhaps the greatest enemy to tree growth which we have. In exposed situations, *i.e.*, where there is no direct shelter from the South-West, the wind tends to dwarf the trees and to prevent the crown on the windward side from developing normally, while the boles of the trees are often bent away from the wind, and the value of the timber reduced in consequence. Proximity to the sea and greater elevation tend to increase the exposure, but in land at low elevations the prevailing winds are rarely a serious obstacle to tree growth.

If shelter is provided from the West and South-West, either by immediately rising ground or by a range of hills a short distance away, the effect of increasing elevation upon exposure may be largely neutralised, and a crop may be grown at 1,500 ft. above sea-level which will show less signs of wind damage than a crop at, say, 500 ft., exposed to the full force of the wind.

Again, while it is true that, on the average, exposure increases with higher elevation above sea-level, very much depends upon the relation of the land upon which a wood is growing to the general level of the surrounding country. It is the relative elevation which is usually all-important, *i.e.*, the height of the wood above the bottom of the valley. In many cases a wood at 1,000 ft. elevation at the bottom of a valley in the hills will be more sheltered and grow much better than a wood on the slope of a hill 500 ft. or more above the valley, even though the valley itself is only 100 ft. above sea-level.

As a rule, in all species the best growth has been found where the relative elevation is low, irrespective of the absolute height above sea-level.

There is no really satisfactory method of estimating the degree of exposure, and the observer is liable to be affected by other factors, such as elevation, or by the weather conditions at the time of measurement. Generally speaking, in the absence of any definite shelter from the South-West or West a sample plot was described as fully exposed; with increasing shelter the plots were described as moderately exposed, slightly or somewhat exposed, moderately sheltered, and fully sheltered. The third category was found in practice to be unsatisfactory, and as a rule only the four terms were used. Sample plots which were apparently sheltered from the South-West and West, but in which the trees showed signs of severe wind damage from other directions, were included in the exposed categories.

For purposes of tabulation the first three classes have been grouped together under the head of "Exposed," and the last two under the head of "Sheltered."

The following table shows the proportion of exposed and sheltered sample plots in each Quality Class of Larch, Scots pine and Spruce.

—	Quality Class I.		Quality Class II.		Quality Class III.		Quality Class IV.		Quality Class V.		Total in all Quality Classes.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
LARCH (over 35 years of age).												
	(80-ft. Class)		(70-ft. Class)		(60-ft. Class)		(50-ft. Class)		(40-ft. Class)			
Exposed ...	8	35	45	45	66	57	52	78	24	83	195	58
Sheltered ...	15	65	56	55	49	43	15	22	5	17	140	42
SCOTS PINE (over 35 years of age .												
	(60-ft. Class)		(50 ft. Class)		(40 ft. Class)		(30-ft. Class)					
Exposed ...	16	31	67	51	53	58	13	62	—	—	149	50
Sheltered ...	36	69	65	49	38	42	8	38	—	—	147	50
SPRUCE (over 35 years of age).												
	(80-ft. Class)		(70-ft. Class)		(60-ft. Class)		(50-ft Class)		(40-ft. Class)			
Exposed	—	—	7	27	19	43	19	51	6	60	51	39
Sheltered	13	100	19	73	25	57	18	49	4	40	79	61

The proportion of exposed sample plots rises in each species as the Quality Class falls with the same regularity as the mean elevation, and it is clear that the two are intimately connected. In Larch the increase in the exposed sample plots is from 35 per cent. to 83 per cent. between Quality Classes I. and V., in Scots pine from 31 per cent. to 62 per cent. between Quality Classes I. and IV., and in Spruce from nil to 60 per cent. between Qualities I. and V.

There can be little doubt, therefore, that in this country exposure to the prevailing wind is a factor of great importance in determining the rate of growth.

Aspect.

The table on p. 85, Appendix C, shows the distribution of the sample plots of the three species according to Quality Class on the different aspects, but in spite of the large amount of data available for both Larch and Scots pine, it is impossible to draw any definite conclusion from the table as to which aspect has produced the best growth of either of these species.

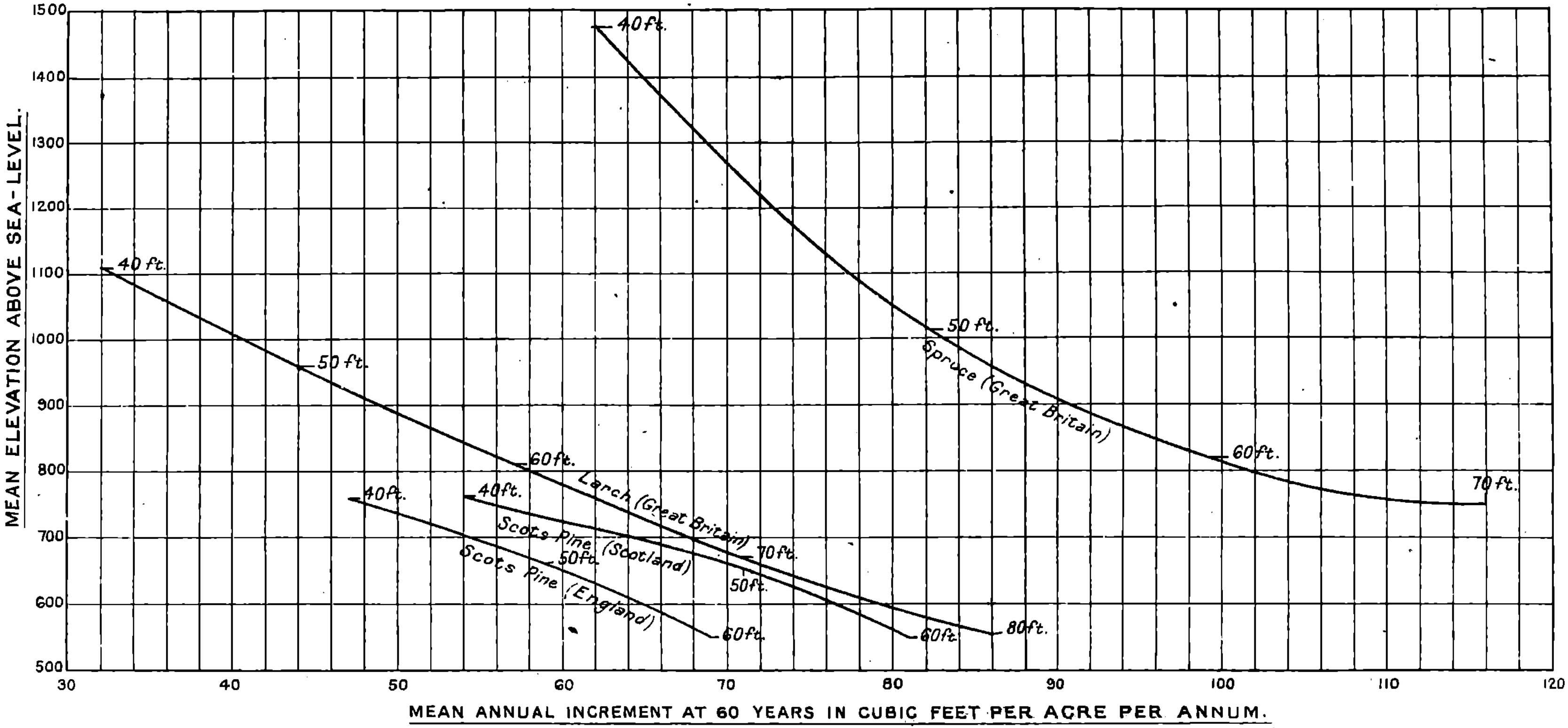


Diagram showing the relation between Elevation & Production for Larch & Spruce in Great Britain & Scots Pine in England & in Scotland.

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The increasing proportion of sample plots of Scots pine on the South-West aspect in the poorer Quality Classes might seem to point to a possible conclusion, but the opposite behaviour of the woods on the adjoining South and West aspects shows that we are probably not dealing with a real tendency.

The distribution of the Larch sample plots in respect of aspect is extraordinarily uniform in all the Quality Classes. It is curious, though, that a larger proportion of woods should have been planted on either North or South slopes than on the remaining aspects.

The table seems to dispose of the theory that Larch grows best on North or North-East aspects. Taking the first two Quality Classes, 30 per cent. of Quality Class I. and 27 per cent. of Quality Class II. were found on North and North-East aspects, and 31 per cent. of Quality Class I. and 27 per cent. of Quality Class II. on South and South-West aspects. Where exposure is feared, however, North and East aspects are preferable, owing to the fact that they are usually more sheltered from the prevailing wind.

The following table condenses the large schedule in Appendix C by grouping the aspects under two heads: (a) Aspects from South to North-West inclusive, and (b) Aspects from North to South-East inclusive, omitting sample plots on flat ground.

— .	Quality Class I.		Quality Class II		Quality Class III.		Quality Class IV.		Quality Class V		Total in all Quality Classes.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
	LARCH (over 35 years of age).											
	(80-ft Class)		(70-ft. Class)		(60-ft. Class)		(50-ft. Class)		(40-ft. Class)			
S. to N.W.	10	48	47	50	68	60	35	53	14	52	174	54
N. to S.E.	11	52	47	50	45	40	31	47	13	48	147	46
	SCOTS PINE (over 35 years of age).											
	(60-ft. Class)		(50-ft. Class)		(40-ft. Class)		(30-ft. Class)					
S. to N.W.	15	45	64	66	49	78	11	61	—	—	139	66
N. to S.E.	18	55	33	34	14	22	7	39	—	—	72	34
	SPRUCE (over 35 years of age).											
	(80-ft. Class)		(70-ft. Class)		(60-ft. Class)		(50-ft. Class)		(40-ft. Class)			
S. to N.W.	6	55	9	45	12	32	14	41	5	63	46	42
N. to S.E.	5	45	11	55	25	68	20	59	3	37	64	58

The first group contains those aspects which are liable to direct exposure from the prevailing winds and also the drier and more sunny aspects, the second group contains the sheltered and colder aspects.

It will be seen that a slightly larger proportion (54 per cent. against 46 per cent.), of the Larch sample plots were obtained on the South to North-West aspects, but that, on the whole, the distribution of the two groups of aspects within the Quality Classes is uniform. There is no tendency for the more exposed group to segregate in the poorer Quality Classes.

The tables for Scots pine and Spruce show that the majority of the sample plots of the former species were obtained upon the

South to North-West group of aspects, and of the latter upon the North to South-East group. In neither case is there any clear evidence of segregation in the Quality Classes.

As far as the relation between aspect and exposure is concerned, much depends upon the degree of slope and presence of higher ground to westward: a gentle slope to the North-East or East near the top of a hill, with no shelter from the South-West, might be severely exposed, while a wood facing West in a narrow, steep-sided valley might be perfectly sheltered.

Slope.

For purposes of convenience seven grades of slope have been formed ranging from flat (0° to 1°) up to very steep (30° and over), and in the Table on p. 86 in Appendix C the proportion of sample plots in each Quality Class occurring on the various grades of slope is shown.

Of the Scots pine sample plots 54 per cent. occurred on flat or very gentle slopes, as compared with 16 per cent. for Larch and 40 per cent. for Spruce. Broadly speaking, Larch has been planted mainly on moderate to steep slopes and Scots pine and Spruce on the gentle slopes.

There appears to be no connection between degree of slope and rate of growth.

An attempt was made to ascertain if Larch woods on steep slopes carried a heavier stocking than on gentle slopes by comparing the figures for the number of stems per acre in sample plots obtained on slopes 20° and over with the average figures for woods of the same height and Quality Class on all grades of slope. The result was not sufficiently definite to be conclusive, but it tended to support the view that a slightly heavier stocking can be carried on steep slopes.

CHAPTER V.

Further Discussion of Certain Factors of Locality in Relation to Larch.

In the previous chapter the sample plots of Larch, Scots pine and Spruce from all parts of the British Isles were assembled together and investigated to determine, if possible, the effect of the main factors of locality upon the growth of each of these species. It is proposed to deal with Larch in somewhat greater detail in the present chapter by analysing the data from four separate geographical areas, namely:—

(1) Wales (including Shropshire), 106 sample plots.
(2) Devon, Dorset and Somerset, 44 sample plots.
(3) Rest of England, 70 sample plots
(4) Scotland, 90 sample plots.

The growth of Larch in Ireland is referred to in a later section.

Of the above areas Wales contains the most data, and is also the most homogeneous in respect of climate, geology and topography. The South-Western Counties of England are treated separately, partly because they contain a considerable number of sample plots and partly because, though somewhat similar to Wales in climate and topography, the geology and soil conditions are different. The Rest of England contains two important mountain areas, namely, the Lake District and the Pennine Range, but very few sample plots of Larch were obtained from either of these regions, and the bulk of the data came from the lesser hills and lowlands.

In the first place it is of interest to note the distribution of the Quality Classes in the different districts.

Proportion of the sample plots in each district belonging to the different Quality Classes,

District.	Quality Class I. (80-ft.)	Quality Class II. (70-ft.)	Quality Class III. (60-ft.)	Quality Class IV. (50-ft.)	Quality Class V. (40-ft.)
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Wales	4	22	47	19	8
Devon, Dorset, Somerset ...	9	40	30	16	5
Rest of England	11	36	27	15	11
Scotland	6	24	31	28	11

It will be seen that nearly 50 per cent. of the sample plots in the two English divisions fall in the first and second Quality Classes, the corresponding figures for Wales and Scotland being 20 per cent. and 30 per cent. respectively.

The preponderance of the good Quality Classes in England is explained by the fact that a larger proportion of the sample plots were planted at low elevations and in sheltered localities than was the case in Wales and Scotland.

Elevation.

The average, maximum, and minimum elevation of each Quality Class in the four districts is shown in the following table :—

District.	Elevation.	Quality Class I. (80-ft.)	Quality Class II. (70-ft.)	Quality Class III. (60-ft.)	Quality Class IV (50-ft.)	Quality Class V. (40-ft)
Wales... ...	Maximum	700	1,050	1,300	1,350	1,550
	Mean ...	530	780	830	930	1,210
	Minimum	50	80	400	350	900
Devon, Dorset, Somerset.	Maximum ...	650	900	1,150	1,100	1,150
	Mean ...	450	530	650	890	1,080
	Minimum ...	300	200	200	600	1,000
Rest of England ...	Maximum ...	680	630	900	850	1,200
	Mean ...	390	400	550	550	780
	Minimum ...	160	100	120	320	350
Scotland ...	Maximum ...	650	1,200	1,450	1,480	1,700
	Mean ...	400	570	630	830	1,220
	Minimum ...	150	200	200	200	800

The maximum figures refer to the elevation of the sample plot measured at the greatest altitude in each Quality Class, and the mean figures to the average elevation of all sample plots within the Quality Class. The fall in Quality Class is correlated with a steady rise in both mean and maximum elevation in each of the four districts, and the table bears out the results obtained with the combined data in the previous chapter. The highest figures for mean elevation are given by Wales, where the range is from 530 ft. to 1,210 ft., and the lowest by the Rest of England, with a range from 390 ft. to 780 ft. of mean elevation.

It is interesting to find that the maximum elevation of Quality Class I. in all districts varies only between 650 ft. and 700 ft. It is evident that this Quality Class has a very limited upward range.

The maximum elevations for Larch in Scotland and Wales indicate that this species has been planted far up in the hills in those countries, and the following details referring to three of the highest sample plots may be of interest :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.
						Feet.	Cubic feet
Invercauld Estate, Western Aberdeenshire.	2000	N.	Very exposed to N.W.	Shallow pockets of black loam on schists.	106	46	2,325
Mar Estate, Western Aberdeenshire.	1700	N.W.	Moderately sheltered.	Shallow pockets of sandy loam on schists.	93	69	4,185
Abbey Cwm Hir Estate, near Rhayader. Radnorshire.	1600	S.E.	Moderately exposed.	Loam.	65	42	1,855

The stocking of the sample plots in the Mar and Abbey Cwm Hir Estates was good and the growth even. The Invercauld plot had suffered greatly from exposure, containing many gaps due to windfall or death of the trees.

Exposure.

The following table shows the percentage of sample plots in each Quality Class and for each sub-division of the country, which were exposed more or less directly to the prevailing wind :—

PERCENTAGE OF EXPOSED SAMPLE PLOTS IN EACH QUALITY CLASS IN THE FOUR DISTRICTS.

District.	I. (80-ft.)	II (70-ft.)	III. (60-ft.)	IV. (50-ft.)	V. (40-ft.)
Wales	40	42	62	90	90
Devon, Dorset, Somerset ...	0	29	43	71	100
Rest of England	44	58	61	100	78
Scotland	20	29	46	56	70

Each of the districts into which the country has been sub-divided exhibits the same feature—namely, that the percentage of exposed sample plots increases with each succeeding Quality Class from the highest to the lowest, Quality Class IV. in the Rest of England forming the only exception. As in the table of mean elevations, interesting differences are seen in the four areas dealt with.

In the South-West of England all the first Quality Class sample plots are sheltered, while in the fifth Quality Class all are exposed. The difference in mean elevation between the first and second Quality Classes is only 80 ft., and between the second and third Quality Classes 120 ft. The percentage of exposed sample plots, however, has risen from nil to 43 per cent. between the first and third Quality Classes. Further, if the exposed and sheltered sample plots over 500 ft. in elevation in Quality Classes II. and III. are separated out, and the mean elevation of each group calculated, the following figures are arrived at :—

Quality Class.	II. (70-ft.)	III. (60-ft.)
Mean elevation of exposed plots...	730	920
Mean elevation of sheltered plots	520	700

The same Quality Class is attained, therefore, in the South-West of England at over 200 ft. greater elevation in sheltered than in exposed localities. It seems reasonable, then, to attribute to exposure the principal part in reducing the rate of growth in this district.

The issue is not so clear-cut in the remaining districts. Neglecting the first Quality Class in Wales, for which there are few data, the second class contains 42 per cent. of exposed plots, the proportion rising to 90 per cent. in the fourth and fifth Quality Classes. The corresponding figures for Scotland are 29 per cent. in the second Quality Class, 56 per cent. in the fourth, and 70 per cent. in the fifth Quality Class. It would seem that the Larch had been planted in more exposed situations at the higher altitudes in Wales than in Scotland. The figures for the Rest of England agree approximately with those for Wales, showing the same increase in exposed plots as the Quality Class falls, although the mean elevation is much lower.

Referring back to the table of elevations for the four districts on p. 37, it will be seen that whereas approximately 700 ft of elevation are required on the average to reduce the growth from Quality Class I. to Quality Class V. in Wales, in the South-West of England, and in Scotland, there is a difference of less than 400 ft. between the mean elevations of Quality Classes I. and V. in the Rest of England. The explanation probably lies in the fact that the three former districts are mountainous, with hills up to 2,000 ft. high in Devonshire and over 4,000 ft. in Scotland, while in the Rest of England, excluding the Lake District and the Pennines, the hills rarely exceed 1,000 ft., and the greater part of the land is at much lower levels. Where the general range of elevation is small a rise in altitude of, say, 200 ft. will, in most cases, increase the degree of exposure much more than a similar rise in mountainous country.

The following sample plots, measured in Cwm Golog Wood, Kerry Hills, Montgomeryshire, illustrate the effect of increasing elevation and degree of exposure upon the growth of the Larch crop.

Elevation.	Aspect	Exposure.	Soil.	Age.	Height.	Volume per acre.
Ft.					Ft.	Cu. ft.
1050	W.	Sheltered.	Deep loam.	29	52	2,385
1150	W.	Somewhat exposed	Deep loam	29	47	2,220
1250	W.	Moderately exposed	12 in. loam on weathered shales	29	42	1,915

Two hundred feet of elevation, resulting in increasing exposure and rather shallower soil, have reduced the height by 10 feet and the volume by 470 cubic feet per acre.

A large wood of Larch on Lady Blair Hill, Haystoun, Peebles, affords another example of the effect of exposure and elevation. A number of sample plots were measured on the comparatively sheltered North side of the hill. At 1,000 ft. elevation the height class was 60 feet, at 1,400 ft. it was 40 feet, and at 1,600 ft., just below the crest of the hill, only 30-foot class growth was obtained. On the exposed side of the hill the wood was a complete failure owing to wind, and a sample plot was out of the question in the stunted and deformed growth which stretched down the slope of the hill. The soil conditions were fairly uniform through the wood.

A series of sample plots in the well-known Braemore Wood, in Western Ross-shire, remarkable for its extraordinarily heavy production, also illustrated the effect of exposure upon Larch. Sixteen sample plots were measured in this wood; the age varied from 48 to 53 years, and the soil, in all cases except one, consisted of a deep sandy loam derived from schists. In the single sample plot of Quality Class IV. the soil was peaty in places and comparatively shallow. The following table sums up the evidence from these sample plots.

Quality Class.	I. (80-ft.)	II (70-ft.)	III. (60-ft.)	IV. (50-ft.)	V. (40-ft.)
No. of sample plots ...	9	6	—	1	—
Mean elevation	420	610	—	900	—
Degree of exposure ...	Sheltered or moderately sheltered.	Moderately exposed or fully exposed.	—	Fully exposed.	—
Average height of trees...	79	71	—	52	—

The effect of the adverse conditions due to increasing elevation has been to reduce the height growth by 8 feet between 420 ft. and 610 ft. above sea-level, and by 19 feet between 610 ft. and 900 ft. above sea-level.

A final illustration may be given of five sample plots in the Corriegour Wood, on Loch Lochy, Inverness-shire, the details of which are tabulated below:

Elevation. Ft.	Aspect.	Exposure.	Soil.	Age.	Height.
					Ft.
350	N.	Moderately sheltered.	Deep sandy loam.	41	58
400	N.	Moderately sheltered.	Deep sandy loam.	41	59
900	N.W.	Moderately exposed.	Deep sandy loam.	39	50
1000	N.W.	Very exposed.	Deep sandy loam.	40	48
1100	N.	Very exposed.	Deep sandy loam.	39	45

The conditions in respect of age, aspect and soil remaining virtually constant, elevation and exposure are clearly the dominating factors.

Soil.

The following table shows the percentage of Larch sample plots in each district obtained on the various classes of soil.

PERCENTAGE OF SAMPLE PLOTS FOUND IN EACH DISTRICT ON THE SPECIFIED SOIL CLASSES.

District.	Sand.	Sandy Loam.	Loam.	Clay Loam.	Clay.	Peat and Peaty Loam over 12 ins. in depth.
Wales	—	24	66	9	2	—
Devon, Dorset, Somerset ...	7	7	57	15	5	9
Rest of England	16	30	22	17	15	—
Scotland	8	80	10	—	2	—

Loam is the dominant type of soil associated with the Larch woods in Wales and the South-West of England, and sandy loam in Scotland. In the Rest of England, where the geological range is greatest, there is the most even distribution over the various types of soil, except the peaty soils, which were only found under Larch in Devon.

Larch has almost invariably been planted on deep soils, the percentage of sample plots on shallow soil being less than three.

Neither sand nor clay is usually regarded as a good type of soil for Larch, yet out of the 27 sample plots on sand 12 are in Quality Classes I. and II. and 9 in Quality Classes IV. and V., the corresponding figures for the sample plots on Clay being 7 in the first two Quality Classes and 3 in the last two out of a total of 14. Taking the sample plots on sand in England, two plots were obtained in Quality Class II. on the Lower Greensand in Sussex and one on the Trias in Devon, while two sample plots in Quality Class IV. were found on the Lower Greensand, the one from Sussex and the other from Bedfordshire, and one on the Trias in Staffordshire. The only sample plot on sand in Quality Class V. was measured on the Millstone Grit in Durham at 800 ft. elevation. These woods, in Quality Classes IV. and V., on sand, were all described as moderately or fully exposed, and it is quite possible that the poor growth was due to exposure rather than to type of soil.

Larch has rarely been planted on peaty land, and it may be of interest to quote the details of two of the woods met with.

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume
	Ft.					Ft.	Cub. Ft.
Corringdon Estate, South Brent, Devon.	800	S.	Moderately sheltered.	14 in. peaty loam on granitic sand.	57	64	3,500
Eggworthy, near Princetown, Devon.	600	W.	Moderately exposed.	18 in. to 2 ft. peaty loam on granitic sand.	53	67	2,980

Both these woods exhibit a fair average rate of growth, and there is no reason to suppose that the peaty soil has hindered the development of the crop. This type of peaty loam, which accumulates over the granitic soils in some parts of Devonshire, appears to be distinctly fertile, and is of a very different type from the sphagnum or cotton grass bogs of the hills in other parts of the country, where the accumulations consists largely, if not wholly, of vegetable remains.

The main conclusion to be drawn from the above data is that Larch is a catholic species as regards type of soil, and, provided other conditions are favourable, growth of second, or even first Quality Class may be obtained on any of the main soil subdivisions, exclusive of peat.

Larch in Ireland.

The statistical investigation in Ireland was confined to four hill areas in the South-West of the country, viz., the Galtee, Knockmealdown, Comeragh and Monavullagh Mountains. The highest peaks range from 3,000 feet above sea-level in the Galtees to 2,600 feet in the Knockmealdown, Comeragh and Monavullagh hills. The upper slopes of these hills are mainly composed of Old Red Sandstone rocks; the lower slopes of the Carboniferous Limestone.

The soils are uniform, and consist typically of a red sandy loam sometimes merging into sand; they are almost always stony, but usually of fair depth.

The land is usually well sheltered up to 600 ft. elevation, and grows excellent Larch; above that elevation the effect of exposure makes itself felt.

The district as a whole is probably the best wooded area in Ireland, and contains about 25,000 acres under plantation, most of which were planted on ground formerly covered by the old indigenous forest of Oak, Hazel and Holly. The principal market is for pitwood for South Wales and Lancashire, and on this account Larch is the chief species found in the older coniferous plantations, and comprises 34 out of the 47 sample plots measured in the district.

The Larch sample plots belong to the following Quality Classes:

Quality Class	I.—80-ft.	4 sample plots.
,, ,,	II.—70-ft.	19 ,, ,,
,, ,,	III.—60-ft.	6 ,, ,,
,, ,,	IV.—50-ft.	5 ,, ,,

The majority, therefore, belong to the second or 70-ft. Class, so that the growth, on the whole, is considerably better than the average in Great Britain.

The woods have been planted, for the most part, at low elevations, the average elevation being 600 ft. above sea-level. Only four sample plots were obtained above the 1,000 ft. contour.

An interesting series of sample plots was obtained at elevations ranging from 550 ft. to 1,000 ft., which shows the effect of elevation and exposure upon the rate of growth; the details are given below:—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume.
	Ft.					Ft.	Cub. Ft.
Killarney Wood, Tipperary.	550	S.W.	Fully exposed.	Deep sandy loam, many stones.	39	56	3,330
Killarney Wood, Tipperary.	850	S.W.	Fully exposed.	Stony, sandy loam.	41	44	2,560
Killarney Wood, Tipperary.	900	S.	Fully exposed.	Stony loam	42	44	2,040
Killarney Wood, Tipperary.	1,000	S.E.	Moderately sheltered.	Stony, sandy loam.	41	46	2,485

The height growth on the moderately sheltered South-East slope at 1,000 ft. is better than on the more exposed slopes at 850 ft. and 900 ft. At 550 ft. deeper soil and less rocky ground may partly account for the better growth.

When the curves obtained from the height analysis of the Irish sample trees were compared with those of the woods in Great Britain. it was found that the height growth in the first forty years in Ireland is considerably faster. The following table compares the rate of growth of the woods in Quality Class II. in Ireland with that in the same Quality Class in Great Britain.

Age in years.	10	20	30	40	50
Ireland Height in feet.	19	39	53	63	70
Great Britain do.	14	31½	48	61	70

The difference is most marked at 20 years, the Irish curve falling after this point until it joins the other at 50 years of age.

Summary.

The marked effect of increasing exposure and elevation upon the rate of growth of Larch stands out clearly from the above investigation. It appears to be the most sensitive of the species in that respect. None the less, on moderately or well-sheltered slopes up to about 1,000 ft. elevation in Wales, the West of England and Scotland, it is capable of producing large crops of valuable timber.

CHAPTER VI.

Further Discussion of Certain Factors of Locality in Relation to Scots Pine.

In order to consider in more detail the effect of the various Factors of Locality on the growth of Scots Pine, a detailed analysis of specific districts was made. For this purpose the following tracts of country were selected, viz. :—

1. Deeside, in the Counties of Aberdeen and Kincardine.
2. Speyside, in the Counties of Banff, Moray and Inverness.
3. The following Southern Counties of England :—Surrey, Sussex, Hants, Dorset, Somerset and Devon.

These districts, in combination, present practically the whole range of conditions under which Scots Pine grows in this country.

Scots Pine in Deeside.

The River Dee rises in the Cairngorm Mountains and flows Eastwards into the North Sea. The valley is protected on the South and West by the Eastern section of the Grampian Mountains. The elevation of the protecting range is, on the average, over 2,000 feet higher than that of the river. The valley is flanked on the North in Upper Deeside by the Cairngorm Mountains, which rise to 4,000 ft. above sea level, and on Lower Deeside by the high ground dividing Dee and Donside, which varies in elevation from 1,000 to 3,000 ft. The rainfall throughout the district investigated is fairly uniform. viz., 30 to 35 ins. per annum.

Scots pine is the principal forest tree in Deeside, and it still forms considerable tracts of natural forest, *e.g.*, Ballochbuie Forest, Balmoral. The Scots Pine woods are generally found in the valleys and lower slopes of the hills, successful plantations (*i.e.*, plantations sufficiently well stocked to enable sample plots to be taken) of this species being rarely met with in this district on slopes more than 500 ft. above the bottom of the valleys. Larch and Spruce are growing at the higher elevations in certain parts, *e.g.*, Scolty Hill, Banchory; Creag nam Ban, Abergeldie; and at Creag an Fhithich, Mar. The growth of these species exceeds that of Scots Pine under such conditions. Single natural Scots Pine are to be found scattered on the hillsides up to 2,000 ft. above sea level, but a study of their growth is not included in this investigation.

In the area drained by the Dee and its tributaries, 37 sample plots of Scots Pine over 35 years of age were obtained. They were distributed from Durris on the East to Linn of Dee on the West, and from the Hill of Fare on the North to Bridge of Dye on the South. These sample plots fell into the following Quality Classes :—

Quality Class.	I. (60-ft.)	II. (50-ft.)	III. (40-ft.)	IV. (30-ft.)	—
No. of Plots	3	16	12	6	Total. 37

It can be seen that there is a considerable range in the rate of growth. Quality Class I. of Scots pine is found in Deeside, but only in specially favourable situations. Quality Class II. contains the best growth over considerable areas. The data were examined to determine, if possible, what are the principal factors causing a slower height growth than 50 ft. in 50 years. For this purpose only three factors were considered, viz., soil, exposure and elevation. Aspect appeared to have no influence, while the majority of the Scots pine Woods are on gentle to moderate slopes. In view of the widespread damage to Scots pine by squirrels in this district the possible effects of this factor on the rate of growth was kept in view.

Geology and Soil.—Regarding the geology of the district two features stand out, first the masses of granite which extend over large areas, and secondly the extensive Post Tertiary beds of glacial and alluvial origin. The data were analysed to determine whether there was a marked variation in the rate of growth on transported soils compared with those derived from granite. The following table shows the division in each Quality Class according to origin of soil :—

Quality Class.	I. (60-ft)	II. (50-ft)	III. (40-ft.)	IV. (30-ft.)	Total.
Glacial and alluvial deposits	1	11	8	3	23
Granite, and in a few cases gneiss and schist...	2	5	4	3	14

The majority of the Scots pine woods are growing on transported soils, which are generally restricted to the valleys and lower slopes of the hills. The origin of the soil, however, did not appear to have a marked influence on the rate of growth of Scots pine.

In Deeside only light soils are found. Over two-thirds of the sample plots were growing on sands, the remainder being on sandy loams. In general, the transported soils are more sandy than the granitic soils. The two kinds of soil were fairly evenly distributed in the various Quality Classes. When depth of soil, however, is examined, a difference appears. With few exceptions, deep soils prevail wherever the best two Quality Classes are found, while over 30 per cent. of the sample Plots in Quality Class III. and 50 per cent. in Quality Class IV. were growing on relatively shallow soil. The lack of depth was due either to the presence of rock or to the formation of a pan a short distance from the surface. The following example shows the type of growth obtained on pan or rock.

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume. per acre.
	Ft.					Ft.	Cub. ft.
(1) Durris Estate.	300	Flat.	Moderately sheltered.	2 in. humus on 10 in. sandy loam on pan.	58	49	2,845
(2) Glentanar Estate.	650	Gentle.	Moderately sheltered.	1 in. humus on 4 in. sand on 12 in. sand and stones on granite.	103	54	4,205

Insufficient depth of soil, therefore, appears to be an important factor limiting the rate of growth of Scots pine on Deeside.

Elevation.—Scots pine is found growing at a wide range of elevations in Deeside. In the area investigated sample plots were measured in woods beside the Dee at elevations from 200 ft. to 1,200 ft. above sea-level, and, in several places, *e.g.*, on the Hill of Fare, at elevations up to 500 ft. above the bottom of the valley.

The following table gives the maximum, mean and minimum elevations of the sample plots in the various Quality Classes :—

Quality Class.	I. (60-ft.)	II. (50-ft.)	III. (40-ft.)	IV. (30-ft.)
Maximum elevation	350	750	1,200	1,350
Mean elevation	250	450	700	1,100
Minimum elevation	200	150	300	650

The first and second Quality Classes are confined to the area East of Ballater. In the upper reaches of the Dee, where the average elevation of the river is about 900 ft., Quality Class III. was the best obtained, although several of the sample plots were in fully sheltered situations and the soil conditions were favourable.

The high mean elevation of Quality Class IV. is interesting. Deeside is one of the few areas in Great Britain where Scots pine is found extensively above 1,000 ft. elevation, and although conditions are exceptionally favourable in respect of shelter, the growth is seen to be slow. The result does not encourage the planting of Scots pine in the upper hills unless the soil is wholly unsuitable for other conifers.

Exposure.—In Deeside there are few plantations growing in markedly exposed situations, due partly to the protecting mountain ranges and partly to the distribution of the Scots pine plantations within the district. Practically all the sample plots in Quality Classes I. and II. were in woods growing in sheltered positions. In fully exposed situations, however, *e.g.*, on the top of Craigendinnie Hill, Aboyne, and at Little Elrick, Invercauld, the growth falls to the lowest class (30-ft.). It is fairly certain that even moderate exposure is one factor tending to reduce the rate of growth of Scots pine both directly and indirectly. Among the indirect effects of exposure is its relation to squirrel damage. Severe winds tend to break off tops which have been partially ringed by squirrels, and which otherwise might recover from the attack. In three of the Deeside sample plots in Quality Class III., 30-50 per cent. of the trees showed deformation due to previous squirrel damage.

Scots Pine in Speyside.

The effects of environment on the growth of Scots pine was also studied in this district, which resembles Deeside in several ways. It is protected on the South and West by a ring of mountains 2,500-4,000 ft. high—viz., the Grampian, Cairngorm and Monadhliath Mountains. As in Deeside, a considerable number of the plantations of Scots pine are growing on moraines, while the rainfall is similar. Scots pine is the principal tree throughout the valley, and forms several natural forests, *e.g.*, Abernethy Forest, in Strathspey, and Glenmore Forest, at the foot of Cairngorm.

Twenty-five sample plots were measured on Speyside between the sea and Abernethy, where the elevation of the river is about 700 ft. above sea level. The majority of the sample plots were in woods near the river, and thus in sheltered positions, and all were growing on sands and sandy loams. The range in elevation of the sample plots was from 200 ft. to 900 ft. above sea level. Eighteen out of the twenty-five sample plots belong to Quality Class II., and this Class was found over the whole range of elevation. The conditions, then, in this portion of Speyside are curiously uniform; soil and exposure remain almost constant, and only elevation varies, without producing any marked effect upon the rate of growth, differing markedly in this respect from Deeside. Some very fine crops of Scots pine have been grown in this valley, notably in Orton Wood, where several sample plots of first Quality Class were measured, giving volumes of 8,000-10,000 cubic feet per acre at 120 years.

The stocking in the natural forests was too irregular to permit of sample plots being taken. A height-growth analysis of groups of trees, however, was taken in Abernethy and Glenmore Forests. Abernethy Forest is growing on sands and gravels at elevations of from 700 to 1,000 ft. Where the stocking approximated to that of silvicultural conditions a height of about 60 ft. was attained in 120 to 150 years, the height at 50 years being about 40 ft. Glenmore Forest is situated in a valley between the Kincardine Hills on the North and Cairngorm on the South. The range of elevation is from about 1,000 ft. at Loch Morlich to 1,500 ft. on Cairngorm. The soil here consists also of sand and gravel. On the average a height of less than 50 ft. was reached in 150 to 200 years in this forest corresponding to a height of less than 20 ft. at 50 years. The growth in these natural forests is therefore extremely slow, but timber of the finest technical quality is produced.

Scots Pine in Southern Counties of England.

Eighty sample plots of Scots pine over 35 years of age were measured in the Counties of Surrey, Sussex, Hants, Dorset, Somerset and Devon. Both in topography and climate this region contrasts with those already reviewed. It consists of a central plain flanked on the East and West by uplands. Many of the plantations even at low elevations are unprotected to the South-West. Geologically, this area consists mainly of Tertiary, Cretaceous and Jurassic formations, with Devonian Shales and large areas of granite in Devon and Somerset. The rainfall varies from 28 ins. in the East to 40 ins. in the West.

The following table shows the number of sample plots in each Quality Class :—

Quality Class.	Over I. (70-ft.)	I. (60-ft.)	II. (50-ft.)	III. (40-ft.)	IV. (30-ft.)
No. of Plots	4	30	24	20	2

When these figures are contrasted with those for Deeside and Speyside in Scotland the much higher proportion of sample plots in Quality Class I. in the South of England will be noted. In a few localities faster growth than Quality Class I. (60-ft. Class) was found, and the following details refer to two of these sample plots in the 70-ft. Class :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.					Ft.	Cub.ft.
Holmhill Enclosure, New Forest.	180	Flat.	Sheltered by surrounding wood.	18 in. dark grey sand.	95	89	6,970
Warborough Plantation, Starcross, Devon.	260	E.	Sheltered.	18 in. sandy loam on Permian conglomerate.	61	73	5,160

Soil.—A large number of trees were felled in different compartments of the Ascot Woods (Windsor Forest). The trees were also cut into sections and the height-growth analysed.

The following table shows the distribution of the compartments according to Quality Class :—

Quality Class.	Over I. (70-ft.)	I. (60-ft.)	II. (50-ft.)	III. (40-ft.)	IV. (30-ft.)
No. of compartments ...	4	28	54	38	4

The average Quality Class is seen to be the second or 50-ft. Class, but the great range in rate of growth—from 30 ft. to 70 ft. at 50 years—under approximately uniform conditions as regards elevation and exposure, illustrates clearly the importance of the third main factor, namely, soil. The term soil, as used in this connection, refers not merely to the texture, *i.e.*, whether sand, loam or clay, but to all the other factors, such as depth, water supply, fertility, etc., which are certainly of equal importance with the texture, though much less easy to define or classify.

The Scots pine has been planted throughout the South and South-West of England mainly on sands and sandy loams, about 70 per cent. of the sample plots being measured on these soils. The soils are mostly derived from the Bagshot Sands of the Eocene formation, which are extensively developed in the Bagshot district, and in the South of Hampshire and Dorset. These soils vary greatly in texture and quality. In parts of the New Forest the soils are loamy and dark in colour, yielding crops in the 60-ft. and 70-ft. Classes. In other areas, notably in Dorset and round Bagshot, the sands are coarse and leached out by the rain, resulting in the formation of pan a short distance below the surface. Where the pan is hard and impermeable a great obstacle is furnished to root development, and much of the poorest growth was due to this cause.

Details are given below of two of the sample plots occurring on pan illustrating the very poor growth produced :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Feet.					Feet.	Cubic feet.
Morden Park, Dorset.	40	Flat.	Exposed to the S.W.	6 in. peaty humus on 12 in. sand on 2 in. hard pan on yellow sand.	108	55	3,390
Ascot Woods, Compartment 130.	415	Flat.	Sheltered.	4 in. peaty humus on 10 in. brown sand on 4 in. pan on yellow sand and gravel.	92	60	3,045

A number of woods were measured growing on peaty soils at higher elevations in Somerset and Devon. The depth of peat was small, and appeared to have no marked effect on the rate of growth.

Elevation.—Sample plots of Scots pine were obtained at wide range of elevations in these counties. Though the elevations in the central region are low, data were obtained in the Surrey Hills up to 500 feet, and in Somerset and Devon up to over 1,000 feet above sea-level. The following table shows the maximum, mean and minimum elevations of the sample plots in the various Quality Classes :—

	Quality Classes				
Elevation.	Over I. (70-ft.)	I. (60-ft.)	II. (50-ft.)	III. (40-ft.)	IV. (30-ft.)
Maximum	300	700	750	1,050	300
Mean	200	200	300	400	200
Minimum	100	50	50	50	50

The mean elevations are consistently lower than those for Deeside, explained by the difference in general topography. In no case did elevation appear to be an important cause of low Quality Class. All the poorer Quality Class sample plots at high elevations were in markedly exposed situations, while sample plots belonging to Quality Classes I. and II. were obtained up to 750 feet above sea-level.

Exposure.—The effects of exposure on the rate of growth was naturally more noticeable in the Counties of Somerset and Devon, where the woods in which sample plots were taken were at higher elevations and in more exposed situations.

An example of the effect of extreme exposure was seen on the top of Culbone Hill, near Porlock, Somerset, where Scots Pine and Spruce were growing near together ; the former were only 15 feet high in 43 years and badly blasted by the wind; the latter were 39 feet high at the same age and form a dense, though badly forked, crop. Exposure, on the whole, appeared to be the principal adverse factor in these South-Western Counties. On the higher ground, in Surrey and Sussex, and in the Hampshire basin and Dorset, even at low elevations, exposure to the S.W. appeared to have a considerable effect upon the growth of the Scots pine.

Summary.

The importance of soil conditions for the growth of Scots pine comes out clearly from this review. In this respect Scots pine is in strong contrast to Larch and Spruce, in which soil conditions appear to play a relatively small part. The reason probably is that the latter species have been planted mainly on soils derived from the weathering of rock *in situ* yielding usually deep, fertile sandy loams or loams, and there is a wide margin of safety. Scots pine, on the other hand, has been largely planted on transported soils or on formations such as the Bagshot sands, which are initially poor in food materials, and the margin of safety is small. Moreover, the occurrence of the majority of the Scots pine on flat ground tends in the same direction, *i.e.*, to reduce the margin of safety, for pan formation is much more liable to take place on flat than on sloping ground, the effect of which is often to hold up water and prevent the necessary aeration of the roots, besides checking root development in a downward direction.

In addition to soil, however, elevation is also an important factor in the growth of Scots pine; the conditions in Deeside and Speyside, with their great block of protecting mountains and morainic deposits in the valleys, are hardly typical of hill conditions in general. Scots pine, of course, will grow in the hills and on very dry soils may be the best species, but the growth is almost always slow.

CHAPTER VII.

The Growth of Spruce at High Elevations.

One hundred and thirty sample plots of Common spruce, of 35 years of age and over, have been measured in England and Scotland in the course of the Survey. The effective number, however, is reduced to one hundred and twenty-two when certain duplicate or abnormal plots are excluded. The corresponding figures for Larch and Scots pine are 335 and 296 respectively.

The relatively small number of Spruce woods measured gives an indication of the restricted occurrence of this species in Great Britain. Pure Spruce woods of any size were rarely met with, while in many cases the sample plot comprised the greater part of the plantation.

The majority of the Spruce sample plots of all ages were obtained in plantations consisting originally of a mixture of Spruce with Scots pine or Larch, or of both, in which the more rapid growth of the Spruce had led to the suppression of the other species. This fact may explain in part the small number of trees per unit area of ground and the large size of the average stem, which form so striking a feature in our Spruce Yield Tables when compared with those on the Continent.

Few young Spruce plantations were met with in the course of the statistical survey, and it seems clear that within the past twenty years even less Spruce has been planted than in earlier decades. The low price of the timber in the past, and the unsaleability of thinnings, are probably mainly responsible for the disfavour into which Spruce has fallen.

The war, however, has done much to break down the prejudice against British Spruce as a timber, while the investigation which follows brings out the way in which the tree responds to conditions which are unfavourable to the growth of other species.

Unfortunately, the sample plots of Spruce are scattered thinly over the country, without a sufficient number in any one district to form the subject of an investigation on the same lines as those carried out for Larch or Scots pine. The most striking feature of the data which have been collected is the large number and good growth of the sample plots measured at relatively high elevations, a point of especial interest at the present time, when much hill planting will probably be done.

It is proposed in the following pages to examine only the Spruce sample plots measured at elevations of 1,000 ft. and over.

Thirty-eight sample plots measured during the present survey, together with four sample plots measured by Mr. R. L. Robinson in the Kerry Hills, Montgomeryshire, in 1912, form the basis of this investigation.

The sample plots were distributed over the following counties in England and Scotland :—

England.

Northumberland ...	2
Cumberland	4
Durham	2
Yorkshire	1
Merionethshire ...	1
Shropshire	3
Montgomeryshire ..	4
Radnorshire ...	3
Somerset	7
Devon	5

Scotland.

Aberdeenshire ...	8
Peebles-shire ...	2

The principal mountain ranges of Great Britain are represented, with the exception of the Lake District Hills, so that a wide range of conditions is obtained.

The number of sample plots in each Quality Class is shown in the following table :—

Quality Class.	I. (80-ft.)	II (70-ft.)	II. (70-ft.)	IV. (50-ft.)	V. (40-ft.)
Number of sample plots... ...	Nil	2	11	19	10

Relatively slow growth is a characteristic of these woods. The average Quality Class of the sample plots at over 1,000 ft. elevation is the fourth or 50-ft. Class. Class I. is unrepresented, and only two plots were obtained in Class II.

Elevation.—The mean elevation of all the sample plots is 1,270 feet above sea-level. The following table shows the maximum and mean elevations of the woods in each Quality Class.

Quality Class.	II. (70-ft.)	III. (60-ft.)	IV. (50-ft.)	V. (40-ft.)
Maximum elevation	1,300	1,500	1,700	1,880
Mean elevation	1,160	1,200	1,220	1,500

The maximum elevations rise steadily from 1,300 ft. in the 70-ft. class to nearly 1,900 ft. in the 40-ft. Class. The mean elevation rises slowly from the 70-ft. to the 50-ft. Class, and then sharply from the 50-ft. to the 40-ft. Class.

The highest sample plots in Quality Classes IV and V. were obtained in Ashgill Wood, near Alston, in the Pennines. The measurements taken in this wood are discussed later.

Other sample plots at over 1,500 ft. elevation were measured in the Pennines of Durham and Yorkshire, in the Kerry Hills and near Rhayader, in Radnorshire.

Exposure.—The majority of the sample plots were measured in woods planted under more or less sheltered conditions. Out of the total of 42 sample plots, only 4 were fully exposed to the South-West or West; of the remainder, 14 were moderately exposed, and 24 moderately to well sheltered. At elevations of 1,000 ft. above sea-level the effect of direct exposure is very great, and trees have rarely been planted without some shelter to westward. The few fully exposed woods which were found are all the more interesting in consequence. Details of these exposed sample plots are given below :—

Situation.	Elevation.	Soil.	Age.	Height.	Volume per acre.
	Ft.			Ft.	Cu. ft.
(1) Near Crickhowell, Brecknock ...	1,200	Loam.	41	44	3,300
(2) Kerry Woods, Radnor	1,530	4 in. peat on loam.	42	41	2,510
(3) On the top of Culbone Hill, N. Somerset.	1,280	Deep peaty loam.	43	39	3,540
4) Near Princetown, Devon ...	1,450	Peaty loam on granitic sand.	38	38	2,240

The remarkable growth of these woods shows that Spruce is able to withstand extreme conditions of exposure and to produce a large volume of timber under the most adverse conditions.

Spruce is generally considered as the least wind-firm of the important conifers owing to its surface-rooting character. The impression gained during the Survey, however, was that Spruce woods withstand the effects of constant wind pressure better than either Larch or Scots pine. The deformation of stem so characteristic of both the latter species under severe exposure was hardly ever seen in the interior of a Spruce wood, provided the latter was grown in a pure block, and not as single trees in mixture with other species. It is true that Spruce is more liable to be thrown by violent winds than Larch or Scots pine, but the danger is less than is often imagined, and may be overcome to some extent by correct silvicultural methods.

Aspect.—All aspects are represented, and the distribution is fairly uniform in each Quality Class. Twenty-five of the sample plots were obtained on aspects ranging from North to South-East and seventeen on aspects ranging from South to North-West. That is to say, the majority of the woods were grown on the sheltered and colder North and East aspects.

Soil.—The number of sample plots occurring on each of the main classes of soil is shown in the following table :—

	Sand.	Sandy Loam.	Loam.	Clay-Loam.	Clay.	Peaty soils.
Number of sample plots	—	13	16	3	—	10

The table reflects, generally speaking, the prevailing type of soil met with in the hills of Great Britain. Pure sands are rarely found at the higher elevations, while the clay-loams and clays, usually of glacial origin, are commonly covered with a layer of peat. Sandy loams and loams would appear to be the typical soils of the well-drained upper slopes of our hills. With few exceptions the soils were deep. The considerable number of Spruce woods on the sandy loams is worth noting, since this type of soil is generally considered too light for Spruce. Of the thirteen sample plots on sandy loam nine were in Aberdeenshire—*i.e.*, in the North-East of Scotland, where the rainfall is considerably lower than in the Western Highlands, and probably not above the average for the hills in the West of England and Wales. In the description of certain of these sample plots particular reference was made to the dry or shallow nature of the soil on which the woods were growing. The following details apply to two of these woods :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.					Ft.	Cu. ft.
Glenkindie Estate, Aberdeenshire.	1,300	S.E.	Moderately sheltered.	Sand to sandy loam.	66	50	3,225
Mar Lodge, Aberdeenshire.	1,500	W.	Sheltered.	Very shallow sandy loam.	84	77	7,175

There is no reason for supposing that Spruce will not thrive on the lighter soils in the hills as well as on the heavier and worse-drained land provided the rainfall is sufficient.

The sample plots growing on peaty soils were found in the Pennines, Wales and Devonshire. In the majority of these woods the soil was described as a brown or black peaty loam, an impure form of peat which gives excellent growth of Spruce.

These peaty loams cover large areas of the granitic sands of Dartmoor and Exmoor. The details of two of the Dartmoor sample plots are given below :—

Situation.	Elevation.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.				Ft.	Cu. ft.
Dartmeet, Devon ...	1,020	Moderately exposed.	18 in. to 24 in. peaty loam on granitic sand.	49	62	5,850
Near Widdicome, Devon	1,000	Sheltered.	Deep light brown peaty loam.	61	63	4,800

A purer form of peat with less admixture of mineral soil was met with in the Northern Pennines, where most of the high land is covered with a layer of peat varying in thickness from a few inches to many feet. The particulars given below refer to three sample plots from this region, two from elevations of over 1,000 ft. above sea level and one obtained on lower ground, but grown on a greater depth of peat :—

Situation.	Elevation.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.				Ft.	Cu. ft.
South of Allendale, Northumberland.	1,100	Well sheltered.	12 in. to 2 ft. of peat on clay loam.	57	63	4,480
Ashgill Wood, Cumberland.	1,600	Moderately sheltered.	6 in. to 9 in. peat on clay.	70	49	3,695
Near Corbridge, Northumberland.	750	Moderately sheltered.	3 ft. to 4 ft. brown peat.	64	67	5,500

Good growth on peat up to 3 ft. in depth was also found in several localities in Scotland.

Production.—The details of several of the Spruce woods at high elevations have already been given, including the wood near Dartmeet, Devonshire, growing on peaty loam, which gave 5,850 cubic feet of timber in 49 years, representing a mean annual increment of just under 120 cubic feet.

Three further outstanding examples of high production are shown below :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height	Volume. per acre.	Mean annual increment per acre.
	Ft.					Ft.	Cu ft.	Cu. ft.
Rhiwlas Estate, Merionethshire.	1,000	Flat.	Moderately exposed.	Loamy sand on rock.	51	61	7,700	151
South of Knighton, Radnorshire.	1,200	N.E.	Well sheltered.	Loam.	54	60	5,800	107
Abergeldie Estate, Aberdeenshire.	1,300	N.N.W.	Moderately exposed.	Sandy loam.	63	64	6,560	104

These sample plots represent the maximum production obtained at elevations of over 1,000 ft.

The minimum production of 41 cubic feet per acre per annum was obtained in Ashgill Wood, Cumberland, at over 1,800 ft. elevation, on the extreme outer edge, where the conditions were scarcely comparable with those in the interior of the wood. Omitting this, and a similar sample plot at 1,700 ft. in the same wood, the lowest yield obtained under normal conditions was that of 48 cubic feet per acre per annum given by two sample plots from Wales and Scotland, to which the following particulars refer :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.	Mean annual increment per acre.
	Ft.					Ft.	Cu. ft.	Cu. ft.
Abbey-Cwmhir, Radnorshire.	1,600	S.E.	Moderately sheltered.	Peaty loam on loam.	68	50	3,380	48
Invercauld Estate, Aberdeenshire.	1,250	S.W.	Moderately exposed.	Sandy loam.	75	61	3,630	48

The most interesting Spruce wood found in the course of the Survey was that of Ashgill, South of Alston, in the Pennines. The wood lies on the west side of the road from Alston to Middleton, in Teesdale, and about 5 miles from the former town. The original area of the wood was about 300 acres, but the greater part, including all the best growth, had been felled before it was reached by the Survey party.

The bottom of the valley below the wood is 1,250 ft. above sea level, while across the valley to the west rises Alston Moor, culminating at a distance of four miles in Cross Fell with a height of 2,800 ft. above sea level. The greater part of the wood faces West and North, but it also extends into a small steep-sided valley called Little Gill, running North and South and sheltered from the West by a tongue of high ground. The highest sample plots were measured in this part of the wood. The main block of the wood on the West and North slope above the road is only sheltered by the high ground across the valley, and was not planted above 1,750 ft., but a narrow belt of mixed Norway Spruce and White Spruce runs over the crest of the hill at 2,000 ft. down into Little Gill Wood, which it joins at 1,900 ft. on the East side of the ridge. The exposure at the top is extreme, but though the Norway Spruce are completely dwarfed, the White Spruce have managed to attain 10 ft. to 15 ft. in height.

Eleven sample plots were measured in the portions of the wood which had not yet been felled; four of these were selected as typical of the varying conditions found, and are included in the 42 plots which form the subject of the present investigation, the other seven were excluded in order not to overweight the data with measurements taken from a single wood.

The lowest sample plot measured in Ashgill Wood was 1,600 ft. above sea level; and the highest 1,880 ft. Five sample plots lay between 1,600 ft. and 1,700 ft., four between 1,700 ft. and 1,800 ft. and two over 1,800 ft. The average elevation of all the sample plots amounted to 1,700 ft. The ages obtained from the ring-counts of sample trees varied considerably, the oldest trees being 73 and the youngest 53 years old. The mean age of the whole wood may be taken as 64 years.

The highest sample plot was measured in Little Gill, just below the juncture of the narrow belt with the main part of the wood. The details of this sample plot given below show the extraordinary value of even 100 ft. of shelter at an elevation of almost 2,000 ft. above sea level.

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.	Mean annual increment.
	Ft.					Ft.	Cu. ft.	Cu. ft.
Little Gill, Ashgill Wood, Cumberland	1,880	N.E.	Moderately sheltered.	Deep loam	66	52	4,230	64

The ground at this point slopes steeply down to the Little Gill, the streamlet which has produced the subsidiary valley up which the wood extends. Just above the stream on the opposite side another sample plot was measured at 1,700, showing an appreciably better rate of growth. The following details apply to this sample plot :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.	Mean annual increment.
	Ft.					Ft.	Cu. ft.	Cu. ft.
Little Gill, Ashgill Wood.	1,700	W.	Well sheltered.	Loam.	73	64	5,300	73

The largest yield and highest mean annual increment of all the sample plots in the 40-ft. class was obtained at 1,650 ft. on the comparatively exposed Western side of Ashgill Wood. One hundred feet higher up the hill the edge of the wood is reached and the trees of the outer belt were severely damaged by wind, but where the plot was taken the crowns showed little, if any, signs of wind damage, and it was clear that the upper part of the wood was functioning as an efficient wind break to the trees below.

The particulars of this sample plot are as follows :—

Situation.	Elevation.	Aspect.	Exposure.	Soil.	Age.	Height.	Volume per acre.	Mean annual increment.
	Ft.					Ft.	Cu. ft.	Cu. ft.
Ashgill Wood (Main Block).	1,650	N.W.	Moderately exposed.	Loam.	66	54	4,760	72

Ten out of the eleven sample plots measured in Ashgill Wood were carefully selected in the usual way so as to exclude gaps, and they provide data from the best stocked areas that were seen. In addition to these, a large sample plot was marked out and measured in a typical poorly-stocked part of the wood at 1,650 ft. elevation on the west slope of the hill above the road. The following figures were obtained for this plot.

Age.	Height.	Quarter girth at 4 ft. 3 in.	Number of stems per acre.	Volume per acre.	Mean annual increment.
	Ft.	Ins.		Cu. ft.	Cu. ft.
61	46	7	380	2,370	39

The soil over the greater part of the wood consists of a layer of peaty loam from 3 in. to 12 in depth, passing into heavy loam or clay.

Samples of the timber were sent to London to be tested, and were found to possess excellent mechanical properties.

It is not suggested that the measurements taken in this wood, remarkable though they are, would justify the indiscriminate planting of land up to 1,800 ft. or 1,900 ft. Spruce woods at lower elevations have failed in the past owing, perhaps, to excessive exposure or unsuitable soil. The general conditions, however, of soil and exposure at Ashgill are fairly typical of large areas of the Central Pennines, and the results appear to justify the planting of Spruce on a larger scale in these hills.

Comparison of the growth of Spruce at high elevations with that of other species.—Direct comparison between the growth of Spruce and Larch in the same locality was possible only in two instances—the one taken from Wales and the other from Somerset.

Details of the sample plots are given in the following table :—

Situation.	Species.	Elevation.	Soil.	Age.	Height.	Volume per acre.	Mean annual increment.
		Ft.			Ft.	Cu. ft.	Cu. ft.
On the Abbey-Cwm-hir Estate, N.W. of Rhayader, Radnorshire.	Spruce.	1,600	4 in. peaty loam on loam.	68	50	3,380	48
	Larch.	1,600	Loam.	65	42	1,855	28
South of Oare, on Exmoor, Somerset.	Spruce.	1,050	Loam.	41	45	2,955	72
	Larch.	1,000	Loam.	46	49	1,615	35

The far heavier volume production of Spruce stands out clearly in this table.

No example was found of Spruce and Scots pine growing in adjacent areas at over 1,000 ft. elevation.

As an indirect method of comparison we might consider an upland district such as the Central Pennine Range between the Tyne and the South of Yorkshire, and analyse the measurements obtained of Spruce, Larch and Scots pine within that area. If this is done in respect of elevation and Quality Class the following table is obtained :—

Quality Class.	Spruce.	Larch.	Scots Pine.
	Mean Elevation.	Mean Elevation.	Mean Elevation.
I.	—	—	—
II.	—	—	830
III.	1,040	—	950
IV.	1,200	840	960
V.	1,450	870	—

It thus appears that in this particular district at an elevation of approximately 1,000 ft. third Quality Class Spruce and third to fourth Quality Class Scots pine can on the average be obtained, while fifth Quality Class Larch is only found at a considerably lower elevation. If, for purposes of comparison, it is assumed that third Quality Class Spruce and Scots pine and fifth Quality Class Larch are produced at 1,000 ft., reference to the Yield Tables shows that the respective final yields at 60 years would be as follows :—

——	Spruce.	Larch.	Scots Pine.
	Cu. ft.	Cu. ft.	Cu ft.
Volumes at 60 years per acre... ...	5,910	1,940	2,790

Thus on the above figures Spruce at 1,000 ft. in the Pennines yields in 60 years more than three times as much as Larch and more than twice as much as Scots pine.

The low production of Larch in the Pennines is interesting. The excellent growth of the species at high elevations in the West of England and Wales and in Scotland has already been referred to. In Wales, for example, 18 sample plots of Quality Class III. were measured at elevations between 1,000 ft. and 1,250 ft. The greater degree of exposure over most of the Pennine country, together with the fact that the soils are usually badly drained and peaty, probably accounts for the inferior rate of growth of Larch in these hills.

As regards the sample plots obtained in the lower hills and plains, reference may be made to the very poor growth found in certain districts at low elevations. As we have seen, the abundant rainfall in the hills enables excellent crops of Spruce to be grown on light, sandy loams (vide details given above of the sample plots measured in Western Aberdeenshire). In areas of low rainfall, however, and near sea-level, it is much more important to plant on the heavier soils, which are able to conserve the moisture.

The details below, which relate to a sample plot measured in a wood planted at a low elevation on light, sandy soil, with low rainfall, clearly illustrates this point :—

Situation.	Elevation.	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.				Ft.	Cu. ft.
Balnagown Estate, Ross and Cromarty.	150	Sheltered.	Gravel and sand on quartzite schist.	63	56	4,000

All the sample trees felled in this plot were rotten at the butt.

Up to the present 80-ft. class Spruce has only been found at low elevations. The highest of the 13 sample plots in this class was measured at only 450 ft. above sea-level, the mean being 300 ft. All were in very sheltered localities. This Quality Class must be regarded as representing exceptionally favourable conditions. Quality Class II. has a very considerably wider range. One sample plot was measured at over 1,000 ft. elevation in the Kerry Hills, Radnorshire, and another at 1,300 ft. elevation on Brown Clee Hill, Shropshire. The following data refer to these sample plots :—

Situation.	Elevation.	Aspect	Exposure.	Soil.	Age.	Height.	Volume per acre.
	Ft.					Ft.	Cu. ft.
Kerry Hills. Radnor.	1020	N.	Sheltered.	Loam.	43	65	4,900
Brown Clee Hill, Shropshire.	1300	N.E.	Sheltered.	Deep sandy loam.	44	66	4,465

Quality Class II. probably represents average good conditions for the species.

Conclusion.—Apart from the more recently introduced exotics such as Douglas fir and Sitka spruce, the Norway spruce is seen to be the best volume producer of our common conifers. It is especially useful as a timber-producing tree at the higher altitudes, where its good height-growth and resistance to exposure make it a more certain crop than either Larch or Scots pine. Larch finds its optimum conditions on well-drained slopes at moderate elevations, where there is no great degree of exposure to the prevailing winds. Finally, the sandy soils in the valley bottoms and plains seem the natural home of the Scots pine, though it has also a place on light soils in the lower hills, which are too dry to carry Larch or Spruce.

CHAPTER VIII.

Larch Canker. Crown Damage in Scots Pine. Heart-rot.

Larch Canker.

The disease caused by the parasitic fungus *Dasyscypha calycina* is extremely widespread on European Larch in Great Britain, and some signs of it were found in almost every wood of that species measured in the course of the survey. The Larch in the South-West of Ireland, on the other hand, appeared to be almost free from disease.

The observations made in the field were of a general character and were confined to notes on the relative abundance of visible canker in the trees. These notes permit a rough classification of the data into (a) badly cankered woods in which a large proportion of the trees were affected so as to cause serious stem deformation and (b) sample plots in which the canker, if present, was not very widespread or of a serious nature.

Out of 438 sample plots measured in Great Britain only 54 plots, *i.e.*, 12 per cent. of the total number, were classified as badly cankered. It must be remembered that the sample plots were measured only in well-stocked woods, a very small proportion of which were under 20 years of age, and plantations which had been so severely attacked that the majority of trees had to be removed would not come under review.

An examination of the sample plots classified as "badly cankered" revealed the following points of interest :—

(1) When the Larch sample plots were divided into two groups, the one containing woods up to 40 years of age and the other woods over that age, it was found that 22 per cent. of the younger woods were badly cankered against only 6 per cent. of the woods over 40 years of age. The smaller proportion of badly cankered sample plots in the older woods is due partly to the removal, in course of time, of

most of the badly cankered stems in the thinnings and partly to the gradual occlusion of the canker wounds on the remaining trees. There is also the possibility that canker may have been less widely spread in former years.

(2) The following table shows the distribution of the badly cankered sample plots over the different Quality Classes for the younger and older woods.

CANKER IN LARCH—GREAT BRITAIN.

Quality Class.	(a) Up to 40 years of age.		(b) Over 40 years of age.	
	No. of badly cankered sample plots.	Proportion of total number in Quality Class.	No. of badly cankered sample plots.	Proportion of total number in Quality Class.
		Per cent.		Per cent.
I. (80-ft.)	7	24	—	—
II. (70-ft.)	12	16	3	4
III. (60-ft.)	13	30	7	8
IV. (50-ft.)	5	31	4	8
V. (40-ft.)	—	—	3	10

There seems a slight tendency for the proportion of badly cankered plots to increase in the poorer Quality Classes, but the small number of cases makes it unsafe to draw any definite conclusions.

(3) The 54 sample plots with which we are dealing were found to occur on all types of soil from sandy loam to clay, but mainly on the sandy loams and loams which form the majority of the Larch soils in this country. Badly cankered woods were found at all elevations up to 1,250 ft. above sea-level and on the gentlest to the steepest slopes. Neither aspect nor exposure appear to bear any relation to degree of canker.

(4) Taking only the sample plots up to 40 years of age, in nearly 50 per cent. of the badly cankered areas the crops were much overstocked. Five woods had received no thinning at all, while twelve had been much under-thinned and were far too dense at the time of measurement. In three of the remaining sample plots the canker was definitely traced to severe frost damage in early youth.

In six cases the Larch had been mixed with Scots pine, Corsican pine or hardwoods which had later been suppressed and killed out by the Larch. It would seem that mixture with other species is no guarantee against severe attack by canker.

Japanese Larch.—A few trees were found showing signs of canker, but the plantations, as a whole, were completely free from the disease.

Crown Damage in Scots pine.

Scots pine is the most subject of the principal conifers to damage in the crowns in early and middle life. In some cases the proportion of broken crowns is so large that it becomes impossible to secure a satisfactory final crop of timber.

There are several contributory causes, of which the most important are: (1) squirrels, (2) insect damage caused by pine beetle and pine tortrix moth, (3) snow break. Squirrels appear to do most damage in Scotland, where there are large tracts of conifers, as in Strathspey and Deeside. They do little harm in areas which contain a fair proportion of Oak or Beech. The squirrels tear off strips of bark from the stem in the lower part of the crown. In partial attacks this wounding of the stems is the only damage, but when the attack is severe trees may be girdled, resulting in the death of the top, which is broken over by snow or wind. Practically all plantations in Lower Deeside show some evidence of squirrel damage, and the amount of harm done in the aggregate is very great. In England the greater part of the damage appeared to be done by snow, especially in the hills. In some hill districts in Scotland, however, and notably in the woods planted by the late Duke of Atholl, between Blair and Dalwhinnie, snow-break largely determined the fate of the woods.

The number of forked stems and damaged crowns was counted when the sample plots were measured, and the results are briefly discussed below. Damage in the crowns after the age of 60 years is not, as a rule, very important if the stem below has not been harmed, and for that reason sample plots over this age have been left out of consideration.

Seventeen sample plots below 60 years of age were found to contain over 30 per cent. of forked and broken crowns, and forty-two to contain between 10 per cent. and 30 per cent. of broken crowns. These 59 sample plots represent 18 per cent. of the total number of Scots pine woods measured.

It has already been remarked that Scots pine has been little planted in the hills in England, and certainly the results of planting at high elevations are not very encouraging. Eleven sample plots under 60 years of age were measured at elevations of over 900 feet above sea-level; of these, five contained over 30 per cent. of forked and broken crowns, and five over 15 per cent. Five of the sample plots contained in addition over 10 per cent. of stems forked below the crown.

It seems probable that the question of origin of seed has a bearing on this problem, and that Scots pine of good type, such as that in parts of Strathspey, is less liable to coarse and branching growth or to snow-break than Scots pine from seed of foreign origin.

Heart-rot in Larch, Scots pine and Spruce.

During the course of the survey a record was kept of stems which were defective at the butt owing to heart-rot. (The origin of the heart-rot was not investigated, but only the degree of damage.) Data were collected from two sources:—

(1) Sample trees felled in sample plots.

(2) Felled groups.

Felled stems were classified into—

(a) Sound.
(b) Stained by incipient decay.
(c) Moderately decayed.
(d) Badly decayed.

As regards the trees felled in sample plots, it should be pointed out that ten stems only were available per plot, and it is possible that in many cases the sample trees, which were specially selected from an altogether different point of view, did not provide a fair sample of the soundness of the whole crop. As regards felled areas, the distribution was less wide than with sample plots, and, moreover, the conditions of growth as a whole were different; the crops were frequently mixed conifers and hardwoods, and an undue proportion was obtained from the Eastern Counties. The data from the two sets of observations are therefore hardly comparable. The following observations, however, may be of interest:—

1. The proportion of defective trees in Scots pine is much less than in either Larch or Spruce.

2. The proportion of defective trees is far higher in the felled groups than in the sample plots. This is true for the three species, but is particularly well marked in Spruce, the sample plots showing 19 per cent. and the felled groups 77 per cent. of defective trees.

3. Age naturally affects the extent and intensity of the disease. The number of woods in which trees showing signs of heart-rot were recorded is approximately doubled between the ages of 30 and 80 years. The felled groups were obtained, on the whole, in older woods than the sample plots, a fact which accounts for part of the difference between the two sets of data.

4. Decay in Larch and Spruce is worst on the light soils and in the dry climate of the East of England. Taking the felled groups alone, more than 60 per cent. of the Spruce woods measured in the Eastern half of England contained a large proportion of trees with heart-rot, as compared with 23 per cent. for woods in the western half of the country. The corresponding figures for Larch were 52 per cent. in the East and 29 per cent. in the West. It is interesting to note that in the West of the country Spruce is slightly less affected by decay at the butt than Larch. This is borne out by the figures for the sample plots for the whole of Great Britain, according to which only 19 per cent. of the Spruce woods contained defective trees, as compared with 28 per cent. of the Larch woods. Many more old woods, however, of the Larch species were measured than of the Spruce.

APPENDIX A.

Yield Tables

for

1. European Larch in the British Isles.
2. Scots Pine in England.
3. Scots Pine in Scotland.
4. Norway Spruce in the British Isles.

The data given in the Yield Tables relate to the production of timber on one acre of fully-stocked wood.

The mean quarter-girth is given in inches at breast height (4 ft. 3 ins. from the ground), the total basal area in square feet quarter-girth at breast height and the volume in cubic feet under bark measured down to 3 ins. diameter.

The following factors may be used for converting these tables from the quarter-girth system with British units of measurements into the diameter system with metric units of measurement :—

Feet to metres = feet x 0.3048.

Inches quarter-girth to centimetres diameter = inches quarter-girth x 3.234.

Number of stems per acre to number of stems per hectare = number of stems per acre x 2.471.

Square feet quarter-girth per acre to square metres per hectare = square feet quarter-girth per acre x 0.2922.

Cubic feet quarter-girth per acre to cubic metres per hectare = cubic feet quarter-girth per acre x 0.0891.

LARCH.

QUALITY CLASS I.

(80-ft.)

Main Crop.							Thinnings.	
Age in Years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	18	—	—	—	—	—	—	—
15	29	3	—	—	—	—	—	—
20	40	4	900	98	·398	1560	—	—
25	50	5	670	114	·403	2300	230	155
30	58	6	520	126	·397	2900	150	190
35	65	6¾	420	134	·394	3430	100	220
40	71	7½	350	140	·390	3880	70	245
45	76	8¼	295	144	·389	4260	55	270
50	80	9	260	148	·386	4570	35	290
55	84	9¾	230	151	·384	4870	30	315
60	87½	10¼	205	153	·383	5130	25	330
65	91	10¾	185	155	·383	5400	20	325
70	94	11½	170	157	·382	5630	15	290
75	97	12	158	158	·382	5850	12	250
80	100	12¼	150	159	·382	6070	8	210

LARCH.

QUALITY CLASS II.

(70-ft.)

Main Crop.							Thinnings.	
Age in Years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	14	—	—	—	—	—	—	—
15	23	—	—	—	—	—	—	—
20	31½	3¼	1160	82	·348	900	—	—
25	40	4¼	850	99	·384	1520	310	120
30	48	5	640	113	·387	2100	210	150
35	55	6	500	123	·384	2600	140	180
40	61	6¾	410	131	·382	3050	90	200
45	66	7½	350	137	·377	3410	60	220
50	70	8¼	310	141	·375	3700	40	240
55	74	8¾	275	145	·373	4000	35	250
60	77½	9½	240	148	·370	4250	35	260
65	81	10	210	151	·369	4510	30	265
70	84½	10¾	190	153	·368	4760	20	260
75	87	11¼	175	155	·368	4960	15	230
80	90	11¾	165	156	·368	5170	10	180

LARCH.

QUALITY CLASS III.

(60-ft.)

Main Crop.							Thinnings.	
Age in Years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	11	—	—	—	—	—	—	—
15	18½	—	—	—	—	—	—	—
20	26	—	—	—	—	—	—	—
25	33	3½	1060	87	·352	1010	—	—
30	39½	4¼	800	100	·370	1460	—	—
35	45½	5	620	111	·374	1890	180	145
40	51	5¾	510	119	·377	2290	110	160
45	56	6½	430	126	·374	2640	80	175
50	60	7¼	370	132	·367	2910	60	185
55	64	7¾	325	137	·365	3200	45	195
60	67½	8½	285	141	·362	3440	40	205
65	71	9	250	144	·362	3700	35	215
70	74	9¾	220	147	·359	3910	30	215
75	77	10½	200	150	·358	4130	20	200
80	79½	11	185	152	.356	4300	15	160

LARCH.

QUALITY CLASS IV.

(50-ft.)

Main Crop.							Thinnings.	
Age in Years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	9	—	—	—	—	—	—	—
15	14½	—	—	—	—	—	—	—
20	20	—	—	—	—	—	—	—
25	26	—	—	—	—	—	—	—
30	31½	3¼	1100	84	·340	900	—	—
35	37	4	810	97	·354	1270	290	100
40	41½	5	640	105	·360	1570	170	120
45	46	5½	520	113	·362	1880	120	130
50	50	6¼	440	120	·360	2160	80	140
55	54	7	380	126	·356	2420	60	150
60	57½	7½	330	131	·353	2660	50	160
65	61	8¼	290	135	·352	2900	40	170
70	64	9	255	139	·348	3100	35	180
75	66½	9½	225	141	·348	3270	30	175
80	69½	10	200	144	·347	3470	25	150

QUALITY CLASS V.
(40-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	6	—	—	—	—	—	—	—
15	10	—	—	—	—	—	—	—
20	14½	—	—	—	—	—	—	—
25	19	—	—	—	—	—	—	—
30	23½	—	—	—	—	—	—	—
35	27½	—	—	—	—	—	—	—
40	32	3½	1010	87	·338	940	—	—
45	36	4¼	790	97	·344	1200	220	75
50	40	5	620	105	·348	1460	170	90
55	44	5¾	500	113	·346	1720	120	100
60	47½	6¼	425	119	·343	1940	75	115
65	50½	7	365	123	·343	2130	60	125
70	53½	7½	320	128	·340	2330	45	140
75	56½	8¼	280	132	·339	2530	40	145
80	59	8¾	250	136	·335	2690	30	140

SCOTS PINE (ENGLAND).
QUALITY CLASS I.
(60-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	13	—	—	—	—	—	—	—
15	19½	—	—	—	—	—	—	—
20	26	—	—	—	—	—	—	—
25	33	3¾	1010	91	·370	1110	—	—
30	40	4½	810	113	·383	1730	—	—
35	46	5¼	655	129	·383	2280	155	135
40	51	6¼	545	141	·380	2730	110	170
45	56	7	445	150	·377	3170	100	195
50	60	7¾	375	156	·377	3530	70	210
55	64	8½	325	162	·375	3890	50	210
60	67	9	285	165	·376	4160	40	225
65	70	9¾	255	169	·374	4430	30	220
70	72½	10¼	230	171	·374	4640	25	220
75	75	11	210	174	·373	4870	20	210
80	77	11½	193	176	·373	5050	17	200
85	79	12	179	179	·370	5230	14	190
90	81	12½	167	180	·371	5410	12	180
95	83	13	157	182	·370	5590	10	170
100	84½	13¼	150	183	·370	5730	7	160

SCOTS PINE (ENGLAND).
QUALITY CLASS II.
(50-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	10	—	—	—	—	—	—	—
15	15	—	—	—	—	—	—	—
20	20	—	—	—	—	—	—	—
25	25½	—	—	—	—	—	—	—
30	31	3¾	1040	93	·392	1130	—	—
35	36½	4½	835	113	·400	1650	—	—
40	41½	5¼	680	128	·397	2110	155	120
45	46	6	570	140	·391	2520	110	140
50	50	6¾	480	149	·388	2890	90	150
55	54	7½	405	157	·386	3270	75	160
60	57	8	350	161	·386	3550	55	170
65	60	8¾	305	165	·386	3820	45	175
70	62½	9½	270	169	·384	4060	35	180
75	65	10	245	172	·384	4300	25	180
80	67	10½	225	173	·385	4470	20	175
85	69	11	207	176	·385	4670	18	165
90	71	11½	192	177	·386	4850	15	155
95	73	12	179	179	·385	5030	13	145
100	74	12¼	170	180	·385	5130	9	130

SCOTS PINE (ENGLAND).

QUALITY CLASS III.

(40-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	8	—	—	—	—	—	—	—
15	12	—	—	—	—	—	—	—
20	16	—	—	—	—	—	—	—
25	20	—	—	—	—	—	—	—
30	24	—	—	—	—	—	—	—
35	28½	3½	1060	93	·392	1040	—	—
40	32½	4¼	885	108	·410	1440	—	—
45	36½	5	720	123	·410	1840	170	85
50	40	5¾	610	134	·408	2190	110	95
55	43	6¼	520	142	·408	2490	90	105
60	46	7	445	150	·404	2790	75	115
65	49	7½	385	156	·404	3090	60	120
70	51	8¼	345	160	·403	3290	40	130
75	53	8¾	310	163	·404	3490	35	130
80	55	9¼	280	166	·403	3680	30	130
85	57	9¾	253	169	·404	3890	27	130
90	59	10¼	230	171	·404	4080	23	125
95	61	10¾	212	174	·404	4280	18	115
100	62	11¼	200	175	·405	4390	12	105

SCOTS PINE (SCOTLAND).
QUALITY CLASS I.
(60-ft.)

	Main Crop.						Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	From factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	13	—	—	—	—	—	—	—
15	19½	—	—	—	—	—	—	—
20	26	—	—	—	—	—	—	—
25	33	3¾	1240	115	·312	1180	—	—
30	40	4½	960	137	·354	1940	280	110
35	46	5¼	760	153	·366	2580	200	125
40	51	6¼	630	165	·371	3120	130	140
45	56	7	525	177	·369	3660	105	155
50	60	7¾	450	185	·369	4100	75	175
55	64	8½	385	192	·368	4520	65	195
60	67	9	340	197	·366	4840	45	220
65	70	9¾	305	202	·365	5160	35	235
70	72½	10¼	275	206	·364	5440	30	250
75	75	11	250	210	·362	5700	25	260
80	77	11½	230	212	·362	5920	20	255
85	79	12	215	215	·361	6130	15	245
90	81	12½	200	218	·360	6350	15	225
95	83	13	190	221	·358	6560	10	205
100	84½	13¼	183	223	·357	6720	7	180

SCOTS PINE (SCOTLAND).
QUALITY CLASS II.
(50-ft.)

	Main Crop.						Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	10	—	—	—	—	—	—	—
15	15	—	—	—	—	—	—	—
20	20	—	—	—	—	—	—	—
25	25½	—	—	—	—	—	—	—
30	31	3¾	1230	116	·361	1300	—	—
35	36½	4½	990	136	·387	1920	240	85
40	41½	5¼	795	152	·393	2480	195	100
45	46	6	655	164	·398	3000	140	115
50	50	6¾	550	174	·397	3450	105	125
55	54	7½	470	182	·398	3910	80	145
60	57	8	410	188	·396	4250	60	160
65	60	8¾	360	194	·395	4600	50	175
70	62½	9½	325	199	·392	4880	35	190
75	65	10	295	204	·390	5170	30	195
80	67	10½	270	207	·389	5400	25	200
85	69	11	250	210	·389	5630	20	195
90	71	11½	230	213	·387	5850	20	185
95	73	12	215	215	·387	6080	15	175
100	74	12¼	207	218	·384	6200	8	160

SCOTS PINE (SCOTLAND).

QUALITY CLASS III.

(40-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	8	—	—	—	—	—	—	—
15	12	—	—	—	—	—	—	—
20	16	—	—	—	—	—	—	—
25	20	—	—	—	—	—	—	—
30	24	—	—	—	—	—	—	—
35	28½	—	—	—	—	—	—	—
40	32½	4¼	1030	130	·395	1670	—	—
45	36½	5	840	144	·407	2140	190	100
50	40	5¾	700	155	·410	2540	140	110
55	43	6¼	600	163	·413	2900	100	120
60	46	7	510	171	·412	3240	90	130
65	49	7½	440	179	·408	3580	70	135
70	51	8¼	400	185	·404	3810	40	145
75	53	8¾	365	189	·404	4050	35	155
80	55	9¼	330	194	·401	4280	35	160
85	57	9¾	300	198	·400	4510	30	165
90	59	10¼	275	202	·398	4750	25	160
95	61	10¾	253	206	·396	4980	22	155
100	62	11¼	237	208	·395	5100	16	145

SPRUCE.
QUALITY CLASS I
(80-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form Factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	12	—	—	—	—	—	—	—
15	21	—	—	—	—	—	—	—
20	31	—	—	—	—	—	—	—
25	41	4½	1080	152	·385	2400	—	—
30	51	5¾	710	171	·401	3500	370	410
35	59	7	535	183	·407	4400	175	440
40	66½	8¼	410	194	·407	5250	125	485
45	73½	9½	335	203	·404	6030	75	490
50	80	10½	280	211	·401	6760	55	470
55	86	11½	240	217	·398	7420	40	445
60	91	12½	210	223	·395	8020	30	415
65	96	13¼	190	228	·391	8530	20	345
70	100	14	175	231	·388	8960	15	320

SPRUCE.
QUALITY CLASS II.
(70-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form Factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	10½	—	—	—	—	—	—	—
15	18	—	—	—	—	—	—	—
20	27	—	—	—	—	—	—	—
25	35½	3¾	1440	141	·382	1910	—	—
30	43½	5	920	160	·408	2840	520	220
35	51	6¼	640	176	·410	3680	280	300
40	58	7½	500	189	·410	4490	140	320
45	64½	8½	400	199	·409	5250	100	350
50	70	9½	325	207	·407	5890	75	350
55	75	10½	275	214	·402	6450	50	340
60	79	11½	240	220	·399	6940	35	330
65	83	12½	210	225	·396	7390	30	315
70	87	13¼	190	229	·392	7800	20	250

SPRUCE.

QUALITY CLASS III.

(60-ft.)

Main Crop.							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form Factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	9	—	—	—	—	—	—	—
15	15	—	—	—	—	—	—	—
20	22	—	—	—	—	—	—	—
25	29½	—	—	—	—	—	—	—
30	36½	4	1310	146	·402	2140	—	—
35	43	5	930	162	·422	2950	380	180
40	49	6¼	665	177	·424	3680	265	210
45	55	7¼	500	188	·420	4360	165	240
50	60	8¼	410	198	·415	4930	90	270
55	64	9¼	350	205	·414	5440	60	280
60	68	10¼	300	212	·409	5910	50	260
65	72	11	260	219	·402	6340	40	240
70	75	11¾	230	224	·401	6730	30	200

SPRUCE.

QUALITY CLASS IV.

(50-ft.)

Main Crop							Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form Factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	7	—	—	—	—	—	—	—
15	12	—	—	—	—	—	—	—
20	17½	—	—	—	—	—	—	—
25	23	—	—	—	—	—	—	—
30	29	—	—	—	—	—	—	—
35	34½	3¾	1450	142	·412	2020	—	—
40	40	4¾	1000	157	·427	2690	450	100
45	45	5¾	755	172	·430	3320	245	120
50	50	6¾	590	183	·426	3900	165	150
55	54½	7¾	470	193	·421	4430	120	180
60	58	8½	400	201	·419	4890	70	195
65	61½	9¼	340	208	·415	5310	60	190
70	64½	10	300	214	·410	5660	40	170

SPRUCE.

QUALITY CLASS V.

(40-ft.)

	Main Crop.						Thinnings.	
Age in years.	Mean Height in feet.	Mean Q.G. ins. at 4ft. 3ins.	No. of stems per acre.	Basal area sq. ft. per acre.	Form Factor.	Volume cu. ft. under bark per acre.	No. of stems per acre.	Volume cu. ft. under bark per acre.
10	5	—	—	—	—	—	—	—
15	8½	—	—	—	—	—	—	—
20	12½	—	—	—	—	—	—	—
25	17	—	—	—	—	—	—	—
30	21½	—	—	—	—	—	—	—
35	26½	—	—	—	—	—	—	—
40	31	3½	1500	130	·414	1670	—	—
45	36	4½	1020	148	·428	2290	480	90
50	40	5½	765	162	·435	2820	255	110
55	44	6½	615	173	·432	3290	150	130
60	47½	7¼	500	183	·427	3700	155	150
65	50½	8	430	191	·424	4080	70	160
70	53	8¾	375	197	·422	4400	55	155

Bark.

The following table indicates the average proportion of bark found in trees belonging to the respective Quality Classes of Larch, Scots pine and Spruce :—

PERCENTAGE OF THE OVER BARK VOLUME WHICH CONSISTS OF BARK IN THE FOLLOWING SPECIES AND QUALITY CLASSES.

Quality Classes.	Larch.	Scots Pine, England.	Scots Pine, Scotland.	Spruce.
80-ft.	18	—	—	10
70-ft.	19·5	—	—	10
60-ft.	21	12·5	13·5	10
50-ft.	22	13	15	11
40-ft.	22·5	13·5	16·5	12
30-ft.	—	16	17	—

Single trees or logs are liable to large variations in respect of proportion of bark, and these figures, which are averages based on a large number of measurements, should not be applied to individual trees.

In all species the proportion of bark is higher in the poorer Quality Classes.

The figures given for Larch correspond closely with the average values obtained for Larch in Austria by Schiffel and in Switzerland by Flury.

APPENDIX B.

Diagrams showing the height growth curves of—

1. European Larch,
2. Scots Pine,
3. Norway Spruce,
4. Douglas Fir,
5. Corsican Pine,
6. Japanese Larch,

are given in the following pages.

The continuous lines represent the mean curves and the broken lines the limiting curves of each Quality Class.

EUROPEAN LARCH.

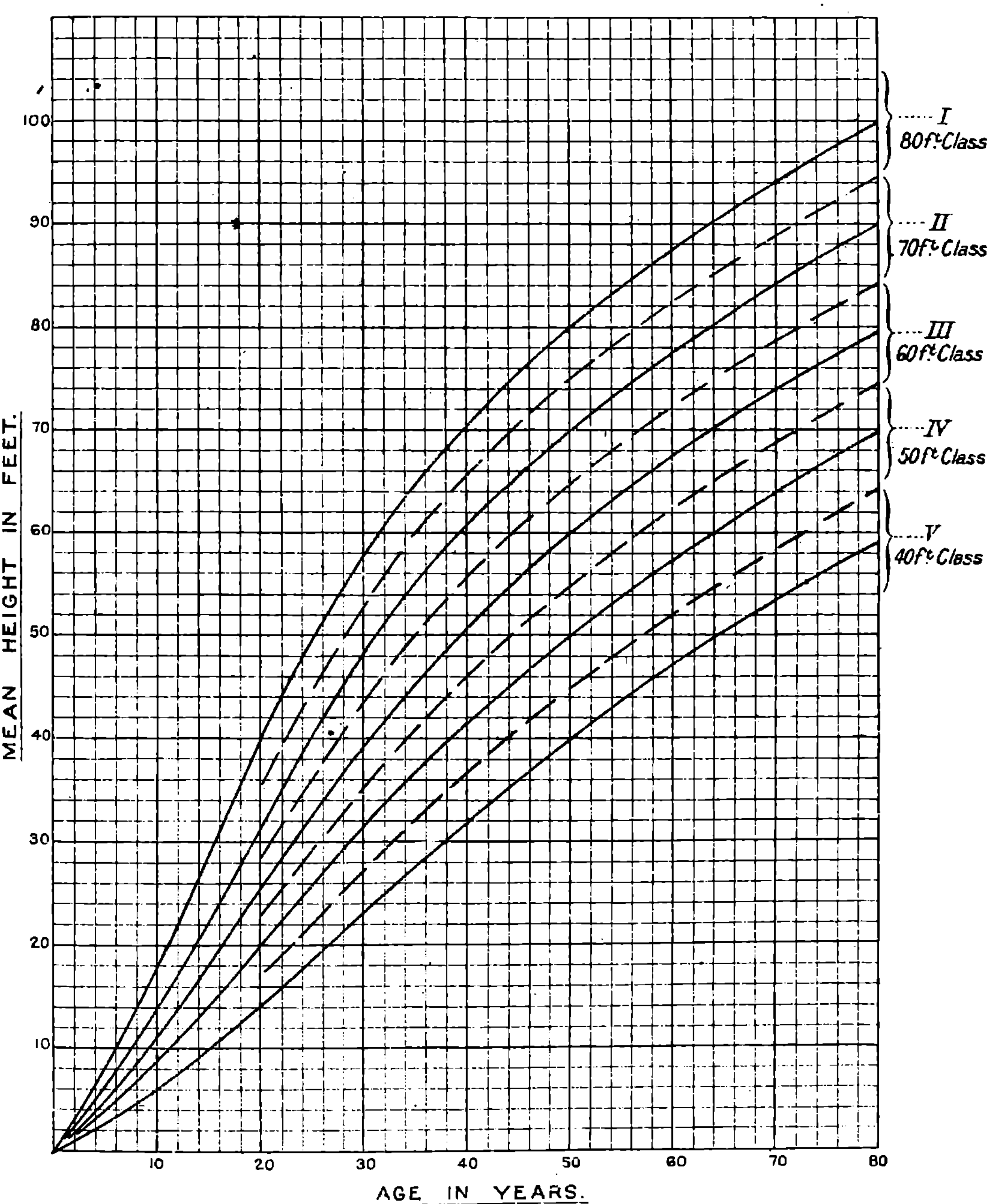

Fig I. Diagram showing Quality Classes of European Larch.

Malby & Sons

SCOTS PINE.

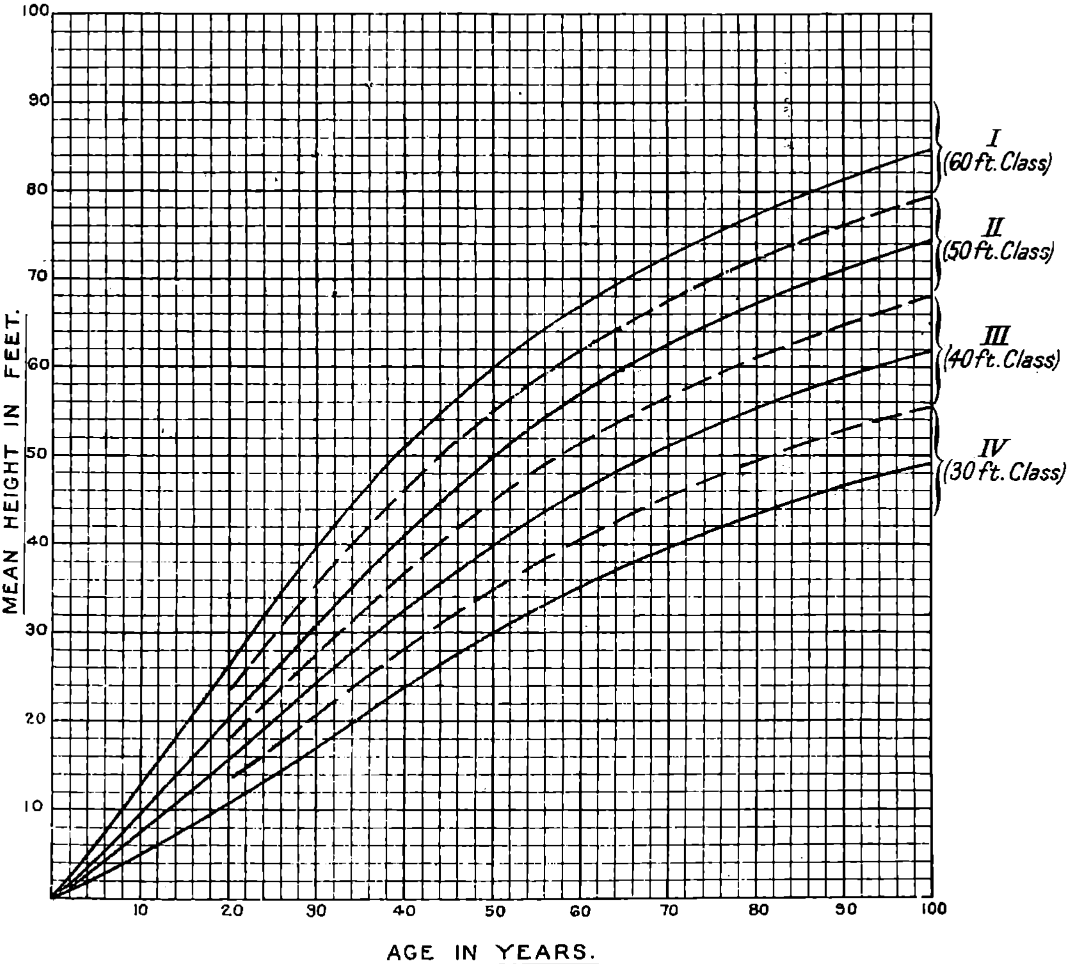

Fig 2. Diagram showing Quality Classes of Scots Pine.

9551-644 · SOP 49/5/2.

Malby & Sons, Lith.

NORWAY SPRUCE.

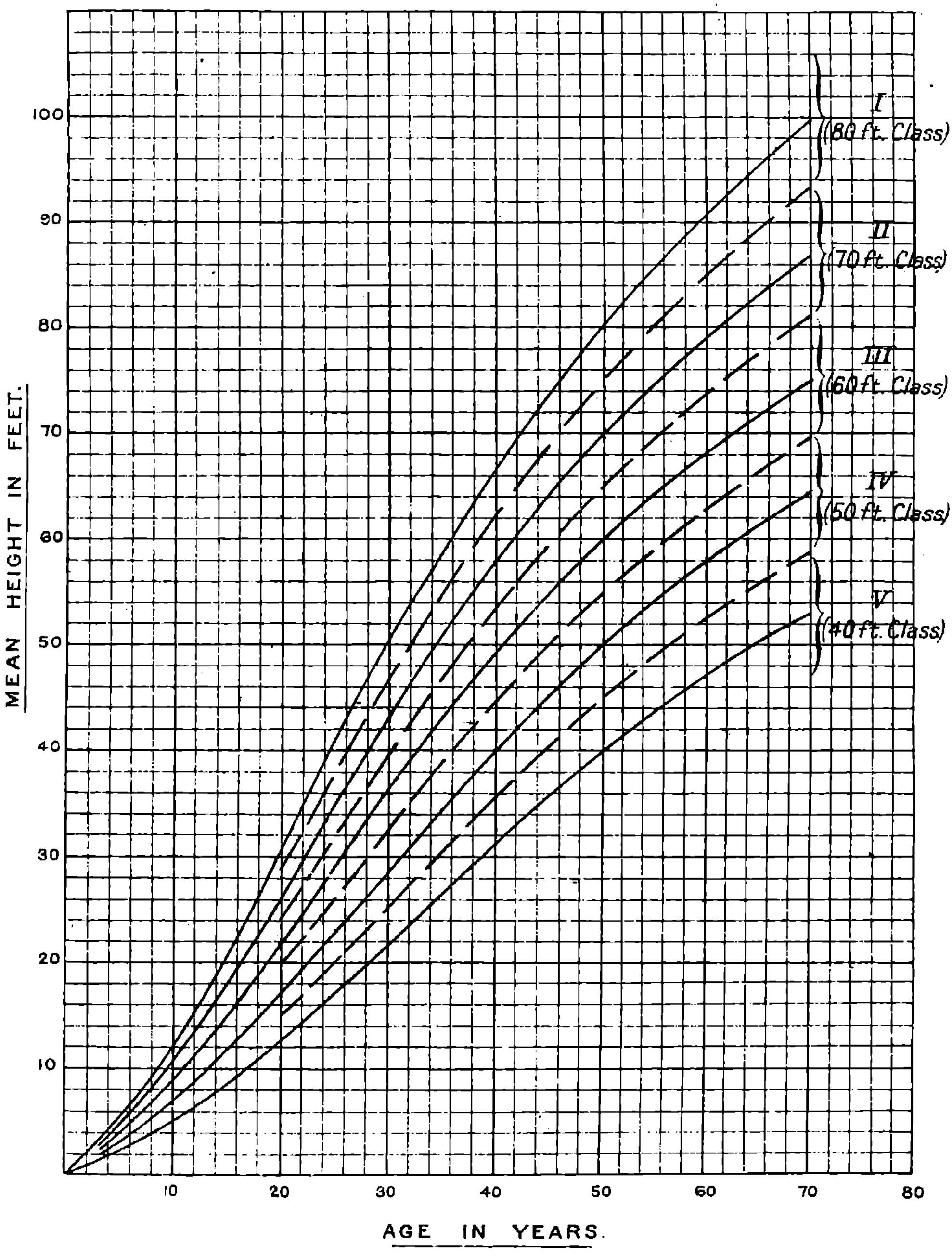

Fig 3. Diagram showing Quality Classes of Norway Spruce.

Malby & Sons, Lith.

DOUGLAS FIR.

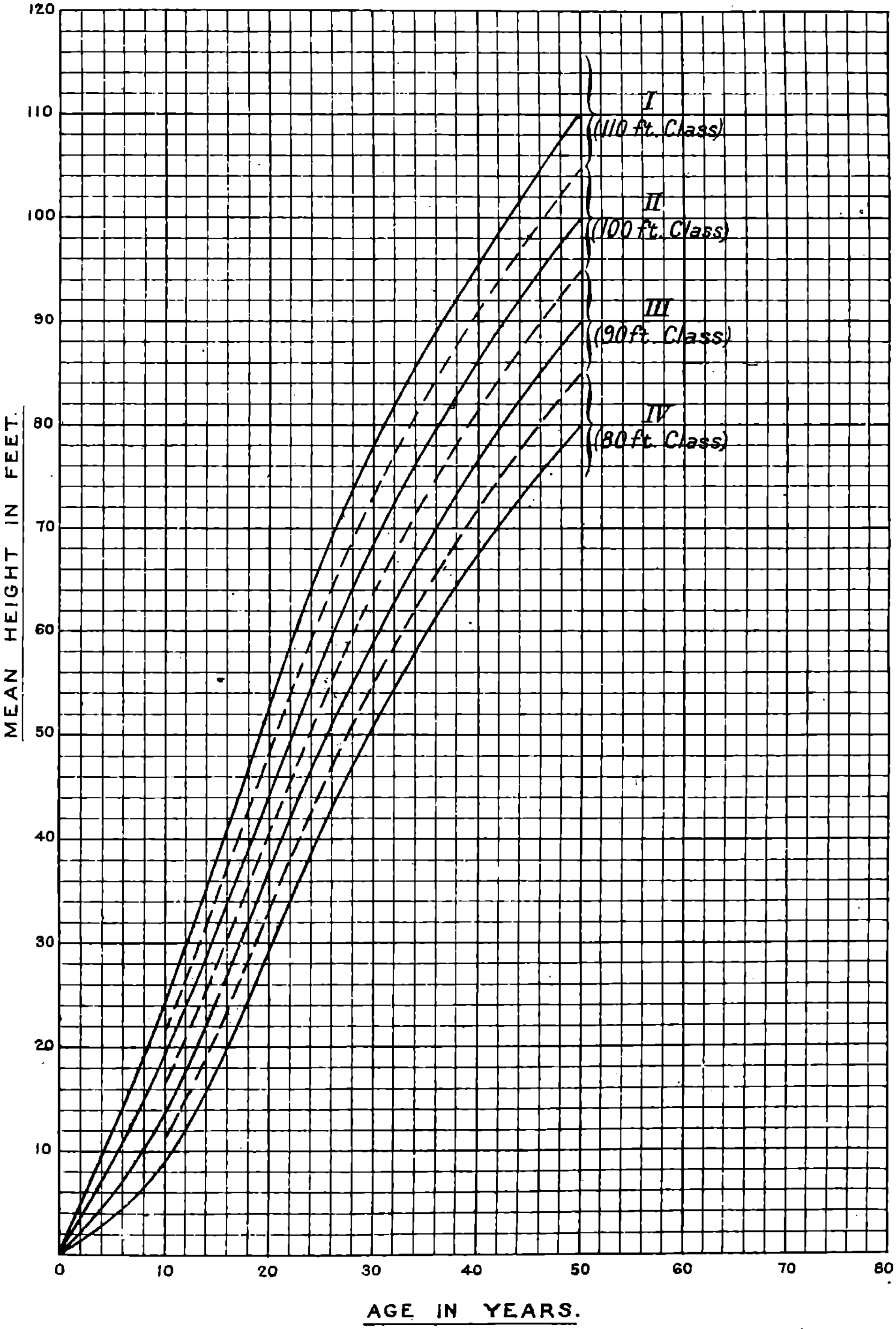

Fig 4. Diagram showing Quality Classes of Douglas Fir.

9551. 644 30 P 49/512 Malby & Sons, Lith.

CORSICAN PINE.

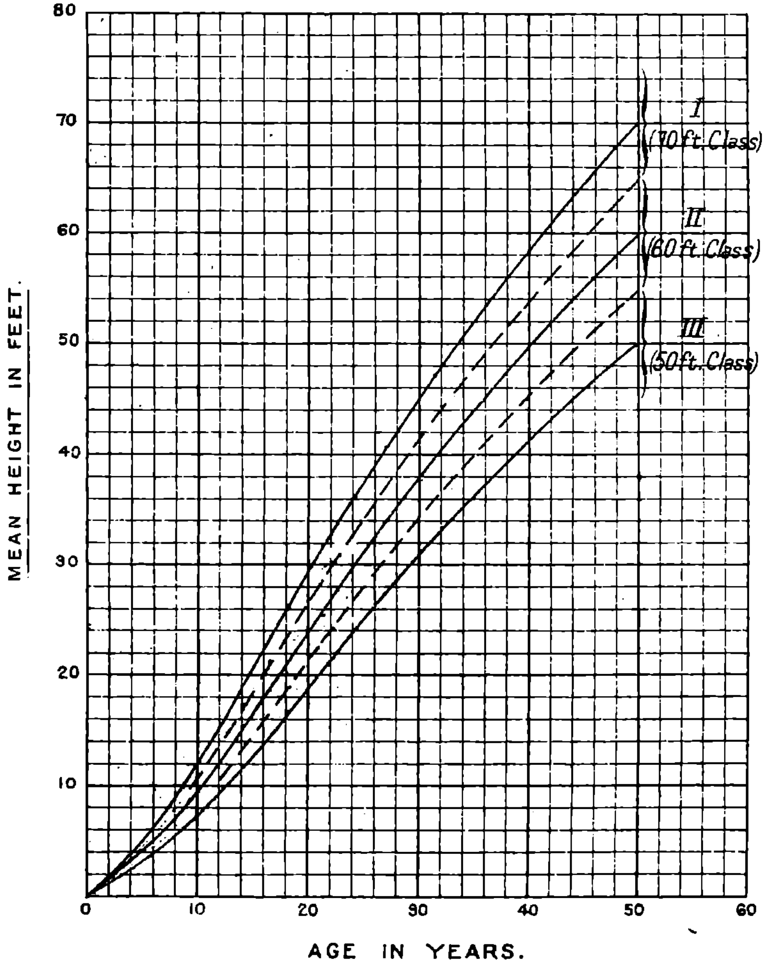

Fig. 5. Diagram showing Quality Classes of Corsican Pine.

555/: 044 · SOP 49 5/2

Malby & Sons, Lith

JAPANESE LARCH.

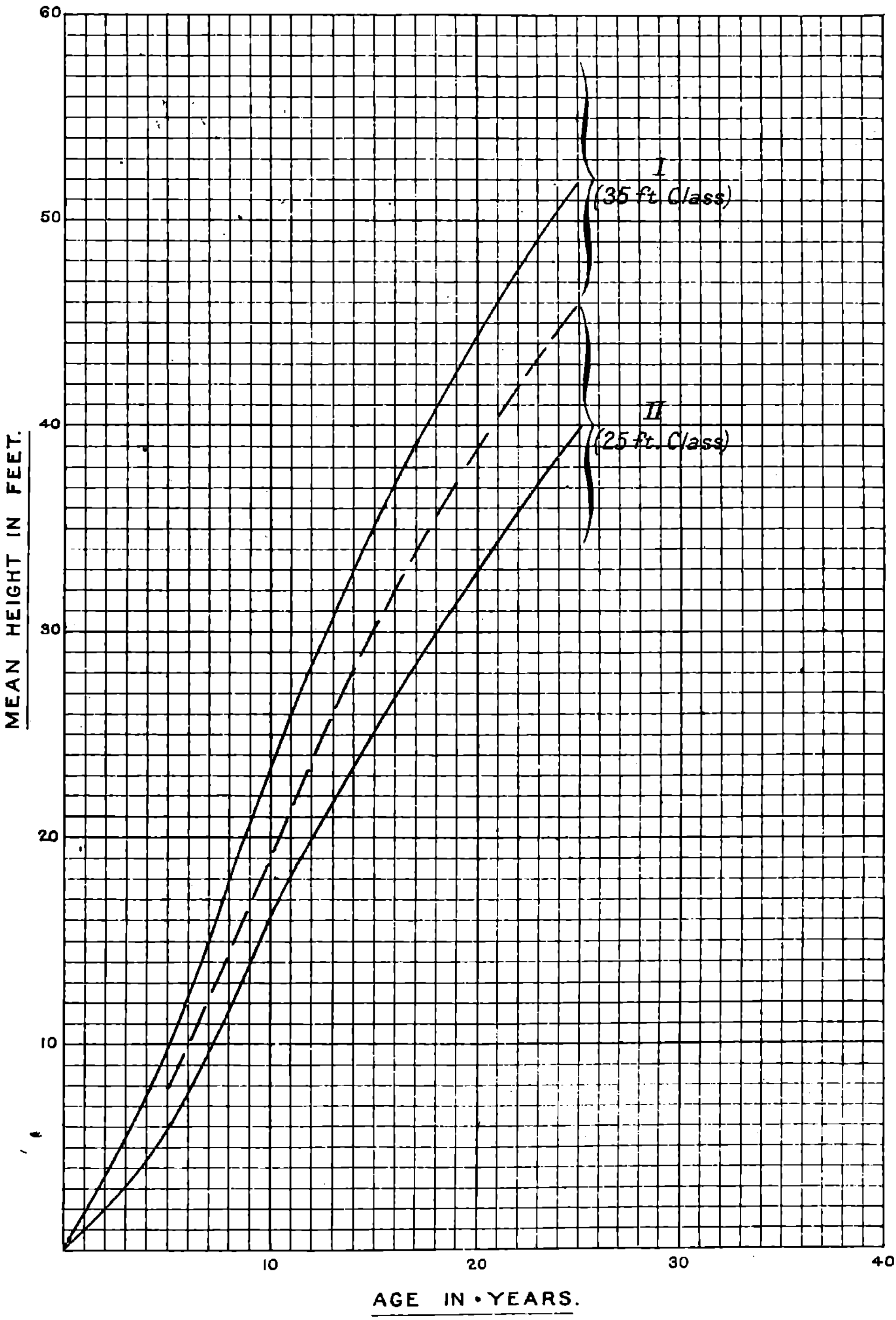

Fig 6. Diagram showing preliminary Quality Classes of Japanese Larch.

8551. 644. S.O.P. 49/512. Malby & Sons, Lith.

APPENDIX C.

Tables showing the distribution of the sample plots of all species according to :—

1. Counties in England and Wales.
2. Counties in Scotland.
3. Counties in Ireland.

And of the sample plots of Larch, Scots pine and Spruce by Quality Classes according to :—

4. Geological Formation in England and Wales.
5. Geological Formation in Scotland.
6. Geological Formation in Ireland.
7. Soil.
8. Aspect.
9. Slope.

TABLE No. 1. DISTRIBUTION OF SAMPLE PLOTS IN ENGLAND AND WALES.

County.	European Larch.		Scots Pine.		Norway Spruce.		Japanese Larch.		Douglas Fir.		Corsican Pine.		Other Conifers.		Total.	
	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.
Northumberland	—	—	10	1	6	3	—	—	—	1	—	—	—	—	16	5
Cumberland	2	1	3	1	4	8	—	—	1	—	—	—	—	—	10	10
Westmoreland	—	—	3	—	—	—	—	—	—	—	—	—	—	—	3	—
Durham	3	1	3	1	1	1	—	—	—	—	—	—	—	—	7	3
Yorkshire	19	8	10	6	7	1	3	—	—	1	—	1	—	—	39	17
Lancashire	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Carnarvon	4	2	1	—	—	—	—	1	—	—	1	—	—	—	6	3
Denbigh	4	2	3	1	—	—	—	—	—	—	—	—	—	—	7	3
Flint	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Merioneth	5	2	—	1	2	—	—	—	—	—	—	—	—	—	7	3
Montgomery	12	3	—	—	1	1	—	—	1	1	—	—	—	—	14	5
Salop	14	2	—	—	3	—	—	—	—	—	—	—	—	—	17	2
Cardigan	17	2	—	—	1	1	—	—	—	—	—	—	—	—	18	3
Radnor	12	3	—	1	1	1	—	—	1	—	—	—	—	—	14	5
Hereford	4	1	—	—	—	—	—	—	—	—	—	—	—	—	4	1
Brecknock	21	14	1	1	1	—	2	1	1	—	—	—	—	—	26	16
Pembroke	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Carmarthen	9	10	—	—	1	3	1	—	—	2	—	—	—	1	11	16
Glamorgan	2	—	2	—	—	—	2	—	—	—	1	—	—	—	7	—
Gloucester	—	1	—	1	—	—	—	1	—	—	—	1	—	—	—	4
Wilts	1	1	1	—	—	—	—	—	—	1	—	—	—	—	2	2
Somerset	14	4	3	—	6	1	—	1	8	1	5	—	—	—	36	7
Dorset	2	—	8	—	2	—	—	—	1	—	—	—	—	—	14	—
Devon	36	9	17	4	15	5	2	—	4	—	1	1	2	—	77	19
Cornwall	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Berks	—	—	8	—	—	—	—	—	—	—	—	—	—	—	8	—
Hants	17	3	20	—	1	1	2	—	1	—	3	1	2	1	46	6
Surrey	4	1	8	1	—	—	—	—	—	—	—	—	—	—	12	2
Sussex	12	8	9	2	1	1	1	—	—	—	—	—	—	—	23	11
Kent	1	—	1	—	—	—	—	—	—	—	1	—	—	—	3	—
Suffolk	1	—	8	1	—	—	—	—	—	—	—	—	—	—	9	1
Norfolk	—	—	4	—	—	—	—	1	2	—	—	—	1	—	7	1
Bucks	2	2	—	—	—	1	1	—	—	—	—	—	—	—	3	3
Beds	2	—	7	—	—	—	—	—	—	—	—	—	—	—	9	—
Totals	221	82	130	22	53	28	14	5	20	7	12	4	6	3	456	151

TABLE No. 2. DISTRIBUTION OF SAMPLE PLOTS IN SCOTLAND.

County.	European Larch.		Scots Pine.		Norway Spruce.		Japanese Larch.		Douglas Fir.		Corsican Pine.		Other Conifers.		Total.	
	Plots.	Sub-Plots.	Plots	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.
Aberdeen	26	1	50	—	20	3	1	—	3	—	1	—	1	—	102	4
Ayrshire	7	—	4	—	—	—	3	—	—	—	—	—	—	—	14	—
Berwickshire	3	—	6	—	1	—	—	—	—	—	—	—	—	—	10	—
Dumfries...	6	1	1	—	6	—	4	3	1	2	—	—	2	3	20	9
Moray	5	—	27	—	3	—	—	—	—	—	—	—	—	—	35	—
Inverness	21	—	8	—	10	—	—	—	—	—	—	—	—	—	39	—
Kincardine	6	—	12	—	4	1	1	1	4	—	—	—	—	—	27	2
Kirkcudbright	9	—	4	1	—	2	6	1	1	2	—	1	1	—	21	7
Nairn	1	—	13	—	—	—	—	—	—	—	—	—	—	—	14	—
Perth	13	—	8	—	6	—	—	—	1	—	—	—	—	—	28	—
Peebles	11	2	—	—	2	2	—	—	—	—	—	—	—	—	13	4
Ross and Cromarty	22	—	12	—	1	—	—	—	—	—	—	—	—	—	35	—
Roxburgh	1	—	9	1	3	—	2	1	—	—	—	—	—	—	15	2
Sutherland	—	—	15	—	2	—	—	—	—	—	—	—	—	—	17	—
Wigtown	4	5	1	—	1	1	3	2	—	2	2	—	—	2	11	12
Totals	135	9	170	2	59	9	20	8	10	6	3	1	4	5	401	40

DISTRIBUTION OF SAMPLE PLOTS IN IRELAND.

UNTY.	EUROPEAN LARCH.		SCOTS PINE.		NORWAY SPRUCE		TOTALS.	
	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.	Plots.	Sub-Plots.
Kerry	—	—	1	—	—	—	1	—
Kilkenny	—	1	—	—	—	—	—	1
Limerick	1	1	—	—	1	—	2	1
Tipperary	14	3	3	—	2	2	19	5
Waterford	13	1	5	1	2	1	20	3
Totals	28	6	9	1	5	3	42	10

TABLE No. 4. DISTRIBUTION OF SAMPLE PLOTS IN ENGLAND AND WALES ACCORDING TO GEOLOGICAL FORMATION.

Quality Class.	Granite, etc.	Pre-Cambrian Cambrian, Ordov. Silurian.	O.R.S. Devonian.	Carbon, Limestone and Yoredale Series.	Mill-stone Grits.	Coal Measures.	Permian and Trias.	Lias Clay.	Lower, Middle and Upper Oolites.	Hastings Beds.	Weald Clay.	Lower Greensand.	Gault.	Chalk.	Oligocene and Upper and Lower Eocene.	Glacial Deposits.	Total No. of Plots.
	No. of Plots	No. of Plots.	No. of Plots.	No. of Plots.	No of Plots	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	
LARCH (over 35 years of age).																	
I. (80-ft. Class) ...	—	—	8	—	2	—	—	—	1	2	—	1	—	1	1	1	17
II. (70-ft. ,,) ...	1	15	12	—	7	—	2	—	5	7	—	3	3	8	2	—	65
III. (60-ft. ,,) ...	3	41	12	2	8	—	2	1	5	—	1	3	—	2	2	—	82
IV. (50-ft. ,,) ...	3	18	5	—	5	1	1	—	2	—	—	2	—	—	—	—	37
V. (40-ft. ,,) ...	2	9	2	—	—	3	—	1	1	—	—	—	—	1	—	—	19
Totals	9	83	39	2	22	4	5	2	14	9	1	9	3	12	5	1	220
Per cent. in all Quality Classes...	4	38	18	1	10	2	2	1	6	4	0·5	4	1	5·5	2	0·5	—
SCOTS PINE (over 35 years of age).																	
I. (60-ft. Class) ...	—	—	1	—	1	—	4	—	—	1	—	11	—	—	15	3	36
II. (50-ft. ,,) ...	—	5	—	3	6	—	8	—	2	1	1	8	2	—	12	6	54
III. (40-ft. ,,) ...	1	1	2	3	9	2	1	—	1	—	—	3	5	—	9	2	39
IV. (30-ft. ,,) ...	1	—	—	1	2	—	1	—	—	—	—	1	—	—	1	—	7
Totals	2	6	3	7	18	2	14	—	3	2	1	23	7	—	37	11	136
Per cent. in all Quality Classes...	1·5	4·5	2	5	13	1·5	10	—	2	1·5	1	17	5	—	27	8	—
SPRUCE (over 35 years of age).																	
I. (80-ft. Class) ...	—	2	—	1	4	—	—	—	—	—	—	—	—	—	1	—	8
II. (70-ft. ,,) ...	1	4	1	1	2	—	1	—	1	1	—	—	—	1	—	—	13
III. (60-ft. ,,) ...	2	3	3	6	8	—	—	—	—	1	—	—	—	—	—	—	23
IV. (50-ft. ,,) ...	3	—	6	5	1	—	—	—	—	—	—	—	1	2	1	—	19
V. (40-ft. ,,) ...	—	1	1	4	—	—	—	—	—	—	—	—	—	—	—	—	6
Totals	6	10	11	17	15	—	1	—	1	2	—	—	1	3	2	—	69
Per cent. in all Quality Classes...	9	14·5	16	24·5	22	—	1·5	—	1·5	3	—	—	1·5	4·5	3	—	—

TABLE No. 5.

DISTRIBUTION OF SAMPLE PLOTS IN SCOTLAND ACCORDING TO GEOLOGICAL FORMATION.

Quality Class.	Total No. of Plots.	Metamorphic (gneisses, schists, etc.)	Granite and other Igneous rocks.	Ordovician and Silurian.	O.R.S. and Devonian	Carboniferous Series.	Glacial and Alluvial Deposits.
		No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.	No. of Plots.
LARCH (*over* 35 *years of age*).							
I. (80-ft. Class)	5	5	—	—	—	—	—
II. (70-ft. ,,)	22	17	1	—	—	1	3
III. (60-ft. ,,)	28	19	4	2	—	1	2
IV. (50-ft. ,,)	25	10	6	5	—	—	4
V. (40-ft. ,,)	10	8	—	1	—	—	1
Totals	90	59	11	8	—	2	10
Per cent. in all Quality Classes		66	12	9	—	2	11
SCOTS PINE (*over* 35 *years of age*).							
I. (60-ft. Class)	14	2	4	—	3	—	5
II. (50-ft. ,,)	74	20	7	1	5	3	38
III. (40-ft. ,,)	51	19	3	—	2	1	26
IV. (30-ft. ,,)	14	7	2	—	2	—	3
Totals	153	48	16	1	12	4	72
Per cent. in all Quality Classes		31	10	1	8	3	47
SPRUCE (*over* 35 *years of age*).							
I. (80-ft. Class)	5	4	1	—	1	—	—
II. (70-ft. ,,)	11	4	3	—	—	—	4
III. (60-ft. ,,)	18	5	5	1	4	1	2
IV. (50-ft. ,,)	16	3	3	1	3	—	6
V. (40-ft. ,,)	4	4	—	—	—	—	—
Totals	54	20	11	2	8	1	12
Per cent. in all Quality Classes		37	20	4	15	2	22

TABLE No. 6.

DISTRIBUTION OF SAMPLE PLOTS IN IRELAND ACCORDING TO GEOLOGICAL FORMATION.

Quality Class.	Total No. of Plots.	Silurian.	Old Red Sandstone.	Carboniferous Limestone.
		No. of Plots.	No. of Plots.	No. of Plots.
LARCH (over 35 years of age).				
I. (80-ft. Class)	1	—	1	—
II. (70-ft. ,,)	14	2	8	4
III. (60-ft. ,,)	5	—	3	2
IV. (50-ft. ,,)	5	—	4	1
Totals	25	2	16	7
Per cent. in all Quality Classes		8	64	28
SCOTS PINE (over 35 years of age).				
I. (60-ft. Class)	2	—	2	—
II. (50-ft. ,,)	4	—	3	1
III. (40-ft. ,,)	1	—	—	1
Totals	7	—	5	2
Per cent. in all Quality Classes		—	72	28
SPRUCE (over 35 years of age).				
II. (70-ft. Class)	2	1	1	—
III. (60-ft. ,,)	3	—	2	1
IV. (50-ft. ,,)	2	—	2	—
Totals	7	1	5	1
Per cent. in all Quality Classes		14	72	14

TABLE No. 7.

DISTRIBUTION OF SAMPLE PLOTS IN THE BRITISH ISLES ACCORDING TO TYPE OF SOIL.

Quality Class.	No. of Sample Plots in each Quality Class.	Proportion of Sample Plots in each Quality Class on the following types of soil.						
		Sand.	Sandy Loam.	Loam.	Clay Loam.	Clay.	Peat and Peaty Loam 6″—12″.	Peat and Peaty Loam over 12″.
		LARCH (*over* 35 *years of age*).						
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. (80-ft. Class) ...	23	4	35	44	13	4	—	—
II. (70-ft. „) ...	101	11	42	27	14	6	1	—
III. (60-ft. „) ...	115	5	34	46	7	3	2	3
IV. (50-ft. „) ...	67	12	45	37	2	3	—	2
V. (40-ft. „) ...	29	3	52	35	7	3	—	—
Per cent. in all Quality Classes		8	40	37	9	4	1	1
		SCOTS PINE (*over* 35 *years of age*).						
I. (60-ft. Class) ...	52	59	15	6	2	4	12	2
II. (50-ft. „) ...	132	48	26	8	7	5	5	1
III. (40-ft. „) ...	91	46	22	7	2	—	18	5
IV. (30-ft. „) ...	21	38	43	5	—	—	9	5
Per cent. in all Quality Classes		49	24	7	4	3	10	3
		SPRUCE (*over* 35 *years of age*).						
I. (80-ft. Class) ...	13	—	46	—	46	—	8	—
II. (70-ft. „) ...	26	8	34	15	19	8	4	12
III. (60-ft. „) ...	44	9	30	18	16	7	4	16
IV. (50-ft. „) ...	37	5	19	41	16	3	8	8
V. (40-ft. „) ...	10	—	30	30	10	—	30	—
Per cent. in all Quality Classes		6	29	23	19	5	8	10

TABLE No. 8.

DISTRIBUTION OF SAMPLE PLOTS IN THE BRITISH ISLES ACCORDING TO ASPECT.

Quality Class.	No. of Sample Plots in each Quality Class.	Proportion of Sample Plots in each Quality Class on the following aspects.								
		Flat with general aspect.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
***LARCH** (over 35 years of age).*										
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. (80-ft. Class) ...	23	9	26	4	4	13	13	18	9	4
II. (70-ft. „) ...	101	7	20	7	12	8	18	9	16	4
III. (60-ft. „) ...	115	2	19	9	8	3	28	9	16	6
IV. (50-ft. „) ...	67	1	24	7	7	8	18	12	15	8
V. (40-ft. „) ...	29	7	14	14	17	—	14	10	10	14
Per cent. in all Quality Classes		4	20	8	10	6	21	10	15	6
***SCOTS PINE** (over 35 years of age).*										
I. (60-ft. Class) ...	52	36	4	6	13	12	6	4	13	6
II. (50-ft. „) ...	132	26	13	4	4	4	20	8	13	8
III. (40-ft. „) ...	91	31	6	2	4	3	18	21	12	3
IV. (30-ft. „) ...	21	14	14	14	—	5	5	38	—	10
Per cent. in all Quality Classes		29	9	4	6	5	16	13	12	6
***SPRUCE** (over 35 years of age).*										
I. (80-ft. Class) ...	13	15	15	8	15	—	39	8	—	—
II. (70-ft. „) ...	26	23	12	15	15	—	19	4	12	—
III. (60-ft. „) ...	44	16	25	14	14	4	14	4	2	7
IV. (50-ft. „) ...	37	8	11	32	8	3	14	5	8	11
V. (40-ft. „) ...	10	20	—	—	10	20	—	30	—	20
Per cent. in all Quality Classes		15	15	18	12	4	16	7	6	7

TABLE No. 9.

DISTRIBUTION OF SAMPLE PLOTS IN THE BRITISH ISLES ACCORDING TO DEGREE OF SLOPE.

Quality Class.	No. of Sample Plots in each Quality Class.	Proportion of Sample Plots occurring in the following classes of slope.						
		Flat 0°–1°	V.Gentle 2°–4°	Gentle 5°–9°	Moderate 10°–14°	Moderate Steep 15°–19°	Steep 20°–29°	V.Steep 30°–
***LARCH** (over 35 years of age).*								
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. (80-ft. Class) ...	23	13	17	22	31	9	4	4
II. (70-ft. „) ...	101	10	10	21	25	10	22	2
III. (60-ft. „) ...	115	4	10	15	24	20	23	4
IV. (50-ft. „) ...	67	1	9	30	32	6	21	1
V. (40-ft. „) ...	29	3	10	17	28	3	22	17
Per cent. in all Quality Classes		6	10	20	27	12	21	4
***SCOTS PINE** (over 35 years of age).*								
I. (60-ft. Class) ...	52	46	12	23	13	4	2	—
II. (50-ft. „) ...	132	28	26	25	11	4	5	1
III. (40-ft. „) ...	91	31	26	23	12	3	2	3
IV. (30-ft. „) ...	21	14	24	29	14	5	14	—
Per cent. in all Quality Classes		31	23	24	12	4	4	2
***SPRUCE** (over 35 years of age).*								
I. (80-ft. Class) ...	13	31	38	8	—	15	8	—
II. (70-ft. „) ...	26	27	23	15	19	12	—	4
III. (60-ft. „) ...	44	18	18	32	23	5	2	2
IV. (50-ft. „) ...	37	8	19	22	16	11	13	11
V. (40-ft. „) ...	10	20	20	20	10	10	20	—
Per cent. in all Quality Classes		18	22	22	17	9	7	5