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VOL. 1

Report on Supplies of Home-Grown Pit-Wood in England and Wales. 1914.

Supplement to The Journal of the Board of Agriculture, 1912. Notes on Kerry Woods, Illustrating Methods of Collecting and Utilizing Information for a Forest Survey.

BOARD OF AGRICULTURE AND FISHERIES.

REPORT

ON

SUPPLIES OF HOME-GROWN PIT-WOOD

IN

ENGLAND AND WALES.

Presented to both Houses of Parliament by Command of His Majesty.

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CONTENTS.

REPORT ON SUPPLIES OF HOME-GROWN PIT-WOOD IN ENGLAND AND WALES.

Board of Agriculture and Fisheries,
Whitehall Place,
London, S.W.
30th November, 1914.

SIR,

I HAVE the honour to submit a Report upon the supplies of home-grown pit-wood in England and Wales.

About half of the total amount of pit-wood imported into the United Kingdom comes from Baltic ports and, as a result of the outbreak of war and the action of Germany in declaring pit-wood contraband, the supplies from this source have been very seriously curtailed. It became necessary, therefore, to ascertain the extent of home resources (from which only a fraction of the total supplies of pit-wood consumed in this country is normally drawn), and the means by which home supplies could, if necessary, be stimulated in order to compensate for the possible deficiency in foreign supplies.

An enquiry into the whole subject was undertaken by the Board's Forestry Branch with the assistance of the Forestry Advisory Officers. The general supervision was entrusted to Mr. R. L. Robinson, and the following officers were engaged in collecting information in the country:—

Inspectors:—
- Mr. L. S. Osmaston.
- Mr. G. H. Crosfield.
- Mr. D. W Young.

Assistant Inspector:—
- Mr. W. H. Guillebaud.

Advisory Officers:—
- Mr. J. F. Annand (Armstrong College, Newcastle-upon-Tyne).
- Professor Fraser Story (University College, Bangor).
- Mr. B. B. Osmaston (Oxford University).
- Mr. C. Hankins (Cambridge University).
- Professor H. A. Pritchard (Royal Agricultural College, Cirencester).

These officers commenced their enquiries in the third week in September. Each one undertook a prescribed district and personally visited the estates upon which he reported. The method of procedure is stated in more detail in the Report. In most districts the enquiry was terminated by the third week of October, but in the case of a few districts further enquiries were made in order to obtain more complete information.

(3230—9.) Wt. 31517—12. 1500 & 90. 12/14. D & S. G. 3.

Making every allowance for errors inseparable from the methods which were necessarily employed, the general effect of the Report is reassuring. As regards the total available supply, errors in estimating made by nine investigators would tend to balance, so that the conclusion that "extraordinary" fellings would provide a year's supply of pit-wood in England and Wales, and that the United Kingdom holds $1\frac{1}{2}$ years' supply, is one that may be put forward with reasonable confidence. The further question of the supplies of pit-wood procurable from other countries is dealt with in a "Report to the Board of Trade upon the supply of imported Pit-timber with special Reference to the Pit-timber Resources of Newfoundland and the Maritime Provinces of Eastern Canada."

The Board are greatly indebted to the Forestry Advisory Officers, who have readily come to the assistance of the officers of the Forestry Branch in all parts of the enquiry, and also to the agents and owners of estates who have given facilities for the inspection of their woods.

I have the honour to be,
Sir,
Your obedient Servant,

T. H. MIDDLETON.

The Secretary,
Board of Agriculture and Fisheries.

REPORT.

Scope of the Enquiry.

The enquiry was set on foot to answer as far as possible the following questions :—

1. What quantity of home-grown pit-wood can be relied on ?
2. At what rate are supplies coming forward ?
3. Is that rate satisfactory ?
4. If not, what are the difficulties which prevent supplies from coming forward ?
5. Is the material being obtained by the most suitable sylvicultural methods ?
6. Is the trade being carried on fairly between all parties concerned ?
7. Is the amount of pit-wood in the country sufficient for the needs of the collieries until normal conditions obtain ?

Method of Enquiry.

The collection of data has been undertaken by the Board's Forestry Inspectors and Advisory Officers who have been able, by personal inspection of woods and consultations with agents, to return more or less complete answers to the above questions for 188 estates representing 249,846 acres of woodland, or approximately 13 per cent. of the total area of woods in England and Wales. In order to get first-hand knowledge of the uses to which mining timber is put these officers have also visited and inspected the surface and underground workings of 20 mines in various districts.

The information collected under each head of the enquiry is discussed below.

1.—*What Quantity of Home-grown Pit-wood can be relied on?*

This section of the enquiry was subdivided under three heads :—

(*a*.) The quantity normally felled.
(*b*.) The quantity which would be forthcoming by anticipating, say, three to five years' fellings.
(*c*.) The total quantity, assuming that it were necessary for national reasons to cut heavily into the capital of the woods.

Table I. below summarises for the estates actually inspected the estimated amount of pit-wood falling under each of the heads (*a*), (*b*), (*c*).

TABLE I.

District.*	Area of woods inspected.	Normal fellings (a).	"Extra-ordinary" fellings (b).	Total volume of pit-wood in the woods (c).
	Acres.	Tons.	Tons.	Tons.
Northern...	38,525	22,750	77,390	77,390
Central and Southern ...	85,820	8,830	87,830	526,690
Welsh	23,639	13,830	105.650	212,350
Eastern	35,835	14,550	106,050	107,090
South-Western	66,027	13,100	109,410	527,060
Total	249,846	73,060	486,330	1,450,580

* The Northern District comprises the counties of Northumberland, Durham, Cumberland, Westmorland, Lancaster and York; the Central and Southern District, the counties of Derby, Stafford, Leicester, Warwick, Oxford, Buckingham, Berks, Surrey, Kent, Sussex, Southampton and Dorset; the Welsh District, the whole of Wales, except Glamorgan, together with Cheshire and Shropshire; the Eastern District, the counties of Lincoln, Nottingham, Rutland, Northampton, Huntingdon, Bedford, Cambridge, Norfolk, Suffolk, Essex, Hertford and Middlesex; and the South-Western District, the counties of Hereford, Worcester, Gloucester, Monmouth, Wilts, Somerset, Devon, Cornwall and Glamorgan.

With these figures as a basis and assuming that the areas of woodlands in each county are those given in the Report of the Forestry Branch for 1912–1913* the proportionate quantities for those counties in which adequate sample areas have been inspected are shown in Table II. below.

TABLE II.

District.	Acreage of woods.	Normal (a).	"Extra-ordinary"(b).	Total (c).
	Acres.	Tons.	Tons.	Tons.
Northern...	323,100	142,290	546,750	546,750
Central and Southern ...	379,600	37,310	538,530	1,948,870
Welsh	238,700	161,270	1,782,000	2,785,750
Eastern	97,400	37,580	384,870	386,650
South-Western	396,000	55,920	656,970	3,344,310
Total	1,434,800	434,370	3,909,120	9,012,330

It will be observed that the total area accounted for in Table II. is 1,434,800 acres. The total area of woodland in England and Wales is 1,884,100 acres, and there remain therefore approximately 449,300 acres for which no adequate sample reports have been obtained. Assuming that this area of woodland is similar in character to the woods already inspected, the quantities for the whole of England and Wales become by proportion :—

(a.) Normal ... . 570,000 tons.
(b.) "Extraordinary" ... 5,120,000 „
(c.) Total ... ... 11,810,000 „

* Cd. 7488. Page 82.

Since the woodlands inspected have been chiefly those of considerable area it is probable that they represent samples above the average value and consequently, to be on the safe side, the figures may be reduced by one-third.

They then read as follows :—

(*a.*) Normal ... ... 380,000 tons.
(*b.*) "Extraordinary" ... 3,410,000 „
(*c.*) Total ... ... 7,870,000 „

It would appear from other sources of information that the normal consumption of home-grown pit timber is about 800,000 tons per annum, and if it may be assumed that one-half comes from Scotland and Ireland, it appears that the above estimate of the "normal" shows a rough approximation to the actual consumption.

It is of importance from the colliery owner's point of view to know what kinds of timber go to make up these quantities. The estimated amounts of each species are as follows :—

TABLE III.

—	Normal (*a*).	"Extraordinary" (*b*).	Total (*c*).
	Tons.	Tons.	Tons.
Pine	127,000	1,110,000	2,720,000
Larch	148,000	1,558,000	3,238,000
Spruce	39,000	314,000	509,000
Hardwoods	66,000	428,000	1,403,000
Total	380,000	3,410,000	7,870,000

The above figures represent a greater proportion of larch and hardwoods than the collieries are accustomed to take, but this disproportion would not appear to be a serious matter.

The total amount of pit-wood consumed annually in the United Kingdom in normal circumstances may be taken as approximately 4,500,000 tons, and it seems a fair conclusion to draw from this section of the enquiry that the volume of the "extraordinary" fellings should suffice in themselves to keep the English and Welsh pits going for one year, exclusive of present stocks or future imports, provided always that suitable steps are taken to draw upon them.

2.—*At what Rate are Supplies coming forward?*

This section of the enquiry was subdivided under the following heads :—

(*a.*) Supplies already felled but not forwarded.
(*b.*) Supplies being felled or mapped out for felling.
(*c.*) Remarks of a general character.

The information obtained on these heads is fragmentary in character. This is due to two reasons: first, the haphazard way in which woods are managed, and secondly, the lack of time at the disposal of the Board's officers for enquiring closely into the circumstances of each estate visited.

(*a.*) Supplies already felled but not forwarded.

Returns for 181 estates representing 235,380 acres of woodlands indicate that 28,340 tons of pit-wood were lying felled at the time of enquiry. The composition of this pit-wood is as follows :—

	Tons.		Tons.
Pine	7,890	Total conifers ...	23,520
Larch	15,020		
Spruce	610		
Hardwoods ...	...	... ...	4,820
		Total ...	28,340

As a basis for proportionate calculations these figures can only be used with extreme reserve, but they would indicate the followin figures for the whole country :—

	Tons.		Tons.
Pine	48,130	Total conifers ...	208,580
Larch	148,750		
Spruce	11,700		
Hardwoods ...	...	... ...	56,770
		Total ..	265,350

On the basis of a total consumption of 4,500,000 tons per annum for the whole of the collieries of the United Kingdom, this amount is equivalent to slightly more than three weeks' supply. At a conservative estimate there should be at least two weeks' supply already felled.

(*b.*) Supplies being felled or mapped out for felling.

The returns under this head are of very unequal value. In some cases they relate to timber already sold or about to be offered for sale. In other cases they relate to timber which would be felled only in certain circumstances — *e.g.*, if adequate prices were offered.

With the above reservation the information collected may be summarised as follows :—

On 181 estates representing 235,380 acres of woods 234,790 tons of pit-wood have been "planned for felling."

The composition of this pit timber is :—

	Tons.		Tons.
Pine	72,780	Total conifers ...	206,400
Larch...	126,010		
Spruce	7,610		
Hardwoods	...	... ...	28,390
		Total ...	234,790

Accepting these figures as a basis for estimating the supply for the whole of England and Wales, the total amount "planned for felling" becomes :—

	Tons.		Tons.
Pine	803,410	Total conifers ...	2,519,880
Larch	1,530,700		
Spruce	185,770		
Hardwoods... ...	...	... ...	311,920
		Total ..	2,831,800

This quantity is equivalent to 33 weeks' normal supply for the collieries ; but, as in estimating the quantities of pit-wood standing in the woods, it would be safer to reduce this figure by one-third. We may therefore put the quantity planned for felling at 1,888,000 tons or 22 weeks' normal supply, making with the amount already felled some 24 weeks' supply in all.

(*c.*) Remarks of a general character.

Generally there appears to be a tendency on the part of owners of woods to hold back supplies until there is a rise in prices of standing timber, or until the need for pit-wood becomes more urgent. This tendency is of course more marked in the case of estates with poorer grades of pit timber and situated more remotely from the coalfields. The knowledge that there was a possibility of railway rates* being reduced also had the effect of holding back supplies. On the other hand, certain owners of estates drawing royalties from mines are felling pit timber recklessly, without regard to the future of their woods.

3.—*Is the Rate at which Supplies are coming forward satisfactory ?*

The term "satisfactory" was intended to indicate the relation between the amount of felling actually being done and the capacity of the particular estate to fell.

Out of 134 estates visited, 72, representing 105,250 acres of woods, were returned as "satisfactory," 12 estates, representing 12,440 acres, fell into an intermediate class, while 50 estates, representing 50,820 acres, were returned as "unsatisfactory" or "no felling."

After the enquiry had proceeded for a few days an attempt was made to ascertain more definitely the rate at which supplies can be placed on rail, and a supplementary form was issued enquiring "*At what rate (in tons and days) can timber be felled and hauled to station with labour and teams at present available?*" Considerable difficulty was experienced in getting satisfactory replies. In the first place the supply of teams is dependent on the demands of other work on the estate, and in the second place haulage is frequently done by timber merchants who move their teams or traction engines from estate to estate.

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* The question of railway rates is discussed later on pages 11, 14.

Definite replies were received from 36 estates only and afford the following information :—

——	No. of Estates in respect of which information was obtained.	Amount of material.	Rate per week.	Number of weeks' labour.
		Tons.	Tons.	
(*a*) Normal fellings	17	13,450	1,615	8
(*b*) "Extraordinary" fellings	33	124,960	2,697	46
(*c*) Total fellings	36	387,550	2,854	136

The estates furnishing the particulars were well distributed over the country and it is probable that the last column approximately represents the position for the whole of England and Wales. In order to get out the supplies under head (*b*) during the felling season of six months the normal resources for felling and hauling would have to be doubled, and the men and teams employed would not be available for any other estate work such as usually falls to them. These figures bear out the contention urged below in representing the desirability of a reduction in railway rates, viz., that it is necessary continuously to draw supplies to the maximum haulage and labour capacity during the winter season. The matter, therefore, is not purely an economic question of supply and demand.

4.—*If the Rate of Marketing is not satisfactory what are the difficulties which prevent Supplies from coming forward?*

It was pointed out in opening the enquiry that difficulties would probably be encountered in the following directions :—

(*a*.) Labour.
(*b*.) Haulage.
(*c*.) Railway rates.
(*d*.) Inadequate prices offered.

Specific information was sought on these heads, but the replies on the whole have scarcely been adequate.

(*a*.) *Labour.*—In respect of 99 estates (178,770 acres of woods) inspected the returns show : for 51 estates (110,290 acres or 61 per cent.) "labour sufficient" ; for 39 estates (45,880 acres or 26 per cent.) "labour difficulties" ; for 9 estates (22,600 acres or 13 per cent.) "sufficient labour at present," but in most of these last cases difficulties might arise if the present rate of felling were exceeded.

These returns appear to indicate that at the present time and working on the present scale there is no general shortage of labour for felling operations, but that difficulties might arise if "extraordinary" fellings were undertaken.

(*b*.) *Haulage.*—In respect of 120 estates (191,800 acres of woods) inspected the returns show : for 73 estates (116,440 acres or 61 per cent.) "haulage sufficient" ; for 32 estates (35,140 acres or 18 per cent.) "haulage insufficient" ; for 15 estates (40,220 acres or 21 per cent.) "sufficient haulage at present," but possible difficulties in abnormal circumstances as above.

(*c.*) *Railway rates.*—There has been a very general consensus of opinion that railway rates have been too high. In certain cases they have been so high that there has been no opportunity of doing a profitable business in pit-wood and, consequently, fellings are being restricted to the high-priced timbers such as larch. Two districts in particular call for observations, viz. :—the South of England and East Anglia. In the counties of Surrey and Hampshire there are probably about 640,000 tons of pine, larch and hardwood timbers suitable for mining purposes. Railway rates between centres of supply and centres of distribution have been as follows :—

	s.	*d.*	
Godalming–Nottingham	17	0	per ton.
Liphook–Sheffield district	23	0	,,
Wokingham–Brandon, Durham ...	28	4	,,
Romsey–Radstock	6	0	,,

Returns showing the quantity of pit-wood in Dorset have not been obtained, but the conditions are very similar to those in Hampshire. The following rates have been quoted :—

	s.	*d.*	
Shillingstone–Chesterfield	25	7	per ton.
,, Doncaster	27	10	,,
,, Rotherham	26	10	,,
,, Tredegar	19	10	,,

Somerset, where there are probably about 350,000 tons of pine, larch (chiefly) and hardwoods, lies nearer to centres of demand and some of the rates are low, but in certain instances they have been practically prohibitive, *e.g.* :—

	s.	*d.*	
Minehead–Radstock	16	0	per ton.
Porlock–Staffordshire Collieries ...	23	6	,,

In the counties of Suffolk and Norfolk there are probably about 260,000 tons of pine, larch, spruce and hardwoods. The following rates have been quoted :—

	s.	*d.*	
Thetford–Stanton Gate Collieries ...	13	10	per ton.
,, Burton-on-Trent	14	10	,,
,, Nuneaton	17	9	,,
Brandon–Nottingham	15	9	,,
,, Swadlincote Collieries ...	19	10	,,
Higham–Nottingham	21	6	,,
,, Staffordshire Collieries ...	21	6	,,

(*d.*) *Inadequate prices offered.*—Generally speaking, merchants appear to have been offering fair prices (compared with the normal prices). Naturally they have been trying to buy up as large quantities as possible, first in the hope of a rise, and secondly because this course presents economies in conversion.

There are so many conditions which affect the value of a given lot of timber (such as accessibility, quality of timber and so on) that it is not always easy to assess prices, but it would appear that in general, where inadequate prices are preventative of supplies coming forward, excessive railway rates are the predominant cause.

5.—*Is the Material being obtained by the best Sylvicultural Methods?*

Although this question lies without the fundamental issue of the enquiry it is of very considerable interest to the welfare of the woods of the country. It was anticipated that rises in the price of pit-wood would lead owners to make excessive and reckless fellings, but, on the other hand, the abnormal condition of the market would present a favourable opportunity in some cases for making much-needed thinnings which could not be hitherto conducted at a profit. The officers engaged on the enquiry were accordingly instructed to give advice, when requested, as to the best sylvicultural methods of treatment.

The returns show that in the case of 83 estates (95,560 acres) visited, 25 estates (34,670 acres) were employing suitable methods and 58 estates (60,890 acres) unsatisfactory methods.

It is of course impossible at the moment to predict the final result on the woods of the country, but it is clear that partial or actual depletion is bound to occur and that the question of regeneration will call for an active policy on the part of the State.

6.—*Is the Trade being carried on fairly between all Parties concerned?*

Enquiries were directed to the following points :—

(*a.*) Names of merchants operating in the various districts visited, with a note as to their reliability.
(*b.*) Prices being offered.
(*c.*) General remarks as to trading.

The information received under this head was generally of a rather vague description. This arises perhaps from the inherent difficulty of the case. The system of trading varies very greatly. As a pretty general rule the crop is sold standing and frequently the vendors have only a shadowy idea of the rate at which they have been paid. It is well known too that the measurements cannot be relied on, and that such measures as a cubic foot or a ton do not always mean the same thing.

The merchants seem, on the whole, to enjoy the confidence of the vendors : out of a total of 82 reported on, the reliability of only 10 is questioned.

Prices naturally show a wide variation. The approximate maximum and minimum prices for standing timber of which a note was obtained, were (assuming 30 cubic feet = 1 ton) :—

		s.			*s.*	
Larch ...	maximum	30/-	per ton,	minimum	8/-	per ton.
Pine... ...	„	30/-	„	„	5/-	„
Spruce ...	„	22/6	„	„	5/-	„
Hardwoods ...	„	37/6	„	„	7/6	„

It is well known that some agents are very careless in marketing timber, and the curious variations in price in similarly situated districts suggest that they are sometimes ignorant as well in the matter. It is believed that the visits of the Board's officers may have been of some value in affording a little enlightenment. Generally, prices show an advance, but it is impossible to state in general terms the percentage increase over the normal. In some instances the owners of woodlands are also royalty owners and are selling their timber at a figure far below the cost of felling and delivery at the mines. There are one or two instances of apparent attempts to corner supplies of home timber, but it is probable that any such attempts will fail owing to the large number of merchants concerned in the home trade.

Enquiries at the pits do not reveal evidence of systematic attempts to obtain extortionate prices. It would appear that for the most part dealers in home and in foreign timbers operate separately and in competition, thus tending to keep prices at a level somewhere near true values. The action of the Board of Trade in sending a committee to Canada to investigate the possibilities of an export trade in pit timber from that country has also probably had a salutary effect.

7.—*Is the Amount of Pit-wood in the Country sufficient for the needs of the Collieries until Normal Conditions obtain?**

About 265,000,000 tons of coal are, on the average, raised each year in the United Kingdom, and the annual consumption of pit-wood may be estimated at 4,500,000 tons or 1·7 per cent. of the weight of coal. Of the former amount 41,000,000 tons are raised in Scotland and the Board of Agriculture for Scotland estimate that there are on thirteen Scotch estates alone 300,000,000 lineal feet of pit-wood, which is estimated to be at least one full year's supply for the Scotch collieries. The total area of woodland in Scotland is 875,000 acres, of which the greater part is coniferous forest containing timber well suited for mining purposes. Assuming the volume of "extraordinary" fellings to be the same per acre as in England (and it is probably considerably greater) there would be approximately 1,600,000 tons: possibly 2,500,000 tons would be a better estimate. If the volume of the "extraordinary" fellings for England and Wales, viz., 3,410,000 tons, be added to this amount, a total of nearly 6,000,000 tons is reached, and it is a fair assumption that the addition of supplies from Ireland would give a total equal to 1½ years' total consumption for the collieries.

It would appear, therefore, that the position, while it requires rational handling, is by no means disconcerting. In order to draw upon home supplies in such measure as to meet adequately the shortage of foreign material it is essential that rural labour and haulage should be kept steadily at work during the winter season. This is the time when men and horses can best be spared from other estate work required for the production of food. Owners of estates will only fell timber when it appears that a reasonable profit is forthcoming, and such profit has hitherto been frequently absent owing to the cost of railway carriage.

In consequence of representations to this effect made to the Board of Trade, the railway companies have agreed to offer reduced emergency rates for pit-wood. These rates, it is understood, will apply to pit-wood not exceeding 14 feet in length, consigned direct to a mine at actual machine weight, station to private siding, 4 tons per truck.

* The question of foreign supplies is dealt with in a report by the Board of Trade. [Cd. 7728.]

Supplement

TO

The Journal

OF THE

BOARD OF AGRICULTURE

SUPPLEMENT No. 9. AUGUST, 1912.

NOTES ON KERRY WOODS

Illustrating Methods of
COLLECTING AND UTILISING INFORMATION
for a
FOREST SURVEY

LONDON:
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SUPPLEMENTS TO THE JOURNAL OF THE BOARD OF AGRICULTURE.

The Board of Agriculture and Fisheries are collecting, as opportunities arise, reliable data relating to forestry and afforestation, and as an example of one of the types of information considered desirable, the reader is referred to the account of the Coombe Plantation in the Board's *Journal* for July and August, 1910, Vol. XVII., pp. 265–283 and 353–370.

The data collected in any one locality will, as a rule, be incomplete, but it is hoped that, as the work of investigation progresses, it may be found possible to co-ordinate the results into a form which will be a useful and fairly complete guide to those undertaking planting operations.

In publishing the following investigations into the growth of timber on mountain soils, the Board desire to thank the executors of the estate of the late John Naylor, Esq., for permission to visit and measure woods and to fell sample trees on the Brynllywarch Estate; and also the agent, Mr. P. Hurlbutt, and the sub-agents, Messrs. Burn-Callendar and Beadon, for valuable assistance in carrying out the work.

BOARD OF AGRICULTURE AND FISHERIES,
4, WHITEHALL PLACE,
LONDON, S.W.

August, 1912.

CONTENTS

NOTES ON KERRY WOODS, ILLUSTRATING METHODS OF COLLECTING AND UTILISING INFORMATION FOR A FOREST SURVEY.

By R. L. ROBINSON.

I.—INTRODUCTION.

The investigations described in the following pages were, primarily, undertaken with the object of obtaining some accurate figures relating to the growth of timber in one of the more hilly districts of Wales. Later, when it was found that the results were of some value for the purpose, the scope of the work was extended to comprise a small survey of adjacent hill land in order to estimate its suitability for forestry purposes, and to settle the lines on which a forestry survey on a large scale should proceed.

The woods described lie chiefly on the Brynllywarch Estate on the boundaries of Radnor, Montgomery and Salop. The total area of the estate is about 7,000 acres, of which approximately 2,000 acres are wooded.

In beginning the work a preliminary inspection was first made of all the woods, and their general characteristics noted. Those plantations most likely to yield useful information were then gone over in detail, sample plots were laid out and measured, and soil samples submitted to mechanical and chemical analysis. The information collected was then critically examined, and was made to form the basis for the survey and valuation for forestry purposes of similar adjacent hill land.

Topography.

The key to the local topography is Kerry Hill, which runs as a long ridge in an E.N.E. and W.S.W. direction at an elevation of from 1490—1570 feet. Kerry Hill is part of a long spur which runs out from the high land lying on the borders of Cardigan, Radnor and Montgomery to the west.

The nearest point on the western sea-coast is about 35 miles distant. The intervening country is mountainous, the culminating point being Plynlimon Fawr (2,468 feet), but on the average the highest land rises to about 1,750 feet. From the top of Kerry

Hill the land slopes steeply to the north, but towards the south the slope is gentler.

CLIMATE.

The district lies on the edge of the very wet belt to the west. The rainfall at Newtown, under very similar conditions to Kerry, is about 40 inches, but westwards the rainfall gradually increases until it reaches 70 or 80 inches at Rhayader. The rainfall, therefore, on the higher land and southern slopes in this district is probably about 50 inches.

The snow-fall is irregular, considerable quantities falling in some winters and practically none in others.

Wind is undoubtedly the chief meteorological factor governing the growth of trees in this district. Frost is not a serious enemy. As pointed out above, Kerry Hill lies on the sheltered side of the central Welsh mountains, but the actual shelter obtained on the top of the hill appears to be very small. Cilfaesty Hill, 3 miles to the west of the woods under observation, rises to 1,760 feet, but to the south and south-west the hills are lower than Kerry Hill and the top of the latter is very bleak and fully exposed to the persistent S.W. and W. winds. The northern slopes are very well sheltered, but the southern are very exposed.

GEOLOGY.

In this district three series of rocks, all of sedimentary origin, come under consideration :—

1. Wenlock Shales.
2. Ludlow Shales.
3. The Old Red Sandstone.

The first two series, of Silurian age, form part of an anticlinal fold which further to the N.E. brings the Ordovician and Cambrian rocks to the surface.

The woods are chiefly on the Ludlow series, which are here rather thin-bedded shales. The Wenlock shales are lithologically similar but thinner, while the Old Red Sandstone series consists of red marls and grey sandstones. The whole three formations dip to the southward at an angle varying from 20° to 55°.

THE SOIL.

The soil, which is the weathered produce of the underlying rocks is, broadly speaking, on the shales, a yellowish brown loam and, on the sandstones as far as the timbered area is concerned, a red clay. Here and there in the lower parts of the valley are small deposits of glacial origin.

The soil generally is of good depth, overlying a rubbly subsoil composed of fine earth and fragments of shale. In the clays overlying the Red Sandstone there is no differentiation into soil and subsoil at a depth of 3 ft.

To obtain accurate information as to the nature of the soils, composite samples were taken of the soil and of the subsoil from a number of holes on some of the sample plots. The mechanical and chemical analyses of these were made at the Government Laboratory under the kind supervision of Dr. Dobbie. The methods of analysis used were those described in Hall and Russell's *Agriculture and Soils of Kent, Surrey and Sussex*.*

The following statement gives particulars of the samples and of the geological and sylvicultural conditions under which they were taken. The number of each soil sample corresponds with a volume sample plot, the depth of sampling being indicated in the fourth column of the table below.

Sample.	Geological Formation.	Elevation. O.D.	Depth of		Crop on Ground.	Surface Covering.	Remarks.
			Soil.	Subsoil.			
		feet.	inches.	inches.			
1 A	Ludlow shales	1,020	9	∞ *	Pure spruce	Spruce needles	Soil, wash from slopes above. Surface flat
2	,,	1,460	4—6	6—12	60 year old Scotch pine	Coarse grass on 6 in. peat	Gentle slope
3	,,	1,460	4—9	9—12	Pure spruce	Spruce needles on 2–6 in. peat	Gentle slope
5 and 6	,,	1,525	4—9	3—9	Spruce	Spruce needles on 4 in. peaty humus	Gentle slope
8	,,	1,300	24	12	Spruce	Spruce needles	Steep
9	,,	1,530	3—6	12	Spruce	Spruce needles on 6–8 in. peat	Gentle slope
A	,,	1,560	5	12	Very irregular spruce	Heather on 4–5 in. peat	Flat
L1	,,	975	15–22	∞	23 year old Larch	Larch needles	Thin sprinkling of wood sorrel on ground. Flat
L3	,,	1,175	24	∞	23 year old Larch	Larch needles	Thin sprinkling of wood sorrel. Steep
L4	,,	1,250	10	3	19 year old Larch	Larch needles	Thin sprinkling of wood sorrel. Steep
L6	,,	1,435	10—12	8—10	19 Year old Larch and mixed conifers	Grass	Gentle slope
12	Old red sandstone	1,400	∞		20 year old mixed conifers	Coarse grass on 6–8 in. peat	Irregular crop Scotch Pine, Spruce and Larch. Flat

*The symbol ∞ is used to indicate the depth of subsoil when the underlying solid rock was not reached at 3 feet depth.

The depth of soil generally is greater on the northern than on the southern slopes owing to the fact that the rocks dip steeply to the southwards, but even on the summit of the hills there is always a depth sufficient for tree growth.

Mechanical Analysis.—Table I. (*Appendix* A, *pp.* 50, 51) gives

* Published by the Board, 2*s.* 6*d.* net., post free.

the results of the mechanical analyses of the samples described above. Sample Ia consisted chiefly of fragments of shale and contained very little clay (2·2 per cent.) or fine silt (4·4 per cent.). The soil was evidently the debris washed down by an adjacent stream. It is remarkable chiefly because of the excellent growth of spruce on it (see Group Ia, p. 23). The remaining soils from the Ludlow Shales, conform, as nearly as one could expect, to a type, considering the large area from which they were selected. The average composition of these 10 samples is given below.

AVERAGE MECHANICAL ANALYSIS OF SOIL ON LUDLOW SHALE.

Character of Constituent.	Soil.	Subsoil.	Range of Variation. Soil.	Range of Variation. Subsoil.
Stones above 3 mm. to 100 parts of fine earth.	57	116	25—90	67—170
Percentage of fine earth:—	per cent.	per cent.	per cent.	per cent.
Fine gravel, above 1 mm.	4·2	6·9	0·7—14·1	1·6—16·0
Coarse sand, 1—0·2 mm.	3·0	5·7	1·3— 7·6	1·9—10·5
Fine sand, 0·2—0·04 mm.	9·7	12·9	4·1—15·2	6·7—21·9
Silt, 0·04—0·01 mm.	30·8	31·5	25·9—34·7	28·1—36·5
Fine silt, 0·01—0·005 mm.... ...	15·3	13·6	12·0—19·5	11·3—15·4
,, 0·005—0·002 mm. ...	9·4	7·5	4·9—12·1	6·1— 9·7
Clay, below 0·002 mm.	11·2	13·0	6·9—16·1	9·4—17·0
Moisture	2·5	15·4	1·6— 3·7	1·0— 2·3
Loss on ignition	9·7	5·2	5·8—15·6	2·4— 7·5
Calcium Carbonate soluble in N/5HCl.	2·2	1·5	1·6— 3·0	0·9— 2·1
	99·1	99·4	—	—

This composition shows the soil to be of a texture which is very suitable for the growth of trees.

Chemical Analysis.—The results of the chemical analysis are given in Table II (*Appendix A*, pp. 52 and 53). As a general rule it may be stated that the chemical composition of a soil is of very much less importance in the case of forest trees, where the produce of the soil is removed only at very long intervals of time, than in the case of agricultural crops.

Provided that the soil is of good mechanical composition, sufficient depth and protected by a proper canopy, trees will thrive, in the presence of sufficient moisture, on soils extremely poor in mineral food. For instance, Henry * gives the following analyses as typical of the dunes of Gascony, where the soil on an average

* "Les Sols Forestiers," *Annales de la Science Agronomique*, 1907, Vol. ii., pp. 246 and 307.

carries 1,760 cub. ft. of maritime pine (130 trees) per acre at an age of 75 years :—

	Water.	Loss on Ignition.	Al_2O_3. Fe_2O_3.	CaO.	MgO.	K_2O.	P_2O_3.	Insoluble in Acid.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil ...	1·47	5·85	0·05	0·03	0·24	0·04	0·02	92·3
Alios ...	2·17	3·00	1·63	0·03	0·27	0·04	0·05	92·8
Lower Sands	0·44	0·28	0·47	0·02	0·02	0·03	0·04	98·9

This soil consists of over 90 per cent. pure sand with extremely small quantities of lime, potash and phosphoric acid.

Ramann † states that the greatest use of chemical analyses in connection with forestry is for peaty soils. The quantities of mineral salts are in such cases a very good guide to the productiveness of the soil. With very sandy soils, according to Schütze, the chief factor governing the yield is the soil content in mineral food.* Ramann summarises Schütze's results in the following table. The quality classes refer to Scotch pine, I. being the best and V. the worst.

Quality Class.	Soluble in boiling HCl.			Phosphoric Acid.	Humus.
	CaO.	MgO.	K_2O.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I.	1·8876	0·0484	0·0457	0·0501	0·892
II.	0·1622	0·0716	0·0632	0·0569	0·555
II.—III.	0·1224	0·0981	0·1235	0·0464	1·401
III.	0·0963	0·0800	0·0392	0·0388	1·825
IV.	0·0270	0·0505	0·0241	0·0299	1·524
V.	0·0433	0·0438	0·0215	0·0236	1·429

From this table it appears that the soils richest in lime and phosphoric acid yield the greatest volume of timber, but that variations in the quantities of potash and humus are of little moment.

With heavier soils, however, the results of chemical analyses are of less use. The effect of varying quantities of mineral salts is masked by other factors such as mechanical composition and general condition.

The analyses of the soils from Kerry show that they are

† *Bodenkunde*, 1905, p. 203.

* The present state of knowledge on the subject is, however, unsatisfactory, recent experiments tending to disprove Schütze's conclusions (see *Int. Mitt. für Bodenkunde*, *Band 1*, 1912, *Heft.* 6).

rich in plant food except as regards nitrogen and lime. The total amount of potash present varies, as regards the soils on the Ludlow Shales, from 1·03 per cent. to 0·61 per cent. in the soil and from 0·91 per cent. to 0·65 per cent. in the subsoil. For total phosphoric acid the figures are, soil 0·22 per cent. to 0·10 per cent.; subsoil 0·187 per cent. to 0·09 per cent.; for nitrogen, soil 0·46 to nil, and subsoil 0·147 to nil.

The amount of "available" potash and phosphoric acid in the soil is, with the possible exception of No. 12, sufficient to grow agricultural crops and amply sufficient for forest growth. In fact, small areas of land are under cultivation on the north side of Kerry Hill up to an elevation of about 1,350 ft., and on the south side up to about 1,400 ft., the chief crops being oats, turnips, swedes, and potatoes.

Nitrogen appears to be very generally absent from the soils, and in two cases, No. 8 (54-year old spruce) and No. 12 (bare), from both soil and subsoil. No. 1A, which carried a very fine crop of 43-year old spruce, shows a large amount of nitrogen (0·228 per cent. in soil and 0·147 per cent. in subsoil), but many of the soils carrying good close-canopied crops, *e.g.* Nos. L_1, L_3, 3, 5, 8, and 9, show only traces of this element in the soil or subsoil.

The chief point which these analyses show is that the soil is not appreciably poorer at higher than at lower elevations. For example, sample L_1 (975 ft.) growing a very fine crop of young larch, is in no wise better than No. 9 (1,530 ft.) under a 38 year old crop of spruce.

On Kerry Hill the soil first begins to get peaty at about 1,400 ft. and at higher elevations there is very generally a layer of 4–8 inches of peaty material. In such case heather is the most abundant plant on the rough grazing land.

A general review of the chemical and mechanical constitution of these samples indicates that the soils throughout are excellently adapted for the growth of timber.

II.—METHODS OF MEASUREMENT AND DETAILS OF GROWTH OF DIFFERENT SPECIES.

Two fairly distinct series of woods come under consideration. First, a large area planted some 20–25 years, and second, a smaller area of 40–60 years of age. Larch is the predominant species, either pure or in mixture with various other species, while Scotch pine and spruce have been grown both in mixture with the above on a large scale and pure in comparatively small groups.

The preliminary inspection of the woods brought out several facts clearly. In the first place, it was obvious that Scotch pine when grown pure is nowhere a success, and is the less flourishing the greater the elevation. Larch, on the other hand, thrives wonderfully on the sheltered localities, but above a certain elevation suffers so badly from the effects of wind that it is impossible to raise a successful crop. Spruce grows well at all elevations and in exposed situations seemed the only tree capable of yielding timber of a useful size.

In the detailed examination small plots of 0·1 to 0·3 acre in extent were laid out for each species, the diameters were calipered, and a sample tree, approximating as nearly as convenient to the mean tree, was felled. In selecting each sample plot an endeavour was made to secure uniformity of stocking in the crop and a fair average sample.

The sample tree was then cut up into sections of either 4 feet or 5 feet length, the rings at each section were counted and two diameters at right angles measured. From these data, it was then possible to find the volume of the sample tree and hence the form-factor, and further to trace the height-growth curve.

The volume per acre (V) was then calculated as

$$V = A \times h \times f,$$

where A = total basal area at breast height of dominant crop,
f = form factor of sample tree,
and h = mean height of dominant crop.

By the dominant crop is meant those trees which would remain on the ground after a thinning. In the case of larch and Scotch and Corsican pines, the imaginary thinning was of moderate intensity, only the suppressed trees being removed, while in the case of spruce the thinning was made to approximate in intensity (as will appear later) to the density in which the crop had hitherto been grown. The trees which would be removed are termed the minor crop. Such a division is necessary where woods are thinned at irregular periods if the results of an investigation are to be of any use for comparative purposes. The volume calculated in this way makes no great pretence to accuracy, since it is difficult to select with precision a sample tree fully representative of the mean tree of the crop.

By felling a greater number of sample trees the volume may be calculated with greater accuracy, but in the present case this was impossible. The volume is, unless otherwise stated, given as true volume including bark.

Each of the species examined will now be dealt with in turn.*

A. **Larch.**

For the investigation into the growth of larch, there was a great deal of material available, both young and mature woods, in sheltered and in exposed localities.

In consideration of the facts that the development of larch is poor here in exposed localities and that the mature woods are not properly stocked, it was decided to measure a series of groups at various elevations in a wood known as Cwm Golog 20–24 years old, and to check the height-growth development of the group sample trees by felling other sample trees among the maturer crops at various elevations.

Cwm Golog occupies a steep northern slope and is sheltered in its lowest parts both to the east and the west by flanking hills. The original crop was obviously a mixture of larch in lines 8 feet apart filled up to 4 feet with Scotch pine, spruce, silver fir, and Corsican pine. The larch has grown so vigorously, however, especially in the lower parts, that all the other species have been killed out and a pure crop is the result. This point is referred to again later.

The following is a description of the various groups :—

GROUP L_1†

Area, 0·3 acre. *Elevation,* 975 feet. *Age,* 23 years.

This Group lies at the foot of a steep slope on deep well-drained

* Most of the sample areas were girthed at breast height in the first instance, but it was considered more suitable to rely on caliper measurements, and the trees were consequently calipered after a year's growth had taken place. These latter figures have been utilised in applying the formula $V = Afh$. The value of the form factor is taken as that of the previous year.

The increase in height during the year has been read off from the height-growth curves of the sample trees. In most cases, therefore, it will be noticed that the value of h used is slightly greater in the formula for calculating the volume than for the sample tree.

† Details are given of the stem diameters for each sample plot in Appendix B., pp. 54–58.

loam. Aspect N. The conditions are very favourable for the growth of larch.

Dominant trees per acre (of mean diameter 6·7 in.)	450
Minor trees per acre (of mean diameter 4·9 in.) ...	100
Total trees per acre	550

There were three Douglas firs on the sample plot, which were counted as dominant larch.

Sample tree: Total length (h) = 44 feet 6 inches.
Diameter breast height (d) = 6·4 inches.
True Volume to 3 inches least diameter (v) = 4·6 cubic feet.
Form factor (f) = 0·470.

Volume per acre $= \frac{32 \cdot 43}{0 \cdot 3} \times 46 \cdot 5$ * $\times 0 \cdot 47 = 2{,}360$ cub. ft. approx.

As remnants of the former crop there were also standing on this plot 80 spruce per acre of a height of from 4 feet to 10 feet. They were very thin in foliage and showed little promise of developing into trees. All the Corsican and Scotch pines were dead, but three Douglas firs had attained a height of about 50 feet.

GROUP L_2.

Area, 0·156 acre. *Elevation,* 1,080 feet. *Age,* 23 years.

Fairly steep slope. Soil deep and well drained loam. Aspect N.

Dominant trees per acre (of a mean diameter 6·0 in.)	545
Minor trees per acre (of a mean diameter 4·2 in.) ...	160
Total trees per acre	705

Sample tree: h = 40 feet 7 inches. d = 5·6 inches.
v = 3·5 cubic feet. f = 0·504.

Volume per acre $= \frac{16 \cdot 81}{0 \cdot 156} \times 42 \cdot 25 \times 0 \cdot 504 = 2{,}280$ cub. ft. approx.

There were also present 40 small spruce per acre, similar to those in Group L_1. The Scotch and Corsican pines were all dead.

GROUP L_3.

Area, 0·2 acre. *Elevation,* 1,175 feet. *Age,* 23 years.

Slope, steep. Soil and aspect as in Groups L_1 and L_2.

Rather irregular group.

Dominant trees per acre (of mean diameter 5·7 in.)	515
Minor trees per acre (of mean diameter 3·8 in.) ...	100
Total trees per acre	615

* See footnote as to the value of *h* on preceding page.

Sample tree: h = 37 feet 4 inches. d = 5·4 inches.
v = 3·05 cubic feet. f = 0·513.

Volume per acre = $\frac{18{\cdot}13}{0{\cdot}2} \times 38{\cdot}25 \times 0{\cdot}513 = 1{,}780$ cub. ft. approx.

Also present 20 small spruce per acre with the Scotch and Corsican pines all dead as in Groups L_1 and L_2.

Group L_4.

Area, 0·2 acre. *Elevation*, 1,250 feet. *Age*, 21 years.

Soil, slope and aspect as in Groups L_2 and L_3.

Dominant trees per acre (of mean diameter 5·8 in.)	470
Minor trees per acre (of mean diameter 4 in.) ...	200
Total trees per acre	670

Sample tree: h = 34 feet 8 inches. d = 5·45 inches.
v = 2·67 cubic feet. f = 0·476.

Volume per acre = $\frac{17{\cdot}6}{0{\cdot}2} \times 36{\cdot}3 \times 0{\cdot}476 = 1{,}520$ cub. feet. approx.

There were also present 45 spruce and 10 suppressed pines per acre. The spruce were mostly badly suppressed though a few were 12 feet high. The heavy early thinnings to which this group had been subjected account for the survival of the pines.

Between Groups L_4 and L_5 the slope becomes gentler and the wood is no longer sheltered to any extent by flanking hills to the west.

Group L_5.

Area, 0·18 acre. *Elevation*, 1,350 feet. *Age*, 20 years.

Aspect N. Slope gentle. Soil shallower than in foregoing groups.

Dominant trees per acre (of mean diameter 4·75 in.)	560
Minor ,, ,, (,, ,, ,, 3·0 ,,)	100
Total per acre	660

Sample tree: h = 24 feet 2 inches. d = 4·85 inches.
v = 1·6 cubic feet. f = 0·512.

Volume per acre = $\frac{12{\cdot}37}{0{\cdot}18} \times 25{\cdot}5 \times 0{\cdot}512 = 900$ cub. feet approx.

Also present 150 spruce, 50 silver firs, 100 Scotch pines and 40 Corsican pines per acre. The two pines and the spruce are of practically the same height and rival the larch, while the silver firs are from 4 feet to 10 feet high.

SUMMARY OF LARCH GROUPS (FIGURES PER ACRE).

Group.	Age.	Elevation. O.D.	Dominant Crop.				Minor Crop.		Other Conifers Present.				
			Number of Trees.	Mean height.	Mean diameter.	Volume.	Number of Trees.	Mean diameter.	Spruce.	Scotch Pine.	Corsican Pine.	Silver Fir.	TOTAL.
	years	*feet*		*feet*	*in.*	*cub. ft.*		*in.*					
L_1	23	975	450	46·5	6·7	2,360	100	4·9	80	—	—	—	80
L_2	23	1,080	545	42·25	6·0	2,280	160	4·2	40	—	—	—	40
L_3	23	1,175	515	38·25	5·7	1,780	100	3·8	20	—	—	—	20
L_4	21	1,250	470	36·3	5·8	1,520	200	4·0	45	5	5	—	55
L_5	20	1,350	560	25·5	4·75	900	100	3·0	150	100	40	50	340
L_6	20	1,435	670	22·0	4·7	910	65	2·5	250	110	55	45	460

GROUP L_6.

Area, 0·2 acre. *Elevation,* 1,435 feet. *Age,* 20 years.
Aspect N.N.W. Slope gentle. Soil as in Group L_5.

Dominant trees per acre (of mean diameter 4·7 in.)	670	
Minor " " (" " 2·5 ")	65	
Total	735	trees per acre

No sample tree felled. Average height of larch 22 feet.

$$\textit{Volume per acre} = \frac{16{\cdot}12}{0{\cdot}2} \times 22 \times 0{\cdot}512 = 910 \text{ cub. feet approx.}$$

Also present 250 spruce, 110 Scotch pines, 45 silver firs and 55 Corsican pines per acre. These species show the same relative development as in Group L_5.

A comparison of the groups (see p. 15) shows that L_1, L_2, L_3 are of the same age, while L_4, L_5, and L_6 are younger, L_5 and L_6 being also of equal age. Only the first three groups therefore may be strictly compared. From the height-growth curves (see p. 20) it is easily possible to predict with fair accuracy the probable height and volume of all groups at the age of the oldest, viz. 23 years.

This has been done and the results graphically represented in the accompanying diagram (p. 17). The broken lines indicate a change in the age of the groups. The volume falls off gradually on the steep slopes ascending to Group L_4, after which the fall is very rapid. This rapid diminution in volume is obviously connected in an intimate way with the local topography. Groups L_1 to L_4 lie on a steep slope under as good conditions of shelter as it is possible to obtain at the given elevations. Above Group L_4 (1,250 feet), however, the slope becomes much gentler and the two remaining groups are somewhat exposed to cross winds, notwithstanding the fact that Kerry Hill rises 120 feet higher immediately to the windward.

The heights and diameters fall off in a very similar way to the volumes, with the exception of Group L_4, which shows slightly better growth than Group L_3 at a lower elevation.

If the density of stocking were uniform throughout, the correspondence of the volume, height, and diameter, curves would probably be still more marked.

The development of Group L_1 is almost as good as the larch attains in this country—the average height growth of the best trees being 2 feet per year for 23 years. In fact, so rapid has been the growth of the larch in Groups L_1, L_2, L_3, and L_4 that only a tree here and there out of the other conifers which formed three-quarters of the original crop has survived. The variations in the number of survivors in these groups are probably due only to accidental causes.

In Groups L_5 and L_6, however, a marked change is to be noticed in the crop. The larch there has made comparatively poor growth, and although still the dominant tree, has not succeeded in completely suppressing the other species. Hence it comes about that in Group L_5 there are present 340 other conifers per acre and in L_6 460 per acre. It will be noticed that in every case the spruce is present in the greatest numbers.

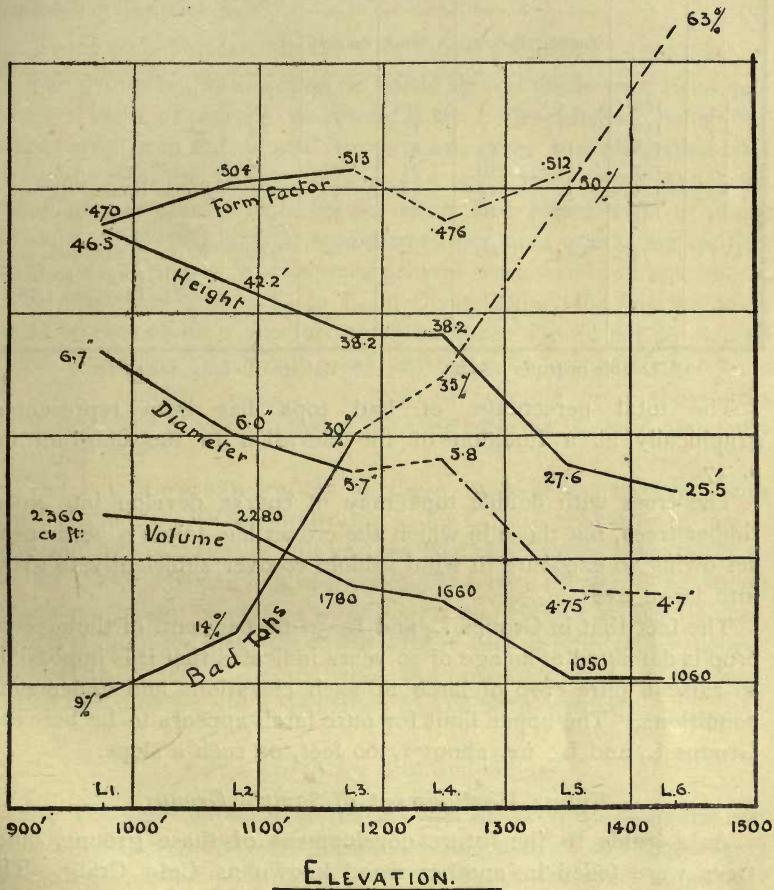


DIAGRAM SHOWING THE DEVELOPMENT OF THE LARCH SAMPLE PLOTS L_1 TO L_6.

Effect of Wind.

In addition, however, to what may be termed the diminishing vegetative activity of the larch at the higher elevations, there is another factor which has probably played an even greater part in accounting for the survival of the other conifers—*viz.*, the wind. In order to obtain some figures relative to the increasing damage due to wind at high elevations even in what appear to be perfectly sheltered localities a count was made of the number of damaged larch tops in each group, with the following results :—

Group.	Total Number of Trees.	Condition of Tops.				Total per cent. of bad Tops.	Remarks.
		Double Leaders.		Permanently deflected.			
		Number.	Per cent.	Number.	Per cent.		
L_1	168	5	3	10	6	9	
L_2	116	1	1	15	13	14	
L_3	158	19	13	25	17	30	
L_4	137	12	10	31	25	35	
L_5	119	17	14	43	36	50	Stems leaning slightly away from direction of wind.
L_6	147	23	16	69	47	63	
IV†	74	44*	60	—	—	60	Exposed situation, but with spruce shelter-belt. Elevation 1,460 ft.

* Double or triple leaders. † Referred to later, see p. 19.

The total percentage of bad tops has been represented graphically as a function of the elevation in the diagram on p. 17.

The trees with double tops may of course develop into good timber trees, but those in which the crown has taken a permanent set owing to exposure to wind seldom recover sufficiently to grow into large trees.

The fact that in Groups L_5 and L_6 50–60 per cent. of the present crop is damaged at an age of 20 years indicates that it is impossible to raise a pure crop of larch at such elevations and under such conditions. The upper limit for pure larch appears to be between Groups L_4 and L_5, *i.e.* about 1,300 feet, on such a slope.

Future Development of Sample Groups.

As a guide to the future development of these groups, older trees were felled in another wood known as Cefn Craig. The conditions as regards soil and exposure are similar to those in Cwm Golog, but the crop is very thin on the ground. The first tree (8 L) growing in a very thin wood, elevation 1,160 feet, was 51 years of age with a total height of 70 feet 4 inches, a volume of 20·5 cubic feet and a diameter at breast height of 10·4 inches. The form factor was 0·494.

The second tree, 40 years old, elevation 1,400 feet, had the following dimensions (Tree 11 L):

$v = 6{\cdot}97$ cubic feet. $h = 44{\cdot}3$ feet. $d = 7{\cdot}25$ inches. $f = {\cdot}474$.

It was growing under similar canopy conditions to the first and was the best tree which could be found at the elevation. About 50 per cent. of its fellow trees had damaged leaders.

The third tree (4 L) was one of the best trees of what was formerly a mixed crop of larch and Scotch pine growing at 1,460 feet elevation under exposed conditions. A sample area (Group IV.) was laid out here but was not worth the trouble of measuring. Tree 4 L was the best tree in the area, and at 54 years of age had the following dimensions:

$v = 6{\cdot}96$ cubic feet. $h = 42{\cdot}2$ feet. $d = 7{\cdot}8$ inches. $f = 0{\cdot}500$

The group lay in a section 60 yards by 150 yards with two-chain shelter belts of spruce on three sides. The shelter belts had apparently been introduced some years after the plantation was formed. On the sample area (0·225 acre) there were 330 larch trees per acre, of which 60 per cent. had either two or more leaders, leaving, say, 100 sound trees per acre averaging 40 feet in height. The few Scotch pines present were wretched specimens.

As with the Groups L_1 to L_6 in Cwm Golog, the conclusion is reached that above 1,300 feet elevation larch should not be planted pure in masses. In small areas protected by spruce shelter belts it grows quickly enough to form a payable crop above this elevation, but in any extensive planting scheme it could play only a minor part.

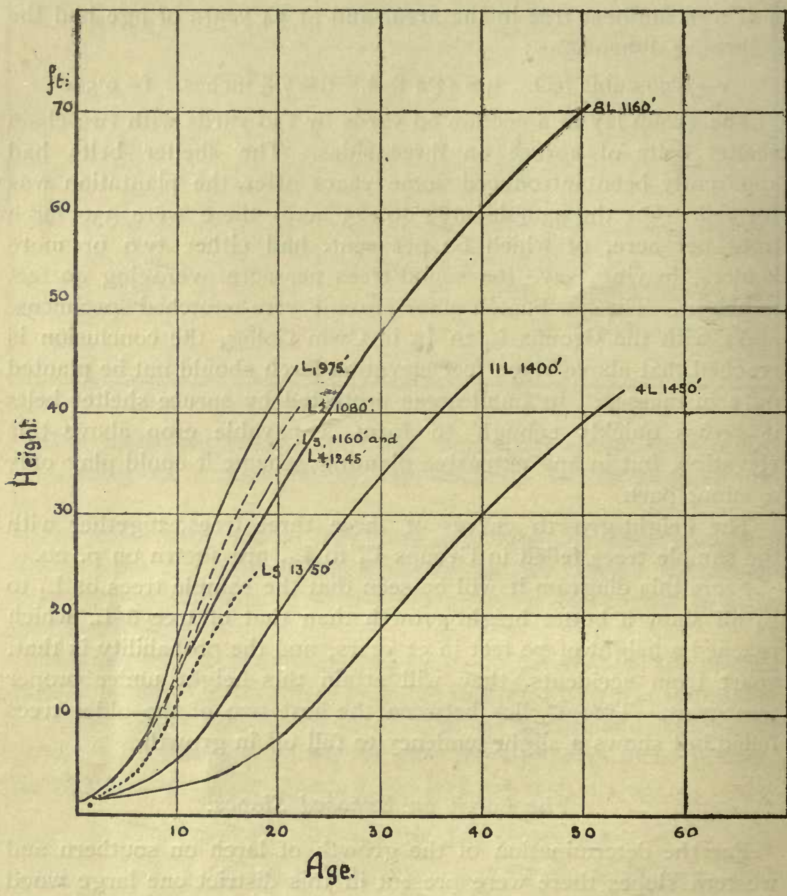
The height-growth curves of these three trees, together with the sample trees felled in Groups L_1 to L_5, are shown on p. 20.

From this diagram it will be seen that the sample trees of L_1 to L_4 all show a better height-growth than that of tree 8 L, which reached a height of 70 feet in 51 years, and the probability is that, apart from accidents, they will attain this height under proper treatment. Tree L_5 lies between the best two of the older trees felled but shows a slight tendency to fall off in growth.

The Larch on Exposed Slopes.

For the determination of the growth of larch on southern and western slopes there were present in this district one large wood known as Cefn Golog lying between 1,250 feet and 1,530 feet elevation with southern aspect, and several smaller woods lying at various elevations of from 1,250 feet to 1,400 feet with south to west aspects. Cefn Golog is practically a continuation of Cwm Golog wood with a mixture of the same species.

No groups were laid out or sample trees felled on these slopes. The preliminary inspection showed that it is only in the bottom of valleys on the south side of Kerry Hill that a pure crop of larch is at all successful at elevations up to 1,250 feet. For instance, between the elevations of 1,300 and 1,350 feet in Cefn Golog wood, 75 per cent. of the 23-year larch had damaged leaders. At 1,500 feet the tree hardly grows higher than a large bush. Descending the hill the growth gradually improves as the shelter becomes better. The rate of growth is wholly dependent on the amount of shelter available. In a word, the larch should only be planted on these slopes under exceptional conditions.



HEIGHT-GROWTH CURVES OF SAMPLE LARCH TREES GROWN AT VARIOUS ELEVATIONS.

Summary.

There is no doubt that if the damage from wind can be eliminated, larch grows rapidly enough, even above the elevation of Group L_6, to form a good crop, but taking into consideration the improbability of getting even half a fully stocked crop on the ground at 60 years, it is considered that larch becomes an exceedingly risky tree to grow above an elevation of about 1,300 feet in this district, even under conditions of exceptional shelter such as are obtained on steep northern and eastern slopes.

B. Scotch Pine.

As far as could be ascertained from the existing woods, Scotch pine does not appear to thrive well in this neighbourhood. This is perhaps due to the high rainfall generally and also in the higher parts to wind and snow-break.

This species has not been planted pure extensively, though it is present to a considerable extent in mixture with larch and other species in woods known as Block wood, Nant-y-Rhynau, Cefn and Cwm Golog and in Cefn and Cwm Vron. The pure plantations are at high elevations, and it was found impossible to get a series of groups to investigate the effect of elevation on this species.

The preliminary inspection showed that there is great difficulty in raising a dense crop of pure pine at altitudes of 1,400 feet and over. So much was this the case that only one group was found that was considered worthy of detailed examination. This was a 54 year old plantation, in Block Wood, standing at an elevation of 1,460 feet in a semi-exposed position (adjacent to Groups IV. and III.). The details are as follows :—

GROUP II. SCOTCH PINE.

Area, 0·225 acre. *Elevation,* 1,460 feet. *Age,* 54 years.

Slope gentle towards south, situation exposed. Soil, 6 inches peat overlying yellow loam (sample 2).

Ground covered with coarse grass.

Dominant trees per acre (of mean diameter 7·2 in.)	470
Minor trees per acre (of mean diameter 5·6 in.) ...	100
Total	570

Sample tree : h = 43 feet. d = 7·5 inches.
v = 6·6 cub. ft. f = 0·488.

Volume of Dominant Crop per acre $= \frac{30{\cdot}91}{0{\cdot}225} \times 43{\cdot}75 \times 0{\cdot}488 = 2{,}930$ cub. ft. approx.

Volume of Minor Crop per acre = 325 cub. ft. approx.

There were standing on this sample plot 470 dominant trees per acre with a total volume, including bark, of 2,930 cubic feet, and 100 minor trees with approximate volume of 325 cubic feet. Reduced to quarter girth volume without bark the approximate volume becomes 2,000 cubic feet, a volume which at 54 years is far from encouraging. Nor is the future of this plantation good. Examination of the crowns of dominant trees showed that 43 per cent. of them were damaged in such a way that the stems could not develop to the proper extent. The height-growth curve of the sample tree shows (see diagram, p. 30) that the crop has now passed the culminating point in this respect and has arrived at a time when the proper development of the crown is of the utmost importance. Plate I shows the condition of this group on its sheltered side.

At the top of Cwm Golog Wood at an elevation of 1,400 feet to 1,500 feet, on a sheltered aspect with slightly peaty soil, there is a considerable area of Scotch pine, aged about 19 years, replacing the larch woods previously referred to. These have reached a height of 12 feet to 15 feet but are already beginning to thin out and develop rough side branches owing to damage to the crowns.

The condition of these Scotch pine woods bears out the general contention that this species is not at all suited in Britain for the planting of hilly land where the rain and snow-fall are heavy and the soil inclined to be peaty. At the same time, it is possible that a variety with a narrower crown would grow much better.

C. Spruce.

Spruce has been grown in the district at all elevations and under all conditions of exposure and aspect, chiefly in mixture with other species, but also pure in small groups up to a couple of acres in extent and in shelter belts 1 to 2 chains in width. There was, therefore, a good deal of material to work on, though much of it was of little use owing to the irregular way in which the woods had been treated.

The following is a list of the results obtained by the examination of what were considered to be the most interesting groups.

GROUP I. NEW POOL SPRUCE.

Area, 0·2 acre. *Elevation*, 1,020 feet. *Age*, 43 years.

Group lies at foot of Kerry Hill (north side) under excellent conditions as regards shelter and soil.

Trees grown in medium density. Canopy complete. Dead branches adhering strongly.

Dominant trees per acre (of mean diameter 9·0 in.)	460
Minor trees per acre (of mean diameter 6·6 in.) ...	160
Total	620

PLATE I.

Group II.—Scotch Pine.

Elevation 1,460 feet. Exposed situation. True volume 2,930 cubic feet per acre at 54 years.

[*To face p.* 22.

Sample tree: h = 52 feet. d = 8·0 inches.
v = 8·73 cubic feet. f = 0·482.

This proved a somewhat poor tree, having lost its leader on two occasions. The average height of the group as determined by Brandis' Hypsometer was 60 feet.

Approximate Volume per acre $= \frac{40 \cdot 1}{0 \cdot 2} \times 62 \times 0 \cdot 482 = 6{,}000$ cub. ft.

GROUP IA. NEW POOL SPRUCE.

Area, 0·125 acre. *Elevation,* 1,020 feet. *Age,* 43 years.

Adjoining Group I., but on somewhat damper soil; other conditions similar.

This group had been neglected for some years and required thinning. In addition to the dominant and minor trees there were also 105 dead trees per acre on the ground. The dead branches were still adhering but not so strongly as those in Group I.

Dominant trees per acre (mean diameter 8·2 in.) ...	600
Minor trees per acre (mean diameter 5·5 in.) ...	375
Total	975

Two sample trees were felled :—

1*A Dominant Tree* h = 63 feet. d = 7·8 inches
v = 10·53 cub. ft. f = 0·502.
1*a Minor Tree* h = 50 feet. d = 4·7 inches.
v = 3·1 cub. ft. f = 0·520.

Volume per acre, Dominant Crop $= \frac{27 \cdot 62}{0 \cdot 125} \times 64 \cdot 5 \times 0 \cdot 502 = 7{,}150$ cub.ft.

" " *Minor* " $= \frac{7 \cdot 71}{0 \cdot 125} \times 50 \times 0 \cdot 52 = 1{,}600$ cub.ft.

Total Volume per acre = 8,750 cub.ft.

GROUP III. SPRUCE: CEFN CRAIG WOOD.

Area, 0·154 acre. *Elevation,* 1,460 feet. *Age,* 43 years.

Gentle northern slope near top of Hill—semi-exposed. Adjacent to Groups II. (Scotch Pine) and IV. (Scotch Pine and Larch). Soil (sample 3) 2″—6″ peat on yellow loam.

Irregular crop growing under light canopy conditions.

Dominant trees per acre (of mean diameter 8·4 in.)	465
Minor trees per acre (of mean diameter 6·1 in.) ...	130
Total	595

Sample tree: h = 52 feet. d = 8·2 inches.
v = 9·25 cub. ft. f = 0·485.

Volume of Dominant Crop per acre = $\frac{27{\cdot}88}{0{\cdot}154} \times 53{\cdot}3 \times 0{\cdot}485 = 4{,}680$ cub. ft.

GROUP V. SPRUCE SHELTER BELT, EAST OF KERRY POLE COTTAGE.

Area, 0·1 acre. *Elevation,* 1,525 feet. *Age,* 42 years.

Situated at the top of Kerry Hill. Slope slightly towards North. Full exposure to S. and S.W. winds. Soil, 4 inches peat on yellow loam (samples 5 and 6).

Grown under moderately dense canopy conditions.

Dominant trees per acre (of mean diameter 6·4 in.)	840
Minor trees per acre (of mean diameter 5·0 in.) ...	210
Total	1,050

Sample tree: h = 40·5 feet. d = 6·2 inches.
v = 4·37 cub. ft. f = 0·513.

Volume of Dominant Crop per acre = $\frac{18{\cdot}95}{0{\cdot}1} \times 41{\cdot}5 \times 0{\cdot}513 = 4{,}030$ cub. ft.

GROUP VI.

Area, 0·221 acre. *Elevation,* 1,525 feet. *Age,* 42 years.

Part of Shelter Belt in which Group V. is situated, but on the windward slope of Kerry Hill. Soil as in Group V.

Grown under moderately dense canopy conditions.

Dominant trees per acre (of mean diameter 6·1 in.)	890
Minor trees per acre (of mean diameter 4·8 in.) ...	290
Total	1,180

Sample tree: h = 40·2 feet. d = 5·8 inches.
v = 3·7 cub. ft f = 0·498.

Volume of Dominant Crop per acre = $\frac{39{\cdot}51}{0{\cdot}221} \times 41{\cdot}2 \times 0{\cdot}498 = 3{,}670$ cub. ft. approx.

GROUP VII. NANT-Y-RHYNAU WOOD.

Area, 0·2 acre. *Elevation,* about 1,400 ft. *Age,* 43 years.

Aspect.—Somewhat steep slope facing S.W. on south side of Kerry Hill. Soil somewhat shallow loam. Exposure.—About three-quarters of full.

Regular and well-grown crop of medium density. Lower branches had been stripped away.

Dominant trees per acre (of mean diameter 7·5 in.)	615
Minor trees per acre (of mean diameter 6 in.) ...	205
Total	820

Sample tree: h = 51·25 feet. d = 7·1 inches.
v = 7·01 cub. ft. f = 0·498.

Cub. ft. approx.

Volume of Dominant Crop per acre $= \frac{37 \cdot 68}{0 \cdot 2} \times 52 \cdot 5 \times 0 \cdot 498 = 4{,}930$

" " *Minor* " " $= \frac{8 \cdot 11}{0 \cdot 2} \times 45 \times 0 \cdot 5 = 910$

Total 5,840

GROUP IX.—CEFN GOLOG WOOD.

Area, 0·213 acre. *Elevation*, 1,530 feet. *Age*, 38 years.

On north side of Kerry Hill, but considerably exposed.

Soil (sample 9) 6–8 inches peat on yellow loam.

Grown under medium to dense canopy conditions.

Dominant trees per acre (of mean diameter 5·4 in.)	1,180
Minor trees per acre (of mean diameter 3·8 in.) ...	330
Total	1,510

Sample tree: h = 37·5 feet. d = 5·4 inches.
v = 3·18 cub. ft. f = 0·534.

Volume of Dominant Crop per acre $= \frac{40 \cdot 49}{0 \cdot 213} \times 38 \cdot 5 \times 0 \cdot 534 = 3{,}900$ cub. ft. approx.

GROUP XIII.

CEFN GOLOG WOOD. *Area*, 0·218 acre. *Elevation*, 1,530 feet. *Age*, 38 years.

Adjacent to Group IX. and under similar conditions as regards soil and exposure.

Grown under medium density.

Dominant trees per acre (of mean diameter 5·8 in.)	900
Minor trees per acre (of mean diameter 4·8 in.) ...	200
Total	1100

Sample tree: h = 41·5 feet. d = 5·75 inches.
v = 4·07 cub. ft. f = 0·542.

Volume of Dominant Crop per acre $= \frac{36 \cdot 62}{0 \cdot 218} \times 41 \cdot 5 \times 0 \cdot 542 = 3{,}780$ cub. ft. approx.

SUMMARY OF SPRUCE GROUPS (DOMINANT CROP).

Group.	Elevation.	Side of Kerry Hill and Aspect.	Canopy-Density.	Age.	Mean Height.	Mean Diameter.	Number of Stems per acre.	Form Factor.	True Vol. per acre.
	feet.			*years.*	*feet.*	*inches.*			*cub. ft.*
I.	1,020	N. side, N. aspect.	Medium.	43	62·00	9·0	460	0·482	6,000
IA.	1,020	,,	Dense.	43	64·50	8·2	600	0·502	7,150
III.	1,460	,,	Light.	43	53·30	8·4	465	0·485	4,680
V.	1,525	Top, N. aspect.	Medium.	42	41·50	6·4	840	0·513	4,030
VI.	1,525	Top, S. aspect.	,,	42	41·20	6·1	890	0·498	3,670
VII.	1,400	S. side, S.W. aspect.	,,	43	52·50	7·5	615	0·498	4,930
IX.	1,530	N. side, near top.	Medium to Dense.	38	38·50	5·4	1,180	0·534	3,900
XIII.	1,530	,,	Medium.	38	41·50	5·8	900	0·542	3,780

PLATE II.

GROUP XII.—CORSICAN PINE.

Elevation about 900 feet. Sheltered situation. True volume 6,300 cubic feet per acre at 40 years.

[*To face p.* 26.

It is not proposed to discuss these results at this stage; this is done fully later, but it may be pointed out here that Groups I. and IA occupy situations which approach the best obtainable in the district, V., VI., and IX. approach the worst, while III. and VII. may be described as growing under poor to moderate conditions. The particulars relating to the growth of the various groups of spruce are summarised in the table on p. 26.

D. Miscellaneous Species and Mixtures of Species.

1. *Corsican Pine.*

Corsican Pine has been grown quite extensively in mixture with other species at various elevations. In many cases it does well and does not suffer from wind and snow to the same extent as Scotch Pine at similar high elevations. At the same time its growth is not always satisfactory. In wet places, especially, many of the trees die off when 12 to 15 feet high, leaving an irregular crop on the ground. Only one group was available for measurement. This stood at an elevation of 900 feet in Fronderw Wood (north side of Kerry Hill) on a steep, well-sheltered western slope. The following are details of the crop.

GROUP XII. CORSICAN PINE.

Area, 0·146 acre. *Elevation,* 900 feet. *Age,* 40 years.

Aspect, West.

Soil—loam, well drained, in excellent condition and well protected with thick layer of needles.

Dominant trees per acre (of mean diameter 10·5 in.)	445
Minor trees per acre (of mean diameter 7·7 in.) ...	110
Total	555

Crop irregular. Density of stocking, about 0·9.

Sample tree: h = 53·3 feet. d = 10·0 inches.
v = 14·34 cub. ft. f = 0·493.

The sample tree was rather higher than the main crop, which may be put at 48 feet high.

$$\textit{Volume of Dominant Crop per acre} = \frac{38{\cdot}92}{0{\cdot}146} \times 48 \times 0{\cdot}493 = 6{,}300 \text{ cub. ft.}$$

The quarter girth volume of the sample tree, without bark, was 9·3 cubic feet, which gives a total volume per acre quarter girth of 4,200 cubic feet for the dominant part of the crop.

These figures show that under favourable circumstances this species will give a very large return per acre—in the given case 105 cubic feet mean annual increment quarter girth at an age of 40 years.

The sample tree was still growing very vigorously and had made leaders of 18 to 20 inches for the last ten years. The height-growth curve is shown on page 30, and from this it will be seen that the rate of growth as yet shows little or no signs of falling off, and it would not be unreasonable to predict a height of 63 feet at 50 years of age.

It must be noted that 28 per cent. of the dominant trees and 31 per cent. of the minor trees on this group had either double tops or had received some injury to their leading shoot. The cause of this injury was not apparent, since the group was well sheltered from wind.

Plate II. illustrates the appearance of the trees in this group. Unfortunately there were no other groups old enough to be worth measuring, but this species is growing wonderfully well everywhere under favourable conditions.

2. *Douglas Fir with Larch.*

Douglas fir has been planted extensively in the sheltered valleys on the north side of Kerry Hill, generally in mixture with larch. Its growth is very rapid and at 24 years the best larch are already in danger of suppression. In situations where the larch has attained a height of 40 feet at 22 years of age, the Douglas fir is about 5 feet taller and rapidly increasing its lead.

Douglas fir could be safely planted on sheltered aspects up to 1,250 feet elevation, and on favoured spots even up to 1,300 feet, but its use is sharply restricted. On wet soils, even at the bottom of valleys, it shows a tendency to be thrown by wind even before its fragile leader has been broken. The height-growth curve given in the diagram, p. 30, was taken from a blown tree on wet soil, and is hardly a fair criterion of the rate of growth.

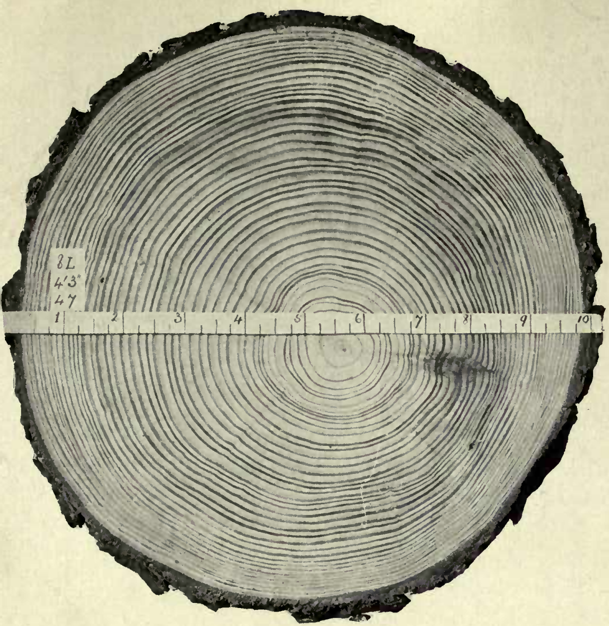
3. *Douglas Fir with Abies Grandis and Larch.*

A considerable area in Llwyn-y-rhŵd wood has been planted with a mixture of these species. The locality is very well sheltered at 900 feet elevation and the soil is deep though inclined to be wet. *Abies grandis* has shown remarkable growth and at 24 years of age averages 60 feet in height. A tree, which had been broken off, had the following dimensions: $v = 10{\cdot}5$ cubic feet quarter girth in first 30 feet of bole; $h = 59$ feet 3 inches; $d = 10{\cdot}8$ inches.

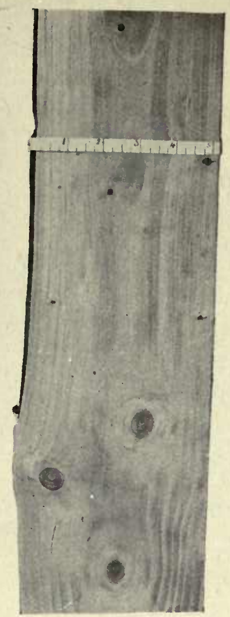
The Douglas fir average 50 feet to 55 feet high, while the larch are completely overshadowed.

4. *Larch, Scotch Pine, and Spruce.*

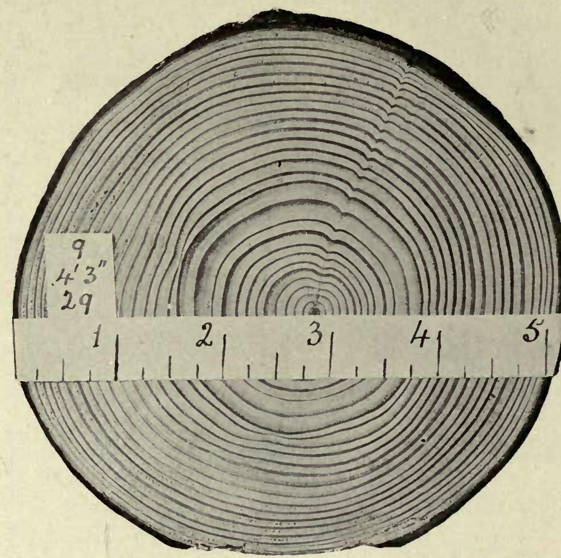
Very large areas have been planted with these three species in about equal proportions or with a larger proportion of larch. The result is not satisfactory. On the lower ground larch suppresses the other two species, while on the upper the spruce is the most vigorous tree and develops large side branches which are not killed off by the less vigorous Scotch pine and larch. The poor quality of the resulting spruce timber is shown in Fig. B, Plate III.



A. Larch. Tree 8L.



B. Spruce.



C. Spruce. Tree 9.

PLATE III.
Timber Sections.

[To face p. 28.

5. *Thuya gigantea, Chamaecyparis Lawsoniana, Cupressus macrocarpa, Pinus ponderosa, Picea sitchensis, and other exotics.* —These have been planted singly or in small groups here and there on the lower ground. They are very interesting as showing the rates of growth of the various species, but, from the way they have been grown, are not of sufficient economic interest for detailed description here.

E. The Relative Rates of Height Growth of the Different Species.

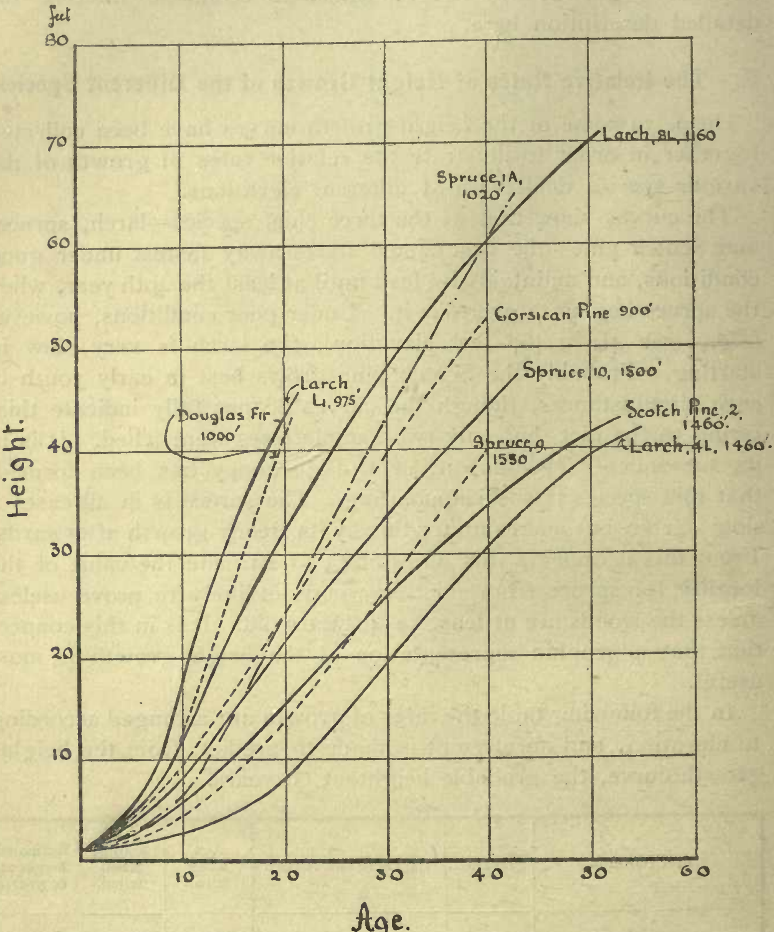
On p. 30 some of the height-growth curves have been collected together in order to illustrate the relative rates of growth of the various species dealt with at different elevations.

The curves show that of the three chief species—larch, spruce, and Scotch pine—the first named starts away fastest under good conditions, and maintains its lead until at least the 40th year, when the spruce begins to overtake it. Under poor conditions, however (*e.g.*, tree 4L, 1,460 feet elevation), the larch is very slow in starting. Probably the Scotch pine grows best in early youth in such circumstances, though the curves do not fully indicate this, owing to the fact that only two sample trees were felled. It is in its subsequent development, after the canopy has been formed, that this species is so disappointing. The spruce is in all cases a slow starter, but makes up for this by its steady growth afterwards. From this it appears that an attempt to estimate the value of the locality for spruce from existing woods is likely to prove useless unless the woods are at least 30–40 years old. It is in this connection that a graphic representation of the height-growth is most useful.

In the following table the rates of growth are arranged according to elevation, and an attempt is made to predict, from the height-growth curve, the probable height at 60 years.

Tree (group).	Elevation.	Exposure and Aspect.	Age when felled.	Height when felled.	Estimated height at 60 years.
	ft.		yrs.	ft. in.	ft.
Larch, L_1	975	N. Sheltered	22	44 6	85 ?
Spruce, 1A	1020	,,	43	63 0	86
Larch, 8L	1160	,,	51	70 4	77
Larch, 11L	1400	,,	40	44 4	54
Spruce, VI	1400	S.W. Exposed	42	51 3	67
Spruce, III ...			42	52 0	67
Scotch Pine II	1460	Semi-exposed Top of hill	53	43 0	46
Larch, 4L ...			54	42 2	45
Spruce, 10	1510	Semi-exposed. N.	45	47 0	58
Spruce, V and VI ...	1525	Full exposure Top of Hill	41	40 3	55
Spruce, IX	1530	Semi-exposed	38	38 0	65

The last column of the table, although it cannot claim to be very accurate, indicates the superior growth of spruce in all except the very best situations. It must be further remembered that the spruces represent in all cases the mean tree of a group, whereas the larches were selected (at higher elevations) from among the best (*i.e.*, undamaged) stems at the given elevations.



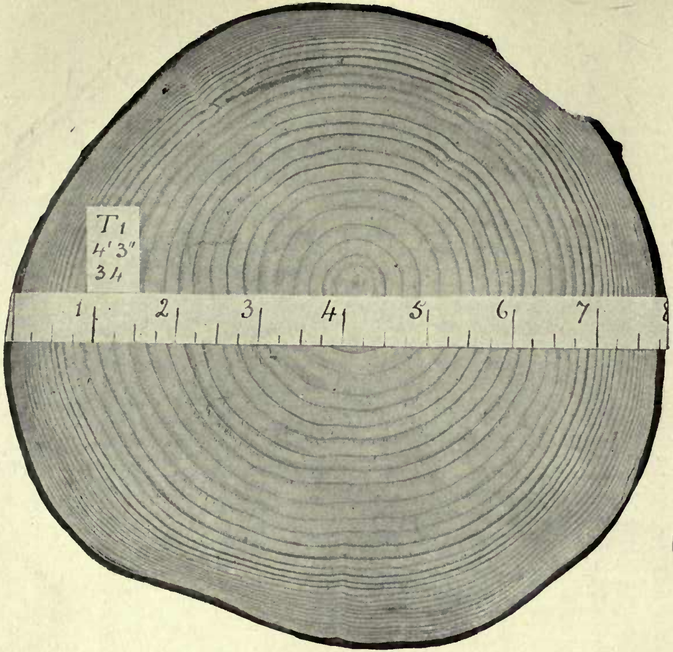
HEIGHT-GROWTH CURVES OF SOME OF THE SAMPLE TREES FELLED.

It may be said that on all aspects the spruce should here attain a height of at least 60 ft. in 60 years at an elevation of 1,500 ft.

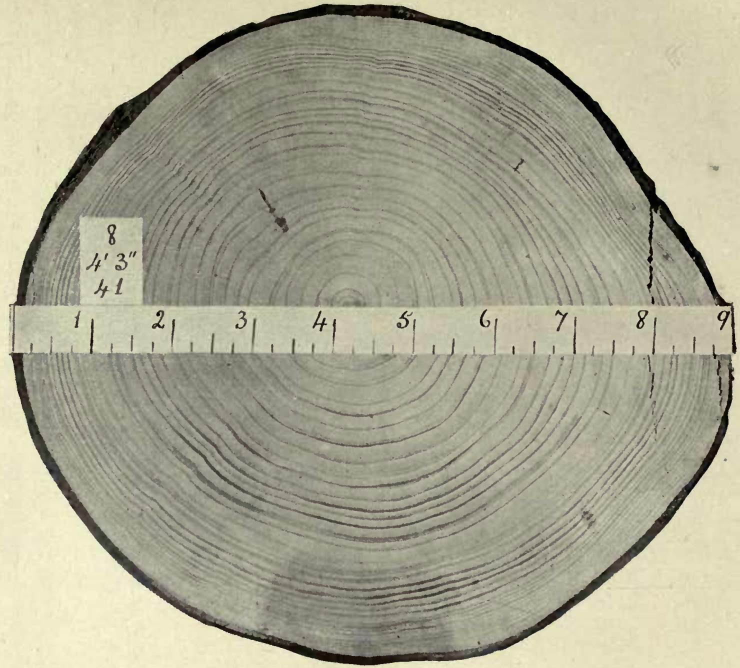
F. Quality of the Timber.

A few of the sections taken from the sample trees felled have been reproduced to show the quality of the timber. Some of these sections bear labels, on which the top number is the number of the sample tree, the second the height of the section from the ground, and the bottom the number of annual rings in the section.

Larch.—The larch timber generally is of good quality. The



Spruce. Tree No. 1.

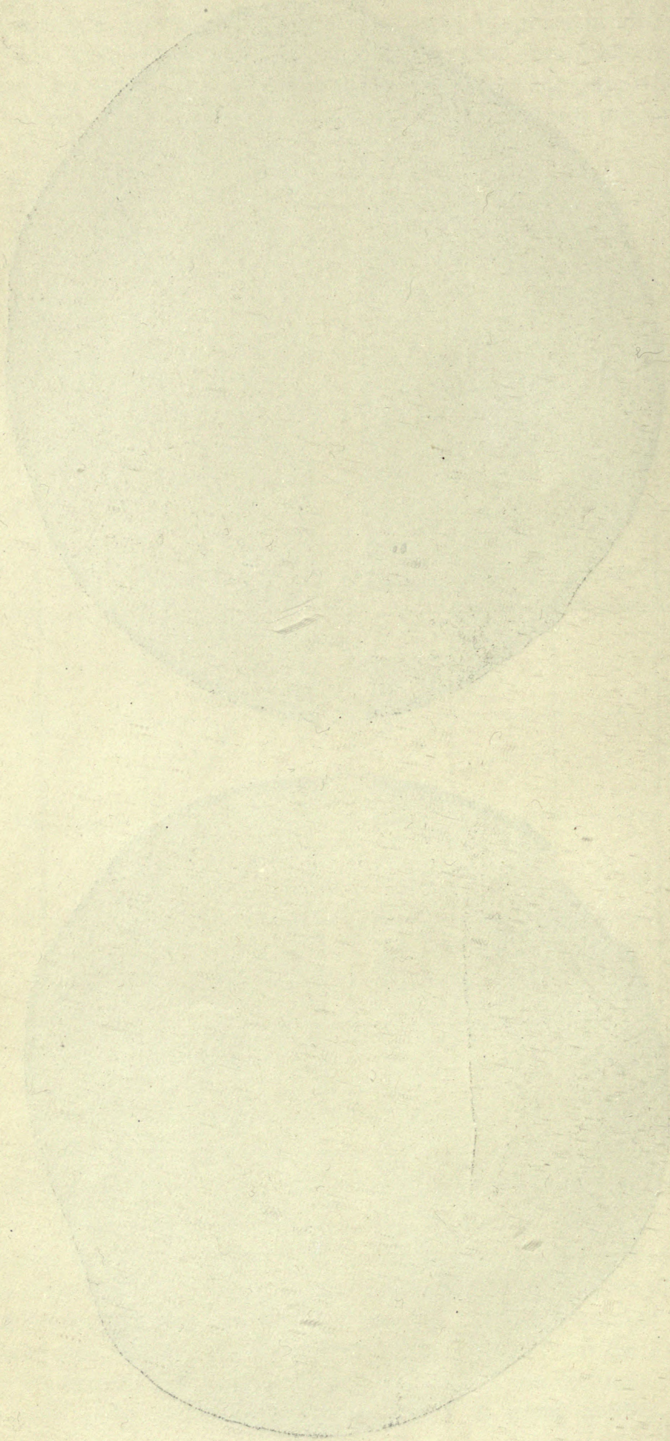


Spruce. Tree No. 8.

PLATE IV.

Timber Sections.

[To face p. 30.



section illustrated in Plate III. (Tree No. 8L) was a particularly good specimen, with an average of about 10 rings per inch of radius and a large proportion of heartwood.

Spruce.—The quality of the spruce timber varies very greatly according to the method of growth. Of the specimens illustrated, No. 9 (Plate III.), was grown under uniformly dense canopy conditions, while Nos. 1 and 8 (Plate IV.), and 3 (Plate V.), varied from moderate canopy conditions in youth to denser conditions later in life. According to Janka,* regularity in the width of the annual rings and a large proportion of summer to spring wood are the chief factors governing the quality of spruce timber, assuming the absence of knots. The narrower the rings the better the timber as a rule. Judged by this standard, No. 9 (1,530 ft. elevation) is a good specimen of spruce timber, while the remaining specimens, with the exception of No. 3 (1,460 feet elevation) (Plate V.), are inferior owing to irregular treatment of the crop. If grown properly, there is no reason why spruce timber of good quality should not be produced at all elevations in the district.

The longitudinal section in Plate III. represents the characteristically coarse and knotty character of spruce timber when grown in mixture with larch and Scotch pine.

The spruce is attacked by heart-rot, especially on dry soils, at an advanced age, but appears to be quite sound up to 70 years of age.

Scotch Pine.—The Scotch pine timber grown on the estate is of poor quality, and up to 54 years of age is very little superior to spruce. No. 2, Plate V., represents the breast-height section from the sample tree of Group II. (54 years old, 1,460 ft. elevation). The tree was just beginning to form heartwood when felled.

Douglas Fir has not been grown under dense conditions, and hence the timber is knotty and broad-ringed. In spite of the wide rings, however, the timber is hard and strong. The section illustrated, Plate VI., was taken from an unknown tree, and apparently at some distance up the stem. The rings are remarkably wide and even, and after thorough seasoning the wood appears to be of excellent quality, with a good proportion of heartwood.

Corsican Pine.—The wood, as illustrated by No. 12, Plate V., indicates, that if properly treated, good Corsican pine timber may be grown in the district. The wood is inclined to be coarse, and at 40 years of age the sample tree had just begun to form heartwood.

Austrian Pine.—The section in Plate VI. was grown in a somewhat open position in an avenue. The timber is broad-ringed and coarse, and splits readily.

* "Elastizität und Festigkeit der österreischen Bauhölzer."—*Mitteilungen aus dem Forstlichen Versuchswesen Österreichs.* Heft XXXV.

III.—UTILISATION OF THE DATA FOR A SURVEY.

A. Method of Arriving at a Basis for a Survey.

General Considerations.

Any survey of land for forestry purposes must rest fundamentally on financial considerations. It is admitted that afforestation might be justifiable on economic grounds other than direct remunerativeness, but even in such cases financial considerations must indicate the land to be afforested. The first question to be asked before planting a piece of land is, "Will it pay?" In answer to this much loose talk on afforestation has been indulged in from time to time, but the evidence adduced in support of opinions has really been of very little value, since, as a rule, it has not been supported by sufficient figures to form any accurate generalisation on the subject.

To give a satisfactory reply, the following data are necessary :—

(*a*) The minimum rate of interest which invested capital is desired to yield.

(*b*) The cost of forming the plantation.

(*c*) The returns in cubic feet of timber per acre from period to period.

(*d*) The nett price of timber per cubic foot at each period.

(*e*) The cost of upkeep, management, &c., per acre per year throughout the whole rotation.

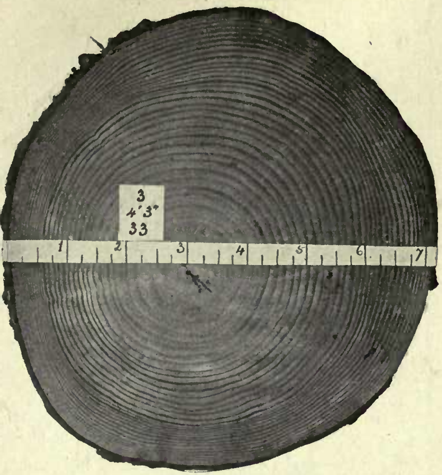
If these data are given, the soil rental, and hence the value of the land for forestry purposes, can be obtained by a simple calculation.

Of these five sets of data, (*a*), (*b*), (*c*), and (*e*) are either known, or are capable of experimental determination within comparatively accurate limits.

(*a*) With regard to the rate of interest, the security offered by forests is considered by most authorities to be very good. In the present calculation 3 per cent. is taken. It is approximately the rate at which the State could borrow money for afforestation purposes.

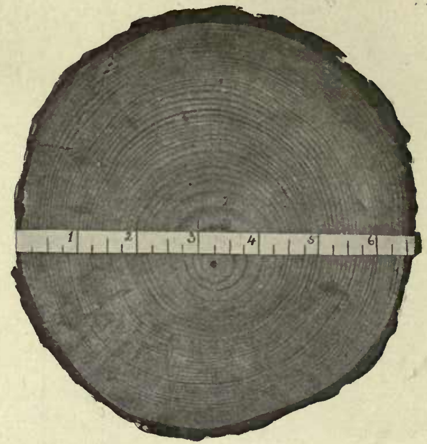
(*b*) The cost of planting spruce should not exceed £5 per acre, including fencing and drainage, if the work is done on a large scale. The actual cost can best be ascertained by experimental afforestation on a large scale.

(*c*) The returns per acre from period to period can be obtained only from yield tables.



SPRUCE. TREE NO. 3.

CORSICAN PINE. TREE NO. 12.



SCOTCH PINE. TREE NO. 2.

PLATE V.

TIMBER SECTIONS.

[*To face p.* 32.

As no reliable tables have been compiled for Britain, this is probably the greatest difficulty at the moment to be faced in making a valuation.

(*d*) The price which timber will bring, say, 60 years hence is very problematical. At present it is known that prices show a tendency to rise, and, as far as can be judged from the available timber supplies, will continue to rise to figures considerably higher than those at which they now stand. The safest method is therefore to take present prices.

It is assumed that the following prices would be obtained for spruce timber if grown on a large scale.*

Size of Tree, cub. ft.	Price per cub. ft. (True Volume).
Less than 0·5	—
0·5 — 1	1*d.*
1 — 5	2*d.*
5 — 10	2½*d.*
10 — 20	3*d.*
20 — 40	3½*d.*
over 40	4*d.*

(*e*) The cost of upkeep and management is assumed to be 4*s.* per acre per year.

From the foregoing it will be seen that calculations as to the probable return from forestry are beset with many difficulties even in the most favourable circumstances. There are many influences which may so modify the returns as considerably to reduce the value of the calculations. At the same time, there is no other method available. The man who recommends a piece of planting

* Schwappach (*Wachstum und Ertrag normaler Fichtenbestände in Preussen*, p. 108) uses approximately the following prices in calculations of a similar nature. The conditions in Britain and in Prussia are, of course, not similar, but the table gives some indication of the prices which spruce timber will bring under good conditions as to utilisation.

Size of Tree, cub. ft.	Nett price in pence per cub. ft. (True Volume).
0·35	2
0·75	2¼
1·0	2½
2·0	3
3·5	3½
7·0	4¼
10·0	4¾
14·0	5¼
20·0	5½
30·0	6
70·0	7
85·0	7½

because it will pay consciously or unconsciously makes an estimate of the probable volume and then of the probable value of the crop.

Use of Yield Tables.

In the preceding pages material has been collected which may be considered fairly representative of woods from which evidence as to the rate of growth of timber in hilly districts will have to be drawn. The important point is how best to utilise these data for the valuation of neighbouring land for forestry purposes, and hence to lay down the method of procedure for a local forestry survey.

The crux of the whole matter is to estimate with reasonable precision the volume which the various woods will develop by the end of the rotation. If yield tables were available for the various species, this would be a comparatively easy matter, since a determination of the factors yielding the existing volume (total basal area per acre, height, and form factor) enables a wood to be placed in its quality class, and if the rotation be well advanced an accurate estimate of the probable volume may be made.

It would considerably simplify matters if the survey of a given district could be made with a single species as the basis, *i.e.*, if the land could be mapped into given classes for the one species, which could be made equivalent to other classes for other species if so desired. It is believed that in the present instance this can be done by using the spruce for the purpose.

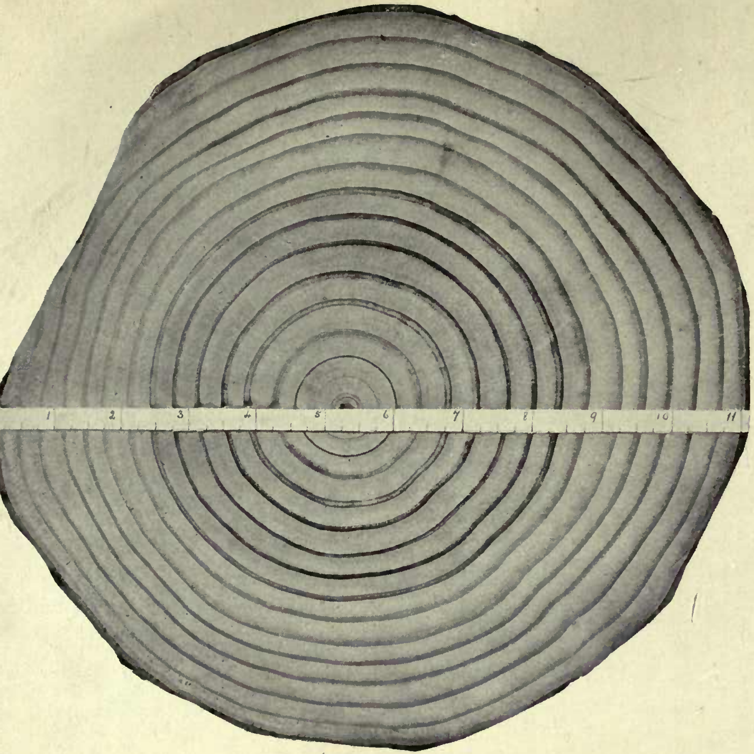
It has been shown that above 1,300 ft. on the best sheltered aspects, and on practically all exposed sites, the larch is too uncertain a crop to be of any use for valuation purposes. The Scotch pine nowhere grows well, and is equally useless. The spruce is apparently the best indicator, and the necessity arises of estimating the development of the 43-year-old woods measured.

After examining several sets of Continental tables, it was resolved to test the applicability of those prepared by Schiffel for Austrian conditions.* These are of peculiar use for British woods, since three separate canopy classes are recognised—dense, medium and light—whereas the usual tables relate only to dense canopy conditions, and are therefore of only very exceptional use for comparative purposes in Britain.

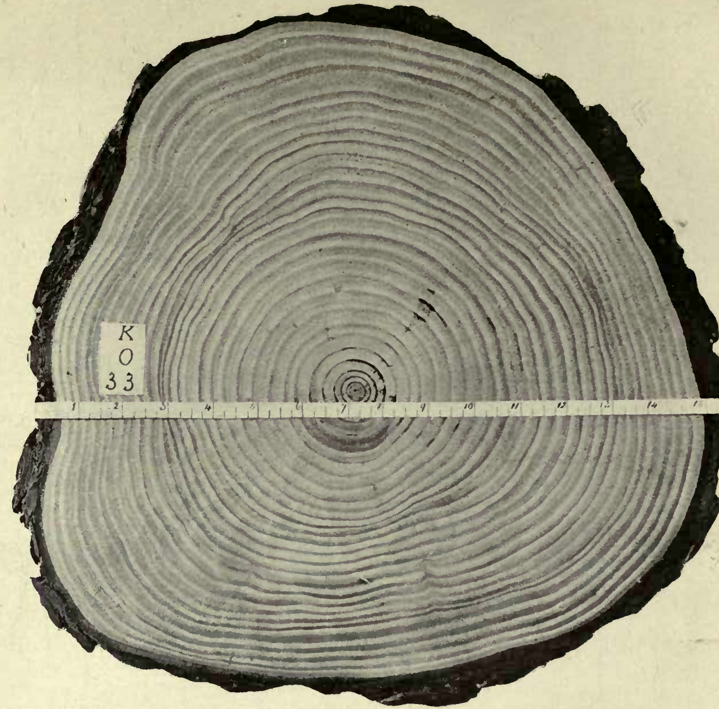
Before making any comparisons, some explanation of the sylvicultural properties of the spruce and of the nature of Schiffel's tables is desirable.

An examination of the tables shows that the factors on which the volume is calculated may vary considerably within the limits of each quality class, according to the density of the canopy

* Wuchsgesetze Normaler Fichtenbestände. *Mitt. aus dem Forst. Versuchsw. Österreichs.* Heft. XXIX.



Douglas Fir.



Austrian Pine.

PLATE VI.

Timber Sections.

[*To face p.* 34.

under which the crop has been grown. The following table, showing the limits of variation for woods 43 years old, has been compiled from Schiffel's figures :—

Quality Class.	h.	d.	N	f.	V
	feet.	inches.	Number of trees per acre.		cub. feet.
(Best) XI.	59 to 74	7·5 to 10·7	600 to 360	0·500 to 0·448	5,400 to 6,900
X.	52 to 66	6·5 to 9·5	700 to 430	0·516 to 0·460	5,100 to 5,900
IX.	46 to 59	5·7 to 8·2	850 to 500	0·529 to 0.470	3,600 to 4,800
VIII.	39 to 52	4·7 to 7·0	1050 to 640	0·546 to 0·490	2,700 to 3,900
VII.	33 to 44	4·0 to 5·9	1350 to 775	0·547 to 0·504	2,150 to 3,350

From this it appears that the values of the different factors may overlap to a considerable extent. For instance, a crop of mean height 52 ft. at 43 years, though most likely to fall nearest quality Class IX., might conceivably fall nearest Class X. or VIII. It is therefore necessary, in making an estimate of the quality of the locality in which a crop is growing, to consider all the factors together.

Schiffel indicates in his introduction to the tables a number of properties of the spruce which are not very generally recognised in this country. The chief of these is that spruce shows a greater height-growth increment in open, than in dense, crops.

With regard to the use of his tables, the following points should be noted :—

(*a*) On soils of the same quality, with crops of the same age, the height and diameter are greatest, but the form factor is smallest, in the case of the least canopy density.

(*b*) The total basal area and total volume per acre are least in the case of light canopy conditions until the crops are 100 years of age, when the three canopy classes merge into one.

(*c*) The number of trees per acre is least in the case of the thin canopy class, and greatest in the case of the dense canopy class.

For each canopy class nine quality classes are prepared, of which III. is the worst, and XI. the best. The number indicating the quality class is arranged for convenience as regards the metric system, since it is the number, in hundreds, of cubic metres which a hectare should carry at the age of 100 years. Thus a spruce crop on soil of quality X. should yield 1,000 f.m. per ha. (or roughly 14,300 cub. ft. per acre) at 100 years of age.

Schiffel gives directions as to the method of estimating the quality of the locality when a crop of spruce is standing on the ground. It is obviously not sufficient simply to take the height and age and then observe the class most nearly corresponding in the tables, since such a method takes no account of the density in which the crop has been grown, and it has been pointed out above (*a*) that the spruce grows more quickly in open than in close stand. Age, height, mean diameter, and number of trees per unit area are at least necessary for proper classification.

The ratio $\frac{\text{number of trees per unit area}}{\text{mean diameter}}$ gives a useful index as to the density in which the crop has been grown, and is called by Schiffel the crop characteristic (*Bestandescharakteristik*). By the method of stem analysis a general view of the height development of the crop can be obtained, which is of interest in comparing the height-growth of the crop under consideration with the ideal given in the Yield Tables.

Comparison of Sample Plots with Schiffel's Tables.

It will now be shown to what extent the measurements made in the sample plots agree with Schiffel's Tables.

The following abbreviations are used throughout for the sake of convenience:—

H = mean height of crop, D = mean diameter, N = number of stems per acre, f = form factor, A = total basal area, V = total true volume per acre, C = crop characteristic $= N/D$, Q = quality class.

GROUP I.—1,020 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H.*	*D.*	*N.*	*f.*	*A.*	*V.*	*C.*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel's XI.	Medium	40	61·0	8·1	518	0·482	185	5,490	64
Group I. ...	,,	43	62·0	9·0	460	0·482	200	6,000	51
Schiffel's XI.	,,	45	68·9	9·3	429	0·474	202	6,620	46

As will be seen in the comparative table above, the height growth of this crop for medium canopy conditions lies between qualities XI. and X. of Schiffel's Tables, but rather nearer the former. The number of trees per acre, the form factor, and the crop characteristic correspond very nearly with those of Class XI., but since the diameter is slightly too high, the total basal area, and consequently the volume, are also too high.

The general results, however, are very similar.

GROUP IA. 1,020 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H.*	*D.*	*N.*	*f.*	*A.*	*V.*	*C.*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel's XI.	Dense	40	58·0	7·3	664	0·508	193	5,720	91
Group IA. ...	,,	43	64·5	8·2	600	0·502	220	7,150	73
Schiffel's XI.	,,	45	65·5	8·4	542	0·498	209	6.830	65

The height growth of this group has been slightly better than the mean of the best quality class (XI.), which at 43 years of age should indicate 62·5 ft.; consequently it is found also that the mean diameter, although approaching very closely to the tables, is a little too large. The number of trees per acre is also slightly too great. The form factor shows very close correspondence. Consequent on the larger diameter and greater number of trees, the total basal area is approximately 10 per cent. larger. For the same reason the volume is larger. The crop characteristic corresponds well with those of the tables.

GROUP III.—1,460 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H.*	*D.*	*N.*	*f.*	*A.*	*V.*	*C.*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel's IX.	Light.	40	50·5	7·0	559	0·473	149	3,550	80
Group III. ...	,,	43	53·3	8·4	465	0·485	181	4,680	55
Schiffel's IX.	,,	45	58·4	8·2	454	0·465	167	4,500	55

Group III. had been treated in an irregular way. This is shown by the relative numbers of trees falling into each diameter class. The result is that, although there were standing 595 trees per acre in all, no less than 130 of these belonged to the minor part of the crop, notwithstanding that the whole had been grown in very open stand. The height-growth is rather too small to fall in the mean of Schiffel's Class IX. light canopy, but approaches more nearly to it than to Class VIII.

The number of dominant trees (465) per acre is too low, and consequently the diameter is too large, and the crop characteristic too low.

The sample tree was felled from the densest part, so as to disturb the crop as little as possible, and consequently the form factor is high. The total basal area, and hence the volume, are also considerably too large.

GROUPS V. AND VI.—1,525 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H*	*D*	*N*	*f*	*A*	*V*	*C*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel VIII.	Medium	40	40·3	5·1	939	0·525	133	2,830	184
Group V. ...	,,	42	41·5	6·4	840	0·513	189	4,030	131
Group VI. ...	,,	42	41·2	6·1	890	0·498	180	3,670	146
Schiffel VIII.	,,	45	47·6	6·25	735	0·509	157	3,660	118

As regards height-growth, Groups V. and VI. lie somewhat below Schiffel's Quality Class VIII. with regard to canopy density. There is a considerable divergence in the values of the diameters, especially in Group V., where the value is much too large. The result is that since the number of trees per acre is approximately correct, the volume is much too large.

GROUP VII.—1,400 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H*	*D*	*N*	*f*	*A*	*V*	*C*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel IX.	Medium	40	47·9	6·26	720	0·499	153	3,670	115
Group VII.	,,	43	52·5	7·5	615	0·498	189	4,930	82
Schiffel IX.	,,	45	55	7·3	590	0·491	172	4,620	81

The height-growth of the group corresponds very nearly with Quality Class IX. of Schiffel's medium canopy density, as do the number of trees per acre and the form factor. The diameter is again considerably too large, with the result that the crop characteristic is too low and the volume too large.

GROUP IX.—1,530 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H.*	*D.*	*N.*	*f.*	*A.*	*V.*	*C*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel IX.	Dense	35	36·3	4·6	1,255	0·552	145	2,930	269
Group IX.	,,	38	38·5	5·4	1,180	0·534	190	3,900	218
Schiffel IX.	,,	40	44·6	5·5	964	0·535	159	3,850	173

The height-growth of the group lies somewhat below that of Schiffel's Class IX. dense canopy. The diameter comes out too large, and the number of trees is too great; consequently the volume is somewhat too large. This group was laid out along a thin belt with poor Scotch pine growing on each side, and although every care was taken to exclude marginal trees, it is considered that the great amount of light reaching the trees from both sides may be responsible in part for the large diameter.

GROUP XIII.—1,530 *ft. Elevation.*

Quality Class.	Canopy Density.	Age.	*H.*	*D.*	*N.*	*f.*	*A.*	*V.*	*C.*
		Years.	*Ft.*	*In.*			*Sq. ft.*	*Cub. ft.*	
Schiffel IX.	Medium	35	40·3	5·2	920	0·509	137	2,770	177
Group XIII.	,,	38	41·5	5·8	900	0·542	168	3,780	155
Schiffel IX.	,,	40	47·9	6·3	720	0·499	156	3,670	114

The height-growth of this group lies slightly below that of Schiffel's Class IX. medium density of canopy. The crop characteristic corresponds very well, as does the mean diameter, but the number of trees per acre is somewhat high, and this, with a larger form factor, gives too high a volume per acre.

A comparison of this group with Group IX., which lies very close to it, shows that both correspond very closely to Quality Class IX., and differ from each other according to their densities in exactly the way Schiffel's Tables would lead one to expect.

Degree of Approximation Attained.

The leading fact brought out by the comparison of the above groups with Schiffel's Tables is that the diameter has been consistently larger in the former. In the first instance, these trees were girthed, and it was then found that the calculated diameters were too large. The groups were consequently carefully calipered after a season's growth, and the results (as indicated on p. 12) are those utilised above.

It would hardly be expected that groups which have been treated somewhat irregularly would show perfect accordance with ideal woods, and it must be noted in this connection that Group I., which was the best grown crop, shows the nearest approximation to the tables. Group IA. is also reasonably close, although it has been neglected for a number of years. Neglect has been of less importance in this particular case, since the canopy has been dense throughout. It is quite conceivable that groups such as V. and VI. should show greater diameters than indicated in the tables. In such exposed positions the leading shoots are frequently broken back by the wind, and consequently the height-growth suffers considerably; but the diameter-growth only to a much smaller extent. Determination of the quality class on the basis of age, height and canopy density is therefore likely to give low results.

The differences indicated between the diameters (and volumes) of these sample plots and the tables may be due to differences of climate or to other causes. The determination of volume by the means adopted might easily lead to an error of ± 10 per cent., with a tendency to give results always too high.*

On the other hand, the greater volume shown by the more exposed groups (*e.g.*, Nos. V. and VI.) is quite possibly a natural feature of the growth of spruce. Such a difference is, in fact, to be noted in the Swiss Yield Tables for the spruce.† These tables are divided into two sets, the one for hilly country (*Hügelland*), and the other for the mountains (*Gebirge*). Comparison of the two sets of tables indicates that for a given height the latter always show a greater volume, the difference being greatest with the poorer soils, and amounting in some cases to over 10 per cent. The table below illustrates this point :—

Yield Table.	Quality Class.	Age.	Height in feet.	Diameter in inches.	Stems per acre.	True Vol. per acre, cb. ft.
Hügelland ...	I.	30	46·9	5·6	1100	4410
Gebirge ..	(best)	35	47·5	5·7	1112	4660
Hügelland ...	II.	40	56·8	6·3	936	6180
Gebirge ...		50	56·8	6·8	892	6600
Hügelland ...	III.	35	43·6	5·0	1440	3530
Gebirge ...		45	42·3	5·3	1368	4060
Hügelland ...	IV.	40	43·3	4·8	1520	3470
Gebirge ...		55	42·6	5·2	1276	3840
Hügelland ...	V.	45	43·0	4·0	1640	3180
Gebirge ...	(worst)	70	42·6	5·0	1128	3560

Yield Tables Employed.

After a full consideration of the case it was considered that a reasonable enough degree of approximation had been attained to justify the use of the tables for survey purposes. The measurements of crops made in this somewhat crude way could not be expected to show a much closer coincidence with ideal woods, and in any case it appears that by using these tables a low estimate of volume is made, especially as regards exposed localities.

It was further decided that the medium density of canopy should be taken as the standard, since the district is on the whole exposed, and it is advisable to give the individual trees as large a root system as possible in order to strengthen them against wind.

* See Flury, *Mitt. der Schweiz. Centralanstalt für das forstliche Versuchswesen*, Vol. VI.

† *Ibid.* Vol. VII.

To facilitate surveying, it is advisable, in the first place, to set an elevation limit, above which it would be impossible to plant with any hope of commercial success.

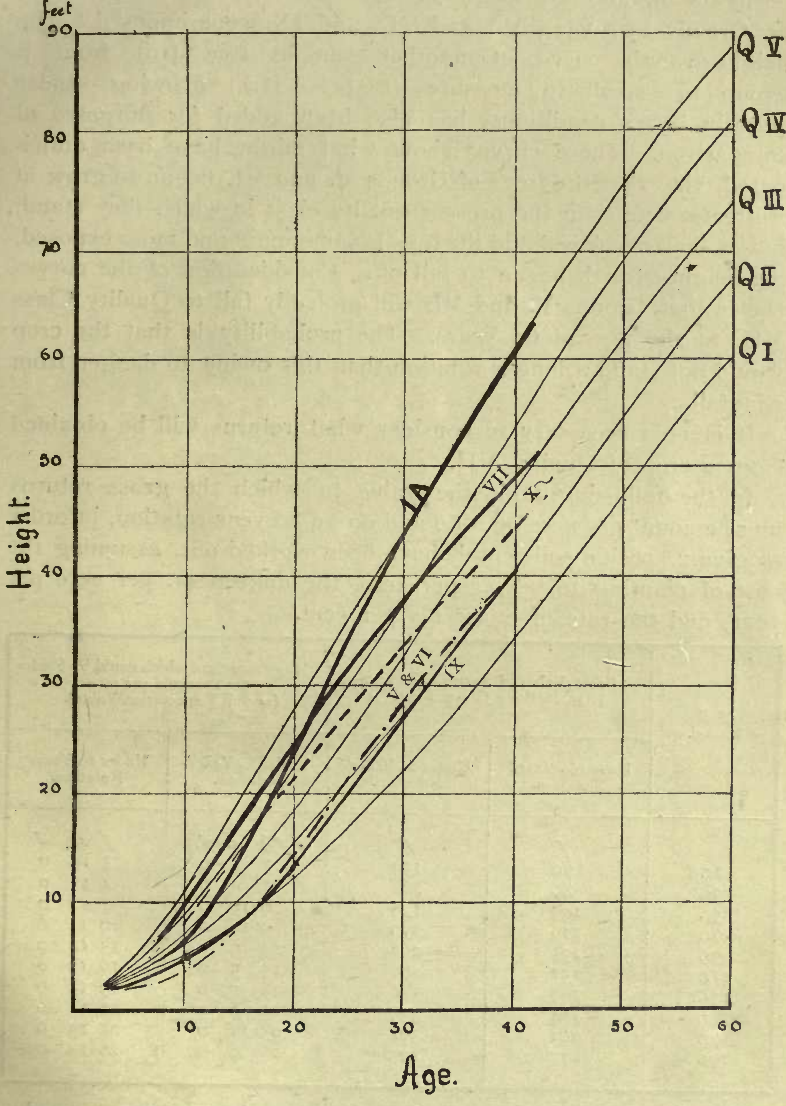


DIAGRAM SHOWING HEIGHT-GROWTH CURVES OF QUALITY CLASSES I—V (SCHIFFEL'S VII—XI), AND OF VARIOUS SAMPLE SPRUCES.

To arrive at a decision on this point, Groups V. and VI. must be further considered. These groups, as already pointed out, lie at an elevation of 1,525 ft. under full exposure to the west and south-west winds. According to their present condition, the locality corresponds to Schiffel's Quality Class VIII., medium density. In the diagram on p. 41 the mean height-growth curves for the various quality classes (medium density of canopy) have been drawn, and the height-growth curves of the sample trees of Groups Ia., VII., V., and VI., and IX. superimposed. The height-growth curve of another sample tree (10) from a group too small to measure (Plate VII.), growing under slightly better conditions, has also been added for purposes of comparison. These curves show what might have been anticipated, viz., that the trees of Groups V. and VI. began to grow at a greater rate than the present quality class in which they stand, but as they developed and the tops became more and more exposed, the height-growth began to fall off. Consideration of the curves shows that Groups V. and VI. will probably fall to Quality Class VII. at the age of 60 years. The probability is that the crop would not stand a longer rotation than this owing to danger from windfall.

It is now necessary to consider what returns will be obtained from a crop of Quality VII.

In the following table the value to which the gross returns must amount per acre on a 60 and on an 80 year rotation, in order to give a specific soil rental, have been worked out, assuming the cost of planting to be £5 per acre, the upkeep 4*s.* per acre per year, and the rate of interest 3 per cent.

Soil Rental.	Gross Value of Returns per acre to Produce Given Rent.		Maximum Sum which could be Paid for Freehold per acre (= Soil Expectation Value).	
	Under 60 Years' Rotation.	Under 80 Years' Rotation.	Under 60 Years' Rotation.	Under 80 Years' Rotation.
	£	£	£ s. d.	£ s. d.
1*s.*	70	134	1 8 0	1 10 0
3*s.*	86	166	4 3 0	4 11 0
5*s.*	103	198	6 19 0	7 11 0
7*s.*	119	230	9 14 0	10 11 0
9*s.*	135	262	12 9 0	13 12 0
11*s.*	152	294	15 5 0	16 12 0
13*s.*	168	326	18 0 0	19 13 0
15*s.*	184	359	20 16 0	22 13 0
17*s.*	201	391	23 11 0	25 13 0
19*s.*	217	423	26 6 0	28 14 0

The last two columns of this table also give the present value of the rents per annum for the next 60 or 80 years as the case may be, or, in other words, the "soil expectation value." * If the land

* The term "soil expectation value" is used here in a restricted sense for a single rotation only and not, as is common, for perpetuity. Owing to the degree of uncertainty which attaches to these calculations, the method adopted is considered accurate enough for the purposes in view. A table giving the soil expectation values for spruce for perpetuity will be found in Appendix D, page 64.

PLATE VII

were purchased, the value of the returns in the second or third columns could be less by the amount of the purchase money, since the land would have a value, presumably its present value, at the end of the rotation.

The tables in Appendix C., pp. 59–63, have in part been taken direct from Schiffel's tables by merely converting the metric into the English system, and assuming that the prices indicated on p. 33 will be obtained for the produce.

For Schiffel's Quality Class VII., the total value of the produce to the end of a 60 year rotation is £86, which is equivalent to a soil rental of 3*s.* per acre.

The value of rough mountain grazing land in this neighbourhood varies from 2*s.* 6*d.* to 5*s.* per acre per year, so that it is evident that a soil rental of 3*s.* from forest is the minimum below which it would be inadvisable, as a general rule, to go.

It would therefore appear that the maximum elevation under full exposure is approximately that of Groups V. and VI., *i.e.*, about 1,525 ft.

The returns from the different quality classes are summarised in the following table:—

Quality Class. (See Appendix C.)	Return on 60 years' rotation.		Return on 80 years' rotation.	
	Total Value at end.	Equivalent Soil Rental per acre per year.	Total Value at end.	Equivalent Soil Rental per acre per year.
	£	*s.*	£	*s.*
I.	86	3	—	—
II.	109	6	—	—
III.	136	9	281	10
IV.	176	13 to 14	319	12 to 13
V.	206	18	364	15 to 16

If now each sample group be put in its proper quality class it is possible to tabulate the data on which a forestry survey may be carried out.

Sample Group.	Elevation.	Aspect.	Exposure.	Quality Class.	Soil Rental obtainable under Forest.
	ft.				*s.*
I.	1,020	N.	Nil.	IV.—V.	15
IA.	1,020	N.	,,	V.	16 to 18
III.	1,460	Flat to N.	½ full	II.—III.	8 to 9
V.	1,525	,,	,,	I.—II.	3
VI.	1,525	,, S.	full	I.—II.	3
VII.	1,400	S.W.	½ full	III.	9
IX.	1,530	N.	¼ ,,	II.	6
XIII.	1,530	N.	¼ ,,	II.	6

As a basis for a survey, this number of determinations is, of course, far too small, but it forms, nevertheless, an excellent guide for the immediate neighbourhood, and to enlarge the scope of the survey all that is necessary is to extend the observations in all directions. Once the applicability of a yield-table to a district can be proved, it is possible to utilise as a check on the work the height-growth of trees in groups which are too small for accurate volume determinations.

It is found in the field that variations in quality of locality are so rapid that it is impossible to map land rapidly and effectively into five grades. Three grades are sufficient for the purpose, and might be called "poor," "medium," and "good," with probable soil rentals in this district for forestry purposes of 4*s*., 10*s*., and 15*s*. per acre.

As "poor" may be designated the flat tops of hills up to 1,500 ft., or even 1,530 ft., steep west and south-west slopes under full exposure, and north slopes of 1,550 ft. to 1,600 ft. where well protected. Under "medium" quality come north and east slopes of from 1,250 ft. to 1,500 ft., and west and south-west slopes of from 1,000 ft. to 1,400 ft. where sheltered by hills to windward and not exposed to winds sweeping up valleys "Good" conditions include land up to 1,250 ft. on sheltered east and north aspects and at the bottom of sheltered valleys generally.

"Good" land will carry larch, Douglas fir, and spruce if so desired; "medium" quality land, larch artificially protected by shelter belts, as well as Corsican pine, but principally spruce; and "poor" land, spruce only.

No attempt is made, in the absence of reliable yield tables, to calculate the financial results of growing larch and Douglas fir, but it may be assumed from the general information available that both species, and particularly the latter, will give better results than spruce on "good" land. The spruce tables therefore indicate the minimum returns which may be expected from forests on this type of soil.

Application of Results of a Survey to Afforestation Schemes.

A survey of the type suggested answers the vexed question as to what area of land in a given district would give a larger rent under forest than under present methods of utilisation. It is obvious that no adequate national scheme of afforestation can be framed until the area of land ultimately to be afforested is known with a fair degree of approximation, and that no scheme will find public support unless supported by accurate data as to the returns which may be expected.

A change from one form of soil utilisation to another, however, must be accompanied by a change in the life of the inhabitants of the district, and, as has been very clearly pointed out in the recent forestry survey of Glen Mor,* this may become a question of great importance. Concurrently with the survey, therefore, inquiries as to the probable economic changes must be made.

A survey of this sort gives roughly the value for forestry purposes of each acre of land surveyed, from the time it is put under crop. When a large area of land is purchased for afforestation purposes, however, it is not planted up in a single year, and for a considerable portion of the first rotation only a part of the land must be managed as a forest, the remainder being utilised as before. In addition, there will be certain expenses of a general nature which have not been included in valuing the soil, such as the provision of buildings, building of roads, clearing off stock, and so on. These are questions which will differ with every specific area which it is proposed to afforest.

As a preliminary to the purchase of a definite area for afforestation purposes, or to the formation of a joint afforestation scheme between a landlord and the State, procedure on the following lines is suggested:—

1. A detailed survey of the area.

2. The preparation of a general working plan, showing as a minimum the order to be followed in planting.

3. A calculation of the probable value of the soil for forestry purposes.

4. Estimation of the probable value of the whole area as a forest after making proper allowances for unforeseen contingencies, such as damage to crops from insects, fire, and meteorological causes.

With regard to the preparation of the working plan it is unnecessary to say anything here.

The calculation as to the probable value of the land under forest may be made on the following lines:—

Let A_1, A_2......A_r be the areas to be afforested in the years 1, 2......r.

Let S_1, S_2......S_r be the average soil expectation value of the land afforested in the years 1, 2......r.

Let g_1, g_2......g_r be the average grazing value per acre of the areas A_1, A_2......A_r.

Then the present value of the area A_n, say, is the present value of all grazing rents up to the (n-1)th year (or year of enclosure), plus the present value of the soil expectation value in the nth year

$$
\begin{aligned}
&= \text{present value } (A_n.g_n \text{ for } (n-1) \text{ years}) \\
&+ \quad ,, \quad ,, \quad (A_n.S_n \text{ due in } n \text{ years}) \\
&= \text{say, } V_n.
\end{aligned}
$$

* *Trans: Royal Scottish Arboricultural Society*, Vol. XXV.

Then the total present gross value of the whole area for forestry purposes $= \Sigma V_n$.

In the same way the sum of the present values of all expenses, such as buildings and roads not included in calculating the soil expectation value, may be represented by ΣE.

Then the net value of the area for forestry purposes $= \Sigma V_n - \Sigma E$.

If the value of the quantity $(\Sigma V_n - \Sigma E)$ be now reduced by some factor (say 25 per cent.) as a margin against risks, a figure is reached which approximates to the highest sum which can be given for the whole of the land if the operations are to yield a minimum return of 3 per cent. (in the present calculations) on all capital invested.

Calculations on these lines reduce the necessity for guesses and the risk of loss to a minimum. The difficulty, as a rule, is to estimate the soil expectation value owing to lack of reliable data on tree growth.

B. Systematic Method of Conducting a Survey.

A systematic survey should proceed on the following lines :—

(1) Districts should be established corresponding as far as possible with the general conditions of forest growth.

(2) The woods in each district should be visited, and the following points noted :

(*a*) Age and composition of the wood; whether pure, mixed, &c.

(*b*) General condition of the wood and the probability of a further detailed examination yielding useful data.

(3) The woods noted under 2 (*b*) above should be examined with special reference to aspect, elevation, volume per acre—both actually standing and under fully stocked conditions—soil, &c.

(4) The physical and chemical properties of the soil should be examined where necessary.

(5) The information collected should be correlated and analysed, and the limits of profitable forestry determined :

(*a*) As far as indicated by data gathered within the district.

(*b*) As far as can be determined from data gathered outside the district, but reasonably applicable within it.

(6) The district should be mapped for afforestation purposes, the available area determined, and the economic side of the question studied.

C. Summary.

The selection of land for afforestation may proceed on one of two lines.

(1) It can be taken for granted that afforestation will pay. The

ground can then be mapped into its suitability for various species, and planted up according to a pre-arranged scheme. The surveying can in such case be carried out by experienced local foresters. The method precludes the employment of a permanent staff for the work, since without a proper study of local conditions a man cannot efficiently survey land. Without a permanent staff there arises a difficulty in co-ordination and a danger that a future generation may regard the work with suspicion.

This method gives no financial basis to go upon, and puts the whole business on an uncertain footing.

(2) The second method is to investigate the commercial aspect of afforestation in a district, and to start the work of surveying or scheduling the land on the basis of accurate information. There is in such case a check on the personal proclivities of the surveyor, and the work is founded on recorded facts. A permanent staff, assisted by local foresters, is necessary. It is on the lines of this method that the work at Kerry has been carried on.

Consideration of the whole question leads to the following conclusions :—

In a forestry survey the determination of the area of land which will grow trees well is only one of a number of important points. A survey in a district presupposes that some scheme of afforestation may follow. Hence the survey should supply as much as possible of the information which is necessary for the framing of such a scheme. The difficulties which will be encountered in framing a scheme are briefly these :—

(1) The determination of the area and distribution of the land available.

(2) The forecast of the financial results.

(3) The disturbances created in putting the scheme into operation.

A survey must strive to solve these difficulties as far as may be possible, and there is only one way of doing this, viz., the collection and analysis of statistics in the district and its neighbourhood. The safest basis for the estimation of the volume of timber which will be produced on a given piece of land is the volume which it has carried under a previous and similar crop. From this degree of accuracy one passes step by step to the comparison of bare and wooded areas side by side, and finally to the bare hillside with no indicating woods, at any rate of a satisfactory character, for miles around.

The collection of statistics of the sort gathered at Kerry will place the surveyor in the position that he will be able to indicate three broad types of land :—

(1) Land on which afforestation should under proper management prove a success.

(2) Land on which success is doubtful owing to lack of sufficient

information as to the growth of timber on that particular type of land.

(3) Land on which profitable forestry appears to be impossible.

The obvious procedure is to afforest land of the first type, and to institute experiments on the very large areas belonging to the second and third types, postponing any extended planting scheme until the experiments have afforded definite results.

APPENDICES

Appendix A.

TABLE I.—Mechanical Analysis of Samples of Soil from Kerry, Montgomeryshire.

Mechanical Analysis.	1A.		2.		3.		5 and 6.		8.		9.		12.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Stones, above 3 mm. (to 100 parts of fine earth)	109	232	86	144	25	82	25	96	90	131	45	101	11	22
Percentage of fine earth.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.
Fine gravel above 1 mm.	21·7	18·9	14·1	11·0	12·1	16·0	1·2	2·5	1·6	4·6	2·4	3·8	0·7	5·4
Coarse sand, 1–0·2 mm.	12·6	10·3	5·9	10·5	7·6	9·1	1·3	1·9	1·5	2·9	3·0	3·0	2·8	10·1
Fine sand, 0·2–0·04 mm.	12·3	13·6	4·1	6·7	6·7	8·6	8·4	10·9	7·5	6·9	13·6	15·5	17·0	16·6
Silt, 0·04–0·01 mm.	25·5	27·5	25·9	28·4	28·1	28·1	33·6	36·5	34·7	36·3	30·8	31·4	26·6	22·6
Fine silt, 0·01–0·005 mm.	11·2	10·3	12·0	13·3	14·0	13·2	15·7	15·4	15·5	13·8	13·1	13·2	16·8	14·8
Fine silt, 0·005–0·002 mm.	4·4	5·9	8·0	7·4	8·0	7·3	11·1	7·2	11·8	9·1	8·2	8·4	12·0	10·1
Clay, below 0·002 mm.	2·2	5·6	15·1	11·5	10·8	9·4	12·8	16·8	10·5	17·0	16·1	15·1	17·1	14·6
Moisture	1·3	1·1	2·8	1·6	1·6	1·3	2·2	1·3	2·3	1·6	2·5	1·4	1·1	0·9
Loss on ignition	7·4	5·5	9·9	7·5	10·2	6·1	12·1	6·1	13·0	7·3	9·0	6·4	4·3	4·2
Calcium Carbonate soluble in N/5 HCl.	1·1	0·9	3·0	1·9	2·8	1·5	1·8	1·5	2·0	1·0	1·6	1·5	1·2	0·9
Total	99·7	99·6	100·8	99·8	101·9	100·6	100·2	100·1	100·4	100·5	100·3	99·7	99·6	100·2

TABLE I. (*continued*).—MECHANICAL ANALYSIS OF SAMPLES OF SOIL FROM KERRY, MONTGOMERYSHIRE.

MECHANICAL ANALYSIS.	Cefn Golog : No. A.		L.1.		L.3.		L.4.		L.6.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Stones, above 3 mm. (to 100 parts of fine earth)	128	67	31	78	62	170	43	142	38	145
Percentage of fine earth.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Fine gravel, above 1 mm.	3·2	6·8	2·9	5·8	2·3	8·3	1·1	8·6	0·7	1·6
Coarse sand, 1—0·2 mm....	2·2	4·0	2·3	6·6	3·6	7·8	1·6	8·6	1·4	2·3
Fine sand, 0·2—0·04 mm.	14·5	21·9	12·1	14·7	14·4	16·8	15·2	12·6	10·6	14·8
Silt, 0·04—0·01 mm.	28·8	28·5	29·5	30·3	31·8	32·3	32·3	29·9	32·9	33·2
Fine silt, 0·01—0·005 mm.	13·5	11·3	17·1	15·4	16·6	12·5	15·9	13·2	19·5	14·2
Fine silt, 0·005—0·002 mm.	4·9	6·1	12·1	7·2	10·2	6·2	10·2	6·6	9·9	9·7
Clay, below 0·002 mm.	9·5	10·3	11·6	14·1	8·8	10·3	10·1	13·1	6·9	12·9
Moisture	3·2	1·9	1·7	1·1	1·9	1·0	2·6	1·9	3·7	2·3
Loss on ignition	15·5	5·2	7·6	3·1	6·4	3·1	5·8	2·4	7·5	4·6
Calcium Carbonate soluble in N/5 HCl.	3·0	2·1	2·0	0·9	1·7	1·5	2·0	1·3	2·2	1·8
TOTAL	98·4	98·1	98·9	99·2	97·7	99·8	96·8	98·2	95·3	97·4

TABLE II.—CHEMICAL ANALYSIS OF SAMPLES OF SOIL (PER CENT)

	1A.		2.		3.		5 and 6.		8.		9.		12.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Moisture	1·32	1·06	2·77	1·56	1·58	1·28	2·16	1·30	2·28	1·62	2·46	1·36	1·08	0·92
Loss on ignition	8·68	6·63	12·72	9·08	11·76	7·44	14·32	7·40	15·32	8·93	11·50	7·82	5·42	5·06
Nitrogen	0·228	0·147	0·036	0·091	Nil	0·091	Nil	0·112	Nil	Nil	Nil	0·051	Nil	Nil
Al O_3	4·53	—	5·12	—	5·39	—	5·63	—	6·33	—	5·24	—	7·75	—
Fe_2O_3	5·12	—	3·78	—	5·79	—	5·14	—	4·73	—	5·36	—	6·38	—
Mn_3O4	0·12	—	0·11	—	0·11	—	0·22	—	0·13	—	0·17	—	0·19	—
MgO	1·70	—	1·16	—	1·66	—	0·99	—	1·36	—	1·20	—	2·06	—
CaO	0·28	—	Nil	—	Nil	—	Nil	—	Nil	—	Nil	—	Nil	—
Carbonates as $CaCO_3$	0·054	0·041	0·073	0·051	0·037	0·047	0·046	0·036	0·054	0·057	0·055	0·053	0·043	0·029
Potash as K_2O	0·79	0·65	0·75	0·86	0·87	0·73	0·65	0·81	0·77	0.81	0·66	0.88	1·41	1·27
Do., Soluble in 1 % Citric Acid...	0·014	—	0·013	—	0·008	—	0·012	—	0·013	—	0·012	—	0·007	—
P_2O_5	0.17	0·15	0·10	0·11	0·10	0·09	0·12	0·10	c·16	0·14	0·16	0·14	0·06	0·09
Do., Soluble in 1 % Citric Acid...	0·034	—	0·023	—	0·025	—	0·031	—	0·025	—	0·031	—	0·007	—
SO_3	0·03	—	0·10	—	0·02	—	0·10	—	0·14	—	0·12	—	0·03	—

TABLE II. (*continued*).—CHEMICAL ANALYSIS OF SAMPLES OF SOIL (PER CENT.)

	Cefn Golog. No. A.		L. 1.		L. 3.		L. 4.		L. 6.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Moisture	3·18	1·92	1·72	1·14	1·88	1·02	2·56	1·86	3·68	2·26
Loss on Ignition	18·84	7·07	9·31	4·24	8·32	4·08	8·40	4·34	11·20	6·94
Nitrogen	0·46	0·03	Nil.	0·06	Nil.	0·07	0·25	0·08	0·38	Nil.
Al_2O_3	4·24	—	6·92	—	5·96	—	6·73	—	5·41	—
Fe_2O_3	2·36	—	5·36	—	5·04	—	5·28	—	4·57	—
Mn_3O_4	0·14	—	0·16	—	0·14	—	0·12	—	0·25	—
MgO	0·18	—	1·39	—	1·64	—	1·51	—	1·20	—
CaO	Nil.	—	Nil.	—	Nil.	—	Nil.	—	Nil.	—
Carbonates, as $CaCO_3$	0·05	0·07	0·067	0·044	0·057	0·045	0·074	0·056	0·078	0·060
Potash, as K_2O	0·68	0·76	1·03	0·91	0·88	0·78	0·72	0·73	0·61	0·83
Do. Soluble in 1% Citric Acid	0·007	—	0·011	—	0·023	—	0·011	—	0·015	—
P_2O_5	0·191	0·187	0·22	0·11	0·199	0·159	0·187	0·171	0·22	0·11
Do. Soluble in 1% Citric Acid	0·033	—	0·022	—	0·046	—	0·024	—	0·029	—
SO_3	0·06	—	0·06	—	0·05	—	0·09	—	0·07	—

APPENDIX B

DETAILS OF CALIPER MEASUREMENTS OF SAMPLE AREAS.

Diameters calipered at breast height (4 ft. 3 in. above the ground.)

GROUP L_1. *Area*, 0·3 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
3	—	—	2	0·0982
4	—	—	7	0·6111
5	17	2·3188	15	2·0460
6	44	8·6372	4	0·7852
7	45	12·0285	1	0·2673
8	22	7·6802	—	—
9	4	1·7672	—	—
—	132	32·4319	29	3·8078

GROUP L_2. *Area*, 0·156 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq ft.
3	—	—	4	0·1964
4	3	0·2619	14	1·2222
5	30	4·0920	6	0·8184
6	32	6·2815	1	0·1963
7	11	2·9403	—	—
8	8	2·7928	—	—
9	1	0·4418	—	—
—	85	16·8103	25	2·4333

GROUP L_3. *Area,* 0·2 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
2	—	—	1	0·0218
3	1	0·0491	8	0·3928
4	12	1·0476	8	0·6984
5	35	4·7740	3	0·4092
6	38	7·4594	—	—
7	15	4·0095	—	—
8	1	0·3491	—	—
9	1	0·4418	—	—
—	103	18·1305	20	1·5222

GROUP L_4. *Area,* 0·2 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
2	—	—	4	0·0872
3	—	—	6	0·2946
4	7	0·6111	20	1·7460
5	39	5·3196	9	1·2276
6	26	5·7038	1	0·1963
7	21	5·6133	—	—
8	1	0·3491	—	—
—	94	17·5969	40	3·5517

GROUP II. SCOTCH PINE. *Area,* 0·225 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
4	—	—	2	0·1746
5	5	0·6820	8	1·0912
6	21	4·1223	12	2·3556
7	39	10·4247	—	—
8	26	9·0766	1	0·3491
9	10	4·4180	—	—
10	4	2·1816	—	—
—	105	30·9052	23	3·9705

GROUP I. NEW POOL SPRUCE. *Area,* 0·2 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
5	—	—	3	0·4092
6	—	—	14	2·7482
7	12	3·2076	12	3·2076
8	24	8·3784	2	0·6982
9	32	14·1376	1	0·4418
10	15	8·1810	—	—
11	7	4·6200	—	—
12	2	1·5708	—	—
—	92	40·0954	32	7·5050

GROUP IA. NEW POOL SPRUCE. *Area,* 0·125 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
4	—	—	10	0·8730
5	—	—	16	2·1824
6	13	2·5519	16	3·1408
7	18	4·8114	4	1·0692
8	16	5·5856	—	—
9	16	7·0588	1	0·4418
10	5	2·7270	—	—
11	5	3·3000	—	—
12	2	1·5708	—	—
—	75	27·6155	47	7·7072

GROUP III. SPRUCE: CEFN CRAIG WOOD. *Area,* 0·154 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
4	—	—	3	0·2619
5	2	0·2728	5	0·6820
6	5	0·9815	4	0·7852
7	15	4·0095	5	1·3365
8	16	5·5856	3	1·0473
9	19	8·3942	—	—
10	11	5·9994	—	—
11	4	2·6400	—	—
—	72	27·8830	20	4·1129

GROUP V. SPRUCE SHELTER BELT, EAST OF KERRY POLE COTTAGE.

Area, 0·1 acre.

Diameter Class.	Dominant Crop.		Miuor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		
4	1	0·0873	3	0·2619
5	14	1·9096	15	2·0460
6	29	5·6927	3	0·5889
7	33	8·8209	—	—
8	7	2·4437	—	—
—	84	18·9542	21	2·8968

GROUP VI. *Area*, 0·221 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
3	—	—	1	0·0491
4	2	0·1746	23	2·0079
5	50	6·8200	34	4·6376
6	96	18·8448	7	1·3741
7	42	11·2266	—	—
8	7	2·4437	—	—
—	197	39·5097	65	8·0687

GROUP VII. NANT-Y-RHYNAU WOOD. *Area*, 0·2 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
5	—	—	6	0·8184
6	15	2·9445	29	5·6927
7	56	14·9688	6	1·6038
8	38	13·2658	—	—
9	11	4·8598	—	—
10	3	1·6362	—	—
—	123	37·6751	41	8·1149

GROUP IX. CEFN GOLOG WOOD. *Area,* 0·213 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
2	—	—	5	0·1090
3	—	—	21	1·0311
4	37	3·2301	36	3·1428
5	113	15·4132	8	1·0912
6	76	14·9188	—	—
7	22	5·8806	—	—
8	3	1·0473	—	—
—	251	40·4900	70	5·3741

GROUP XII. CORSICAN PINE. *Area,* 0·146 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basa Area.
inches.		sq. ft.		sq. ft.
5	—	—	1	0·1364
6	—	—	2	0·3926
7	8	2·1384	4	1·0692
8	7	2·4437	4	1·3964
9	6	2·6508	5	2·2090
10	11	5·9994	—	—
11	13	8·5800	—	—
12	12	9·4248	—	—
13	7	6·4526	—	—
14	—	—	—	—
15	1	1·2272	—	—
—	65	38·9169	16	5·2036

GROUP XIII. CEFN GOLOG WOOD. *Area,* 0·218 acre.

Diameter Class.	Dominant Crop.		Minor Crop.	
	Number.	Basal Area.	Number.	Basal Area.
inches.		sq. ft.		sq. ft.
3	—	—	3	0·1473
4	9	0·7857	21	1·8333
5	66	9·0024	17	2·3188
6	86	16·8818	2	1·1778
7	32	8·5536	—	—
8	4	1·3964	—	—
—	197	36·6199	43	5·4772

Volume and Money Yield Tables for Spruce (after Schiffel).

QUALITY CLASS I.—(Schiffel's Class VII. Medium Density of Canopy).

Age.	Dominant Crop.					Crop Character-istic.	Thinnings.					Total Value at 60 Years.
	Mean Height.	Mean Diameter.	Number of Trees per acre.	Form Factor.	True Volume per acre.		Number of Trees per acre.	True Volume per acre.	Assumed price per cubic foot.	Value at time felled.	Value at end of Rotation at 3 per cent.	
	feet	inches			cubic feet			cubic feet		£	£	£
10	4·9	--	—	—	—	—	—	—	—	—	—	—
15	8·5	0·9	2,834	1·000	100	3,149	—	—	—	—	—	—
20	12·1	1·5	2,834	0·705	300	1,889	—	—	—	—	—	—
25	16·4	2·0	2,834	0·629	615	1,417	—	—	—	—	—	—
30	22·0	2·6	2,113	0·593	1040	813	721	129	—	—	—	—
35	27·9	3·4	1,587	0·568	1570	467	526	200	—	—	—	—
40	34·1	4·3	1,186	0·544	2170	276	401	315	1*d.*	1·312	2·37	Value of thinnings £21·55
45	40·7	5·2	907	0·527	2860	174	279	386	2*d.*	3·217	5·01	
50	47·6	6·2	713	0·509	3630	115	194	458	2*d.*	3·817	5·13	Value of final felling at 3*d.* per cubic foot £64·50
55	53·8	7·2	587	0·500	4400	82	126	458	2*d.*	3·817	4·43	
60	59·7	8·0	502	0·491	5160	63	(85)	(443)	2½*d.*	4·61	4·61	
									Total returns	...	...	£86·05

QUALITY CLASS II.—(SCHIFFEL'S CLASS VIII. MEDIUM DENSITY OF CANOPY).

Age.	Dominant Crop.					Crop Characteristic.	Thinnings.					Total Value at 60 Years.
	Mean Height.	Mean Diameter.	Number of Trees per acre.	Form Factor.	True Volume per acre.		Number of Trees per acre.	True Volume per acre.	Assumed price per cubic foot.	Value at time felled.	Value at end of Rotation at 3 per cent.	
	feet	inches			cubic feet			cubic feet		£	£	£
10	6·2	—	—	—	—	—	—	—	—	—	—	—
15	10·5	—	—	—	—	—	—	—	—	—	—	—
20	15·7	1·9	2,968	0·636	570	1,562	—	—	—	—	—	—
25	21·3	2·5	2,231	0·596	990	892	737	114	—	—	—	
30	27·2	3·3	1,623	0·562	1,490	492	607	215	—	—	—	
35	33·5	4·2	1,215	0·536	2,070	289	409	300	1*d.*	1·25	2·61	
40	40·3	5·1	939	0·525	2,830	184	275	358	2*d.*	2·983	5·39	Value of thinnings £31·44
45	47·6	6·1	735	0·509	3,660	120	204	458	2*d.*	3·817	5·95	
50	54·4	7·2	591	0·497	4,520	82	144	515	2*d.*	4·292	5·75	Value of final felling at 3*d.* per cubic foot £77·87
55	61·0	8·2	494	0·487	5,380	60	97	515	2½*d.*	5·364	6·22	
60	67·2	9·2	422	0·479	6,230	46	(72)	(530)	2½*d.*	5·52	5·52	
									TOTAL RETURNS			£109·31

QUALITY CLASS III. (SCHIFFEL'S CLASS IX. MEDIUM DENSITY OF CANOPY).

Age.	Dominant Crop. Mean Height.	Dominant Crop. Mean Diameter.	Dominant Crop. Number of Trees per acre.	Dominant Crop. Form Factor.	Dominant Crop. True Volume per acre.	Crop Characteristic.	Thinnings. Number of Trees per acre.	Thinnings. True Volume per acre.	Thinnings. Assumed price per cubic foot.	Thinnings. Value at time felled.	Thinnings. Value at 60 years at 3 per cent.	Thinnings. Value at 80 years at 3 per cent.	Total value at end of 60 Years' Rotation.	Total value at end of 80 Years' Rotation.
	feet	inches			cubic feet			cubic ft.		£	£	£	£	£
10	7·5	—	—	—	—	—	—	—	—	—	—	—	—	—
15	12·5	—	—	—	—	—	—	—	—	—	—	—	—	—
20	18·7	2·2	2652	0·622	800	1205	—	—	—	—	—		Value of thinnings £44·40	
25	25·6	3·0	1860	0·577	1370	620	792	200	—	—	—			
30	32·8	4·1	1280	0·541	2030	312	580	343	1d.	1·429	3·47	6·26		Value of thinnings £108·70
35	40·3	5·2	920	0·509	2770	177	360	443	2d.	3·692	7·73	13·96	Value of final felling at 3*d.* per cubic foot £91·87	
40	47·9	6·3	720	0·499	3670	114	200	443	2d.	3·692	6·67	12·04		
45	55·1	7·3	590	0·491	4620	81	130	472	2d.	3·933	6·13	11·07		
50	62·0	8·3	495	0·483	5560	60	95	529	2½d.	5·510	7·40	13·37		Value of final felling at 4*d.* per cubic foot £172·50
55	68·6	9·3	420	0·477	6490	45	75	543	2½d.	5·656	6·56	11·84		
60	74·5	10·2	370	0·471	7350	36	50	515	3d.	6·437	6·44	11·62		
65	79·7	11·1	330	0·465	7990	30	40	515	3d.	6·437	—	10·03		
70	84·6	11·9	298	0·460	8900	25	32	457	3d.	5·713	—	7·68		
75	89·2	12·6	275	0·458	9650	22	23	415	3d.	5·188	—	6·01		
80	93·5	13·2	255	0·455	10350	19	(20)	(386)	3d.	4·825	—	4·82	—	
										TOTAL RETURNS ...		...	£136·27	£281·20

QUALITY CLASS IV.—(SCHIFFEL'S CLASS X. MEDIUM DENSITY OF CANOPY).

Age.	DOMINANT CROP.					Crop Characteristic.	THINNINGS.						Total value at end of 60 Years' Rotation.	Total value at end of 80 Years' Rotation.
	Mean Height.	Mean Diameter.	Number of Trees per acre.	Form Factor.	True Volume per acre.		Number of Trees per acre.	True Volume per acre.	Assumed price per cubic foot.	Value at time felled.	Value at 60 years at 3 per cent.	Value at 80 years at 3 per cent.		
	feet	inches			cubic feet			cubic ft.		£	£	£	£	£
10	8·9	—	—	—	—	—	—	—	—	—	—	—	—	—
15	15·4	—	—	—	—	—	—	—	—	—	—	—	—	—
20	23·3	2·8	2,025	0·578	1,140	730	—	—	—	—	—	—		
25	30·5	3·7	1,446	0·549	1,800	391	579	257	—	—	—	—	Value of thinnings £52·90 Value of final felling at 3½*d.* per cubic foot £123 52	Value of thinnings £125·64 Value of final felling at 4*d.* per cubic foot £193·33
30	37·7	4·6	1,085	0·532	2,570	236	361	358	1d.	1·487	3·63	6·54		
35	45·6	5·8	802	0·510	3,460	138	283	500	2d.	4·167	8·73	15 78		
40	54·1	7·1	616	0·493	4,490	87	186	586	2d.	4·883	8·84	15·92		
45	62·0	8 3	494	0·481	5,530	59	122	615	2½d.	6·406	9·99	18·00		
50	69·2	9·4	417	0·473	6,560	44	77	586	2½d.	6·103	8·18	14·83		
55	75 8	10·4	362	0·468	7,550	35	55	558	2½d.	5·812	6·74	12·15		
60	81·7	11·3	320	0·462	8,470	28	42	543	3d.	6·785	6·79	12·29		
65	87·2	12·2	289	0·457	9,350	24	31	500	3d.	6·250	—	9·75		
70	92·2	13·0	264	0·454	10,150	20	25	472	3d.	5·900	—	7·93		
75	96·4	13·7	245	0·452	10,910	18	19	415	3½d.	6·052	—	7·02		
80	100·4	14·3	229	0·450	11,600	16	(16)	(372)	3½d.	5·425	—	5·43	—	
										TOTAL RETURNS ...		...	£176·42	£318·97

QUALITY CLASS V. (SCHIFFEL'S CLASS XI. MEDIUM DENSITY OF CANOPY).

Age.	Dominant Crop: Mean Height.	Dominant Crop: Mean Diameter.	Dominant Crop: Number of Trees per acre.	Dominant Crop: Form Factor.	Dominant Crop: True Volume per acre.	Crop Characteristic.	Thinnings: Number of Trees per acre.	Thinnings: True Volume per acre.	Thinnings: Assumed price per cubic foot.	Thinnings: Value at time felled.	Thinnings: Value at 60 years at 3 per cent.	Thinnings: Value at 80 years at 3 per cent.	Total value at end of 60 Years' Rotation.	Total value at end of 80 Years' Rotation.
	feet.	inches.			cubic feet.			cubic ft.		£	£	£	£	£
10	11 2	—	—	—	—	—	—	—	—	—	—	—	—	—
15	19·7	2·3	2,515	0·607	858	1,093	—	—	—	—	—	—		
20	27·6	3·3	1,717	0·566	1,545	520	798	229	—	—	—	—		
25	35·8	4·4	1,179	0·534	2,360	268	538	386	1*d.*	1·608	4·52	8·17	Value of thinnings £64·70 Value of final felling at 3½*d.* per cubic foot £141·38	
30	44·3	5·6	853	0·511	3,320	152	326	586	1*d.*	2·441	5·93	10·69		Value of thinnings £147·02 Value of final felling at 4*d.* per cubic foot £216·33
35	52·8	6·9	642	0·489	4,400	93	211	600	2*d.*	5·000	10·47	18·93		
40	61·0	8·1	518	0·482	5,490	64	124	615	2*d.*	5·125	9·28	16·71		
45	68·9	9·3	429	0·474	6,620	46	89	629	2½*d.*	6·550	10·22	18·41		
50	76·1	10·4	366	0·466	7,690	35	63	629	2½*d.*	6·550	8·78	15·92		
55	82·7	11·5	321	0·460	8,740	28	45	586	3*d.*	7·325	8·50	15·31		
60	88 6	12·4	287	0·455	9,695	23	34	560	3*d.*	7·000	7·00	12·62		
65	93·8	13·2	262	0·451	10,580	20	25	486	3*d.*	6·075	—	9·48		
70	98·7	14·0	243	0·449	11,450	17	19	430	3½*d.*	6·271	—	8·38		
75	103 0	14·7	227	0·448	12,230	15	16	400	3½*d.*	5·833	—	6·77		
80	106 9	15·3	214	0·446	12,980	14	(13)	(386)	3½*d.*	(5·629)	—	5·63		
										TOTAL RETURNS		...	£206·08	£363·35

APPENDIX D.

SOIL EXPECTATION VALUES FOR SPRUCE.

Table showing the Expectation Value of Soil of Qualities I. to V. when planted up with and maintained permanently under a Crop of Spruce.

Quality Class.	I.	II.	III.		IV.		V.	
	60-year Rotation.	60-year Rotation.	60-year Rotation.	80-year Rotation.	60-year Rotation.	80-year Rotation.	60-year Rotation.	80-year Rotation.
	£	£	£	£	£	£	£	£
Value of returns at end of a single rotation	86	109	136	281	176	319	206	364
Present value of all future returns (for ever)	17·6	22·3	27·8	29·1	36·0	33·1	42·1	37·6
Capital value of cost of forming plantation now and again at end of every rotation at £5 per acre	6·0	6·0	6·0	5·5	6·0	5·5	6·0	5·5
Capital value of cost of upkeep and management at 4/- per acre per year for ever	6·7	6·7	6·7	6·7	6·7	6·7	6·7	6·7
Present value of all expenses (for ever) ...	12·7	12·7	12·7	12·2	12·7	12·2	12·7	12·2
Soil Expectation Value	4·9	9·6	15·1	16·9	23·3	20·9	29·4	25·4