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FORESTRY

Translated from the German of

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By

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PREFACE

By way of preface to this translation of Professor Schwappach's *Forstwissenschaft*, a word or two of explanation seems necessary.

The author has been careful to avoid anything which is only locally applicable, so that the matter which the book contains is quite as suitable for British as for German readers. Forest conditions change within Germany as they do within our own country, but the principles—the natural laws—governing forest practice are unalterable, being the same at all times and in all places. This being so, the English adaptation of a book dealing concisely with these principles and emanating from such an able author must surely be useful. Forestry in its economic aspect is the subject treated, and anything peculiar to Germany or any other country is specifically mentioned. Some portions of the original, particularly Forest History and Valuation, have been abridged; while those bearing on Sowing and Planting, Insects, Fungi, and Forest Management have been somewhat extended. The illustrations also have been added.

I must, no doubt, hold myself responsible for the book in the form in which it is now given to English readers, but I desire to acknowledge my indebtedness to Dr. Eric A. Nobbs, of the Department of Agriculture, Cape of Good Hope, who began the translation. Also to Dr. William Somerville, of the Board of Agriculture and Fisheries, my thanks are due for the helpful interest he has taken in the work.

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INTRODUCTION

It is curious that the term "forest," the general meaning of which everyone understands, is difficult or impossible of definition. At one time the forest signified the hunting grounds of the sovereign. At another it was explained as an area on which were found trees and shrubs growing wild. The former description is no longer satisfactory, and the latter makes no allowance for cultivated forest, nor, indeed, for the "deer forest," which may be entirely destitute of trees.

Game coverts are one type of forest, protection forests for preserving the soil quite another. The park, or pleasure ground, is different again; and the primeval forest may be distinct from any. Further than this, one may have tree-growing land merging so gradually into heath or moor, or bearing so poor a timber crop, that opinions may differ as to where forest ends and field begins.

For our present purpose the forest may be defined as an area wholly or partially covered with trees, the principal object in growing the trees being the production of timber. From the foregoing remarks it is obvious, however, that such a definition is far from being universally applicable.

A forest which develops under the regenerating control of nature, without man's interference, is termed "natural," "virgin," or "primeval" forest. Such forests have practically disappeared from Western and Southern Europe, and towards the east they are in many parts rapidly diminishing. Eastern Europe—Russia particularly, but also Sweden and the southern portion of Norway—still possesses very considerable tracts of undisturbed natural forest.

Until recently the practice of economic forestry was confined to certain parts of Europe and India; but now Japan, Cape Colony, and the United States of America have at least made a beginning in forest organisation. Apart from these cases, the world's timber resources are being exploited with wanton carelessness without regard to future needs. The treatment accorded to most of the forest regions in the United States may be specially instanced in this connection.

So soon as man cuts into the primeval forest and begins to appropriate its stores, the country affected quickly undergoes a change. It may be that the area becomes permanently the site of fields and pastures; too often, however, it becomes a barren waste. When the forest is systematically handled, the cleared ground is regenerated and further timber raised. But, though still forest, the term "primeval" is, of course, no longer applicable.

Any definite subdivision of a forest may be called a "wood." Both the land and the crop of trees upon it are included in the terms "forest" and "wood." Woods may be intended only to beautify the landscape, or to add to the amenity of the district, and if they really serve their æsthetic purpose, this may be considered as an end in itself. It does not follow, however, that a wooded area, managed simply with a view to the production of timber on economic lines, is necessarily unlovely. Sylviculture certainly is based upon commercial principles, but in its results it often rivals for beauty the much less valuable productions of the landscape gardener. As dealt with in this volume, forestry is the science or art of raising trees mainly for profit. Together with this subject are considered the methods of harvesting, extracting, and valuing forest produce.

FORESTRY

CHAPTER I

HISTORIC SKETCH OF THE DEVELOPMENT OF FORESTRY

1. In the Most Remote Periods

To the work of Romans, writing at the dawn of ancient history, we are indebted for a description of several European forest districts. But there is an unwritten history equally eloquent in the timber of lake-dwellings and other primitive habitations, as well as the remains found in peat mosses. These latter tell us something of the distribution and extent of the forests at a period still more remote than that dealt with by historians. By searching into the origin of the names of places also much light has been shed on this subject. Thus we have the terminations *holt* (a wood especially the haunt of wild animals), *toft* (a grove), *shaw*, *scau*, *hurst*, *wood*, and *woot*. Then many place-names are compounded with the names of species of trees; thus, of British origin, *derry* (the Oak) in Londonderry; *sale* (from *sahl*, the Willow) in Salehurst; and of Saxon derivation, *aec* (the Oak) in Acton; *withig* (the Willow) in Withington, *æsce* (the Ash) in Ashton, Askham, and many others.[1]

Evidence of this kind proves that there has been but little change in our forest flora since very ancient times. The

[1] See Flavell Edmunds' *Traces of History in the Names of Places*.—Tr.

following broad-leaved trees are indigenous in Britain: Oak, Ash, Beech, Wych Elm, Birch, Aspen, Hazel, and Alder. The Scots Pine and Yew appear to be the only conifers natural to our islands. The distribution and numerical occurrence of the trees were not quite the same as they are now; in Britain, the Oak, for instance, was formerly much more common, and remains of it are found in nearly all parts of Scotland, even in the north of the country, and at considerable altitudes. Any alteration that has taken place in regard to the species grown, has been brought about principally during the last two or three hundred years.

As is well known, the forests, both in this country and abroad, originally occupied a very much greater area than they do at the present day. It would be wrong, however, to imagine that in the earliest times with which history deals Western Europe was entirely covered with uninterrupted forest.

In order to understand the history or development of forestry in a country, it is necessary to study to a certain extent the social and political changes that have been active. Some account of these, referring more particularly to Germany, will therefore be given in the following pages.

In very early times the forests of Germany belonged either to the king, or, communally, to all the inhabitants of a district or settlement. For long there lay between these claimed areas—themselves but insecurely held—wide stretches of absolutely unowned land.

With the growth of a strong sovereignty, and with the introduction of Christianity, the country's conditions altered very considerably.

From the seventh century onward the great ecclesiastic and civil magnates gradually asserted their power, and during the course of the next few hundred years they possessed themselves not only of the previously unclaimed land, but also of the larger part of the national forests. Similarly they appropriated, almost everywhere, the forests belonging to the original free settlements, but this they did without restricting the use the peasants made of them. In order to get the value out of their extensive possessions, the owners of the land carried on schemes of settlement in which each community was, as a rule, assigned a part of the forest for common use.

About the year 1000 A.D. we find the forest divided as follows :—

(*a*) The private property of the sovereign, or of ecclesiastical and civil authorities.

(*b*) Communal woods belonging to the original free settlers or to communities subordinate to the lord of the manor.

Smaller woods, privately owned, were at that time quite the exception.

In the political economy of early times, and even in the Middle Ages, the forest played a part of great importance. Wood was almost the only material used for heating, lighting, and building; from wood also domestic utensils and agricultural implements were principally made. No less important were the other uses of the forests of those days. They provided the animals of the chase, pasturage for cattle and sheep, and pannage for swine.

In course of time the system of coteries or tribes gave way somewhat. At first the social binding was necessary, for in that capacity alone were the people able to resist their enemies. Land possession had been practically non-existent, for these wandering peoples had to be ready at a sign to change their homes. But now the ownership of land became more fixed, the population rapidly increased, and a larger supply of food was demanded. This brought agriculture into greater prominence. The forests had become a hindrance to agricultural development, and their clearance was the necessary preliminary to the founding of farm holdings.

2. In the Later Middle Ages

The ancient national forests suffered seriously during the later Middle Ages owing chiefly to two causes—the impecunious state of the exchequer and the growth of feudalism. The system of communal ownership gradually decayed, though it never disappeared.

But a new form of proprietorship now appeared—that of the towns. These, partly at the time of their foundation, partly during their palmy days after the end of the thirteenth century, frequently acquired very considerable areas of woodland, and preserved them well.

The efforts of the greater landed proprietors continued to be directed towards the appropriation of the lands of the peasantry, the more so as, with the development of sovereignty, political power was connected with territorial possession. With the reorganisation of economic conditions and the development of the feudal system the peasantry as a class lost their importance. On the other hand, the continual economic progress of the country led to a further subdivision of the old national forests. At first this took place between districts only, but during the thirteenth century the old communal forests also came to be divided among the respective owners. In both cases the feudal lords took good care, especially if they held protective rights, to get a larger or smaller share of the lands.

The value of forest land for agricultural purposes, and the general prosperity of the times, caused the forests to rise rapidly in value, so that owners of property held always more and more tenaciously to their possessions. Following the ancient style of bargaining, proprietors granted rights of use for labour done. At first the contents of the forest were held to be of small value; little restraint was put upon the inhabitants' interpretation of their rights, and as a result, they often took more than they were entitled to. In course of time this privilege developed into a demand which could not be refused, and so arose that system of so-called "servitudes," or forest rights, which still exists in many parts of Germany.

Conversion of the forest into arable land was a common practice far into the later Middle Ages. The particularly rapid growth of the population during the eleventh and twelfth centuries gave rise to a period of active forest destruction. Favouring this was the improvement in agricultural methods, which gradually spread from west to east.

Before the end of the Middle Ages it became apparent that the destruction of the forests was endangering the timber supply of the towns and trades dependent on the forest for their raw material. Not unimportant also, as an incentive for legislation, was the necessity of forests for the purposes of the chase. Prohibitions limiting further clearances were brought about, first in the more settled and, for those early times, comparatively densely populated parts of Germany.

In the Rheingau, restrictions were made in 1226, and many enactments in the fourteenth and fifteenth centuries laid down laws and prescriptions for the regulation of the fellings. These ordinances were welcomed alike by individual landowners and village communities. Their object was to introduce methodical treatment in place of previous haphazard utilisation of forest products, and to ensure the permanence of the supply.

Even thus early, we find such subjects dealt with as estimates of the actual requirements for timber and fuel, extent of existing woods, supervision of work done in the forest, regulation of grazing cattle, and similar matters.

At the same time, rules were formulated prescribing the means whereby exhausted forest might be reproduced. The oldest method of regeneration was the protection of young growth which had arisen spontaneously. This led very naturally to the preservation of seed trees whose function was to sow the ground, and any persons destroying trees left for this purpose were severely punished.

The earliest effort to control utilisation so that uniformity of forest yield might result, was made in the year 1359, at Erfurt, in Germany. The forest was divided into parts, one of which was annually cut over in rotation. Coppice shoots restocked the area by natural means, and the falls were so planned that a sustained yield was rendered possible.

The first mention of the formation of pine woods by direct sowing occurs ten years later in connection with the town forest of Nürnberg. During the fifteenth century, this practice became general throughout South-west Germany.

3. From the end of the Middle Ages to the middle of the Eighteenth Century

During the period from the beginning of the sixteenth to the middle of the eighteenth century no new form of ownership of woodlands arose, but those already existing underwent considerable modification. More particularly the possessions of the Crown were enormously extended. This came about in three ways: (1) by the appropriation of hitherto unclaimed land; (2) by the secularisation of much Church property as a consequence of the Reformation; and (3) by the decline of the village communal system.

Chiefly through the working of the last of these factors the possessions of the landed nobility were increased. During the sweeping changes in the political and social conditions the communes had completely lost their former status, and the Thirty Years' War gave the death-blow to the political influence of the peasantry. The ever-increasing power of the Crown gradually embraced the control of forests belonging to the peasants, and with the feeling of independence gone, the latter lost also their interest in their common property. Thus it came about that the great nobles obtained more and more power, and managed, by various devices, to possess themselves of the former communal forests. At first the commoners exercised their prerogatives much as of old, but this they did in an ever-diminishing degree.

Growth of the population, with the consequent increase in the requirements for wood and other forest produce, led to further legal enactments to prevent the destruction of forests. In spite of these laws, reckless cutting continued to be practised in Eastern Germany and other parts of Central Europe up till the middle of the eighteenth century and even later, the original object being to attract farmers to these densely wooded but thinly peopled regions. Reaction, in the latter part of the Middle Ages, led to restriction of the use of forests, and this policy grew and gradually came to be actively enforced.

It was fortunate for the fulfilling of the regulations that the pressing need for improved forest conservation was backed by the authority of the sovereign, so that they were no longer mere general resolutions passed by the community. The practical aim of these laws was to replace the exploited woods by new ones. It was observed that the growth of self-sown seedlings depended upon the judicious admission of light to the forest floor. When woods of Spruce and Silver Fir were heavily thinned for timber, this was readily seen. The trees left standing acted as parents, producing a subsequent crop of trees.

In the course of the sixteenth century various improvements on the former crude sylvicultural methods suggested themselves. Amongst these may be mentioned the systematic arrangement of the felling areas, the removal in the thinnings not of the best but of the inferior classes of trees, the selection of good trees to produce seed, and the fostering of such natural growth as was already present.

The devastation of the Thirty Years' War not only put a stop to all progress, but brought about a return of the old misuse of the forest, and this continued till the end of the seventeenth century. When consideration was again given to sylviculture, the initiative was taken in the north-west of Germany, more particularly in the Harz Mountains. Most of the credit for the revival of sound principles is due to the labours and energy of Von Langen. The natural regeneration of coniferous woods had long been rendered difficult by damage wrought in them by storms. Von Langen devised a scheme whereby the woods were sheltered in their most critical period by means of suitable Cutting Series.

Before the commencement of the eighteenth century forests of broad-leaved trees were managed as coppice or coppice with standards. But as timber of larger size came more into request, the length of the rotation was extended. Then came the question of regeneration, High forests being generally raised, not from stool shoots, but from seed.

Natural regeneration by seed from deciduous trees seems to have been almost entirely neglected up to this time. The formation of woods by means of the natural fall of seed had long been practised with conifers, but was only now successfully attempted with broad-leaved trees, more especially with the Beech. This problem was first satisfactorily solved in Hesse about the year 1730 by giving special attention to the requirements of the young plants for shelter. In 1736 the forest ordinance of Hanau-Munzenberg—a decree regulating the management of the forests there—prescribed that special attention be paid to the interests of the new rather than merely to the utilisation of the old crop. The felling was divided into three stages—a felling for seed, a felling for light, and a final felling. In 1764 an advance or preparatory stage in the felling was made to precede, by a few years, the cutting for the production of seed.

Artificial regeneration of pines and firs by sowing and planting became general in the sixteenth century, being first practised in South Germany. In the north, at the same time, the ancient custom of forming groves of Oaks by planting saplings in the neighbourhood of homesteads, was applied to the open forest, where also the sowing of pine cones—a method now rarely employed—was introduced. Towards the close of the seventeenth century the planting of Spruce was tried, though with little success; but at the beginning of the next century direct sowing of Spruce seed was followed by much better results, and this method came rapidly into general use both in North Germany and in Thuringia.

The demand for timber continuing to increase, it became compulsory, or at least highly desirable, to institute definite plans for the regulation of the yearly fellings.

Until woods which had been recently formed became of serviceable size, the older forest was the only source of supply, and the object of these early working plans was so to allocate the annual fellings that the old forest would not be exhausted before the younger woods were available.

Two fundamentally distinct ways of attaining this end occur in practice. The forest may be divided into sections of approximately equal area. The number of parts is made to correspond to the number of years over which it is desired to spread the fellings, and one of the sections is then felled each year.[1] The alternative method is to make an estimate of the total stock of timber, and this amount, divided by the number of years over which its utilisation must extend, gives the quantity that can be felled annually.[2] It was some time before it was appreciated that to this estimate might be added a quantity representing the wood increment during the rotation or lifetime of the trees.

The former of these two ways appears to be, and often is, the simpler, and, as previously mentioned, it was the first to be employed (in the fourteenth century). In large forests, however, the measurement and division of the area were beyond the skill of the times to deal with, while the nature of the crop was too uneven to admit of the method being successfully applied. The method of calculation by volume was accordingly resorted to, but in its roughest form. The earliest information on this point dates back to the middle of the sixteenth century, and refers to the Harz and the district of Salzkammergut, in Upper Austria.

[1] See p. 134: "Method of Periods by Area."
[2] See p. 135: "Method of Periods by Volume."

4. The Transition to Present Conditions

Still further alterations in the ownership of German forest lands occurred in the latter half of the eighteenth century. These were brought about chiefly by the extension of public rights, much land passing out of the possession of the nobility to become the property of the State. The communal forests that had escaped distribution among their joint owners, or seizure by the overlords, were now cared for by the respective townships.

The burdens on the forest in the shape of rights continued to increase till the beginning of the nineteenth century. The augmented value of forest products and agricultural changes have since led to the gradual reduction of these obligations by arrangement with the beneficiaries, though this has necessitated considerable expenditure.

An important step in the progress of sylviculture was the evolution of the so-called Selection System, introduced at the end of the eighteenth century. By it, single trees or small groups in the forest are chosen and felled, according as their state of maturity suggests, and the necessity for younger growth requires. Originally adopted for the utilisation and regeneration of deciduous species, particularly Beech, the system met with the commendation of those pioneers in scientific forestry, G. L. Hartig and Heinrich von Cotta. Upon the selection method being applied to the Scots Pine—the species least suited to this treatment—failure resulted, which caused a sudden reaction in favour of clear-felling with subsequent planting. Both the selection and the clear-felling systems have their peculiar advantages under particular circumstances; but the indiscriminate use of either leads naturally enough to disappointment.

The financial crisis consequent upon the great wars at the beginning of the nineteenth century had its effect upon the forest. Natural regeneration by seed, being a cheap method of restocking, rose again in favour. This period passed, however, and with the return of normal financial conditions, more intensive working became possible. The formation of woods by planting and direct sowing was given much attention, and many methods were evolved, the most important of which will here receive consideration.

In the history of the tending of woods, thinnings are first mentioned as having taken place at the beginning of the sixteenth century. The writings of the time contain many observations worthy of remark regarding the aim and importance of this operation. But their effect upon practical management seems to have been that the smaller timber was removed from the older woods, and that it consisted of the suppressed and superfluous material, while the actively growing younger woods received no attention.

G. L. Hartig was the first to give systematic instruction on the care of woods by means of thinning. In the early years of the nineteenth century this important branch of forestry developed further through the work of Späth, Cotta, Pfeil, and König; but it still made slow progress in practical application.

This period was also marked by an advance in systems of forest management. Annual and periodic increment, previously overlooked, was now included in calculations connected with working plans. Experiments conducted in Thuringia about 1750 had most important results. They consisted of a comparative study of the volume accretion of woods of similar character at different ages. From these investigations it was seen that there was a very considerable diversity in the amount of timber produced per acre at the various periods throughout the lifetime of a wood—this being connected with corresponding alterations in the activity of growth. It was shown that to postpone the act of felling beyond a certain age—dependent on species and situation—led to serious loss of timber increment.

As has been explained, woods may be allotted to the periods of a rotation by the taking of a like volume each felling time, or by cutting over the trees upon an equal area.

The method by means of volume had the support of G. L. Hartig. Cotta and others, however, considered the areal distribution preferable, but tried to combine with it an equalisation of the return by volume as well.

In the beginning of the nineteenth century a further method of calculating the produce was evolved. It was based on a series of formulæ representing the actual stock and its increment in relation to the ideal or so-called "normal" stock and increment.

5. Forest Literature

The middle of the eighteenth century marks a turning point in the history of sylviculture. Till then forestry had been almost unknown in literature. A few scattered writings had previously appeared, but now there was evinced an earnest desire on the part of foresters to bring to public notice results of inquiry and experience.

Of the early works, that entitled *Ruralium commodorum* appeared in the year 1300. It is a scholarly compilation on agriculture taken from the writings of Roman authors. Quaint views upon natural history occur throughout its pages, and forestry is occasionally referred to. Upon the invention of printing, several editions of the book were issued and it was translated into many languages. It inspired much of the popular *Prædium rusticum* of Charles Estienne, which appeared in 1554. Among other works of a like character, the only one requiring mention is the *Occonomia ruralis*, by Colerus, of interest as being the first based on actual observation of nature and direct personal experience. The book is, in this way, a striking contrast to the pedantic efforts of all previous writers. *Sylvicultura œconomica* (1713), by Von Carlowitz, like Evelyn's *Silva*, is wholly devoted to forestry, and deals with its subject from a practical standpoint. It contains precepts, many of which are still recognised as of fundamental importance in sylviculture.

The first encyclopædic work in which forest science is presented in systematic arrangement, emanated from a number of professors and others interested in the subject. This book appeared in the latter half of the eighteenth century, but was sadly deficient in technical knowledge. In their terminology the compilers availed themselves largely of the works of a French author (Duhamel du Monceau). This class of literature continued to become more involved later in the same century, owing to a confusion of ill-understood yet increasingly numerous terms.

For long a process had been working wherein the forester gradually replaced the huntsman in the woods. These men, giving their attention to woodcraft, were able to chronicle their observations for the benefit of their profession. Late faulty writings found their corrective in the literary efforts of those more practical men.

At the beginning of the nineteenth century forestry was still dealt with in literature as a comprehensive whole. Thus the works of Hartig, Cotta, Hundeshagen, and Pfeil traverse the whole range of sylvicultural science and practice. This ceased about 1830. Writers have specialised more since then, and have usually preferred to deal with particular branches of the subject.

CHAPTER II

FOREST STATISTICS

Scope and Arrangement of Forest Statistics

STATISTICS bear very directly upon the economic problems of forestry. If carefully gathered, they are excellent guides for future action, being based on experience in the past or on existing conditions. They consist of the collection and arrangement of facts bearing on many topics, such as matters of profit and expenditure, forest resources, area and distribution of forest lands, imports and exports, and means of conveyance of timber. Subjects for statistical inquiry may, indeed, be multiplied indefinitely; at present, however, the records are scanty enough even upon the subject of forest area.

Some of the European states provide fairly reliable data, but the figures of others (Russia, Turkey, Sweden, and Norway) leave much to be desired. For lands outside of Europe the data are scarcely trustworthy.

Forest Area of the World

It is improbable that the world's forest area and available timber supply have been under-estimated. It is, indeed, more likely that the reverse is the case. Much land designated "forest" has but a poor scrub growth upon it—portions are even desert. A very extensive area in the United States, for instance, is not productive, though described in the official returns as "wooded area." Great stretches of forest in Sweden, Canada, Australia, and other lands also come under this category. They are forest lands, but unless prices rise very considerably they will prove altogether unremunerative for exploitation, the material being much too remotely or unfavourably situated to warrant its extraction. Yearly it is becoming more difficult to reach the products of the natural forests. All the most serviceable timber is taken first from the easily accessible areas, but this supply becoming exhausted, lumbermen are being forced to fetch the timber from an ever-increasing distance. The forest area alone does not allow one to judge of a country's capabilities for the supply of timber. The following tables are therefore submitted with the qualification that they give only an idea of the relative position of the countries specified.

DISTRIBUTION OF FORESTS

I. BRITISH POSSESSIONS

Country.	Total Wooded Area. Acres.	Percentage of Land Area.
CANADA	799,231,000[1]	38
Prince Edward Island	510,000	40
Nova Scotia	4,137,000	31
New Brunswick	9,450,000	53
Ontario	65,356,000	46
Quebec	74,573,000	51
British Columbia	182,755,000	75
Manitoba	16,401,000	40
N.W. Territories	446,049,000	29
AUSTRALASIA	106,037,000	18
Victoria	11,797,000	21
South Australia	3,840,000	0·6
Queensland	40,000,000	9
New South Wales	19,000,000	10
West Australia	20,400,000	3·2
Tasmania	11,000,000	64
New Zealand	20,578,000	30
SOUTH AFRICA—		
Cape Colony	519,175	0·3
Natal	30,000	0·3
Orange River	Practically treeless	0·0
Transvaal	Not known	—
BRITISH INDIA	155,000,000	25

II. FOREIGN COUNTRIES

Country.	Total Wooded Area. Acres.	Percentage of Land Area under Forest.	Percentage belonging to State.
United States	500,000,000[2]	26	1
Japan	57,000,000	60	30
Russia[3]	516,000,000	40	61
Sweden	48,000,000	44	27
Germany	34,490,000	26	33
Austria proper	23,990,000	32	7

1 The timber on less than half this acreage only may be available.—Tr.

2 See B. E. Fernow's *Economics of Forestry*, 1902, p. 339.

3 See article "The Outlook of the World's Timber Supply," by Dr. W. Schlich, in the *Journal of the Society of Arts*, March 1, 1901.

Country.	Total Wooded Area. Acres.		Percentage of Land Area under Forest.		Percentage belonging to State.
France	23,530,000	...	18	...	12
Hungary	22,420,000	...	28	...	16
Spain	20,960,000	...	17	...	84
Norway	17,000,000	...	21	...	21
Bulgaria	10,650,000	...	45	...	—
Italy	10,110,000	...	14	...	4
Bosnia and Herzegovina	6,790,000	...	53	...	70
Turkey	6,180,000	...	8	...	—
Roumania	5,030,000	...	17	...	47
Servia	2,390,000	...	20	...	—
Switzerland	2,051,670	...	20	...	4
Greece	2,030,000	...	16	...	80
Belgium	1,250,000	...	17	...	5
Portugal	770,000	...	3	...	8
Denmark	600,000	...	6	...	24
Holland	570,000	...	7	...	—
Luxembourg	190,000	...	30	...	—

III. BRITISH ISLES[1]

Counties.	Total Wooded Area. Acres.		Percentage of Land Area.
ENGLAND—			
Bedford	12,542	...	4·12
Berks	35,791	...	7·07
Buckingham	32,125	...	6·69
Cambridge	6,146	...	1·11
Cheshire	24,836	...	3·79
Cornwall	31,043	...	3·57
Cumberland	35,054	...	3·61
Derby	25,760	...	3·94
Devon	86,050	...	5·14
Dorset	37,615	...	6·04
Durham	29,469	...	4·53
Essex	30,860	...	3·15
Gloucester	58,407	...	7·27
Hants	125,674	...	11·93
Hereford	41,957	...	7·77
Hertford	24,545	...	6·06
Huntingdon	4,714	...	2·01

[1] See Agricultural Returns for Great Britain, 1901, London, 1902; and Agricultural Statistics of Ireland, 1901, Dublin, 1902.

Counties.	Total Wooded Area. Acres.	Percentage of Land Area.
ENGLAND—		
Kent	98,302	10·07
Lancashire	41,906	3·5
Leicester	14,282	2·66
Lincoln	43,127	2·54
London	367	0·49
Middlesex	3,656	2·45
Monmouth	32,733	9·37
Norfolk	53,870	4·09
Northampton	28,017	4·3
Northumberland	49,626	3·84
Nottingham	28,517	5·27
Oxford	26,611	5·53
Rutland	3,838	3·94
Shropshire	50,493	5·85
Somerset	45,650	4·4
Stafford	39,191	5·55
Suffolk	34,771	3·66
Surrey	54,437	11·77
Sussex	124,632	13·36
Warwick	21,261	3·68
Westmoreland	17,334	3·43
Wilts	51,755	5·99
Worcester	19,188	3·99
Yorkshire	139,589	3·35
ENGLAND—Total	1,665,741	5·11
WALES—		
Anglesey	2,193	1·23
Brecon	13,956	2·97
Cardigan	15,989	3·68
Carmarthen	23,290	3·96
Carnarvon	12,593	3·44
Denbigh	18,422	4·32
Flint	8,209	5·5
Glamorgan	27,206	5·06
Merioneth	14,407	3·42
Montgomery	24,730	4·84
Pembroke	9,698	2·46
Radnor	10,917	3·62
WALES—Total	181,610	3·76

Counties.	Total Wooded Area. Acres.		Percentage of Land Area.
SCOTLAND—			
Aberdeen	108,976	...	8·51
Argyll	48,412	...	2·38
Ayr	25,725	...	3·51
Banff	30,955	...	7·63
Berwick	15,378	...	5·23
Bute	3,806	...	2·7
Caithness	952	...	0·21
Clackmannan	3,026	...	8·6
Dumbarton	8,772	...	5·07
Dumfries	31,531	...	4·56
Edinburgh	12,117	...	5·01
Elgin and Moray	48,688	...	15·77
Fife	24,130	...	7·43
Forfar	31,972	...	5·68
Haddington	10,472	...	6·11
Inverness	150,929	...	10·86
Kincardine	25,795	...	10·51
Kinross	3,258	...	5·81
Kirkcudbright	19,285	...	3·31
Lanark	21,499	...	3·81
Linlithgow	5,206	...	6·76
Nairn	12,767	...	12·19
Orkney	11	...	0·004
Peebles	9,477	...	4·24
Perth	94,103	...	5·15
Renfrew	6,661	...	4·26
Ross and Cromarty	61,482	...	3·0
Roxburgh	16,285	...	3·8
Selkirk	4,942	...	2·86
Shetland	0	...	0·0
Stirling	14,920	...	5·02
Sutherland	19,641	...	1·46
Wigtown	7,592	...	2·41
SCOTLAND—Total	878,765	...	4·51
IRELAND	309,741	...	1·5
BRITISH ISLES	3,035,857	...	3·9

IV. AREAS UNDER WOOD IN THE UNITED KINGDOM BELONGING TO THE CROWN[1]

Name of Wood or Forest.	County.		Area in Acres.
Dean Forest	Gloucester	...	15,664
Highmeadow Woods	Gloucester	...	3,404
Abbotswood Estate	Gloucester	...	524
Tintern Estate	Monmouth	...	3,000
New Forest	Hants	...	23,088
Alice Holt Woods	Hants	...	1,892
Woolmer Estate	Hants	...	856
Bere Woods	Hants	...	1,420
Parkhurst Woods	Hants	...	1,160
Windsor, exclusive of Great Park	Berks	...	10,000
Delamere Woods	Cheshire	...	2,100
Chopwell Woods	Durham	...	870
Eltham Woods	Kent	...	240
Hazelborough and Salcey Woods	Northampton	...	1,700
Esher Woods	Surrey	...	840
	Total		66,758

The forest areas owned by the State form only 2·2 per cent. of Britain's woodlands; they are wholly situated in England—Scotland, Ireland, and Wales being practically without Crown woods. Much subdivided and subject to the rights and claims of commoners, they cannot easily be treated in a manner suitable for making them models or typical examples of forest management — so important a function of government forests abroad.

Barely 4 per cent. of the total area of the United Kingdom has a covering of trees, and for the most part the existing woods have been created for no economic purpose. It is a curious condition for a country where the climate and soil are admirably adapted for the growth of trees, where millions of acres of waste land and moorland invite afforestation, where the consumption of timber[2] is very great and rapidly increasing, and where the foreign timber supply is slowly but assuredly failing.

[1] From figures supplied through the Government Office of Woods and Forests, by E. Stafford Howard, C.B., Commissioner.

[2] The average sum spent upon imported timber for the five years preceding 1899 amounted to over £22,000,000 per annum.—Tr.

CHAPTER III

FOREST INFLUENCES

The Importance of Forests

The importance of the forest lies chiefly in the numerous uses to which timber is applied. But extensive woodlands have also their significance in providing shelter and food for certain of the domestic animals, protecting agricultural land in their vicinity, harbouring game, preventing erosion in one quarter and fixing drifting sand in another, in beautifying the landscape, and giving opportunity for employment in healthy labour. The industrial aspect is indeed of great moment, especially at a time when depopulation of the country districts is causing grave concern.

It seems almost unnecessary to say that timber and firewood are the most valued products of the forest. Still, there was a time when, even in Western Europe, what we now consider to be mere subsidiary attributes of the forest—the animals of the chase, mast, leaf litter, etc.—were more highly esteemed than the trees themselves. The minor products, as such material is called, could be easily transported, while of timber there was positively a superabundance.

The utilisation of the crop of timber is effected very frequently by the clearance of larger or smaller areas, this operation being followed by restocking. But the stems are also in part removed in the thinnings as is required in the course of sylvicultural treatment, with the view of promoting the well-being of the remainder. Timber removed in effecting the regeneration of the wood or immediately before replanting is called the chief or *final* yield. All the rest, including thinnings, forms the *intermediate* yield. In initiating schemes for the working of forest lands it is customary to expressly define the limits of these terms. The purpose they serve is to make easier the regulation of the work, and determine the results of past management.

Forestry and Labour

The management and protection of the forest, the harvesting of the products, the transport and manufacture of the timber, offer wide scope for remunerative labour.

The figures given in the census returns for Germany for 1895 show that 111,926 people had their chief employment, and 47,410 their partial employment in forestry work. Upon the former class, 240,640 family members were dependent. In addition, 899,956 found their occupation in the timber industry, and the families maintained by these numbered 1,547,847 persons.

Forestry finds work for fewer persons, relatively, than agriculture, there being quite a marked difference. Thus in Germany we find that arable farming employs one man for 10·6 acres, but forestry requires only one for 308·8 acres.[1]

Even the smaller by-products of the woods, such as fruits and branchwood for burning, have their importance. In collecting them, occupation is given to those who are physically unable for more arduous work. The value of such incidental crops will be appreciated from the fact that on a certain conservancy in Germany the dealers pay the gatherers, in a good year, the sum of 100,000 marks (£5,000) for blaeberries alone.

Influence of the Forest on Climate and Soil

The beneficial effects of forests on the land in their vicinity was formerly, and to some extent still is, somewhat exaggerated, or at least sought for in a wrong direction. To the forest was ascribed a far-reaching action in altering the temperature, regulating precipitations, and modifying the

[1] These figures refer only to persons permanently and directly engaged in forest work, and do not take cognisance of the large number temporarily employed. Forest land gives much more employment to workmen than pastoral land.

humidity of the atmosphere. Indeed, the impression conveyed by these statements was that whatever imperfection the climate of the district possessed might be cured by the establishment of forests. Thus the forest was supposed to increase or diminish heat and cold, attract rain, or prevent downpours and floodings as circumstances demanded!

The more careful research and exact study of recent years have, however, shown that the climatic influence of forests is quite inconsiderable, and that neither afforestation nor the destruction of forests has any appreciable effect. This may, at least, be said of the British Isles and continental lands in North-western Europe.

The difference of the mean annual temperature without and within the forest amounts to only about 1° Fahr. In fact, it is occasionally less than the difference which arises between two methods of observation. Perhaps the rainfall over the forest is slightly greater than that in the open, but though the finest tests have been made, even this has not as yet been clearly demonstrated. On the other hand, owing to the rapid evaporation of rain from the crowns of the trees, considerably less water reaches the soil in woods than in the open country. This is especially marked in countries like Great Britain, where a considerable portion of the annual precipitation is in the form of showers and mist.

But the forest is not without its favourable effects by any means. Apart from the fact that they add organic matter to the soil, forests have a beneficial action in—

(1) Preventing direct sunlight from reaching the soil, a condition of things associated with certain prejudicial influences.
(2) Breaking the force of the wind.
(3) Reducing the mechanical force of very heavy rain.
(4) Binding soils apt to be carried away by flooding or drifting.

In hilly country the prevention of erosion is, without doubt, of great importance, and for fixing the light, easily blown sand of the plains the binding action of the forest is no less useful. The water from heavy rains, checked in its descent by meeting first with the foliage of the trees, is better retained in forest soil than on bare land. Under a close cover of trees there collects a humus soil formed from the decay of fallen leaves. Through this sponge-like soil-covering the rainwater slowly filters, and its passage is further retarded by the stems and roots of the trees. In this way the erosive effect of violent rains upon bare hillsides is obviated. This is often a very serious danger, not only because the good soil is washed away, but also on account of lower lying fertile lands being covered by boulders, gravel, and sand brought down in the flooded waters. An importance must be attached to forests in such localities quite apart from the timber they produce. The Alps afford, perhaps, the best examples of this class of forest, but the unchecked, wasting action of violent rains can be clearly seen in Britain upon many hills reduced to a state of barrenness.

In the case of shifting sands, the roots of trees, shrubs, and wild plants, and the covering of vegetable humus formed from dead leaves serve to bind the soil. What forest growth has done in this matter may be clearly seen in the "Landes" of Gascony, or along the southern shores of the Baltic. On the other hand, and in striking contrast to these districts, are the great arid wastes of Central Russia, which bear such melancholy evidence to the improper handling of the natural forest over this precarious class of land. When level tracts of loose soil, without forest or other cover, are exposed to the wind, sand-dunes are apt to be formed. These advance in the direction of the prevailing wind, often invading valuable agricultural land.

Woods, which, from their position or the nature of the ground, exist not merely for the sake of what they produce, but also for the physical benefit of the area or of neighbouring districts, are called Protection Forests.

CHAPTER IV

SYLVICULTURE

In the establishment of forests the aim must always be to produce for the given conditions the most valuable timber crop with the least expenditure of time and money consistent with permanently good results.

Species of Trees Employed

Of the many different kinds of trees growing in Europe, comparatively few are capable of forming "pure" woods—that is, woods consisting of one species only. Of this class we have, however, among conifers the Silver Fir (*Abies pectinata*), Spruce (*Picea excelsa*), Scots Pine (*Pinus sylvestris*), Larch (*Larix europæa*), and Weymouth Pine (*Pinus strobus*); and of broad-leaved trees, Beech (*Fagus sylvatica*), Oak (*Quercus pedunculata* and *Q. sessiliflora*), Hornbeam (*Carpinus betulus*), Ash (*Fraxinus excelsior*), Birch (*Betula alba*, L. = *B. verrucosa*, and *B. pubescens*, Ehrh.), and Alder (*Alnus glutinosa*). Various Willows also appear pure in osier beds.

The above-mentioned trees are known as "ruling" species, the remainder are called "subordinate," being found in mixed woods, or pure only very exceptionally.

Of the species here enumerated, five are of particular importance, namely, Oak, Beech, Scots Pine, Spruce, and Silver Fir. To the cultivation of these chief attention is directed. All the trees just mentioned have long been grown in Northern Europe except two—the Larch, which, occurring naturally in the Alps, was introduced to England in the seventeenth century (to Scotland in the eighteenth century); and the Weymouth Pine, introduced during the eighteenth century.

Recently much attention has been given, particularly in Germany, to the cultivation as forest trees of various

American and Asiatic species, several of which may in the course of time become generally recognised as valuable additions to the forest flora of Western Europe. From a sylvicultural point of view, those especially deserving mention are: American White Ash (*Fraxinus alba Americana*), Red Oak (*Quercus rubra*), Black Walnut (*Juglans nigra*), Douglas Fir (*Pseudotsuga Douglasii*), Sitka Spruce (*Picea sitchensis* or *Abies Menziesii*), Western Hemlock (*Tsuga Mertensiana* or *Abies Albertiana*), Lawson's Cypress (*Chamæcyparis* or *Cupressus Lawsoniana*), Pacific Arborvitæ (*Thuya gigantea*, *T. Lobbi*, or *T. Menziesii*), Bank's Pine (*Pinus Banksiana*), Japanese Larch (*Larix leptolepis*), Great Silver Fir (*Abies grandis*), Concolor White Fir (*Abies concolor*).

Tree Growth in Relation to Soil and Situation

A term much used in technical forestry is "locality." It comprehends both soil and climate—the latter being influenced by situation—as they affect tree growth. The locality largely determines the species to grow and the sylvicultural treatment to adopt for any given area. The estimation of the capabilities of the locality forms, perhaps, the chief concern of the practical forester.

Apart from the general management of the forest, the prosperity of the trees depends upon the physical and chemical composition of the soil, the geographical position, the altitude, slope, and aspect of the ground.

Owing to the great number of factors collectively constituting the locality, there is difficulty in determining the importance of each individually. In selecting trees, the general conditions that are found to prevail must overrule opposing but non-vital considerations.

As regards the demands which trees make upon the physical properties of the soil, the most important qualities are depth, moisture, consistency, and permeability. A soil of at least moderate depth, fairly fresh, and of a porous and friable character is suitable for all species. Oak, Beech, Silver Fir, Ash, and Elm are, in this matter of the soil's mechanical state, decidedly exacting. Others are not so much so, and will grow in spite of less favourable circumstances. This is especially true of the Scots Pine, which on several kinds of soil—and, indeed, where many species could not live, such as poor sandy and peaty ground—manages to grow and even thrive. The predominance of the Scots Pine in European forests is chiefly due to this power of adaptability. The more that agriculture extended its boundaries—as was formerly the tendency—the more did the forest become limited to the poorer soils, where little else but Scots Pine could grow. This result is also in part attributable to the harmful effect of extracting the humus (vegetable mould) from the forest and by past faulty management in the tending of the woods. But though Scots Pine is an adaptable species, it must not be thought that it is suitable to plant everywhere. On the contrary, many soils (clays and marls) grow the fastidious Oak better than the Pine.

The degree of depth of soil has its effect upon all species, but many are able to accommodate themselves to situations where the depth is deficient. Other conditions being favourable, Spruce and Beech will grow on shallow soils; but Oak, Ash, and Sweet Chestnut require considerable depth.

The quantity of moisture in the soil has a very great influence in determining the species which will grow. Upon very dry soils occur Scots Pine, Acacia, and Birch. The wettest situations, where water is almost stagnant, can be occupied by only common Alder and Birch (both *Betula verrucosa* and *pubescens*).

As regards the demands made upon the mineral strength and nourishing matter in the soil, the most exacting species are respectively Elm, Sweet Chestnut, Ash, Oak, Sycamore, and Silver Fir; the least exacting, Birch and Scots Pine.

Altitude is often the deciding agent for forest vegetation. Along with it, however, the geographical position or latitude must be taken into account. The height above sea-level reached by trees is to a great extent regulated by climatic conditions—warmth particularly. The greatest altitudes are reached by Spruce and Mountain Pine (*Pinus montana*); following them, in order, come the Cembran Pine (*Pinus cembra*) and Mountain Alder (*Alnus viridis*), Larch, Sycamore, White Alder (*Alnus incana*), and Rowan or Mountain Ash. Cembran Pine and Mountain Alder are practically confined to the Alps. As failing to reach any considerable altitude Sweet Chestnut, Poplar, Acacia, and Osier Willows may be mentioned.

Tree Growth in Relation to Light

For the raising of woods and the management of them, it is most necessary to understand the requirements for light of the various trees.

A few species, especially Silver Fir and Beech, do not demand a full degree of light in order to grow well. The Yew tree possesses this faculty of toleration to a wonderful extent. On the other hand, there are species for whose growth, and life itself, much light is absolutely essential. To this latter class belong Birch, Larch, Oak, and Scots Pine.

Trees that have been allowed to grow in free positions, and to develop their natural character, can be judged in their relation to light by the foliage of their crowns.

Under like conditions of shade, the twigs and crowns of shade-bearing species are alive and healthy, while those of the light-demanders are languishing or dead. The crowns of the individual trees, as well as of the wood as a whole, appear thick and close in the case of the former, but light and open in that of the species intolerant of shade. That shade-bearing trees can also develop to perfection in open positions must be evident to all who have observed their growth in any of our wooded parks.

The habit of growth characteristic of the various species, as shown in the development of their crowns and in the density of the timber crop, does not generally appear till middle age is attained. In early youth all species, even the most light-demanding, can tolerate a certain amount of shade. Plants in their first stages of growth are always grateful for some protection against great heat, and the over-rapid loss of warmth by radiation. Shade and shelter may in this case be considered together. In the later life of our forest trees there is no call for protection. A plentiful supply of light then acts favourably upon the growth of all species. The foliage becomes more luxuriant, the process of assimilation is stimulated to greater activity, and an increased production of wood results. With an accession of light, seed production is encouraged, but takes place at the expense of wood increment.

Thus it is that man has it in his power to accelerate the processes of timber or seed production as he will, and advantage is taken of this fact in forest practice.

The forester thins out the material which interferes with the objects of his management. The result of his operations is not equally marked with all species, nor, indeed, with all trees of the same kind in one wood. Species like the Scots Pine and Birch, which tend naturally to form thin, open woods, when given more light and space, respond in growth less quickly than do the shade-bearers. In all woods there are found individual trees with their crowns so raised above those of their neighbours that they are practically independent of man's assistance. These are the so-called dominant trees. On the other hand, there are stems already so hopelessly crippled and suppressed that interference on their behalf would be useless. The class which really can take advantage of a more free position is that formed by actively growing average trees. These have the power through crown, root, and stem quickly and energetically to increase in size. The behaviour in regard to light is to some extent influenced by age, and the condition of the locality in which the wood is situated. The better the situation the more shade are the species able to bear.

Between light-requiring and shade-enduring species the transition is by no means sharply defined. The one class gradually merges into the other. To the light-demanders belong Larch, Birch, Ash, Scots Pine, and Oak; to the shade-bearers, Spruce, Hornbeam, Beech, and Silver Fir. Taking only the species that are sylviculturally most important, the arrangement according to their capacity for bearing shade is in the following order: Silver Fir, Beech, Spruce, Oak, Scots Pine.

Pure Woods and Mixed Woods

A wood consisting of one species, with, perhaps, a few stray specimens of other trees, is known as a *pure* wood. On the other hand, when the crop is composed of several species —usually two, but frequently more—it is said to be a *mixed* wood. In mixed woods, the constituent species may be uniformly distributed by means of single trees, or the arrangement can be by lines, strips, groups, etc. Seldom are the species found in equal numbers, one of them being usually more or less predominant. The species composing a mixed wood may all be planted simultaneously, or one or more may be added at a subsequent period. A primary distinction, then, is made between even-aged and uneven-aged mixtures. Again, a mixture is not necessarily permanent. Frequently, certain of the component species have only a temporary purpose to fulfil. This may be either as shelter for the other members in the mixture, or for soil protection. The former is much employed where delicate species are raised upon bare situations. In cases where natural shelter is absent on exposed places, one may first plant a hardy species, such as Scots Pine, Larch, or Birch, and under the protection thus afforded, the permanent crop can be raised. The purpose which the species first introduced fulfils is that of nursing the young crop. As soon as this function is accomplished, or the progress of the main crop is in any way threatened, these "nurses" must be removed.

Under-planting, or otherwise introducing species for the purpose of protecting the soil, comes into use in the case of older woods. When, either from natural causes or past mismanagement, woods have become too open to shield the soil from wind and sun, an underwood is frequently planted in order to restore or maintain the productivity of the ground. The desirability for this lies in the fact that under an insufficient leaf-canopy, unfavourable changes occur in the condition of the upper layers of the soil, resulting in retarding the older wood's further development, and threatening to add difficulties to the regeneration of the area. To avoid this deterioration, shade-bearing species—usually Beech or Silver Fir, less often Spruce—are introduced below the existing crop.

The conspicuous merit of mixed woods consists in the additional value and quantity of the material raised. Especially is this so when light-loving and shade-bearing species are together in the mixture. The productive capacity of the soil is in such cases more fully utilised than in a wood composed only of light-demanders. The action of the shade-bearing species lies in the early and complete removal of the light-demanders' side branches, consequent on these being killed from want of light. Cleaner and better-shaped boles result, and the timber is enhanced in value.

Further, there is the effect upon the soil. Under the thin canopy provided by light-demanders in their later periods, heavy rains wash away valuable chemical substances from light soils, while heavy clay is rendered more impervious. Strong light upon forest soil encourages the growth of heather, blaeberry, and so forth, which gives rise to accumulations of fibrous organic matter; grass also springs up, impoverishing and drying the soil. All this is prejudicial to forest growth, and can be prevented by maintaining a close canopy such as may be had from the association of shade-bearing with light-demanding species.

Mixed woods are less exposed to certain dangers than woods consisting of a single species. Against wind the combination of deep-rooting with shallow-rooting trees is very desirable; for lessening the risk from forest fires a mixture of deciduous with coniferous trees is serviceable; insect and fungus attacks may to a certain extent be combated in a similar manner by interspersing species which are particularly prone to these dangers (Scots Pine, Spruce, Larch) with the less frequently injured broad-leaved trees. Such action is, however, no complete protection, and mixtures that in some ways appear to be excellent must often be renounced on account of more weighty considerations.

Species selected for even-aged mixture must realise the following conditions: (1) they must be suitable to the situation; (2) they must not be too dissimilar in their rate of growth; and (3) they should possess different forms of root system. Only rarely can all these requirements be satisfied, and so it happens that instead of the best form of mixture—that of even age, with a distribution of the species by single trees—other means have often to be adopted in bringing the different kinds together.

The arrangement may be made by grouping the species suitably, or if by single trees, having them of dissimilar age. In mixing by area in woods of even age, single rows and narrow strips are not to be recommended. With unequal rate of development the more slowly growing species become suppressed, and interference through the removal of the aggressive members—an operation often delayed too long—generally results in making a deficient crop of badly formed stems. The group system of mixture is that best adapted to utilising the varying quality of the ground; but in its adoption it must be kept in mind that the larger the clumps, the less likely are the other advantages of a mixture to be realised.

Formation of Woods by Sowing and Planting

The establishment of woods may be by the spontaneous action of nature, when the term *natural regeneration* is used;

or by the artificial introduction of plants or seeds, the general system being known as *artificial regeneration*.

Generally speaking, the natural means is the cheaper method. It frequently happens, however, that artificial regeneration is the only treatment possible or, at least, desirable. Such is always the case when there is no old crop already on the area to be dealt with, or when there are too few trees capable of giving seed; and, again, when it is wished to change the species from that previously grown. Unfavourable condition of the soil or parent trees may make it inadvisable to adopt natural reproduction.

With certain trees, particularly Spruce and Scots Pine, natural regeneration is indeed possible, but so many difficulties are connected with it, that it is usually both surer and cheaper to completely remove the standing crop and to replace the species artificially. In nearly all cases one must assist natural regeneration to a greater or less extent in order to obtain woods of the desired composition.

The artificial establishment of woods may be either by sowing or planting. With the latter, in ordinary forest practice, the plants are nearly always raised from seed sown in nurseries; but cuttings, layers, and root-suckers are also employed. In favour of the direct sowing of forest ground it is claimed that it approaches nature's method of reproduction more closely, that it is usually cheaper than planting, and that it provides a denser crop of young trees. Planting, however, is often preferable. With it there is not the same risk in depending upon a particular season's yield of seed; it gives a start in age and in power to resist many dangers that seriously affect small plants springing from seed directly sown in the forest. Planting is therefore clearly indicated under difficult conditions, such as high exposed situations, or where there is a strong growth of grass or other herbage. For the filling of vacancies that have occurred in recently stocked areas, plants, not seeds, are used.

If from economic grounds sylviculture is to be practised with as small an expenditure as possible, the choice of the method of procedure must be very carefully considered. It is not sufficient to have regard only to the initial cost, but the sureness and permanence of the result must also be thought of. False economy frequently leads to very defective work in planting. This, by necessitating the repeated and extensive filling in of blanks, makes what appeared at first to be a cheap method of regeneration actually more costly than had a greater sum been originally spent and an immediately successful result obtained.

Reclamation

It may happen that before planting operations can be taken in hand the land requires to be specially treated because of peculiarly unfavourable conditions. Draining may be necessary; an impermeable substratum may be met with near the surface of the soil; shifting sands may have to be fixed, or thick masses of vegetable matter treated.

Of the many methods of **draining** land, that by means of open ditches is the only one generally applicable within the woods. Pipe drainage is frequently made use of in forest nurseries. The drainage of woodland is an expensive operation, and if not very cautiously carried out, much harm may be done by it, particularly to adjoining lands. It therefore behoves the forester to proceed with it only after very careful consideration.

As regards an **impermeable substratum,** the common form is known by the term moor-pan. It consists of a layer of sandy material cemented by organic acids into a yellow or brown stone-like mass of varying hardness. On exposure to the influences of air and frost, it becomes pulverised and loses its injurious properties. Frequent in land bearing a growth of heather, moor-pan is found chiefly in poor sandy districts. It occurs at various depths, and in quite thin sheets, as well as layers as much as one foot thick. The ill effects of moor-pan consist in preventing the roots of trees from reaching the deeper soil, and in hindering the percolation of water into the subsoil in wet weather, while it stops the upward passage of moisture in time of drought.

If an impenetrable stratum of this kind be found at a depth that will interfere with root formation, it must be broken. Where the conditions permit, this may be effected by subsoil stirring—for work on a large scale, by means of the steam plough, and for small areas by picking (Fig. 1) and trenching, so that the soil is inverted. Owing to the great cost of the operation, it is not usual to plough or trench the whole ground, but to limit the work to strips where the trees will be planted. If insufficiently broken up, a fresh moor-pan is apt to form within a few years, therefore the cultivation should be deep and thorough enough to ensure complete disintegration.

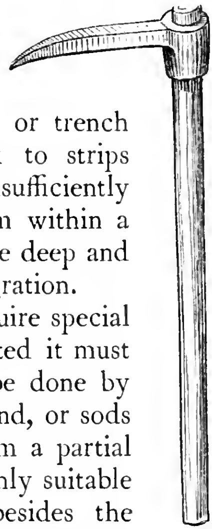


FIG. 1

Localities in which **sand-dunes** occur require special attention. Before shifting sand can be planted it must be at least temporarily fixed. This may be done by strewing Scots Pine branches over the ground, or sods of a convenient size can be arranged to form a partial covering over the unstable surface. The only suitable species to plant on inland dunes are, besides the common Scots Pine, *Pinus Banksiana* and *Pinus rigida*. For sea-coast sand-dunes Maritime Pine (*Pinus maritima* or *P. Pinaster*) has proved of great value.

Another work of reclamation is the **treatment of excessive quantities of organic matter.** These offer great difficulties to afforestation. Peat mosses approaching a depth of three feet cannot be successfully planted; the difficulties are too great and the expense of formation too high to be at all in keeping with the returns. Where, upon turning over the peat in simple digging, the mineral soil is met with, planting may usually be carried out successfully. If, in an old wood, leaf litter has accumulated, as it frequently does in hollows, to an extent that would be harmful to the introduction of a new crop, the excess must be disposed of before commencing the regeneration work.

Direct Sowing: Soil Cultivation

The task of reclaiming the land having been carried out, or happily found to be unnecessary, the forester's attention is directed to soil preparation. This consists in rendering the forest area suitable for the reception of seeds or plants. Soil preparation must aim at making the conditions favourable for the germination of seed, or for the proper development of young plants. It consists of, first, the removal of any harmful soil covering; second, the cultivation of the soil.

Should there be but a sparse growth of grass or a thin coating of leaves or moss, the soil cover will require no attention; but if there be shrubs, heather, blaeberry, broom, or rough grass, these must be disposed of by cutting, paring the surface, or in some cases by burning.

On light soils liable to become unstable, or on slopes where washing away of the soil is to be feared, complete removal of the surface cover should never be resorted to; to expose only strips or patches of the soil is then infinitely preferable.

Soil cultivation may be accomplished through the complete tillage of the soil—by the loosening of the surface only, or by partial working at the spots where the plants or seeds are to be introduced.

Complete working of the whole area is seldom practised. It is only advisable where agricultural land is being transformed into woodland. The ground, after being cultivated, may bear agricultural crops for a few (two to four) years. It may then be sown or lines of forest trees planted, and between these lines the ground may still be utilised for a year or two for the growth of crops. This cheapens the formation of the wood, and furthers its growth by the thorough cultivation of the soil. On the other hand, the agricultural crop extracts much of the soil's nourishing matter, so that by taking several crops from poor land the trees suffer.

Surface loosening of the soil is effected by the use of the grubber or cultivator, horse-hoe, harrow, hand-hoe, and rake.

The system most in vogue in well-conducted forestry is the thorough preparation of patches or strips of limited size. On level ground strips are formed parallel to the longest side of the area. On slopes, whether made with the plough or by hand labour, they should run horizontally, following the contour of the hill. A type of strong forest plough is shown in Fig. 2. With hand labour the strips may be hoed,

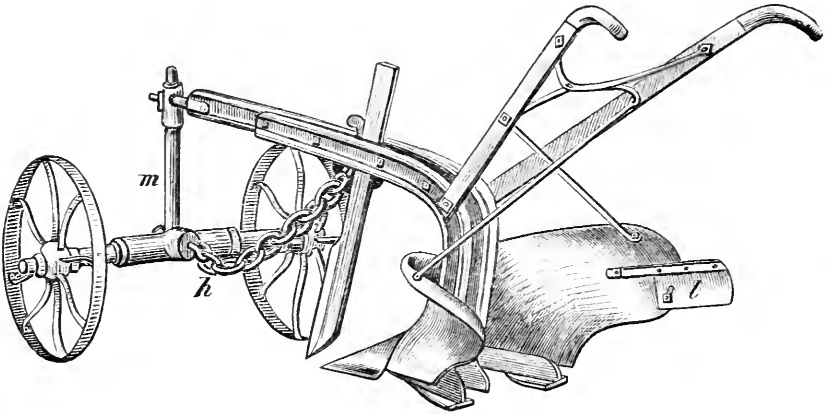


FIG. 2. FOREST PLOUGH
(Only one "wing" (*l*) is shown in the figure)

dug, or trenched. The depth to which the soil is stirred may be only a few inches as with the hoe, nine or ten inches in digging, and in trenching considerably more than a foot. The width of the strips varies from a few inches up to about three feet, according as the plants are threatened by weed growth from the unprepared ground. The distance between the strips is regulated by the width of the strips, and also with regard to the nature of the soil's surface cover, the selected species' rate of growth, and the density of the crop. Strips of a foot broad may be from three to four feet apart.

Cultivation of the soil in *patches* occurs either in the form of squares of from one to five feet on the side, or as interrupted rectangular strips. It is useful chiefly in situations where the presence of large stones and roots makes long connected strips difficult or impossible. By its means a species may be brought into mixture with others already on the ground. For very broken land or peat moors, where soil is conveyed to each planting spot at much cost, patch-planting is the only method suitable.

As the area cultivated is less than by strips, preparation of the soil by patches is cheaper, though not quite proportionately so.

Collection of Seeds

In part, seeds can be collected in the woods locally, or they may be obtained from a seed-merchant. The former means is preferable in the case of those seeds which should be sown shortly after ripening, viz. Silver Fir, Elm, Oak, and Beech; but Scots Pine, Spruce, Larch, and Weymouth Pine seed must usually be bought, as the cones have to be treated in seed-kilns.

Storing of Seeds

In the storing of seeds certain difficulties present themselves. The seeds of some species must be kept dry, others moist; a few lose their vitality if stored for a few weeks only, others require a year or more to germinate. The method of storage must vary with the nature of the seed. Many seeds, including those of conifers, are stored in sacks or barrels, in cool, airy lofts. Ash and Hornbeam seeds which remain inactive for eighteen months can be preserved in well-drained trenches in the soil, or they may be mixed with damp sand and stored in boxes under cover. Acorns and beech-nuts, when these are to be sown in spring, lie during winter in low, closed-in sheds that have preferably earthen floors, and there they are turned over every three weeks or so. After being gathered, acorns and beech-nuts, previous to their being stored, should be spread out on an airy place to a depth of about eight inches, and daily turned until dry. They can afterwards be mixed with sand to remain in the sheds in heaps about one foot deep.

Testing of Seeds

The quality of seed may be judged to some extent by close inspection, helped by the cutting open of a considerable number. But the only reliable test is that of germination. For finding the germinative power of seed many contrivances have been devised, from the simple earthenware dish or moistened blotting-paper to fairly complicated apparatus ; for work on an extensive scale the most desirable forms of seed-tester are those of Nobbe and Steiner. In testing, the operator must always keep in mind that besides moisture, seeds require for their germination a favourable degree of warmth and a supply of fresh air.

Season for Sowing

To sow, as nature does, just when seed becomes ripe, is not possible in the forest except in autumn and in spring ; but in the nursery during suitable weather one can sow at any season. Owing to the many dangers, especially mice and birds, that beset seed lying in the ground over winter, spring sowing is generally preferred. Still, for Silver Fir, Oak, and Beech, autumn has much to recommend it. From the time of inserting the seed, trapping should be proceeded with in order to lessen the damage by mice.

Methods of Sowing

The method of sowing depends largely upon the state of the soil and its previous cultivation. Broadcast sowing, whereby the whole of the ground is sown, may be resorted to, or partial sowings may be preferred—by drills, in strips, in prepared patches, or, in the case of large seeds, by dibbling. Broadcast sowing is best carried out by distributing the seed half in one direction, half in the other, at right angles to the first, either by hand, as is usual, or with the aid of a sowing machine. Machines, in the form of drillbarrows, similar to those used in agricultural practice, are often used for sowing Scots Pine seed, but less frequently for the larger seeds—acorns and beech-nuts.

It is necessary to cover most seeds with soil after sowing. The amount of covering varies according to the method of sowing and the size of the seed. The larger the seeds, the deeper should they be covered; acorns are buried one to one and a half inches deep, the seeds of conifers not more than half an inch, Alder and Birch seeds have at most only a little fine soil strewn over them. The rake is the implement usually employed for covering seed. With Alder and Birch seeds, it is only necessary to roll or otherwise firm the soil after sowing.

A difference, which is very marked in the case of delicate species, exists between sowing under the protection of a wood and quite in the open. Where a position is much exposed, a temporary protection wood may be first grown, and in the shelter it affords seeds can be sown. For instance, Birch may be planted, and after a few years acorns can be inserted in intermediate lines. The system of sowing forest seeds along with an agricultural crop may also be alluded to as one that affords some shelter in the first year.

Planting

Direct sowing of forest ground has many disadvantages. Upon poor soil more young plants may spring up than can well be nourished; upon fertile situations other forms of vegetation grow so quickly that tiny forest seedlings are suppressed, or only saved after expensive measures for "cleaning" have been resorted to. Only the medium soils are suitable subjects for sowing, and they must be tolerably free from weed growth.

Owing to the rather uncertain nature of direct sowing, the system of planting by which stock that has been raised elsewhere is made use of, is largely practised. The young plants come either from nurseries or they are taken as self-sown plants from existing woods. It usually costs less to collect plants that have sprung up naturally and abundantly in the woods, than to buy young stock or raise plants from seed in a nursery. But the results are not nearly so sure as in the latter case. The use of wild seedlings is, at any rate, limited. Such plants are not generally employed for establishing a wood, but for the filling in of blanks that have occurred in a recently regenerated area they are frequently found useful. Especially is this so if the plants are lifted without loosening the earth attached to their roots. The secret of success with such plants depends almost entirely upon the treatment they receive when being lifted and transported. In all cases only the best developed should be selected; ill-thriving or stunted plants must not be taken.

Apart from Willows, Poplars, and Limes, the use of cuttings, layers, etc., hardly comes into consideration in practical forestry, though in arboriculture many species are thus propagated. Occasionally young plants of broad-leaved species, particularly Oaks, are cut down to within half an inch of the collar or root-head. Thus only root and stock are planted, and the latter sends out coppice shoots. It is at times a useful practice, as, for instance, when the upper portions of young Oaks have been frozen in an unfavourable season.

The care taken in planting out forest stock cannot be too great. It is a delicate operation, demanding the utmost caution in the treatment of the plant. For the greater certainty in preserving vitality, the plants are sometimes removed and inserted into new ground, each with a clod of earth still adhering to the roots. Such ball-plants, as they are called, are practically undisturbed in their growth, but they are awkward to transport, and are on this account expensive. They require to be raised in soil which is fairly binding, and altogether present difficulties that circumscribe their use. So it is, that plants with naked roots are generally found most suitable.

Bunch-planting, the insertion together of two or more plants, is a practice now rarely followed; single planting allows of more natural development, and has every advantage over the former method.

Ordinary nursery stock comprises, apart from layers and cuttings, seedling plants, transplants, and saplings. In Britain, plants are called "seedlings" so long as they are not removed from the seed-bed. They are generally from one to three years old. Transplants, on the other hand, are small plants that have been once or several times set out in nursery lines; and saplings are older transplants of deciduous species, usually from four to nine feet high.

Forest Nurseries

Nurseries may be either of a temporary or permanent nature. Both forms have their advantages. The former are more simply formed, and being placed adjacent to the area about to be planted, save distant transport. In hilly country, plants so raised have the advantage of remaining in the altitude and under the conditions in which they were reared. But perhaps the greatest advantage gained by using a nursery for only a few years is that it requires little or no manuring, and a portion of the plants may be left upon the ground to form a plantation after the purpose of raising nursery stock has been fulfilled. The manuring of permanent nurseries to supply materials withdrawn in the removal of young plants, is not effected without considerable outlay; but, again, such nurseries generally yield better plants under the more intensive treatment which they receive; the most suitable site as regards soil, aspect, etc., may be chosen for them, and protective measures can be more easily enforced than is the case with shifting nurseries.

The site most suitable for a nursery is a well-sheltered piece of ground having a gentle slope to the north or north-east—the exposure least dangerous for frost. The soil should be deep, fresh, friable, and as clear of stones as possible. A sandy loam is far superior to strong clay soil. Temporary nurseries are usually formed on newly cleared areas.

The size of the nursery depends upon the number of trees required, and on whether the seedlings raised are to be set out in nursery lines once or oftener. To give an approximate idea, the area necessary to provide three- or four-years-old transplants must be ten times that of the seed-beds, and for six-years-old plants, twenty times.

For temporary nurseries a lighter type of fence than is necessary for permanent nurseries is sufficient. The latter may have strong wooden or iron railings or hedges round them, but usually require substantial wire-netting fences as well.

Land intended for nurseries generally requires to be trenched to a depth of over a foot. During this operation, all weeds and the larger roots and stones should be gathered and removed. For light soils and on shallow land, digging is generally all that is needed. On account of the damage done by frost-lifting on Alder seed beds, digging is, in that case also, more suitable than trenching. In raising Scots Pine ball-plants from seed, the uppermost layer only of the soil is bared, and lightly hoed or raked. Here the object is to keep the ground as compact as possible, so that the soil may cling to the roots when the plants are lifted. On steep slopes it is occasionally necessary to grade or even terrace the ground. Permanent nurseries require periodic trenching of the soil, chiefly for the destruction of weeds.

Manures may be applied to nurseries in three forms—(*a*) as farmyard dung, which is particularly good for tenacious soils; (*b*) as vegetable matter in the form of compost, leaf mould, or as "green manuring," *i.e.* the growing of such crops as lupines, vetches, or rape, with the view of digging them into the soil to enrich it and improve its physical qualities. (*c*) The land may receive a dressing of artificial manures—basic slag, dried blood, bone meal, nitrate, kainit, etc. These are often applied along with compost or leaf mould.

Lupines should be mown when they commence to bloom, and at once dug in. Farmyard and similar manures should be buried to a depth of from eight to twelve inches, whereas artificial manures, owing to their solubility, should be sown broadcast over the surface and lightly raked in. Spitzenberg's soil-mixer ("Wühlrechen") is a very useful implement for incorporating compost and artificial manures with the soil.

Cultivation should be carried out some considerable time before sowing, in order that the land may settle; otherwise light land must be firmed by treading. A convenient arrangement is to make the seed-beds four feet six inches broad, with paths of one foot in width between them.

Sowing Seeds in the Nursery

Small light seeds (Birch, Alder, Elm) should be sown broadcast, all others are better sown in drills. Several modes of making the drills are practised. Two of the best implements for the purpose are the *markeur*, which resembles a

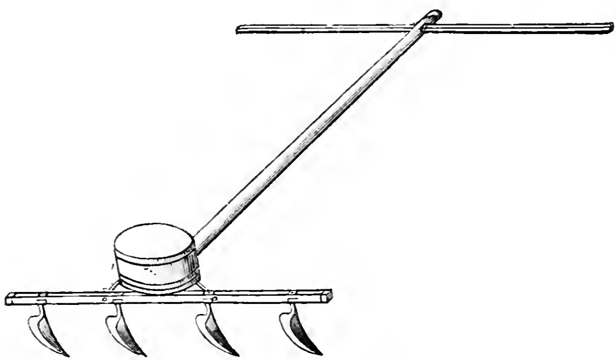


FIG. 3. MARKEUR

large rake, and Spitzenberg's patent drill-maker. A form of the first of these is shown in Fig. 3. The implement is drawn down the length of the bed, making small furrows for the seed to lie in. The drill-maker also works excellently. It forms the drills crosswise over the bed, and can be adjusted to suit any size of seed and any width between the drills. Nothing is better than the hand for broadcast sowing and for distributing the larger sized seeds, but smaller seeds can be sown more quickly and regularly with a "seed-horn" (Fig. 4) specially constructed for the purpose.

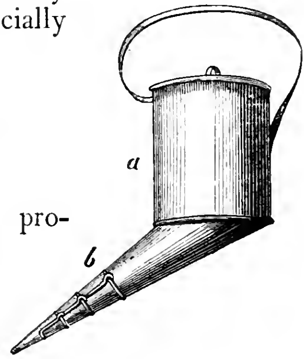


FIG. 4. SEED-HORN

Protection of Seeds and Seedlings

The seeds of conifers should be protected from birds by a coating of red lead. One pound of red lead is sufficient for ten pounds of seed. In the mixing as little water as possible should be used—one pint to fifteen pounds of seed. Most seeds require at least a slight covering of fine earth after having been sown, and the bed should be made moderately firm by light rolling.

The season in which the seed ought to be sown depends on when the seed ripens, but ordinarily it is in spring, at the same time as agricultural crops are sown.

The young seedlings must be kept free from weeds, and certain of them protected from frost and drought. Specially sensitive are the seedlings of Beech, Silver Fir, Birch, Sycamore, Ash, and Alder. Suitable shelter is easily erected. One form effective in keeping off birds, and reducing or preventing damage from frost and excess of sunshine, is shown in Fig. 5. Temporary screens made from Spruce or other branches usually fulfil their purpose satisfactorily. Such cover should be gradually reduced, until during dull weather in July it is completely removed.

As protection against frost-lifting during the small plants' first winter, particularly with slow-growing species, a sprinkling of pine leaves over the bed, or the laying of moss between the rows, helps greatly.

Transplanting

Plants are not usually taken directly from the seed-bed to the forest, but are transplanted once or several times in order to produce sturdy plants with well-developed root systems. As a rule, transplanting is first carried out either one year or two years after the germination of the seed, and it is repeated when the small crowns and roots are beginning to meet in the lines—very often after two years. In consequence of the shock unavoidably sustained during the transplanting, young plants take most of the first year to heal their injuries, and only in the second season make real progress in growth. Hence, with very few exceptions, plants should remain at least two years in the nursery lines.

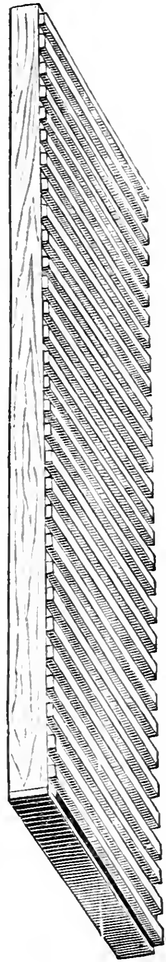


FIG. 5

In *lifting* seedlings the plants should be handled with very great care; in this operation the benefit is felt of having them in rows instead of broadcast. The spade, fork or grape should be inserted vertically and deeply enough, a few inches to one side of the plants. The spadeful of earth and plants is raised and allowed to fall again, so that the clod may be broken. Any system of pulling up the plants from imperfectly loosened soil is much to be deprecated. After freeing the roots from the earth the plants are collected, and small bunches of them are placed temporarily in the soil for protection against drying. Nothing is more important than attention to young plants to make certain that their rootlets be kept constantly moist. Exposure of conifers to sun and drying wind kills or seriously injures them in an incredibly short space of time.

The work of transplanting is done by means of a trench; small plants and all tap-rooted species may be set against the perpendicular side of the trench, which must be made deep enough to allow the roots to assume a vertical position. No bending to one side or doubling up of any portion of the roots is permissible. The plant is held in the left hand until soil is pressed against it to keep it in its place. When a row is thus prepared, the remainder of the soil is returned to the trench and the plants firmed by treading with the foot. Larger plants, and such as have a spreading root system, are better brought into the middle of the trench, where their roots are arranged in their natural form and the earth closely packed about them.

Space sufficient for free growth should always be given to nursery plants. In this connection it should be remembered that an over-wide distance between the nursery lines does not compensate for the crowding of the plants in the lines themselves—they must have room to all sides. A little additional expenditure, which may be incurred by adopting thorough methods, will eventually justify itself in the production of greatly superior plants.

At the time of transplanting, any bruised roots and tap-roots of excessive length must be cut off cleanly; broad-leaved species should have their crowns curtailed in proportion to the reduction of the root system, care being taken at the same time to improve the shape.

In transplanting "heeled-in" stock in dry weather, it is of much advantage to dip the roots of the plants into liquid mud. This "puddling," as it is called, gives to the delicate rootlets and root-hairs—the true absorbents of the plant—a protective coat which helps them to resist drying influences.

By "heeling in" is understood the covering of plants that have been lifted until such time as they may be inserted in the nursery or elsewhere. A trench with a slanting face is dug, preferably in a shaded place; plants with their roots well puddled are laid closely along this, earth is packed about the roots, and a second row of plants laid against the first. When there are several rows, the last one, being to the outside, is specially well earthed up.

In the later care of nursery stock, attention should be given chiefly to weeding and occasional loosening of the surface soil. It is found that keeping the upper layer of the soil stirred is the best way of conserving the moisture for the plants.

Packing of Plants and Arrangement in Planting

When the plants require to be transported any considerable distance they must be well packed. Small plants are conveniently placed in round baskets, a layer of moss being inserted between each layer of plants, the roots being to the middle; larger ones are laid on their sides upon moss and straw, these materials also cover them, and this admits of the package being tightly bound. Large saplings are tied in simple bundles, only the roots being protected as a rule, though hoops may be arranged to guard the stems. On arrival at the place where they will be planted out, the young trees must again be carefully heeled into trenches. As the plants become required, they are taken out, small quantities at a time, and brought to the planters in boxes or baskets, the roots having moss or earth about them.

The PLANTING SEASON may be either spring or autumn. The latter is chosen when there is fear that all the work could not be carried out in spring, and often for trees—like Larch—whose buds develop early.

In ARRANGEMENT, trees may be planted irregularly or at prescribed intervals—in the latter case, usually in rows forming square or triangular figures. By the quadrilateral arrangement, the space between the rows and that between the plants in them is the same. Rows with forms other than this are generally made so that the distance between plants is less than that between rows, but in the equilateral triangle, the distance between the plants in the rows is greater than between the rows themselves.

The GROWING SPACE of the trees in a wood or nursery is found by multiplying the distance between the rows by the space between the plants in the rows. The total area divided by this product gives the desired number of trees.

Irregular planting is resorted to in filling up vacancies in naturally regenerated woods and on stony ground where the distribution cannot possibly be governed by rule.

As to PLANTING DENSITY, it varies according to the object in view. Where the desire is to produce the maximum quantity of branchwood per acre without regard to quality of bole, wide planting may be advisable; but in planting for economic purposes, fairly close stocking is necessary. The aim should be to secure an interlacing of the crowns and branches between five and ten years after planting. Once this cover is produced, all the beneficial effects of competition for space and light commence. In the struggle, lower branches die and fall off, and length is given to the stems in the effort of the trees to reach the light. These are the conditions which make for long, clean timber.

The distance at which to plant must be regulated by the poverty or fertility of the soil, whether quick-growing or slow-growing species are to stock the ground, and whether the intention is to use seedlings, transplants, or saplings. On a good situation, and where rapid-growing or very large plants are employed, the number required will be fewer than under opposite conditions. Trees should not be planted so closely that their vigour is interfered with, but their activity should be directed towards increase in height rather than to lateral development.

It will usually be found suitable to plant four-years-old conifers at from three feet to three feet six inches apart. Commonly the planting distance does not vary more than from two and a half to five feet each way, when the object is a strictly economic one.

Methods of Planting

In planting, the special notching spade may be used, or the ordinary spade making an L or T notch; but in proper sylvicultural practice the most largely employed method is pit-planting.

The various shapes and sizes of pits, and the means taken to make them, depend on the age of the plants and the character of the ground. A very good form is shown in

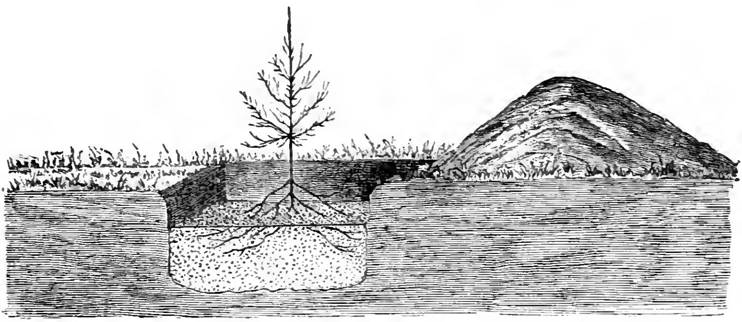


FIG. 6

Fig. 6. The surface sod is first skimmed off (the broad hoe, Fig. 7, will be found useful for this), then with the spade the upper soil is lifted to one side and the deeper soil to the other. Kneeling before the pit thus made, the worker takes a plant out of the receptacle, and holding it in his left hand, with his right he gathers the better soil about the roots. In the case of Spruce and several other trees, a small mound, composed of a few handfuls of loosened earth, is formed in the bottom of the pit, and the roots are arranged ("straddled") over this, allowing them freedom to strike in all directions through the soil. The earth is gradually brought into the pit and worked in between the roots, so that the latter are brought into close contact with the soil. Throughout this process the roots at different levels are each given their natural positions until all are carefully buried.

The soil is then pressed down, the rest of the earth filled in, and the whole tramped firm.

Some form of small planting hoe may be used to assist in gathering together the dug-out soil, and care must be taken to set the plant at the same depth at which it stood in the nursery. As a protection against drought, the skimmed-off sods should be placed, inverted, upon the top of the patch or pit.

For the preparation of the soil, which should always be done in autumn if possible, a narrow hacking hoe (Figs. 8 and 9) may be employed. These hoes are much used in

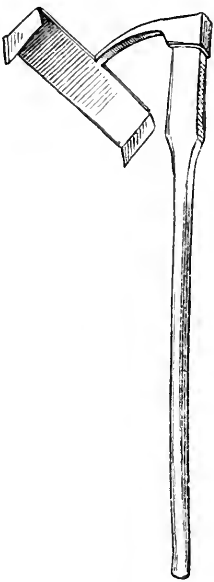


FIG. 7

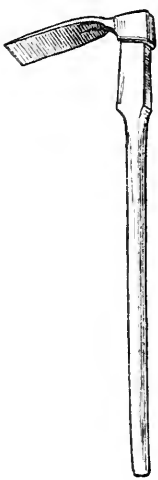


FIG. 8

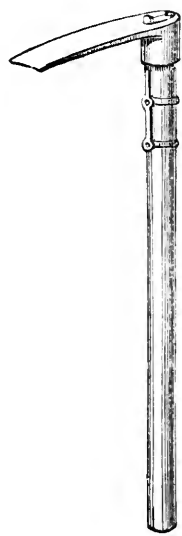


FIG. 9

hilly districts where Spruce is planted, and the cultivation need not be deep. There they do both better and cheaper work than the spade.

Following upon skimming and cultivation of the soil, or, indeed, without cultivation where the soil is naturally loose, the "notching" or "wedge" spade comes into operation. Fig. 10 shows one of those spades made of wood shod with iron. For most soils, however, the iron one, with only the handle of wood, is much better. It is narrower, and being also heavier, it pierces the soil more easily. Especially is it useful for the quick and efficient planting of small plants with tap-roots, as, for example, two-years-old seedling Oaks. As may be seen from Fig. 10, the blade of the tool is wedge-shaped. When plunged into the ground the tool makes a notch or nick (Fig. 11); by pressing to and fro the worker widens and deepens this notch, and gives it, upon the side further from him, a vertical face. Against this another worker places one of the plants which he carries, holding it at the proper depth. The notcher then drops a little soil down into the hole in order to satisfy himself that the roots are hanging perpendicularly, and drives the notching spade down again about two inches back from the plant. While thus sunk in the ground the spade is forced to close up the bottom of the hole by the operator drawing the handle back towards him, then by pressing it forward again he completely closes the notch. Children may be employed for inserting the plants.

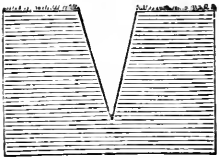


FIG. 11

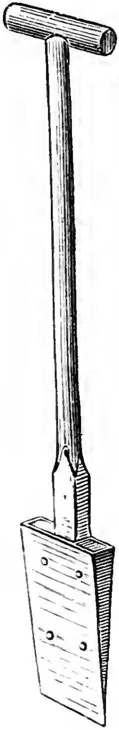


FIG. 10

It will be seen that this operation differs from the "notching" or "slit-planting" so commonly adopted for conifers in Britain. Using the common spade, two incisions are made into the soil either in the form of an L or a T. The corners of the sod are raised somewhat with the spade, the plant is slipped into the opening, the flap of sod is allowed to fall back, and by treading with the foot the operation is finished. Roots, which are twisted into the slit, lie horizontally and huddled together. They are unable to assume a normal form until after a lengthy period, during which time the development of the plant is retarded. If the weather conditions be in the least unfavourable after such planting, a great mortality ensues. With this kind of notch planting there is a constant danger of the roots being buried too deeply, as the depth is regulated by the thickness of the sod.

Occasionally, on very retentive soils, it is necessary to resort to the following practice: In autumn a sod about twelve to sixteen inches square is lifted and turned over on to the ground close at hand; in spring a small plant is inserted in the centre of the inverted sod. This plan enables the plant to get twice the ordinary depth of organic matter and a more friable soil to grow in.

When it is found desirable to plant marshy land which cannot well be drained, the soil may be raised into small mounds, into which the young plants are placed. This method is sometimes useful for the planting of Alder and Spruce.

A further modification of this last system is to make trenches, from which the earth is thrown up in flat-topped beds where the plants may grow. This is, of course, an exceedingly expensive method, to be employed only in emergency.

In all cases the mode of planting to be adopted must be determined by circumstances, as, for instance, the size of plants used, the condition of the soil, the amount of weed growth, and the cost of the operation. But the broad aim ought to be to secure to the young plant the most favourable conditions for growth at the minimum of expenditure. In other words, choice should fall upon the cheapest method that will prove effective. But efficiency is of first importance, and all the costs of formation must be reckoned upon the ultimate, not merely the initial, outlay.

Cultivation of the soil has many advantages, some of which may be shortly stated. It enables the roots to assume their natural position, the roots develop better, nourishing matter in the soil is converted into a more available form, and the physical condition of the soil is improved; the young plant is better able to resist drought, weed growth is repressed, and, along with this, encouragement is given to the young plant. As a result, less "beating up" is required, and a greater regularity of crop is assured.

In propagating trees from cuttings, "slips" are usually made, from eight to twelve inches long, from small stems or not too slender branches of one to two years old growth. They must be cut in the winter season—February suiting very well—and should bear two or three healthy buds. Cuttings are set in spring into soil prepared as for an ordinary nursery bed; they should be planted in such a way that only an inch or two of stalk, bearing a bud, appears above the surface. The earth is made very firm about them, and if the weather be at all dry they must be attended to with water. This system of propagation is best adapted for the raising of Willows and Poplars.

Natural Regeneration by Seed

Without man's interference, trees reproduce themselves either by seed or by coppice shoots. For the practical purposes of the forester the latter power is confined to the broad-leaved species.

The old method of stocking a felled area by means of seed shed from adjoining woods is no longer practised to any great extent. Instead, regeneration is effected by seed sown from parent trees left standing upon the felling area itself.

For the success of this operation certain conditions are essential:—

(1) The trees must be able to produce an abundance of good seed.

(2) The ground must be brought into a condition favourable to germination and the growth of young plants.

(3) Provision should be made for suitable shelter for the young crop.

The first two of these conditions are secured by a series of thinnings of increasing severity being carried out in the old woods. There results an accession of light and warmth which favours both the production of seed and the decomposition of the vegetable matter covering the soil. Without preparatory treatment the thick layer of humus that collects under the dense shade of a close crop may prove too much for the tender radicles of seedlings to penetrate, and unless they can reach the mineral or true soil, the embryo plants die as soon as they have exhausted the nourishment stored in the seed.

The age of the wood which it is proposed to fell and regenerate has also to be taken into consideration. Immature woods supply no fertile seed, or an insufficient quantity of it, while very old trees get past their best for seed production. Moreover, the ground below such old woods is apt to become dry, overgrown with weeds, and otherwise unfit, not only for the reception of the seed, but also for the development of the young plants. The limits of age within which the natural regeneration of our common forest trees is most certain to be successful, lie between eighty and one hundred years, or even a greater age in the case of Oak.

In an ordinarily dense wood where only moderate thinnings have been carried out, the process leading to reproduction is commenced by a preparatory cutting ; about one-fifth to one-quarter of the trees are taken, the removed material consisting chiefly of the smaller stems from which good seed cannot be expected.

The new crop is then obtained by means of a "seed-felling," which so far reduces the number of the existing older trees that seedlings are able to spring up and establish themselves. This cutting should, however, preserve for the young plants enough of the old wood to act as shelter from frost and drought. It should remove about one-quarter to one-third of the existing wood, the largest trees being those that are felled. The overhead shade ought to be better maintained where, as on limy soils, a strong growth of grass and weeds is feared; and also where tender species, like Beech and Silver Fir, are being raised, or where considerable danger from late frost exists. Under contrary circumstances the cutting may be a heavy one—especially when dealing with Scots Pine and Oak.

The seed-felling is usually carried out in a year in which the parent trees are bearing seed plentifully. With species that only rarely have a good seed year (*e.g.* Beech), it is important to take full advantage of each opportunity as it presents itself.

Where only occasional blades of grass are appearing, or where there is a slight covering of moss with the humus matter over the soil well decomposed, conditions may be said to be at their best for natural regeneration. If the earlier treatment of the wood has led to a different state of matters, some soil preparation becomes necessary. Generally this consists of hoeing strips about fifteen inches wide, running in parallel lines at intervals apart of three to four feet, in order to expose the mineral soil, which is then able to act as a seed-bed. For this work a broad hoe (Fig. 12) is suitable. Harrows and the grubber or cultivator are also frequently employed.

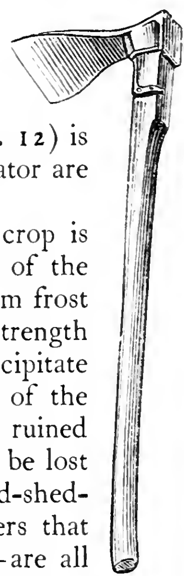


FIG. 12

After the seeding is well effected, the old crop is gradually removed according to the demands of the young trees for more light, and as the risk from frost becomes lessened by the greater height and strength of the plants. It is not advisable to be too precipitate with these subsequent fellings; hasty removal of the shelter wood has too often injured and even ruined promising young crops. What must also not be lost sight of is the fact that the sheltering and seed-shedding trees—particularly if they be shade-bearers that have long been confined in crowded woods—are all the time attaining a more profitable size by increasing rapidly in girth.

The appearance of the young trees gives the best indication as to when more light is required. When the leaves become small and have an ill-nourished look about them, and the rate of height growth of the leading shoots is diminished instead of increased each successive year, it is time to take action.

With most species several cuttings for the gaining of light take place—the first one usually in the second winter after the trees have sown the ground. The removal of the old crop is therefore somewhat protracted, but eventually, at a time indicated by the growth of the young crop, a clearance or final felling removes all the shelter trees. Occasionally, but not commonly, a few standards are left to grow through another rotation.

The period from the commencement of the operations to the final removal of the older trees varies with each species, situation, and method of working. It ranges between four years with Scots Pine to forty years (in some cases) with Silver Fir, but the usual time occupied is from ten to twenty years.

Upon the removal of the last of the old crop any spots left bare are filled up with strong plants.

The system of forming a new wood by natural seeding as just described, is that usually applied to Beech woods, and has been chosen as being the simplest form. The method is capable of very considerable modification.

The regeneration fellings may be carried on in a series of narrow *strips*, of which each, in order outwards from the fully stocked portion of the forest, represents a successive phase of the process. This plan is more commonly adopted in the case of Silver Fir and Spruce than with Oak and Beech, the regeneration of the latter being usually carried out over the whole area simultaneously.

Parts of the forest, where light has gained entrance prematurely, are often found to be already carrying a young crop at the time when systematic operations are taken in hand. In order to give uniformity to the new wood, the trees on these spots may be somewhat repressed by allowing the overhead or surrounding cover to become denser, or such clumps of "advance growth" can be used as centres for larger groups. Opportunity is sometimes taken of utilising small clearings in a pure wood to introduce other species either by sowing or planting, and thus to convert it gradually into mixed forest, wherein the new species have the advantage of a start. With these groups as nuclei, regeneration proceeds in widening circles, until, after a while, the connecting wood comes under treatment.

In the case of regeneration occurring over a *whole wood* or compartment ("Compartment System of Natural Regeneration under a Shelter Wood"), the process generally extends over a long number of years, and the method of stocking the ground bears a resemblance to that followed in the "Selection System." The forest is divided into a number of sections, among which the fellings are undertaken at short intervals (five to ten years). At each felling the largest trees, and any that are badly misshapen, damaged, or diseased, are removed. Attention is paid to the requirements of the young plants for light, and the needs—as regards thinning, etc.—of trees of all ages. In this way there are represented upon the area at the same time nearly all stages of forest growth.

Natural Regeneration by Coppice Shoots

Broad-leaved trees have the power, varying in the different species, of reproducing themselves through the production of coppice shoots. These latter spring from the stool and roots after the trees have been felled close to the ground. Areas restocked by this means are called Coppice woods.

Certain trees (Willows, Poplars) may be cut over at some distance from the ground, and shoots allowed to grow from the stems and cut surfaces. Pollarding is a well-known form of this, but is without importance sylviculturally.

The faculty of throwing up stool shoots of sufficient vigour to be useful can be artificially assisted by paying attention to a few matters. It is of importance that the trees be not too old and that the manner of felling favour the formation of buds. Although all broad-leaved trees may be able to produce stool shoots, only a limited number are thus treated in practical forestry. Formerly, more than nowadays, Oak was raised in this manner for the sake of its bark; Alders and Willows in marshes are customarily coppiced; and upon fertile soil in the south the Sweet Chestnut and Ash are often treated in this way.

Coppice woods, as a rule, demand a good soil; Oak, to give bark, requires a warm situation, and for Alders plenty of moisture is indispensable. Consideration should be given in practice to the fact that younger parts of trees are those relatively most rich in ash constituents. These being removed from coppice woods, it follows that the drain upon the nutrient strength of the soil is greater than is the case with close high forest, where generally the stem alone is taken.

Under this system, Oak and Ash are usually cut at fifteen to twenty-five, Alder thirty to forty, Osiers one to two years.

As a rule, coppice is harvested in the latter part of winter or in early spring before the buds begin to swell. Oak, for bark, however, is taken in May and June when the sap is flowing, and Alder in winter when the marshy ground on which it grows allows of the removal of the produce over the ice.

In cutting, care must be taken to use sharp tools so that a smooth surface on the stool may be left, and on no account must the bark be separated from the wood.

Large Alders may require the saw, but the axe is most commonly used.

In order to provide somewhat larger timber, a few straight, well-grown stems are frequently kept over to another felling.

Exhausted stools should be replaced by strong saplings from a nursery, or truncated plants may be used. In the case of Willows and Poplars, cuttings are often inserted directly into forest ground.

In the hilly district of Western Germany, a "catch crop" is frequently taken just after a coppice wood has been cut over. The surface covering and the refuse are burnt, and between the budding stools of the trees, rye or buckwheat is sown. Sometimes two such agricultural crops are raised before the coppice interferes to prevent further operations of this kind.

Coppice with Standards

The system of coppice with standards is a combination of an overwood of high forest with an underwood of coppice. The number per acre of standards or "stores" is not fixed, and the character of the wood varies according to whether they or the coppice form the predominant class. In the former case the method of management approaches that of the high forest selection system, and in the latter, that of even-aged coppice.

Coppice with standards has its typical form where consideration is given to both classes, and where the standards consist of light-crowned species uniformly distributed over the area. It is then a system affording special advantages to private proprietors, for it supplies a great variety of material much of which is useful for estate purposes.

It makes considerable demands on the fertility of the soil, and is really only in its proper place when upon rich, low-lying lands which are subject to occasional inundation. Beyond such localities the system fails to realise the volume and monetary returns of well-managed high forest.

The overwood is recruited partly from good stool shoots, partly from seedling or nursery stock. As the introduction of fresh plants can be effected only after a cutting, the age of the standards is always some multiple of the age of the coppice. It follows, also, that the interval of years between each even-aged class of standards corresponds to one rotation of the coppice. At each fall of the coppice the oldest class of standards is felled and the younger classes are inspected carefully, with a view, chiefly, to the removal of stems, which, from any reason—in themselves, or in their relation to the underwood—have become objectionable.

When the standards are very numerous, it is necessary to choose for the underwood, species, which, besides stooling out well, can tolerate a certain amount of shade. The Hornbeam, Lime, and Hazel are all very suitable for such use, and serve the good purpose of soil-protection. Very commonly the harvesting of the underwood takes place each ten to twenty years.

Practically all coniferous and broad-leaved trees occur as standards, but amongst the most suitable are Oak, Sycamore, Ash, Birch, and Larch. The Beech is by nature quite unfit for this purpose.

As woods treated under this system are largely made use of as game preserves, it is nearly always necessary to use saplings where fresh plants have to be introduced.

CHAPTER V

TENDING OF WOODS

In the management of growing woods, attention must be given not only to the immediate wants of a crop, but also to the preservation of the fertility of the soil.

There is an intimate relationship between the forest and the forest soil. The former is very much what the covering of leaf mould makes it. Leaves, needles, and dead twigs, cast down by the trees, form a mulch of decomposed and decomposing organic matter. Gardeners have long recognised the value of this mulch, or humus, as it is generally called, and it is as precious to the forester as to the gardener. It supplies plant food in a form pleasing to the tree, it retains moisture in the soil and absorbs it from a damp atmosphere, it renders a stiff soil porous, and to an over-loose soil it gives cohesion.

Forests should both produce and protect the humus. The maintenance of a dense cover of trees, forming a canopy with their crowns, alone makes this possible. A full crop naturally casts more leaves than a sparse one. Not only so, but under the shelter and shade of the former a much better kind of mould, known as "mild" humus, is formed, which easily becomes incorporated with the mineral soil. The preservation of this valuable product ought to be the constant care of the forester. Its presence makes a poor soil rich; without it, even the best soil deteriorates. The importance of humus and its origin must not be forgotten when considering the subject of the following pages.

Weeding, or Preliminary Thinning

The term "weeding" is here used in its sylvicultural sense of a preliminary thinning, and implies the act of removing, early, material not intended to take part in the development of the wood.

Weedings are the cuttings that take place from the time of the formation of the wood to the stage when the lower branches of the trees begin to fall off—a condition brought about by keeping the young plants close together and limiting the light to the upper portion of the crowns.

Twisted and prematurely broad-crowned trees, and species (*e.g.* Birch, Aspen, and Mountain Ash) that have sprung up from naturally sown seed or coppice, but which are not desired, are "weeded out." Where a wood contains trees (nurses), whose one object is to provide temporary shelter, the opportunity is taken at this time to remove them. In situations where the young trees are apt to suffer badly from bending or crushing by snow, it is found serviceable to merely take the tops from the undesirable members rather than to at once cut them away entirely.

The financial returns from any standard trees that may remain from the previous rotation, and which are felled during this period of the young wood's life, ought to be credited to the late, not to the present crop.

Weedings should be begun early, be cautiously carried out, and confined to the clearing away of individuals that threaten to injure the welfare of the young wood. The fact that the material they produce has commonly little or no value too often leads to these preliminary thinnings being neglected. But even neglect is greatly preferable to over-cutting, for the taking away of many stems at this time is highly prejudicial.

Thinning

No distinction can be drawn between a late "weeding" and an early "thinning." In the latter, as in the former, the removal of wide-spreading, misshapen, and other objectionable young trees is the chief thing aimed at. As the process of crowding begins to have its effect, the dead and dying trees increase in number, and the young wood should be relieved of these. The age at which the first thinning should take place varies, but it may be said to range commonly between the twentieth and thirtieth years, though it is often delayed still longer, as in the case of Beech, Spruce, and Silver Fir. If the so-called thinning be properly conducted—*i.e.* limited to the extraction of mischievous material—nothing but the cost of the operation need deter the forester from making it at any time, however early. But such cuttings should result in increasing, not in lessening, the struggle between the members composing the crop by freeing these latter from the domination of a few over-assertive individuals. The later thinnings differ somewhat in this respect, and the final thinnings still more. The last mentioned must often take into account the suitable preparation of the soil for the next regeneration.

The objects of thinning, in the sylvicultural sense, may be defined as aiming at the production of healthy, straight stems of proportionate thickness, but free from side branches. There is (1) the care of the better stems to be considered, and (2) the removal of actively harmful trees and those which have ceased to be useful. As a result of these cuttings, a certain amount of material is gained, but this should not be regarded as the object of thinning.

From the somewhat indiscriminate encouragement of the whole wood, through the maintenance of a very close crop in the early periods of growth, the later thinnings are devoted more and more to the furtherance of the better trees. This consists partly in freeing them from the encroachments of less desirable rivals, and at the same time trees that have recently passed into a sickly, dying, and dead condition are taken out.

Species, locality, and the condition of the wood greatly influence the treatment of the thinnings. It is an established principle in forestry that one should proceed more cautiously with young woods and with those in poor situations than with older woods or woods on very fertile soil. Naturally enough, trees growing under disadvantageous conditions are more readily affected by any violation of sylvicultural laws than are those more happily placed. Thinning may begin later, and should be lighter and more frequent when the forest site is a poor one. In woods deficiently stocked—whether this state arise from failure at the time of regeneration, or through faulty treatment in the past—stems have frequently to be left, which under better circumstances would certainly be removed.

There is a struggle for existence in woods of proper density, which continues throughout the life of the wood. This struggle is chiefly amongst the crowns, which keenly compete with each other for space and light. The competition results from there being many more trees upon the area than can possibly grow and survive. Only the most forward in the race can reach the light and live; as the light is to be had above only, all the trees press upward in long, straight growths. The shade of the crowns has, further, the effect of making clean stems by ridding the trees of their side branches, and the condition of the soil is improved by the addition of organic matter produced by both the dead and living trees.

The influence of density is thus seen to work powerfully in the interests of the forester. Its action should, however, be regulated to the objects in view, and this makes it desirable to have certain cuttings or thinnings periodically. The frequency with which thinnings should be repeated is determined by the energy of growth shown in the wood's development; in young woods the interval is generally about five or six years, and in older woods, ten years.

In order to have some sort of guide for the carrying out of the thinnings, a division has been made classifying the trees of a wood according to their crown development. Two great sections may be recognised—the dominant and the secondary trees.. To the former class belong those which, possessing well-formed crowns, occupy the upper position in the crop. The main mass of their foliage may also be said to be at a fairly equal height from the ground. The secondary trees comprise the lagging, overtopped, and dying stems.

The boundary between the two groups is, of course, not sharply drawn, and there is a constant process going on whereby members are crowded out of the principal into the inferior class. Occasionally, but more rarely, a portion of the crop raises itself from the latter to the former rank.

Up to the present, thinning has been conducted on the principle that the material to be removed should be looked for only amongst the secondary class of stems, and that the dominant trees ought not to be interfered with unless under quite exceptional circumstances. This has been the view held in Germany until recently, and it has obtained currency in Britain also.

Thinnings were distinguished as of three grades:—

(1) Light thinning: the removal of dead and dying trees.

(2) Moderate thinning: by which, in addition, the suppressed trees are taken.

(3) Heavy thinning: when also lagging members—*i.e.* those with somewhat reduced crowns that are being pressed upon from the side by dominant trees—are cut into.

In all cases the practice was to maintain a complete canopy overhead.

The new method departs from these principles in two ways. It does not countenance the taking away of weak and partially suppressed trees; and secondly, it is not afraid to attack the dominant class, nor even to interrupt the canopy, if it be to effect the removal of badly formed, abnormally broad-crowned, and tall "whipping" stems for the benefit of the remainder.

Attention to soil and wood-crop and the increase of the total production of useful timber are the objects aimed at in the modern system of thinning—the yield which the cuttings give is of quite minor importance.

Instead of ordinary thinnings which remove only the stems, which it is necessary or advisable to take for the well-directed growth of the others, a special kind of intermediate felling is sometimes resorted to. It is really an opening out of the stock, and quite distinct from thinning. By it a greater or smaller portion of the principal stems in the crop is taken—sound, healthy, and vigorous trees are removed, and the leaf canopy becomes permanently broken. Operations of this kind are carried out partly to encourage the remaining stems to increased production—especially in diameter growth—and partly to realise more timber from the cuttings than is possible from regular thinnings. Occasionally woods are thus opened out in order to introduce a new crop under the shelter of the older trees.

A great reduction in the number of stems on the ground has a very marked effect upon the soil. To prevent its deterioration a soil-protection wood, generally of Beech, Spruce, or Silver Fir, is often established. Should the existing wood itself consist of shade-bearing species, underplanting may be impracticable.

The desirability or otherwise of these heavy cuttings has not yet been definitely decided. As a rule, however, the practice of making a series of cuttings which become gradually more severe—the plan followed in the new process of thinning—will be found more satisfactory. The latter system furnishes a greater aggregate production and preserves the yield capacity of the soil better than sudden heavy fellings.

Pruning

Natural pruning is the rule in sylviculture. The crowns of the trees in a close wood monopolise the light and compel the lower branches to die through overshading. But there are cases when artificial pruning is required—either to enhance the value of stems so treated, or to prevent young plants being harmed by the branches of larger trees whipping and suppressing them. Trees with strong lower branches, left as shelter or for seed when regenerating forest ground, are often pruned to relieve the young crop at a time when their complete removal would be dangerous. Birch and Aspen occurring accidentally in a rising wood may also be severely pruned with good effect some years before being cut over. Pruning carried out to increase the commercial value of the timber should be restricted to the removal of dead and the lower of the weak green branches. All trees in a wood should not be treated in this way, but only those likely to remain to the end of the rotation.

Care ought to be taken to remove branches with a clean, sharp cut—flush with the stem. The only exception to the latter rule is in the case of strong limbs belonging to shelter trees shortly to be felled. It is then better to leave a projecting stump, in order to prevent any injury to the tree stem. At other times such shortened branches are very objectionable, for the cut surface heals with great difficulty; or occlusion may fail altogether, and decay is conducted into the bole.

Ordinarily, when the pruning is done with a view to the production of good timber, only those branches which are under two inches in diameter should be taken. When a larger branch is pruned from broad-leaved trees, the wound should be painted with coal-tar or other antiseptic material.

The season for pruning is from October to February, but preferably in the early part of winter.

CHAPTER VI

FOREST PROTECTION

By Forest Protection is understood the preservation of woodlands against damage caused by man and that brought about by external natural influences, such as noxious plants, animals, and unfavourable atmospheric phenomena. It considers measures for establishing and maintaining the security of woods and forests, so far as action is within the power of the forest owner in his private capacity. Regulations coming within the jurisdiction of the state belong to the subject of Forest Laws.

Protection Against Offences Caused by Man

In safeguarding the forest against the encroachments of man, it is of importance that all boundaries of woodlands be properly defined by means of permanent marks. The natural features of a district are frequently of too indefinite a character to be useful for purposes of demarcation, though streams, valleys, and ridges may certainly help in the task. In the division of forests, trees are to be avoided as being of unstable durability and apt to lead to confusion by becoming incorporated in the forest growth. Fixed points of boundary are mounds, fences, ditches, stones, and posts of iron, and these may be said to include the most usual forms of artificial landmarks.

Objects designating boundaries should be numbered where possible, described in a special register, and have their position exactly indicated upon plans or maps. The cost of construction and preservation of such marks is ordinarily borne as a mutual concern between adjoining proprietors. The marches or boundaries should be inspected periodically, so that damage may be immediately repaired and any changes noted.

Against theft of forest produce the best protection is the maintenance of a sufficient staff of wood reeves or keepers, along with effective penal laws. Much may also be done by avoiding undue exposure of material under circumstances calculated to provoke the temptation to steal. In localities where there is an indigent population, permission can be given for the gathering of dead, fallen wood; or the less valuable parts of trees and cheaper kinds of wood may be sold at specially low rates. Happy relations are thus established with persons whose uncontrolled entrance might be very harmful to the forest.

Protection against Fire

In the virgin forest, fires originate in making clearances for agricultural land, in extending pasturages, in failing to extinguish camp fires, etc. They are generally the result of carelessness or wanton recklessness, the throwing down of lighted matches, lack of proper attention to fires lighted for the disposal of forest refuse, heather burning, and so forth. Occasionally they can be traced to incendiarism, though sparks from railway engines are a much more fruitful source. Great Britain with its moist climate is not specially subject to forest fires, but a large proportion of those which do occur are due to the last-mentioned cause; and it is a remarkable fact that forest owners have as yet no proper security against incurring the loss thus occasioned.

Forest fires are most common in March, April, and May during dry east winds, because at that season there is much withered grass and dead leaves, but they may also occur in summer, especially after a long period of drought.

Young coniferous woods are those most endangered. The soil-covering of needles and twigs is exceedingly inflammable, and, when lighted, leads not only to its own destruction, but generally to that of the trees as well. Mainly on account of

Spruce occupying situations that are more moist than in the case of Scots Pine woods, the latter species suffers more seriously.

According to the nature of the forest fire, the following distinctions are made :—

Surface or ground fires—the commonest form, a burning of the litter or soil-covering of leaves, twigs, grass, etc.

Crown fires—so frequent and disastrous in North America. These burn the crowns, *i.e.* foliage and branches; they nearly always originate in a surface fire.

Stem fires—of little importance, taking place usually in single trees when hollow.

Deep soil-fires—of comparatively rare occurrence. Peaty moorland may become ignited in this way, and burn slowly but persistently. Practically the only measure to adopt against it is to isolate the part on fire by cutting trenches down to the mineral soil.

Preventive measures should aim at diminishing the risk, and limiting the possible extent of forest fires.

A system of fire lines, that is, intersecting paths or rides, commonly from eighteen to thirty-six feet wide, should be arranged through the forest, so that though one division may have to be sacrificed, the whole may not be lost. They form the best means of restricting the area of the outbreak, and provide points of attack against it. Marginal belts of relatively non-inflammable, broad-leaved species—as Birch, Oak, and Poplar—ought to be planted where Pine woods border upon roads and railway lines. Restrictions as to lighting fires within the forest and the smoking of tobacco can be drawn up—coming into effect during the dangerous seasons of the year. Locomotives running through forests should be fitted with means to prevent the emission of glowing cinders and sparks, and the place and manner of supplying the engine furnaces with fuel can be regulated.

A ground fire should be attacked from both sides simultaneously by beating, or rather sweeping, the edge of the burning surface with green branches, so that it becomes gradually narrowed into a wedge-like shape, and ultimately extinguished. A spadeful of earth dug hastily and thrown over any part where the fire threatens to cross the protection lines is found to be most efficacious.

Crown fires are customarily stopped by felling a strip of trees along a road or fire line sufficiently far in advance of the fire to enable the operation to be complete before the flames reach the point selected. The trees are felled in the direction of the fire, and, if time allow, their crowns are cut off and removed beyond reach of sparks.

In extreme cases, it is necessary to counter-fire. Counter-firing, or "back-firing," as it is sometimes called, consists in burning the woods along one of the defence lines to prevent the fire spreading into adjoining parts. It is able to proceed against the wind that is bringing on the main fire, owing to the fact that there is a draught towards the centre of conflagration. When the counter-fire meets the main one, both are extinguished from want of fuel.

After a fire has apparently spent itself, careful watching is still necessary until all danger of recrudescence is past.

Young woods of conifers that have suffered severely should be at once cleared and replanted. Dead and sickly conifers left from a forest fire are apt to become infested with insect enemies, particularly *Hylesinus piniperda* (the pine beetle). With broad-leaved trees there is not the same cause for haste, and it is often advisable to wait another season to exactly ascertain the extent of the injury. Where a surface fire has passed over an area occupied by young Oaks, and damaged them, the plants will usually send up an abundant stock of coppice shoots if they are at once cut over close to the ground.

Protection against Mammals and Birds

The Mammalia harmful to woods may be considered in the following order: (*a*) Domestic Grazing Animals, (*b*) Game, (*c*) The smaller Rodents.

Domestic grazing animals destroy the forest by nibbling buds, shoots, and leaves, trampling upon seedlings and young growth, loosening the soil upon steep slopes, damaging open drains, and in other ways. The *goat* is the most injurious, and where it occurs plentifully, natural reproduction of the forest is out of the question; *sheep* may be classed as coming next to the goat in point of harmfulness; *cattle*, in the forest, do not damage trees to a very great extent, preferring grass, if it be present; still, both they and *horses* bite and tear plants, and also injure surface roots by treading; they are exceedingly destructive to isolated young trees in parks. The practice of driving *pigs* into woods for pannage has nearly ceased. It is, perhaps, unfortunate, as they were more serviceable than harmful. They certainly eat a considerable quantity of Beech and Oak mast, and uproot some of the weaker plants; but on the whole their action is beneficial through the grubbing or stirring of the soil preparing the way for seed, and by their destruction of caterpillars and mice.

The conclusion come to in regard to the relation of grazing animals to the forest is that goats and sheep should be rigorously excluded, and that cattle, horses, or pigs should be allowed entrance only where they can do the minimum of damage. None can be given grazing in a wood from the time it is established by sowing or planting till the foliage is quite beyond reach of the animals. Should it be decided to admit a limited number of stock, adequate supervision by a herdsman is a necessity, and it must be certain that the legitimate food is present in sufficient quantity.

Game

The reconciliation of the game interest with sylviculture is a difficult problem in Britain. A great number—possibly the majority—of the woods in the country have been regarded merely or mainly as harbours for game. For this end they have been created and expensively maintained; the choice of the species, the severe early thinnings, the later treatment of the open woods, the mode of conducting the fellings, are all carried out as required by the gamekeeper rather than the forester. No doubt, the woods have generally fulfilled their object, and so may be said to have succeeded. Still, it is now seen that woodlands are capable of more. They should continue to give shelter and cover to animals of the chase, and certain plantations may always exist exclusively for these purposes; but the serious pursuit of forestry should limit sport to a place subordinate to that of timber production. The two are not incompatible: sylviculturally managed woods need not be, and in reality are not, without game; but owing to their interests being somewhat opposed, the kind and quantity of game must be regulated by, and made subservient to, the well-being of the forest.

The most harmful of the animals maintained for sport is the RABBIT. It bites and gnaws the bark of woody plants, nibbles the young shoots of practically all species of forest trees, and does a certain amount of harm by burrowing. Rabbits render natural regeneration impossible, and a very small number of them will quickly ruin any young plantation. They will even attack and kill smooth-barked trees of a foot or more in diameter by stripping the bark from the base of the stems.

Fences three to four feet in height, having wire-netting of fine mesh, buried partly in the ground and curved to the outside to prevent the animals scraping a way through, are some protection. But very young rabbits often get through the meshes, and older ones jump and climb over. During snowstorms in winter fences become hidden by accumulations of drifted snow, and then the creatures, ravenous for food, easily effect an entrance and do an immense amount of damage. Ferreting is useful; and foxes and weasels, as natural enemies, should be protected. Trapping is a general practice, but is not usually thorough enough; suffocation by poisonous fumes may well be brought to bear upon this dreadful scourge for its extermination. Burrows within enclosures should be dug out. Rabbits and trees cannot exist together, and as the female rabbit may rear four to eight litters, each of three to eight young, in a single season, it is obvious that to cope with the pest suppressive measures must be very severe.

The HARE is much less injurious than the rabbit, though the damage done is of a similar character. Hares nibble the shoots of deciduous trees, including Larch, more than the evergreen conifers; they also gnaw the bark to some extent. They are particularly troublesome in forest nurseries, where they do a great deal of harm in little time.

ROE-DEER injure young trees very seriously by browsing on the twigs, thus crippling and cankering the plants. The roe-buck in rubbing off the velvet from his horns does much damage to slender stems. Curiously enough, he is specially apt to select for this purpose any rare species that may be interspersed throughout a crop, so that these require special protection.

RED-DEER bite off buds and tender shoots, eat forest fruits, especially acorns and beech nuts, rub with their antlers, and, worst of all, strip the bark from stems with their teeth. For peeling, Spruce is preferred; but Scots Pine, Oak, and Beech also suffer badly. In some districts an extraordinary amount of damage has been wrought by red-deer; but, on the whole, the roe-deer is more destructive. Stems injured by peeling have a reduced timber value; they are more liable to windbreak and snowbreak, the weakened trees attract insect pests, and fungi are apt to take lodgment upon the wounds.

The best protection against damage done by game is the reduction of their number, together with the careful enclosure of all young woods and nurseries. For the latter purpose close wire-netting fences of sufficient height are generally most effective. Young conifers may have their leading shoots protected against nibbling by coating the needles with coal-tar, but care must be taken to avoid smearing the buds. Broad-leaved trees, saplings especially, are sometimes painted with fetid substances from the byre or pig-sty, mixed with milk of lime. Individual plants of rarer species, occurring sparsely in a young wood, can have guards provided for them consisting of rough branches. The felling of a few young trees in thickets frequented by red-deer is found to assist in checking the peeling of bark.

Of the SMALLER INJURIOUS RODENTS, squirrels, mice, and voles inflict most damage.

The SQUIRREL is well known to eat and store away fruits and seeds, and to bite off twigs for the sake of the buds on which it feeds. It has also a partiality for birds' eggs and young in the nest; but its chief harmfulness, not so generally acknowledged, is its habit of stripping the bark from trees. In this last respect, Larch, Scots Pine, Spruce, and Birch, about twenty years old, suffer severely. The attack, which usually takes place in June, seems to be worse in hot summers than in cool, wet ones. The squirrel removes the bark in irregular strips, in broad rings, or spirals from the stem at varying heights, but always in the crown of the tree. As a result, the portion of stem above the wound generally dies or is broken over by the first high wind. Very serious destruction has been done in this way in various parts of Britain.

In defence, squirrels ought to be greatly restricted in numbers. Dogs trained for squirrel-hunting may be employed; they can detect and "point," thus solving the difficulty of tracing the agile little creatures. Combined action should be taken by the proprietors of affected districts in order to get rid of the troublesome pest.

Various MICE cause serious damage by gnawing the bark of young broad-leaved trees, eating acorns and beech nuts, and wasting seed-beds in nurseries. The wood or long-tailed field-mouse (*Mus sylvaticus*) kills plants by severing the roots just below the surface of the ground, and by gnawing the stems.

The bank-vole (*Arvicola glareolus*) and the common field-vole (*Arvicola agrestis*) do mischief similar to that of mice, and, in addition, burrow very extensively, cutting through roots and uprooting plants. Even more than mice, voles are capable of increasing alarmingly in numbers, owing to the short gestation period of the females and the quantity produced at a birth. Their attacks have frequently amounted to a scourge.

The water-vole (*Arvicola amphibius*), or water-rat, as it is commonly but erroneously called, considered individually, is the most injurious of the voles. It forms branching galleries in the soil and bites through the thickest roots of trees. Fortunately, it is of somewhat solitary habits.

As a preventive measure against mice, the keeping down of grass by maintaining a full crop of trees up to the time of regeneration is recommended. When possible, seed should be sown in spring rather than in autumn. Drain tiles, with poisoned baits, may be placed about; the drain tile prevents larger animals from reaching the poison, and a piece of celery hollowed to contain phosphorus answers well as bait. Gamekeepers, by destroying owls, kestrels, weasels, and stoats, greatly favour the numerical increase of mice and voles.

Birds are troublesome chiefly in the forest nursery, where the finches, sparrows, and other small birds attack seed and the cotyledons, or first leaves, of germinated seed. Protection is given by mixing the seed with one-tenth part by weight of red lead, or by placing a framework such as that shown in Fig. 5 (p. 45) over the seed-bed.

Black game (*Tetrao tetrix*) occasion some damage by nipping out the buds, preferring Birch and Scots Pine.

Crossbills (*Loxia* sp.) attack the cones of Scots Pine and Spruce, and eat the seeds.

Woodpeckers (*Picus* sp.), especially the green species, do a certain amount of damage.

Most birds, by destroying insects, are much more useful than injurious.

Protection Against Forest Insects

In the insect world the forest has many enemies, some of which do a great deal of harm. Only in comparatively few cases are effectual remedies available. Among the most dangerous insect pests are the following:—

Coleoptera

Pine weevil, *Hylobius abietis*. The larva or grub (Fig. 13*a*) is harmless, living upon the inner bark of the roots and stumps of recently felled coniferous trees. The pupal (chrysalid) stage (Fig. 13*b*) is passed in a chamber or depression formed in the sap wood. Altogether the metamorphosis, from egg to perfect insect or imago (Fig. 13*c*), occupies about fifteen

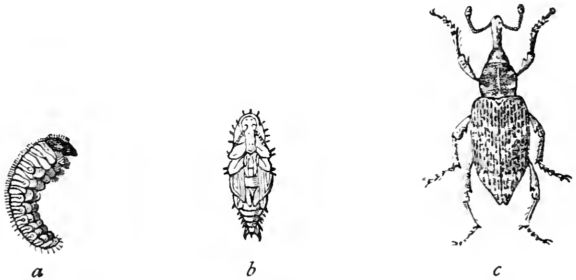


FIG. 13. PINE WEEVIL (*Hylobius abietis*)
a. Larva or grub. *b*. Pupa or chrysalis. *c*. Imago or adult.

months. The damage done by the weevils consists in gnawing small patches of bark from the stems of Scots Pine, Spruce, and other conifers, a preference being shown for three- to five-years-old plants.

The attack is combated with difficulty. To prevent oviposition, stumps and roots of conifers may be extracted ; or, in order that young plants may not be directly at hand upon the emergence of the weevils, the land may be allowed to lie fallow for a few years, when the stumps will have become old and unattractive for egg-laying. Unfortunately the soil deteriorates if the latter plan be adopted, grass and weed growth spring up to interfere with the process of restocking, and there is the loss in wood increment of the non-productive years. Such considerations may make it advisable to regenerate the area immediately after the felling and clearance of the old crop, and to depend on remedial measures

The latter consist of bark traps or pit-fall trenches Small pieces of fresh bark from Scots Pine or Spruce (kept in place by a stone being laid over each) are laid in lines at regular intervals over the area. The weevils collect under these, and are easily caught. Renewal of the bark becomes necessary after it has lost its resinous odour. Another method adopted in free, sandy soils is that of surrounding new plantations with small trenches, about eight inches deep, having perpendicular sides. The sluggish weevils, which prefer to crawl rather than use their wings, fall into these narrow cuttings, and are gathered and killed.

SMALLER PINE WEEVIL, *Pissodes notatus*. This insect closely resembles *Hylobius abietis*, but is smaller and has not the toothed femur characteristic of the latter. The larvæ live under the bark of two- to ten-years-old Pines, which may die in consequence. It is not so universally distributed as the last. Remedy lies in uprooting the attacked plants and burning them, in order to check the continuance of the pest.

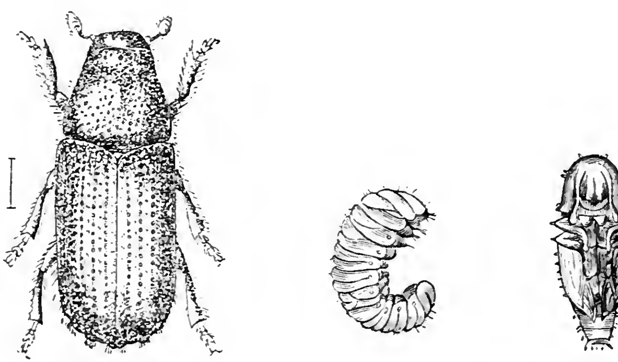
COCKCHAFER BEETLE, *Melolontha vulgaris*. From the date of egg-laying to the emergence of the mature insect four years are occupied. During nearly the whole of that long period the grubs are busily engaged devouring the roots of young trees, grasses, and other plants. Scots Pine and other conifers suffer more particularly. Finer roots are bitten through, and from the larger ones the bark is eaten away. Upon the Continent it is no uncommon experience to have large tracts that have been carefully stocked with strong plants, turned to barren wastes through the repeated depredations of the grubs of this insect.

The beetle eats the leaves of broad-leaved trees, and even the needles of Larch and Spruce, as well as the male cones of Scots Pine. But any damage which it does is of small importance compared to that wrought by the larva. Both in the nursery and in the open, the grubs are greatly to be feared, especially in countries having a hot, dry summer.

As a means of prevention, the avoidance of large clearings, which are selected for oviposition in preference to smaller strips, is advocated, but does not prove very effective. Starlings and rooks are of great benefit, preying upon both the grubs and beetles. Collection of the beetles is the surest exterminative measure. In France and Germany, during the "swarm month" of May, school hours are altered in many districts to allow the children to gather the beetles from young broad-leaved trees. In the early morning the beetles are sluggish and easily dislodged from the leaves and twigs. The young poles only require to be shaken with the hand; larger trees may be beaten with a padded mallet. The beetles fall to the ground and the children gather them into pails, being paid according to the quantity collected. Broad-leaved trees—Birch frequently—are planted on the borders of Pine woods to act as decoy-trees for the beetles.

The smaller Cockchafer, *Melolontha hippocastani*, appears along with the common one; its life-habits are the same except that it lives longer—four or five years—as a larva.

PINE BEETLE, *Hylesinus* (*Hylurgus*) *piniperda* (Fig. 14). The



a *b* *c*

FIG. 14. PINE BEETLE (*Hylesinus piniperda*)
a. Imago. *b*. Larva. *c*. Pupa.

mature beetle is about one-sixth of an inch in length, of a dark brown to glossy black colour, with antennæ and legs brownish red. On the wing covers, longitudinally arranged lines of fine punctures alternate with rows of tubercles. The latter are absent at the hinder end of the second row, counting from the suture between the elytra. The want of these few tubercles serves to determine this insect from the less frequently occurring *Hylesinus minor*.

Eggs are laid in March and April in felled stems and sickly and dying trees of Scots Pine, in galleries bored underneath the bark. The larvæ hatch out in a few weeks, and feed between the bark and wood until about the end of June when they pupate. In July or August the beetles appear, and at once fly to the crowns of the Scots Pine. There they bore straight into the pith of the youngest shoots at a distance of about two or three inches from the terminal bud. Either leaders or side branches may be chosen, and from the place of entrance the insect proceeds to work its way, in the centre of the shoot, towards the end bud. The hollowed shoots are easily broken over by high wind, and may be found lying under the trees, frequently in large numbers. The loss of these often gives the tree a curious appearance, as though it had been pruned—which, indeed, it has been, by the boring insect. In warm localities there may be two generations in the same year. Hibernation takes place under thick bark at the base of older Scots Pine.

As prevention, sickly trees should be felled and barked in May, before which time they will have attracted beetles to lay their eggs, and the larvæ will be destroyed upon exposure. When possible, Pines felled in winter should be allowed to lie in the forest until after the beetle's breeding season (March and April); then about May they must be barked to destroy the developing insects. If this manœuvre be impracticable, early removal of Pine timber and the use of trap-trees is the best measure to adopt.

The insect is one of the commonest and most destructive in this country.

Spruce-bark beetle, *Bostrichus* (*Tomicus*) *typographus*. Both as beetle and larva, this insect destroys Spruce trees by tunnelling just below the bark. As a rule, only trees in a non-flourishing condition, half uprooted and so forth, are selected, but when the beetles become very numerous they attack perfectly healthy trees also—beginning with those round the margins of cleared areas.

Prevention lies in the timely removal of all sickly and wind-thrown trees, and in stripping the bark from logs left lying in the woods over summer.

Striped conifer-boring beetle, *Tomicus* (*Bostrichus*) *lineatus*. Conifers not in full vigorous strength and felled trees are attacked. The female beetle bores a horizontal gallery into the wood and then, following along an annual ring, she lays eggs both above and below, in small depressions formed for them. The larvæ eat out short galleries to the upper and under sides of the main passage and pupate in these. The borings render the timber useless for many purposes, and its commercial value is thus reduced.

There is little likelihood of suffering from this pest if reasonable care be taken in the early removal of winter-felled timber from the woods.

Conifers felled when the sap is flowing should be immediately barked in districts where this beetle is to be feared.

Lepidoptera

Pine looper-moth, *Fidonia* (*Geometra*) *piniaria* (Fig. 15). From July till October the caterpillars attack the needles of Scots Pine, preferring trees from twenty to seventy years old. At first the needles are gnawed from the side, but later, as the larvæ gain more strength, the needles are bitten through and the base alone is eaten. Before the approach of winter the larvæ let themselves down from the tree-tops by means of threads, and pupate under the soil-covering. The pupa, about half an inch in length, is at first green, but becomes brown.

Where there is danger from this insect, the humus matter should be searched for pupæ, and if many be present, the leaf litter must be gathered together and burned. Insect-eating birds should be encouraged.

PINE BEAUTY or PINE NOCTUA, *Trachea piniperda.* The eggs are laid along the needles of Scots Pine. The resulting larvæ feed upon the needles, and may completely defoliate the trees. The chrysalid stage is passed in the leaf litter at the surface of the soil. Remedial measures as recommended in the preceding paragraph.

PINE MOTH, *Gastropacha pini.*[1] From eggs laid on the bark

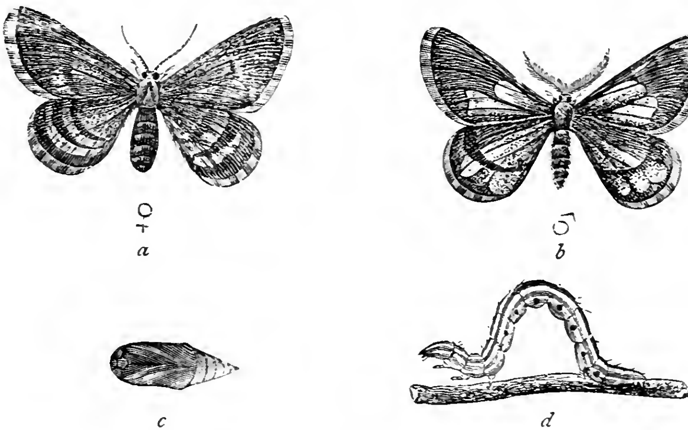


FIG. 15. PINE LOOPER-MOTH (*Fidonia piniaria*)
a. Female moth. *b.* Male moth. *c.* Pupa. *d.* Larva.

and needles of the Scots Pine come caterpillars, which gnaw the needles. They, however, make their appearance fairly late in the season (during August), and being at first of small size, they do comparatively little harm at this time, and soon seek winter quarters under the moss, needles, etc., that obtain in pure forests. Here they remain until March of the following year; they then ascend to the crowns, and resume their feeding till June, when they pupate. Attack generally takes place when the trees are in the pole forest stage or later.

As remedy, the ringing or girdling of the stems with tar

[1] This moth is not a native of Britain.

is effective in preventing the larvæ which have hibernated in the soil from again reaching the tree-tops. A special and inexpensive "caterpillar-lime" is the preparation now commonly used; it remains semi-liquid much longer than ordinary tar. The bark, at about breast height up the stem, is made smoother by rapidly scraping off the rough outside scales from a band about two inches broad, and this it is which is afterwards painted with the glutinous substance.

Pale tussock moth, *Dasychira* (*Orgyia*) *pudibunda*. In early summer (May and June) eggs are laid in clusters low down on the stems of Beech, and from thence the larvæ crawl to the crowns of the trees, where they feed upon the leaves. They descend from the trees in autumn, and pupate in the fallen material on the ground. The protective measure by means of bands of viscous tar, suggested for the eradication of the Pine Moth, is also applicable for this insect. The bands, of course, must be made before the eggs are hatched, and at a height (about nine feet) that will ensure most of the larvæ being caught.

Remedial treatment in this way is rendered fairly easy owing to the pest being generally confined to older woods, but it is not always necessary.

Black arches or nun moth, *Liparis monacha*. The ova are deposited in small clusters between fissures in the bark, and there they lie over winter. The young caterpillars, on emerging in April or May, begin by feeding upon the undermost twigs, but the attack generally ends by leaving conifers practically destitute of needles. In feeding, the caterpillars waste as much as they devour; they bite needles through about the middle, and eat only the short stump; leaves are nibbled only at the stalk and midrib, the rest falling to the ground.

Pupation takes place in a cocoon loosely attached to the stem, or about the lower branches, or upon underwood.

Few forest insects have caused so great destruction as the Nun Moth; Spruce and Scots Pine suffer very severely, while Beech, Oak, and Birch do not entirely escape.

Really effective means of prevention are wanting, though in this case, again, rings of patent tar round the stems are of much assistance. They prevent larvæ, hatched from eggs laid low down on the stems, from reaching the crowns; and they are even more useful in another way—the caterpillars while young let themselves down from the tree-tops by long spun threads, but to re-ascend they require to crawl up the stem. The sticky band, however, intercepts their progress, and they die in thousands below it. On the Continent this measure has frequently been carried out on an extensive scale, and has saved many forests. The pest invariably spreads from quite small centres of infection, so that every effort should be made to check an attack in its first stages. If then neglected, it is impossible to prevent a calamity.

OAK-LEAF ROLLER MOTH, *Tortrix viridana* (Fig. 16). The

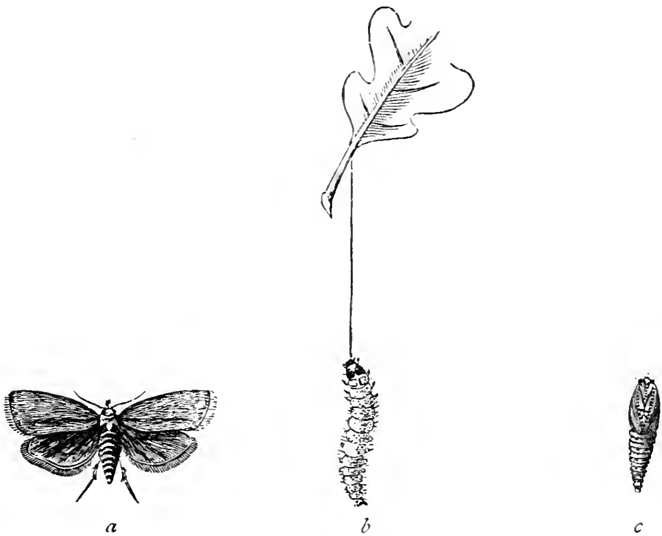


FIG. 16. OAK-LEAF ROLLER MOTH (*Tortrix viridana*)
a. Moth. *b.* Larva. *c.* Pupa.

caterpillars, which are of a dirty green colour and about half an inch in length, appear in spring from eggs laid in the previous year. Oaks only are attacked, often very severely. The leaves are bitten, at first slightly, then rolled into a tube-like form and more thoroughly devoured. At midsummer cocoons are formed upon the tree—either on the bark or amongst the twigs and remnants of leaves. From the chrysalis the winged insect escapes about three weeks later. The trees may be practically bereft of green leaves, with a consequent loss in timber production.

PINE-SHOOT TORTRIX, *Retinia buoliana*. In July eggs are laid singly on the terminal buds of young trees of the Scots Pine, and all the stages of the insect's metamorphosis are passed in that region. The small caterpillar bores into the terminal bud, where it passes the winter; next spring it pierces and hollows out not only the leading shoot, but also most of the surrounding whorl of lateral buds. Any of the latter which escape, curve upward in order to take the place of the destroyed leader. This gives a very characteristic and objectionable twist to the stem in after-life.

LARCH MINING MOTH, *Coleophora* (*Tinea*) *laricella* (Fig. 17).

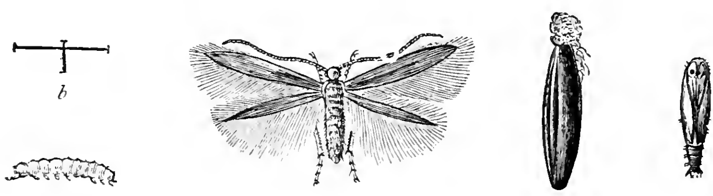


FIG. 17. LARCH MINING MOTH (*Coleophora laricella*)
a. Moth (magnified). *b*. Lines to show natural size. *c*. Larva. *d*. Larval case. *e*. Pupa.

The female moth lays her eggs in the needles of the Larch in May and June. In the latter month the larvæ appear, and hollow or mine out the needles. The caterpillar, which is very small, lives inside a case formed from a Larch needle. In this it spends the winter, but shortly after hibernation a larger case is demanded on account of its increased size. The larva obtains this by attaching a second empty needle to the side of the first, thus doubling the accommodation. Pupation also is effected within this peculiar covering. Young Larches (from ten to forty years old) are those attacked; the partially hollowed needles (Fig. 18*c*), with their flaccid yellow tips, give the trees a very striking appearance, as though they had suffered from frost.

Prevention consists in planting Larch only upon suitable situations, where it has good and naturally well-drained soil, with free circulation of air about the crowns. Close woods of Larch are therefore not to be recommended. The Larch Mining Moth is very generally associated with the fungus which causes Larch disease.

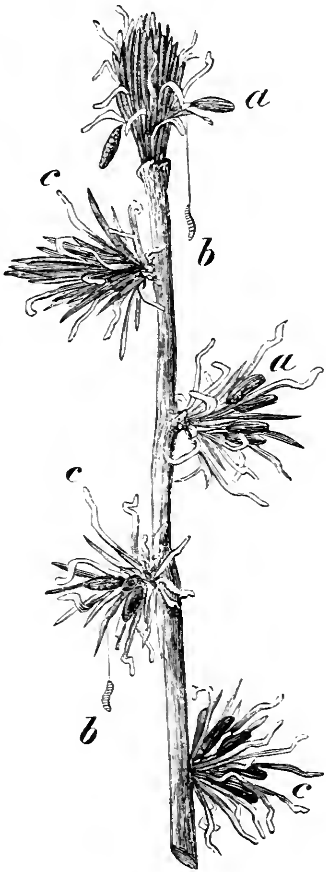


FIG. 18
TWIG OF LARCH SHOWING NEEDLES ATTACKED BY LARCH MINING MOTH

a. Larval cases.
b. Larvæ suspended by threads.
c. Hollowed needles.

Hymenoptera

PINE SAWFLY, *Lophyrus pini*. The female, with her saw-like ovipositor, bores into the needles of the Scots Pine and deposits a large number of eggs. The caterpillars, which are green and grow to one inch in length, have twenty-two legs. They feed in clusters, gnawing and totally destroying the needles. There may be two generations in the year. Larvæ, hatched early in the season, pupate in June on the needles and bark; those of a later brood turn to chrysalides under the soil covering of leaf litter.

In young plantations the colonies of larvæ may be crushed with the hand, but it is impossible to cope with the pest in older woods.

Hemiptera

SPRUCE-GALL APHIS, *Chermes abietis*. After wintering under scales in the bark, the so-called "mother" aphis appears in spring. She pierces into the twigs of the Spruce, and through irritation thus caused a cone-like gall (Fig. 19) arises. Here eggs are laid amongst a woolly secretion, and the tiny aphides coming from these suck the juices of the gall, which, from being quite insignificant, increases to the size of a small pine cone. The aphides become enclosed in the gall, where they occupy cells or chambers until full-grown in August. At that time the galls turn to a brown colour, and the chambers split open, allowing the green-fly to escape. If Larch be at hand, some of them fly to it and deposit eggs; from these a female form is hatched, which seeks protection under scales of the bark during winter. This is the "Larch aphis," *Chermes laricis*, so well known in connection with Larch canker.

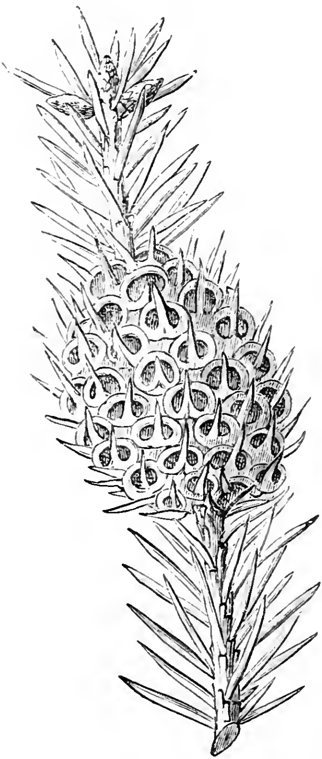


FIG. 19. GALL FORMED BY SPRUCE-GALL APHIS (*Chermes abietis*)

LARCH APHIS. With the arrival of spring the wingless females creep from their winter shelters, and lay eggs on the twigs of the Larch. The chermes from these are covered with a white woolly down. Both they and the parent form settle upon the needles, which they pierce and suck, weakening them and causing them to bend angularly. The appearance of the trees is as though they had been sprinkled with snow. After midsummer, wings are acquired, and the insects spread from larch to larch and to the spruce.

In the case of both Spruce and Larch the attack is worst upon sickly trees, and those at the margins of woods. Where the pest on the Larch is very persistent and the damage severe, it is usually found that the situation is also in other ways unsuitable for the growth of that species.

As prevention, the Larch should not be grown in pure woods nor in close, "muggy" situations, nor on cold, damp soil. The crowns of the trees should not be much restricted, but be given liberty of space and air.

Young Larches in the nursery may be sprayed, by means of one of the "Knapsack" sprayers, with paraffin emulsion. Against the aphis on Spruce, nothing can be done in the forest except the removal of weak trees.

Useful Forest Insects

Insects are not all harmful, on the contrary, quite a number are most useful, performing direct service for man. But it is the indirectly beneficial carnivorous insects that more especially interest the forester. These consist of predatory and parasitic species living upon injurious forms. They have repeatedly put an end to insect scourges that had got beyond human control.

To the predatory class belong several beetles, amongst them *Calosoma sycophanta*, *Calosoma inquisitor*, lady-birds (*Coccinellidæ*), and tiger-beetles (*Cicindelidæ*). As parasites, the Ichneumon flies render good service: *Microgaster nemorum* and *Microgaster glomeratus* lay their eggs in the body of the Pine Moth larva. *Anomalon circumflexum* is another and frequently occurring ichneumon, whose habits are altogether beneficial through the killing of destructive caterpillars, and of the true flies (*Diptera*), the genus *Tachina* supplies several species which are very active in this direction.

Protection Against Fungoid Diseases

As enemies of the forest, parasitic fungi have to be reckoned with amongst our most dreaded pests. Trees are harmed by other forms of plant life, but by none so severely as by fungi. They are the more to be feared because in many cases it is practically impossible to combat, or, at least, cure, their attacks. Only the more important pests are here considered.

THE HONEY AGARIC, *Agaricus melleus* (Fig. 20). This

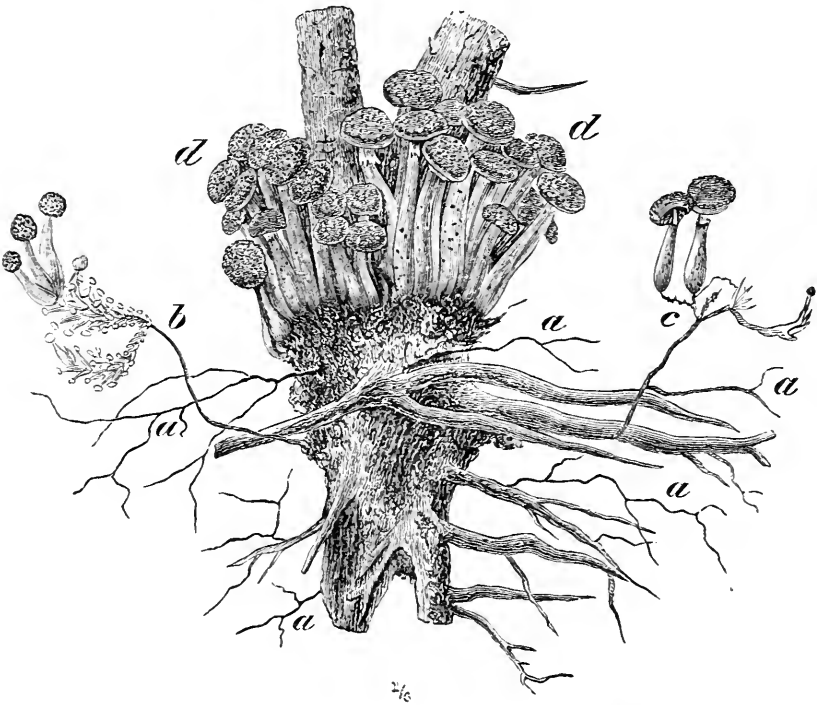


FIG. 20. SCOTS PINE KILLED BY "AGARICUS MELLEUS"
a, b, c. Rhizomorph strands. *b, c,* bear sporophores, some of which are abortive. *d, d.* Cluster of sporophores arising from the mycelium in the cortex.

fungus preys upon Scots Pine, Spruce, Larch, and other conifers, and occurs saprophytically on broad-leaved trees.

As a parasite on conifers, it proves fatal to young and old trees alike. The fine white *mycelium* between the wood and the bark, the black *rhizomorphs* and the clotted mass of earth and resin adhering to the roots and collar, serve to determine the fungus in the absence of the yellow or honey-coloured caps which appear in late autumn. The strong mycelial strands or rhizomorphs extend under the surface of the ground in search of healthy roots, which they pierce and enter, to the destruction of the plant; also infection is brought about by spores from the fructifications.

Prevention: Pull up and burn infected young conifers.

Peridermium Pini corticola. On the upper part of the stem or in the crown of the Scots Pine a black resinous patch, or "blister," and in June the orange-yellow *sporophores* (fructifications), mark the presence of this common fungus. The mycelium lives in the soft bast and in the region of the cambium, which it kills. As the canker on the stem increases in size, the passage of the elaborated sap is confined more and more to the healthy side; the sap-wood, too, may become clogged with turpentine to such a degree that the supply of water from the roots is interfered with, and the portion above the canker dies in consequence. Young trees are quickly killed by it, though often indirectly, for they get suppressed by neighbouring trees. Older stems are able to hold out longer against it.

Trees affected by the disease should be at once removed.

Aecidium elatinum, a canker of the Silver Fir. Swellings with deep cracks or fissures occur on the stems, caused by the mycelium working in the cortex. The "witches'-broom" of the Silver Fir is attributable to this fungus, and branches with these curious growths should be pruned off before the shedding of the spores in June or July. Infested stems are rendered more liable to wind-break, and should be removed in all cuttings as they occur.

Trametes radiciperda is the most destructive root fungus of the Scots Pine, Weymouth Pine, and Spruce. If one tree dies from it, others whose roots are in contact soon follow, and a gap in the forest crop results. This gap always tends to increase in size owing to surrounding healthy trees being contaminated by the diseased ones. The roots become completely decayed. Under the bark scales at the "collar" of the tree the delicate white mycelium may be seen, and there —often below a mossy covering—the snow-white polyporous fructifications are borne. The latter also appear upon diseased roots that have been laid bare; the spores from them are apt to be distributed upon the fur of rabbits and other burrowing animals, thus starting new centres of infection.

In North Germany it is found that Scots Pine upon land previously under tillage seldom escapes the ravages of this fungus. In this country also the pest is of very frequent occurrence.

Trametes pini produces a form of "ring-shake" and decomposition of the wood. As its specific name implies, the fungus assails Pines principally; but it is not confined to them —Spruce, Larch, and Silver Fir also being subject to its attack. The oldest class of trees are the chief sufferers, and those under forty or fifty years old are practically free from it. It is a "wound-parasite," *i.e.* it can effect an entrance only through a wound or abrasion, such as that left by a broken branch, which exposes the unprotected wood. In the case of the Pine, it is only at those parts on the stem where dead branches have left a way through the sap-wood that the woody, bracket-like fructifications make their appearance. In the heart-wood the mycelium delights to spread circularly in an annual ring, causing the separation known as ring- or cup-shake. But it may break down the woody tissue throughout the whole duramen, spreading both upward and downward in the stem from the place of entrance.

Prevention: As the fungus is distributed only by spores, felling the infected trees puts an end to the trouble, and also saves further deterioration of the timber. The breaking or pruning away of green branches should be avoided, as wounds thus caused provide the necessary germinating bed for the spores. If artificial pruning be necessary, the larger wound surfaces should be painted with an antiseptic substance, such as coal-tar.

LARCH CANKER, *Peziza Willkommii.* In countries with a moist climate, and especially in low-lying situations subject to mist and frost, Larch is subject to this fungoid pest. The tendency is aggravated when the species is grown in pure woods, upon unsuitable soil, or in crowded plantations.

Somewhat oval-shaped "blisters," exudation of resin from fissures in the bark, and the small cup-shaped ascophores (with their whitish borders and orange-coloured centres) are evidence of the pest. Both the stem and branches become cankered and bear the fructifications. The mycelium lives in the soft bast, kills the cambium, and can pierce to the pith along the medullary rays. The canker or blister extends by growth around its periphery; when its increase is more rapid than that of the tree-stem, the latter is encircled and killed, or the flow of sap may be so impeded that death results. In all cases affected stems are seriously crippled by the disease.

Amongst predisposing influences are the attacks of the Larch Aphis (*Chermes laricis*) and the Larch Mining Moth (*Coleophora laricella*).

Prevention: Careful selection of site. Avoidance of pure woods. Thin mixture of Larch—where possible with Beech. Where conditions are at all unfavourable to the growth of Larch, other species should be substituted for it.

NEEDLE-SHEDDING FUNGUS, *Hysterium (Lophodermium) pinastri.* Occurs to some extent upon Scots Pine of all ages, but it is only two- to six-years-old plants that suffer severely. Upon the latter it comes as a dreadful scourge in some localities, for it destroys the assimilating organs of the plants. In autumn discoloured spots or blotches may be seen, and later the needles turn brown and fall off. With weak plants the disease is apt to prove fatal. It especially haunts closely sown nursery beds, and if these be situated in the vicinity of Pine woods the danger is intensified.

Prevention: Spraying with Bordeaux Mixture, consisting of sulphate of copper, lime, and water.[1]

Seedling fungus, *Phytophthora omnivora*, is the cause of "damping off" in seedlings in the cotyledon (seed-leaf) stage. Beech is particularly subject to the pest, but Maples and conifers also may be attacked. The cotyledons become black, and die. Wet weather and close situations favour the disease. Spores of this fungus lying in the soil, have the faculty of maintaining their germinative power for a number of years. It is therefore advisable to refrain for a time from using polluted nursery ground for seed-beds, and rather utilise it for transplants, which will not be endangered.

Various polyporus species. *Polyporus vaporarius* is destructive to Spruce and Scots Pine, converting the wood of these trees into a mass of brown dust.

The common *P. sulphureus*, which gains entrance by a wound, attacks the timber of Oaks, Poplars, Willows, and other broad-leaved trees, causing the timber to turn brown and dry.

P. dryadeus and *P. igniarius* are parasitic upon Oak and other hard woods.

Oak-root fungus, *Rosellinia quercina*. During damp weather, in July and August, this fungus is apt to spread very rapidly from root to root among plants in close contact with each other. The roots of one- and two-years-old seedling Oaks are those which suffer. When from no apparent cause young Oaks in seed-beds have a faded appearance, with the leaves pale and sickly, this fungus should be suspected and investigation made, for it is very contagious. Close inspection reveals small black pustules upon the tap-roots of attacked plants. Prevention of further damage consists in the prompt removal of those infected.

Canker fungus, *Nectria ditissima*. Though of so frequent occurrence upon the Beech that it has been called "beech

[1] To twenty-two gallons of soft water add four pounds of copper sulphate and eight pounds freshly slaked lime, and apply with a Knapsack sprayer.—Tr.

canker," *Nectria ditissima* is by no means confined to that tree, but is the common cause of canker in apple trees, Ash, and many other broad-leaved trees.

The disease enters by a wound, and the mycelium lives in the rind or cortex, inducing malformation and more or less deep, unsightly, open sores.

Cankered stems should be removed in the thinnings.

Protection Against Forest Weeds

The usual definition of a weed as "a plant out of place" is universally applicable. Under the familiar term are included all the small growth which causes difficulty in forest cultivation. It thus embraces various grasses, heaths, blaeberry, bramble, raspberry, the coarser ferns, woodbine, etc.

The damage done by weeds comes under the following heads :—

1. The roots of certain weeds give a matted surface to the soil which may make natural regeneration impossible, and certainly renders cultivation difficult and costly.

2. Weeds lead to an accumulation of raw humus (*i.e.* vegetable matter in a dry and unassimilable form), and thus to the diminution of the soil's productive capacity.

3. Felted fibrous roots hinder the penetration of moisture into the soil, especially when precipitation is in a fine form.

4. Weeds impede the growth of young forest plants by shading them, causing the air to remain for a long time moist and stagnant about them ; they increase the danger from frost, and frequently overlie and choke young trees.

5. They harbour injurious animals, particularly mice.

6. They are the cause of malformations, and those of a twining habit may even strangle young trees.

The surest means of protection against weeds is by careful management, avoiding sudden heavy thinnings, and long exposure of the soil without a wood crop at the time of regeneration, especially on the stronger classes of soil. In afforesting bare land, the work of soil-preparation and planting ought to be done in a thoroughly efficient manner, even should apparently expensive methods have to be adopted.

Protection Against Atmospheric Influences

The forest is exposed to many dangers difficult to combat, but in respect to none is it more defenceless than against the natural phenomena of storm, snow, frost, and drought. Yet even in resistance to these, man has devised certain precautionary measures, which, while they are not able at all times to prevent damage being done, can frequently obviate it to a considerable extent.

Storms. Windstorms may affect quite a limited area, cutting out belts or strips of trees, very often only thirty or forty yards in breadth, and leaving the rest of the forest practically untouched; or they may be of more general distribution. The former are erratic in the direction that they take; but the latter, in the west and centre of Europe, with very few exceptions, come from the west, south-west, or north-west. It is when gales follow immediately upon heavy rains that have saturated the soil with water that they prove most destructive, for the soft ground is then least able to afford the roots support. The direct damage caused by high wind consists in trees being "thrown," or uprooted, and in stems being broken or snapped over at some height above the surface of the ground. The latter form occasions the greater loss, because the timber suffers more.

Against winds of tornado force there is no protection, and it is fortunate that these are of extremely rare occurrence in temperate climes. But to mitigate or to avoid calamity from strong winds and gales, some precautionary measures are adopted. A forest can be made more storm-firm by mixing shallow-rooted with deep-rooted species; trees are better able to resist wind if regular and fairly heavy thinnings be made, or direct shelter may be provided. A belt of trees—the fringe of a previous wood—may be left on the sides from which there is most fear of damage by storm. Such trees form a very resistant barrier to wind, having long adapted themselves to their environment by the formation of powerful root-fastenings. A very important measure, and one constantly employed in systematic woodland management, is to arrange the fellings into a series whereby clearings always proceed from the east or north-east to the west or south-west. A forest block thus treated is composed of graded steps—the woods of different ages; in it the oldest are found on the east side, and the youngest on the west (see Fig. 30, p. 138).

A shelter-belt may be produced and maintained along exposed borders of woods by thinning, from youth onwards, the fringe of say thirty to forty feet of the plantation, so that stout, thickly branched, storm-resistant trees result. Instead of laying bare a young wood by felling part of the forest close beside it, from which in the past it has received protection, a *severance-cutting* is sometimes made. A strip of twenty to forty yards broad is cleared from the portion that is shortly to be utilised, in order to encourage the margin trees of the younger wood to develop stronger root and branch systems. When possible, severance-cuttings should be made at right angles to the direction of the prevailing wind, and when the woods are in the pole-forest stage of growth.

Felling operations in large even-aged forests are greatly facilitated by these severance-cuttings.

Snow. Damp snow falling in large flakes clings to trees, and in the case of Pine and Spruce it is apt to form one continuous cover or layer upon the crowns of a close forest. This, owing to its great weight, bends and breaks the trees, the danger being increased if frost follows the snowstorm and prolongs the period that the trees have to sustain the burden.

Evergreen conifers from twenty to sixty years old are those which suffer most. In Germany it is found that forests growing between 1,200 and 2,200 feet altitude are more subject to injury than those at either greater or less elevations.

Broad-leaved forest trees are able to resist damage from snow through being without foliage in winter; with them injury is possible only when snowfall takes place unusually early or late.

Very little can be done in defending woods against snow. Sometimes it will be found desirable to obviate the risk by selecting species not liable to injury; or, instead of growing them in pure woods, one may mix the species for which there is fear, among resistant sorts. In the case of Scots Pine this latter precaution is specially worthy of attention at elevations of 600 to 1,200 feet. The Spruce may there be mixed with the Pine in order that it may be present to fill vacancies caused by snow-break of the latter. For the Spruce itself, this rule hardly holds good, for it is the only species which can be grown on a large scale in high situations of 1,300 to 3,000 feet. In such positions the lessening of damage is possible only by the production of symmetrical, well-developed crowns and strong growth. Careful planting, together with early and frequent thinning, have their influence in saving the trees. Even this treatment, however, does not prevent Spruce and Silver Fir from losing their leaders in localities specially subject to snow.

Against extremes of HEAT, DROUGHT, and COLD, all rules which tend to prevent or regulate insolation and radiation should receive consideration. The humus covering natural to the forest floor must be carefully conserved.

Danger from frost and drought is to be feared chiefly during the plants' earliest youth; natural regeneration may therefore be necessary, for under that system the young crop is gradually introduced under the shelter of the old. The production of a special protection in the shape of a shelter wood of forward growth is also applicable in extensive operations, while for work in the forest nursery, artificial shading and covering sensitive species with branches, leaves, etc., are of service.

Special forms of injury induced by frost and the sun's heat are frost-crack, frost-lifting, and bark-scorching.

Frost-cracks are longitudinal fissures in the stem caused by intense cold in winter; starting at the bark, they reach more or less deeply into the wood, and may even penetrate to the centre of the tree. Each growing season the trees make an effort to heal the cracks; but, as a rule, they are reopened during the succeeding winter. "Frost-ribs" are the result of the repeated opening and closing. This injury to the timber, producing what is known as frost-shake, occurs most commonly with Oak and Elm, but is met with in other species, especially in frosty hollows.

Frost-lifting affects small plants on loose soil. It is most common in early spring, but may occur at any time when a very marked difference between the temperatures of day and night brings frost and thaw alternately. Owing to crystallisation of the water present, the soil is heaved up, and seedlings with shallow roots are raised with it; the soil regains its former position when mild weather sets in, but the small plants which have been torn away from their original hold upon the soil are not able to do so, and fall over on the surface of the soil.

To prevent frost-lifting, avoid weeding or otherwise stirring the surface soil of nurseries in late summer or autumn, and provide a covering of leaves, needles, moss, or other litter over the beds or between the plants.

Bark-scorching occurs on all species of trees which have a smooth bark. Beech suffers most frequently, but Ash, Maple, Sycamore, and Spruce may also be affected, when, in middle life or as older trees, they are suddenly exposed by the clearance of surrounding forest. Injury is generally confined to the west side of the trees, for the hot rays of the afternoon sun strike horizontally enough to get below the crowns. As a result, the bark becomes excessively heated, dies, cracks, and falls off on the side affected; underneath the sunburned cortex, the wood is then apt to be destroyed by a form of dry-rot. Trees with low-branched crowns do not suffer harm.

CHAPTER VII

FOREST UTILISATION

UNDER Forest Utilisation are considered the harvesting, conversion, and disposal of wood, and the transport of forest products, so far as these actions lie within the sphere of the forester's business. In all of the above departments, the systems employed tend to change greatly according to time and place; that is to say, the uses or modes of preparation of wood in one country may be different in another, or even within the same country; and the same remark applies to the period or date of utilisation. Frequently forest products receive partial conversion before passing out of the hands of the forest owner, and this forms a special or independent branch of the subject.

The Properties of Timber

Weight. The weight of wood depends upon species, age, portion of stem being dealt with, degree of moistness, internal form or structure, and conditions under which the timber has been grown.

A division of our timber trees into three groups, according to the weight of their timbers when dried, is as follows:—

Light woods, having a specific gravity of 0·55 and less: Scots Pine, Weymouth Pine, Silver Fir, Spruce, Lime, Poplar, Alder.

Moderately heavy, having a specific gravity of 0·56 to 0·70: Larch, Birch, Sycamore, Sweet Chestnut, Elm, Beech.

Heavy, having a specific gravity over 0·70: Acacia, Hornbeam, Ash, Oak.

The lower portions of a stem are generally heavier than the middle parts, but above that again, in the crown, the weight increases.

As a rule, the better the soil and situation, the heavier is the timber of trees of like species and of similar age.

Distinction is made in the condition of timber, in respect of the moisture which it contains. It is said to be "green" when, as in the case of freshly felled trees, half of its weight is water; "forest-dried" timber, which has long remained in the wood, but still contains from twenty to thirty per cent. of moisture; while "air-dried" timber is that which has been long stored under cover in a dry, airy place, and contains, on an average, ten per cent. of water.

Timbers are subject to SHRINKING, SWELLING, and WARPING. Shrinkage takes place during the process of drying. As a piece of timber parts with the water it contains, its volume decreases; the change is dependent on the species—hard woods shrinking more than soft woods. It does not occur to the same extent in all directions, but is most marked along the annual rings, and least along the grain, *i.e.* lengthwise with the vessels and wood-fibres. When the reduction in volume proceeds unevenly cracks are produced in the timber.

If laid in water or in a damp atmosphere, wood absorbs the moisture lost in the drying process and swells, gradually regaining its original volume. Irregular shrinkage and swelling, together with the not absolutely straight course of the wood fibres, account for the warping of manufactured timber. The more quickly a wood is dried, the faster does it shrink, and the greater is the tendency to crack.

Strength. Timber has to resist strain put upon it in different ways, but it is most important practically that it withstand the transverse straining action, as in beams and rafters; and also the crushing action, as when weight is put upon upright posts or pillars. The heavier a wood is, the greater, as a rule, is its strength. Unsoundness and the presence of knots or irregularity of grain affect timber most prejudicially as regards its strength.

The order which the species take in respect to resistance to transverse strain is as follows: Oak, Ash, Spruce, and Scots Pine; and in relation to pressure or crushing: Oak, Beech, Acacia, Larch, Scots Pine, Spruce.

Hardness affects the working of timber chiefly in two ways, in its cleavage (separation of the wood-fibres longitudinally), and in the resistance of wood to the penetration of the saw in the transverse direction. The straighter and longer the fibres of the wood and the larger and more numerous the medullary rays, the easier does a timber split or cleave. The timber of conifers is sawn through with less difficulty than that of broad-leaved species, and timber which is fresh and green gives less resistance in this way than that which is dry or frozen.

Elasticity. If wood when bent into a change of form by the external application of force offers resistance, and on being released, tends to resume its original shape, it is said to have elasticity; for example, Ash, Oak, and Elm have this quality in a marked degree. Flexible wood is different from this; it retains its new shape after the pressure is removed, but will not break as brittle timber does. Birch, Aspen, Poplar, Spruce, and Hickory are flexible woods.

Durability. The durability of timber depends greatly upon the treatment it receives and the use to which it is put. Decomposition is most active when, by frequent changes from a wet state to a dry one, unprotected wood allows the entrance of fungi and insects. Wood well dried and thoroughly seasoned, or that which is completely submerged in water, remains sound exceptionally long. Faulty ventilation, especially of imperfectly seasoned wood, or where wood comes in contact with the soil, leads to rapid decay. The lasting qualities of timber are much affected by the soil and situation where the trees are grown; careful choice of species should therefore be made at the time of forming plantations. All that tends to the production of clean, healthy trees favours the durability of the timber.

The preservation of timber can be brought about by treat-ing it with antiseptic substances, such as carbolineum, sulphate of copper, corrosive sublimate, or creosote. As a rule, heavy woods are also durable, but Beech, which quickly decays on exposure to the weather, forms an exception.

Heating power. There is at present no satisfactory measure for testing heat-values. The calorimeter, which is used for the purpose, is not of practical utility, for it does not take sufficiently into account the quick development of heat by coniferous woods compared to the slow, equal fire of Beech wood burning with little smoke.

Defects in Timber

The more important of the fungoid diseases causing decay in wood have already been mentioned. Of other defects, one deserving notice, as affecting sound wood, is the reddening or "*false heartwood*" of Beech. This discolouration in the neighbourhood of a wound, very often at a broken branch, is due to a change in the construction of the cells, and is an effort to prevent the entrance of spore-containing water into the tree. The timber is rendered unfit for many purposes.

The *blueness* sometimes seen in summer on coniferous timber that has lain long without drying sufficiently is caused by a fungus, *Ceratostoma piliferum*. According to the most recent investigations, it appears that this is only a blemish as regards appearance, and that it does not in any way harm the timber's strength, weight, or other qualities.

Of defects occurring in sound wood, the following are those of most consequence :—

Heart-shake cracks, or rents proceeding from the pith radially, are generally the result of rapid drying of the timber. *Frost-rib* and *frost-crack* have been dealt with in a previous paragraph under "frost." *Ring-shake* is a separation of the tissues along the line of an annual ring. It may be caused by a sudden acceleration in the growth of a tree, when, for instance, a Silver Fir which has long been kept under shade is suddenly given full liberty of light.

Abnormal direction of fibres. Common forms of this are *spiral growth*, *wavy wood*, and *burrs*. In the first of these the direction of the fibres is spiral to the stem's axis; burrs result from the incomplete development of clusters of adventitious buds; in some woods (*e.g.* American Bird's-eye Maple) they are of much beauty.

Loose knots are the remains of dead branches which have been gradually embraced by the stem during growth in thickness. Though enclosed in the wood they are not incorporated by it, and considerably lower the value of sawn-up timber. Knots of this kind are apt to occur in conifers, especially Spruce.

The Harvesting of Timber

It is usual throughout Germany and Austria (with the exception of the mountainous districts) for the owner of a forest to engage the labour necessary for harvesting the timber crop. Only very rarely is this work given over to the employees of timber merchants. So far as possible local labour is employed. In this way the system of small holdings suits well in conjunction with forests held by the State, or proprietors owning large tracts. Most forest work is done at seasons of the year when there is least necessity for attendance on small farms. Especially is this the case with fellings, which are best carried out in winter, when the agricultural occupations of the crofter reach their lowest ebb. But if such workmen are not available, others, probably less keenly interested in woodcraft, must be engaged.

To secure a sufficient number of good men, it is essential above all to pay a fair wage and provide adequate housing accommodation, in bothies or otherwise, for the staff. At the same time, this is an item of expenditure that may easily exceed the limits of profitable management, and must be kept strictly within bounds.

It is usual to divide the number of woodcutters into gangs, and to apportion to them work in keeping with their skill and experience. Each gang should have its foreman-worker, who is held responsible for the behaviour of the rest.

The work of felling may be conveniently done by contract (piecework) according to fixed standards. For specially difficult operations it is advisable to pay day's wages. If the timber, when felled, must be dragged to depôts or into lots, an additional sum to that for cutting alone should be allowed. When the workers' engagement may be broken at a day's notice, and when payment is reckoned by the piece, it ought to be borne in mind that the operation is subject to interruption through unfavourable weather, and a somewhat higher rate than that current locally for agricultural labour may require to be paid.

The usual and most suitable season for the main fellings is winter; where the bark is desired from Oak, cuttings are carried out after the period of active vegetation has set in—that is to say, in spring. Trees from very marshy land should be felled and extracted during severe frost; often it is at such times only that Alder clumps can be approached. Thinnings or other intermediate cuttings allow of the widest choice as regards season of felling; indeed, they may be undertaken when there is nothing else to afford the woodcutters employment.

In felling trees the axe is generally used conjointly with the saw; first a deep notch is hewn out with the axe upon the side to which it is desired that the tree should fall, then from the side opposite to this the saw is entered and the stem cut through. Wedges, either of wood or iron, follow the saw to ease it and to guide the felling direction more precisely. For smaller stems the axe alone is used, and slender young growth may be cut over with the bill-hook.

Trees may be felled "by the root"—that is to say, the larger roots, laid bare by digging, are cut through, and at the same time, with ropes, cables, or the help of the "forest devil," the stem is drawn over and falls to the ground; weaker stems may be pressed over with a pole after severing the roots. The felling of trees in this manner has much to recommend it; it permits of the fullest use being made of the whole tree, and it is the surest way of giving the proper direction to the fall. For the removal of trees from very stony ground the method is quite unsuitable.

The tree being felled, the stem is freed from branches, and the material is duly assorted. Timber is kept distinct from firewood, and the former is arranged according to species, size, quality, etc. It should be suitably lotted into logs, butts, poles, pit-props, bark for tanning purposes, and so forth. Dimensions of the various classes of each vary much in different districts, but a great deal of importance should be attached to proper lotting. Short timber lengths can be arranged as firewood, stavewood, wood for paper-pulp manufacture, or as its particular nature and the demands of the market suggest. Cordwood is either put up in stacks and its cubic contents measured, or it is bound in faggots of a predetermined size.

The method adopted to clear the felling area depends upon the size of the material and local conditions.

It is very convenient to gather the timber into a forest depôt, though very heavy logs are usually taken delivery of directly by the purchaser. The means of removal may be by carrying the smaller material by hand or on barrows, but more frequently carts, timber wagons, and sledges are employed, or the logs brought together by dragging or sliding. Any timber converted in the forest—fuel-wood and poles—should be arranged immediately beside the nearest roads or rides. Billets may be conveniently piled in stacks of four or five feet high, each pile containing a known number of cubic feet. Special regard must be paid to the assortment of the logs, which are generally sold in small lots of even character—species, size, and quality being taken into account.

Where proper care is exercised, each lot is measured and receives its sale number. A catalogue is then prepared showing, opposite to each number, the length, middle diameter, and volume contents. Without this, valuation and exact accounting are impossible. Revolving die-hammers are useful in marking and numbering the lots, though this may also be done by hand.

Minor Products of the Forest

All forest products other than timber and wood come under the term minor produce. The most important article included in the latter category is bark—the bark of Oak, and though to a very much less extent, that of Spruce and Larch. Bark is collected for the tannin which it contains, but its price has fallen considerably of recent years owing to the more extended use of substitutes, among which Quebracho wood from South America may be mentioned.

Oak coppice bark (smooth or silver bark) provides the best material for tanning, being much preferred to the fissured and more corky bark from older stems.

The bark from the lower portions is most easily removed while the tree is still standing; when all has been peeled from the base to a height that can be conveniently reached, the tree is felled and the bark from the upper parts is taken.

The operation of peeling is carried out generally in May; special instruments—the most important of which is the peeling-scalpel or barking-iron—being used. Mallets for beating and loosening the bark, chisels, etc., are also employed. The bark is easily injured by rain, and the speedier and more thoroughly the drying process can be effected, the better are the results. Airy sheds or mere temporary erections, such as iron sheeting, or tarpaulins, are made use of, or simple frames and trestles can be employed to allow free circulation of air about the bark, and thus hasten the drying.

Spruce and Silver Fir, if felled in summer, should have their bark removed to prevent the spread of injurious insects, which make such stems their breeding places. The bark thus obtained, if not valued for tanning purposes, may be of use as fuel.

The soil-covering of the forest, consisting of fallen leaves, twigs, and so forth, in process of decomposition, is often much valued by the agriculturist, who applies it as manure to his fields. This litter sometimes requires to be disturbed, as, for instance, in hoeing it aside from strips in preparation for reproduction by seed, or from roads and ditches where it has accumulated. In such cases its removal is quite justifiable; but the frequent systematic abstraction of this natural fertiliser should not be permitted. Much of the mineral matter which a tree takes from the soil it stores in its leaves, which in turn are shed, and in course of time form first a mulch upon the surface, and later rich, black earth. Should the leaves or the leaf mould be removed, there is a distinct loss, and the soil suffers both in its chemical and physical qualities. No tree suffers so much by the removal of forest litter as the Beech—the very tree whose leaves are most attractive to cottars and small holders.

The gathering of dead wood and pruned branches is quite a different matter, and does no harm; while clearing away heather, grass, and similar growth from open places, rides, and fire lines, may even be of service, especially in reducing the risk of fire.

Naturally enough, the extent of the damage wrought by the removal of leaf litter depends very much on the length of time allowed the forest to recuperate. Should the extraction be made annually or biennially, a marked decrease in timber production quickly results. To revisit a forest for this purpose once in six years is as often as is permissible. When the litter is allowed to collect for ten years, woods in middle age and those approaching maturity are not injured appreciably except on the poorest situations. In any case, only the mere surface material should be taken, and the work ought to be under the immediate control of the proprietor. Under adverse conditions of growth the removal of forest litter should be most strictly forbidden.

Another source of revenue secured in many forests lies in the collection of seeds and fruits, more especially seeds to supply trade nurseries. The crop of seed obtainable varies in amount in different years, being full, moderate, or even wholly wanting, as the case may be. An abundant "seed-year" occurs only at long intervals with Oak and Beech, Spruce frequently proves unsatisfactory, whereas Hornbeam, Birch, and Alder bear practically every alternate year; Scots Pine and Silver Fir have full crops every third or fourth year, though their periodicity is not so regular as with Oak and Beech.

Certain seeds must be collected before they fall to the ground—Silver Fir, Spruce, Scots Pine, Hornbeam, Sycamore, Lime, and Acacia. The seeds or fruits of other trees may be gathered after being naturally shed; this plan is invariably adopted with acorns and beech nuts. With Elm, Ash, Birch, Alder, Maple, and Sycamore the seed is either taken direct from the boughs, or the twigs are picked off and subsequently stripped.

The once almost universal practice of feeding pigs on mast in Oak and Beech woods has nearly ceased to exist. From the forester's point of view the absence of these animals is rather regrettable, for they did good work in turning over the soil and devouring injurious insects.

The use of the forest during certain periods for grazing purposes has become more and more restricted in recent times, and the cutting of grass ought to be kept strictly under the control of the woodland owners.

Peat need only be referred to as a commodity frequently used as fuel by the people employed in the forest, though much of it, not well adapted for burning, can be profitably utilised as moss litter, while even the dusty residue is used in stables and auction marts on account of its disinfectant properties.

Formerly resin-tapping obtained extensively in the coniferous forests of Germany; the practice has been discontinued in that country, but in France resin-tapping gives rise to an important industry.

Fallen branches for fuel, berries, and edible fungi can considerably benefit the industrious poor, but are without value to the proprietor.

In certain parts some return is obtained from such by-products as sand, gravel, stones, etc.; the value of these materials is, of course, entirely dependent on local circumstances.

Disposal and Sale of Forest Products

In some parts of the country the practice is to sell whole plantations as they stand, thus leaving the work of felling for the purchaser to carry out. But this system is not common for large timber as distinct from coppice. As a rule, the crop is felled before being sold, though with species and sizes for which there is only a limited outlet, offers may be taken before felling operations are commenced, so that if there be little or no demand the wood need not be sacrificed, but can remain standing, or other means may be sought for its disposal.

Much of the success of a timber sale depends upon the way in which the material has been brought together. This having received every attention according to the requirements of the market, the timber is advertised for sale. If sold by public auction, it is disposed of to the highest bidder after a system of increased bids—the purchasers outbidding each other. In some countries (France, Holland, Alsace-Lorraine) the mode of bidding is contrary to that common in Britain. There, what is called Dutch auction is preferred; the auctioneer, beginning at a very high figure, gradually reduces the amount asked, and the first to make a bid becomes the purchaser—his being the highest offer. Sales may also be by private tender, whereby the seller usually receives a number of offers from which he makes a selection. A less common system is to sell the timber at a fixed price on a more or less permanent contract or according to a stipulated rate.

Minor forest produce may also be sold in all the ways just mentioned. To grant a portion of such material in payment for its collection and preparation is often an advantage to both the forest owner and the workman. In the disposal of timber the aim is, by means of competition amongst purchasers, to get the highest price possible; but with minor produce other considerations may require attention, making it difficult to extract the full financial value. For instance, the weeding out of undesirable trees from very young woods may not be directly remunerative, though highly beneficial to the growing crop.

The purchase price is frequently paid immediately after a sale by auction, in which case discount is allowed; more usually a deposit is made and security given for the remaining sum payable within a stated time. In the conditions of sale a date should be fixed to limit the time given to the purchaser for the removal of the timber.

Transport of Forest Products

The removal of the produce is commonly undertaken by the forest owner's workpeople or those employed by his agents. Transport may be by water or by land, the topography of the country most generally controlling the choice. In both cases the methods vary according to the conditions met with locally.

Water Transport. In early times, rivers, even with but small preparation to regulate their flow, were much used for carrying down short pieces of timber and split billets—these being simply thrown into the water and allowed to drift. The loss of a portion of the material through stranding, theft, and sinking from becoming saturated with water, could not well be obviated, but as good public roads did not exist, there was scarcely an alternative. In districts where suitable conditions prevail, particularly in mountainous parts, the floating of wood (firewood especially) is practised at the present time. For successful work, a considerable *fall* in the stream is requisite—only then can the wood be expected to proceed downward with sufficient ease, and without undue loss in time and material.

Dams constructed in order to collect a sufficient head of water to carry down any large quantity of wood are usually necessary. Wood about to be transported is gathered together in the bed of the stream, and on the banks below the dam. All being in readiness, the sluices are opened and the wood is launched into the flood as quickly as possible. By one or more of these rushes of water the material is brought to its destination, where, with the aid of *booms*, its onward course is intercepted. Booms (bars which extend across stream) are erected at the collecting basin; some forms act by diverting the floating wood; others, by stopping it entirely.

On the middle and lower reaches of rivers, and on canals and lakes, the transport of long logs fastened together in the form of rafts is very general. According to the character of the waterway and the size of the timber, a number of logs are fastened together into so-called raft sections. Each section consists of six to ten logs as a rule; where circumstances permit, several of these are coupled together, and may form rafts of considerable length.

Transport by Land. Roads within the forest area are necessary for the carriage of produce, and for communication through the woods. Nothing conduces more surely to the economical management of a forest than an efficient system of roads. A distinction may be drawn between roads which are used only for the extraction of timber (and to facilitate sport) and public roads which can be made use of by the forest proprietor for timber transport.

Apart from forest rides and paths, timber-slides, both "dry" and "wet," sleepered sledge-roads, and forest tramways have their particular merits. The means of transport should always receive the most careful consideration, and all aspects of the matter ought to be looked at before any decision is made. Neglect is poor economy.

For ordinary traffic the plain turf road frequently suffices; in its case, attention to drainage is the main consideration. Where the ground tends to be wet a fairly firm track can be made by laying short logs, poles or sleepers packed closely together crosswise over the line of road. Such tracks are known in some parts as corduroy roads.

For the most precipitous places the so-called "wire-tramway" is employed. It consists of a cable, or very strong wire, that is stretched from the side of a valley into the depth below. To the cable the logs are suspended by chains, while wheels running on the cable are the means of lowering the timber.

Timber-slides and Sledge-roads are formed for the removal of wood from high-lying ground down to lower land. They should be provided with such a declivity that little or no force need be used to bring the produce down—gravitation being relied upon for its transmission. The work of the men in charge is then reduced to setting the timber in motion, guiding its course, or, in the case of sledges, occasionally moderating the speed and steering.

The best gradient depends on the character of the path; a prepared snow or ice path does well, with a fall of 8 in 100 feet; without snow (earth slide) ten to eighteen per cent. is necessary. When pieces of wood have been laid on the sides of the sliding track to prevent the logs from leaving it, fifteen to eighteen per cent. is usual; while for use only over snow in winter the same type of slide should have a gradient of ten to twelve per cent.

A special kind of timber-slide is a prepared channel made from six or eight logs or poles arranged together laterally in the form of a trough. Much wood is, of course, necessary for the construction and maintenance of the wooden timber-slide. Down such channels timber travels by its own weight. Slides of this description are used both in summer and winter. When the presence of snow during a lengthened period is assured, and the intention is to employ the slide in winter, the declivity ought to be only about half of that for a slide used in summer. In the former case, for long timber the fall should be eight to ten per cent., for shorter logs ten to fifteen per cent.; and for those in summer transport, fifteen to twenty per cent. and twenty-five to thirty per cent. respectively. Short sliding tracks or skidways often serve to bring the produce down out of the woods, depositing it at the nearest road, where the further conveyance of the timber is undertaken by carts, timber-wagons, jankers, etc. Where the state of the roads admits, the traction engine with wagons usually works most economically. In Germany the four-wheeled timber-cart is largely employed for transport; it has an advantage in that the front and back portions may be detached and placed at either end of very long logs. When this is done, the front pair of wheels bears the butt ends above, while the back wheels support the upper parts, hanging from the axle as a rule.

Reference must also be made to forest tramways, or light railways. These are usually in part fixed or permanent, leading to regular railway lines or sawmills, and in part portable. They are of narrow gauge, and the movable portion consists of sections of twelve to fifteen feet in length, a size which admits of ready shifting to the felling areas and even to individual stems. In addition to their usefulness in carrying timber, light railways are often of much aid in the construction of ordinary roads, conveying sand, gravel, stones, etc., cheaply and with expedition. To be remunerative, however, the permanent line must have an assured traffic of large quantities of material. Considerable capital is necessarily sunk in the enterprise, and only rarely is it satisfactory. In mountainous districts the difficulty of obtaining suitable gradients renders permanent tramways impracticable; and among the lower hills, and in level country, roads are generally available, and lead in more divergent directions than the fixed railway can be expected to take. It is different with the portable form of railway; especially where a timber-growing district is sparsely populated, the narrow-gauge line will be found serviceable and economical. The short sections may have a gauge of eighteen to twenty-four inches; they are easily carried by one man, and are connected without the slightest difficulty. They adapt themselves readily to the slope and surface of the land, so that very little preliminary preparation is required.

Of roads used for general traffic, the best are the macadamised. They are much to be preferred to the causeway, another permanent form of highway. Roads of less importance may need only to be formed of coarse gravel bound together with a little clay, sand, or peaty earth, as the foundation may require. The drawback to poorly constructed roads is that it is impossible to use them in any but the driest weather in summer, and in time of frost in winter. Carting over them at other seasons soon renders them impassable, so that their utility is obviously restricted.

Occasionally forest material has to be taken across low, marshy land, and then the fascine road or path proves useful It consists of bound bundles of branchwood laid horizontally; sods of grass or heather make a suitable covering to the fascines.

When tracks are required only for temporary use, as, for example, in the clearing of a recently felled area, the only preparation generally given is the removal of a few awkwardly lying stumps of trees. Thus, while the more important forest roads are practically as well made as public highways, others of more occasional utility need be of only the simplest construction. The latter can be much more steep and have sharper curves than are permissible on the main roads. Whereas the maximum gradient for public roads should not exceed five or six per cent., that for forest roads may be seven per cent. or more. Auxiliary roads and tracks may have a fall of ten per cent. where the traffic with laden carts is only downhill.

The length of the timber to be removed often regulates the degree of abruptness of a road's turnings. For short pieces a minimum radius of twelve yards is sufficient, while for the removal of long logs it must not be less than thirty to forty yards. At the time of a road's formation insufficient attention is apt to be given to the matter of suitable curves. Especially is there a tendency to curtail these, to an inconvenient extent, when there is no immediate prospect of an output of lengthy timber; a word of caution to the engineer is therefore necessary, so that he may allow sufficiently for the future growth of the forest. Much forethought is necessary in laying down the whole system of roadways and intersecting rides. Too often present convenience influences a manager's choice to the prejudice of permanent efficiency. Regard must be paid not only to the transport of the harvested material, but also to matters of forest management connected with the proper division of the area. The aim should be to extract the produce in the most direct manner consistent with a low expenditure in money, time, and labour; but along with this to give consideration to the interests of the growing stock.

CHAPTER VIII

FOREST MANAGEMENT

For the economic management of the forest, it is necessary to ascertain its possible permanent yield, and in order to treat the woods systematically, operations must proceed according to a definite plan. The work in connection with forest management embraces: (1) The survey and division of the area, and the projection of the same on a map or maps; calculation of the volume contents, and the increment or rate of growth; and a detailed description of the woods. (2) The scheme of management: determination of the future treatment of the wooded area, selection of species and length of rotation, calculation of the yield—in short, the preparation of what is called a "Working Plan." (3) The guidance towards fulfilment of the work indicated in the plan.

Survey and Division of Forests

There must, in the first instance, be a partition of very large tracts of forest into conservancies, ranges, and inspection areas. These are further considered in their individual parts as blocks, compartments, and subdivisions. The compartment may be called the unit of division as regards management; in extensive forests its area is often fifty or sixty acres, but it may be much less. In level country a system of cleared lines, forming a rectangular network of roads, serves to separate compartments. These divisional lines are also generally useful as providing means of communication between the various parts of the forest, and as defence lines against forest fires; they usually run directly from north to south, and from east to west. In forming compartments, due regard must be paid to roads already existent, so as to avoid awkwardly shaped areas.

Amongst the hills, roads and paths, supplemented by rides, provide a convenient means of division, as do ridges, valleys, and watercourses, where advantage can be taken of them. In hilly districts it is especially necessary to give consideration to the proper arrangement of the Felling Series at the time of fixing the divisions of the forest.

Within the limits of one compartment there may be many differences as regards the species, age, and condition of the woods, and these should be noted in the survey—at least, if over half an acre in extent. In future management such irregularities ought to be eliminated as far as possible.

Frequently a forest district is divided into a series of blocks. Natural boundaries, as a rule, form the limits of the block, because the progression of fellings and, indeed, the regeneration of the areas and general facilities for control are dependent largely on local topography. Such blocks often have considerable significance when they form the primary divisions of a conservancy. Independent series of fellings may be arranged for them, and each can with advantage be placed under the supervision of one responsible forester.

The "working section" is another management-division, the usefulness of which will be explained later. When a conservancy is in the hands of more than one proprietor, the boundaries of the working sections generally correspond with those of the several estates. Still, even with the land in the ownership of a single party, the presence of dissimilar species or divergent systems of treatment often makes it advisable to fix different felling ages (*rotations*), and each of these necessitates a working section.

Measurement of Felled and Standing Trees, and Determination of Increment

Instruments used. A large number of instruments have been devised to aid the forester in taking the measurement of trees. A few of these must be described and their utility explained.

The *Calliper* (Fig. 21) is employed to find the diameter

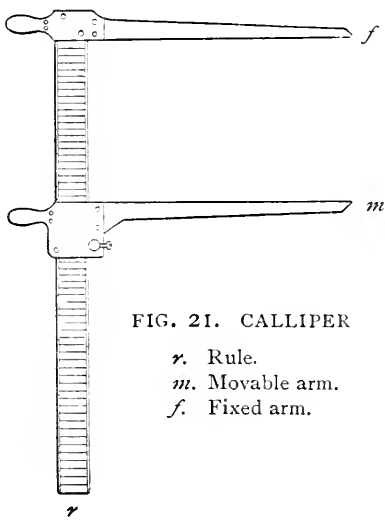


FIG. 21. CALLIPER

r. Rule.
m. Movable arm.
f. Fixed arm.

of the stem. It is constructed in a variety of forms, and has long been in use for many purposes. In forest mensuration callipers are of greatest value, though as yet they have found little favour in Britain, chiefly because ocular measurements and rough approximate estimates have been very generally considered to be sufficient. The instrument consists of a rule having a scale upon it graduated conveniently in inches and tenths. Upon the rule and at right-angles to it are two arms—one, placed at the end, being fixed, while the other is movable. The movable arm is slid along the rule until the object which it is desired to measure is clasped between it and the fixed arm, when the diameter can at once be read from the main bar of the instrument (Fig. 22).

Callipers are usually from three to four feet long, with the arms about half the length of the rule. They are generally made of wood, though aluminium is also suitable. The construction of Heyer's calliper is shown at Fig. 23; the

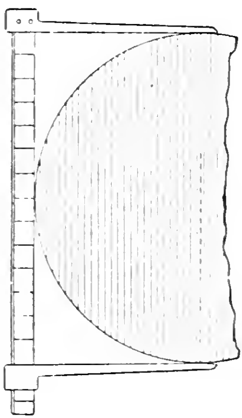


FIG. 22

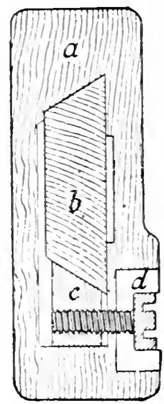


FIG. 23

a. Movable arm. *b.* Graduated rule. *c.* Metal wedge. *d.* Screw.

rule *b* is seen to have the form of a trapezium in cross-section; the wedge *c* is of metal and is attached to a screw *d*, which may be moved backward and forward to counteract the influences of swelling and shrinkage due to the wetting and drying of the wood.

For measuring the diameter-increment of standing trees Pressler's *Increment Borer* (Fig. 24) is used. It consists essentially of three parts: (1) a hollow boring tube which is slightly conical towards the point; (2) the handle, which, being hollow, accommodates the other parts of the instrument when not in use; and (3) the wedge-needle, which is toothed on one side, to press and hold fast the little cylinder of wood when breaking it from the body of the stem. On the

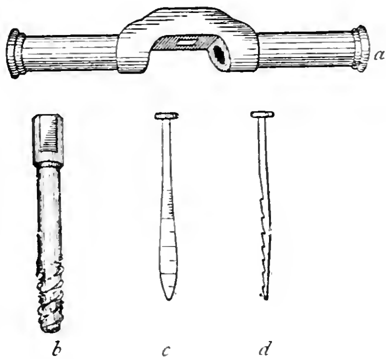


FIG. 24
PRESSLER'S INCREMENT BORER

a. Hollow metal handle.
b. Boring tube.
c. Wedge-needle with scale.
d. Wedge-needle showing toothed edge.

reverse side the wedge-needle bears a scale for measurement.

In using the instrument the auger-like borer is made to enter the stem in as radial a direction as possible, *i.e.* at right-angles to the axis of the tree. At first the boring should proceed slowly, later at any desired speed, until the instrument has entered deeply enough. The wedge-needle is then carefully inserted between the side of the boring tube and the wood within. A turn of the handle backward is given in order to detach the cylinder of wood at its further end, and with the toothed needle the little column of wood is drawn out. The latter shows along its length the annual rings of the stem; these rings are measured, and the rate of increase computed. The instrument is thus of assistance in deciding whether or not the trees have arrived at their financial maturity.

In *height measurement* the geometric method is often adopted; it rests upon the theory of similar triangles. Referring to Fig. 25, a vertical staff is placed in the ground at some distance (6 to 8 feet) from the eye (D) of the observer. The staff forms a line parallel with the stem of the tree, and the rays or lines of vision to the top and foot of the stem cross it at *b* and *a*. The ray DC is horizontal. Taking the measurement of the distances from the observer

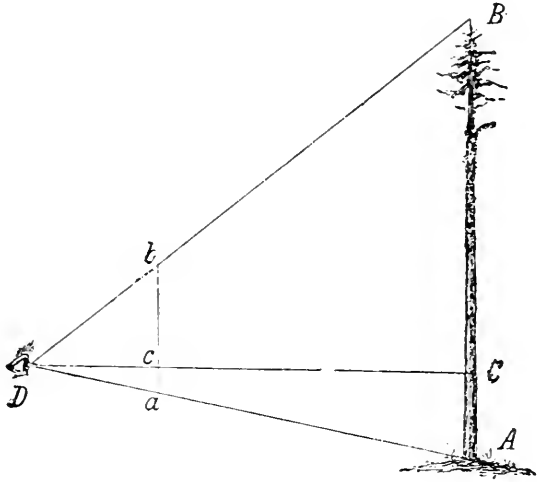


FIG. 25

to the staff and to the tree, the height can be obtained by the formula—

$$H = \frac{ba \times DC}{Dc}.$$

Faustmann's Hypsometer, or height measurer, is shown in Fig. 26. With it a tree's height can be ascertained from any convenient position from the stem, provided one can see from it both the top and the base of the tree. The distance from the observer to the base of the tree is measured, and the vertical scale (*g*, *e*) is adjusted accordingly. Then, sighting through *a* and *b* to the tree top, the pendulum (S), with the plumb-line resting on the horizontal scale, gives the height *plus* or *minus* the difference in level between the eye of the observer and the foot of the tree. This latter point is quickly decided by sighting to the tree's base, and adding or subtracting according as the result indicates.

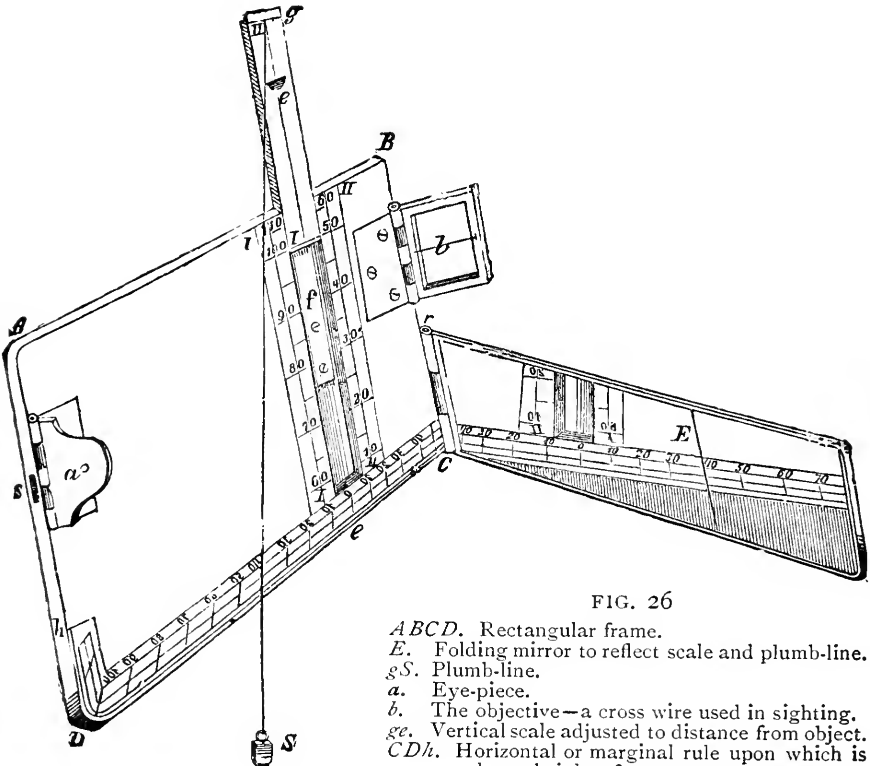


FIG. 26

ABCD. Rectangular frame.
E. Folding mirror to reflect scale and plumb-line.
gS. Plumb-line.
a. Eye-piece.
b. The objective—a cross wire used in sighting.
ge. Vertical scale adjusted to distance from object.
CDh. Horizontal or marginal rule upon which is shown height of tree.

Weise's Hypsometer (Fig. 27) is constructed on exactly the same principle. It is even handier than Faustmann's instrument, though both are simple and reliable. Sighting is here effected through a metal tube, on the side of which is fastened a toothed scale, upon which the plumb-line indicates the height. The units of distance from the observer to the base of the tree must be shown upon a second scale—that which has its position at right-angles to the "height scale"—before the operator commences sighting.

In order to ascertain the condition of a wood, it is necessary to take into consideration the growing stock, its age and increment, and the quality of the locality (*i.e.* soil and situation).

Stem measurement. The cubic contents of the stem of a single felled tree are determined accurately enough for ordinary purposes by multiplying the middle sectional area by the length. At a point taken by measurement half-way along the stem, the diameter is found — most conveniently by callipers. The area of the cross-section is then calculated (obtained by squaring the radius and multiplying the result by 3·14) and the result multiplied by the length of the stem. Specially prepared tables may be used to accelerate the operation.

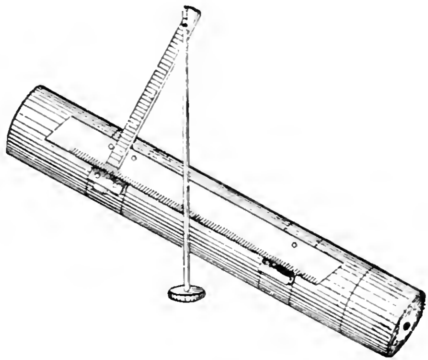


FIG. 27

In Britain the practice is materially different, the quarter-girth system being in vogue. By it the length is multiplied by the square of the mean quarter-girth. Thus a tree 32 feet long, having an average circumference under bark of 44 inches, is calculated as

$$11^2 \times \frac{32}{144} = 27 \text{ cubic feet.}$$

This is often supposed to give the actual cubic contents, whereas the result thus obtained is about one-fifth less than the actual volume. To state it otherwise, timber reckoned by quarter-girth measurement to have a volume of 100 cubic feet contains in reality about 125 cubic feet. The difference is understood to equalise itself in the price obtained, and that the surplus allowed to the purchaser provides for loss and waste in squaring the stem. Only the force of custom, however, can defend the use of such an incorrect system.

For scientific investigation the stem is measured as though divided into short sections—say, 6 feet in length. The diameter is taken at the middle of each piece, thus at 3 feet, 9 feet, 15 feet, etc., along the stem. The volume of each piece is calculated as the product of the middle sectional area multiplied by the length. All the volumes added together give the total contents of the stem. The topmost portion is measured apart from the rest of the stem as partaking of the nature of branchwood.

Measurement of a standing tree. The volume of a standing tree for any given species and age may be found by means of *form-factors*[1] (factors of shape). First of all, the diameter of a tree should always be taken at breast height, or, to be exact, at 4 feet 3 inches from the ground. The diameter being taken at this point, the area of a cross-section is found, and the tree's height measured. The volume is then the product of s (area of the cross-section) $\times$ h (height) $\times$ f (form-factor). By form-factor is understood the quotient $\frac{v}{s \times h}$, where v is the volume of a stem or of a whole wood, and s and h are as before. A form-factor represents the relation of the tree's volume to the volume of a cylinder whose basal area is the same as the area of a cross-section of the stem at 4 feet 3 inches from the ground, and whose height equals the total height of the tree. The principle is illustrated in Fig. 28.

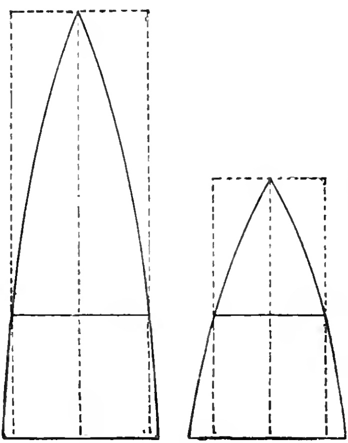


FIG. 28

Of the various methods by which the present volume of a wood may be ascertained, form-factors and volume tables are most generally employed. In using form-factors, all the trees in the wood are callipered at

[1] In Germany three kinds of form-factors are recognised: Tree form-factor (*Baumformzahl*), representing all wood upon the tree. Timber form-factor (*Derbholzformzahl*) = all timber having a diameter of over 7 cm. (nearly 3 inches). Stem form-factor (*Schaftformzahl*) = timber over 7 cm. upon the stem only.

breast height, thereby finding the diameter. From special tables giving the areas of circular surfaces of known diameter ready calculated, the contents of all transverse sections of the several trees are found. By the addition of these sums the sectional area S of the wood is obtained. The average height H is found by measuring a considerable number of trees. From tables prepared from averages, the form-factor F is obtained. The contents of the wood are then as $V = S \times H \times F$.

When volume tables are used, the trees are callipered and the number of stems in each diameter class is found. The diameter classes are generally made to differ from each other by gradations of 2 inches; thus all stems of 10 inches are arranged together, then 12, 14, 16 inches. The mean height of trees of the several diameters is then taken. On finely squared paper the heights are shown graphically as ordinates, and with the respective diameters as abscissæ a "height-curve" is drawn. Fig. 29 gives one of these

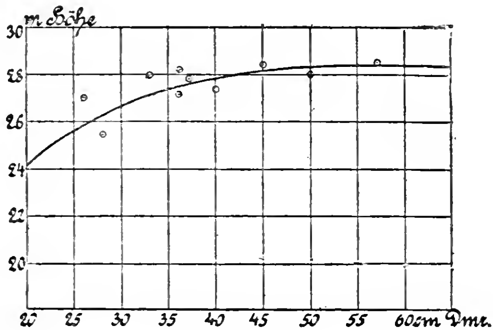


FIG. 29

curves. In the figure the heights are shown in metres (= 39 inches), and the diameters in centimetres (= ·39 of an inch), but it is similar when expressed in feet and inches. Such a curve being constructed, one may read from it the average height of trees of every diameter. The age does not require to be more than approximately estimated. The volume of each diameter class is found by the multiplication of the number of stems by the volume of a single stem of the respective diameter and height. The individual contents are obtained from prepared volume tables. By addition of the volumes of the several classes, the volume of the whole wood is found.

Where conditions make it unsuitable to make use of the two methods just described, Draudt's treatment may recommend itself. By it a certain proportion of the stems of each diameter class are felled as sample trees. The basal area (sectional area) is measured as explained above, both for the whole wood and for each sample tree. The volume of the wood, V, is then obtained by multiplying the volume of the sample trees, v', by the quotient of the standing crop's basal area, and dividing by the sample trees' basal area—

$$V = v'\frac{S}{s}.$$

The volume of the sample trees is usually reckoned from the middle sectional area multiplied by length of stem. Smaller split timber, as distinct from whole stems or logs, is arranged in stacked measure, and to find its cubic contents reducing factors must be employed. These are coefficients, representing the proportion of actual wood to the space occupied in the heaps. The converting factor ·7 may be accepted for stacked timber, and ·2 for branchwood, when estimating these in solid cubic feet. By Draudt's method an advantage is gained in that the volume of the timber is calculated in assortments in which it may be sold. Should the prices obtainable be known, the total value of the forest can at once be ascertained. To find this, it is only necessary to replace v' by the quantities of the respective assortments, and to multiply by $\frac{S}{s}$.

The best way of taking the age of a wood is to count the number of annual rings upon the stool of a felled tree, adding two to three years to the average age, the first few years' growth not being always visible on the stool.

Increment

In order to determine the rate of accretion of a given wood from the date of measurement to the time when felling will take place, either the system of *increment percentages* or that of *yield tables* is adopted. The former is most useful when it is wished to determine the increment for a short period only, say ten years; for longer periods than this the latter is more applicable.

Of the various formulæ for ascertaining the rate of increment, that of Schneider is the simplest. It is expressed as

$$p = \frac{400}{n \times d}.$$

The numerator 400 is here a "constant," which in the case of vigorously growing woods must be increased to 500 or 600; d is the actual diameter in centimetres without bark, and n is the number of annual rings in the outermost centimetre of the stem—measurement being taken at breast height, and usually with the help of Pressler's increment borer.

Yield tables show the progression of a wood's growth per acre by giving the volume of the trees forming the principal part of the crop, the returns from thinnings, and the factors which determine the volume (height, number of stems, basal area). They are founded upon a careful collection of statistics regarding the important species. In the tables the latter are arranged according to the quality of the locality, most usually into five classes—I. denoting the best, and V. the poorest condition.

The term "quality of locality" signifies the yield capacity of the situation—the timber volume which under proper management and without accident a crop of trees is able to produce. Height growth gives the surest indication of the quality of the locality. Under ordinary circumstances, therefore, it is sufficient merely to find the average height and age of the trees in order to assign the wood to its suitable class.

For the application of yield tables the composition of a wood comes into consideration along with the examination of the locality. One has to decide in how far a wood differs from the perfect, or, as it is called, "normal" state, it being understood in economic forestry that the forest is in a normal condition when the crop is so complete that it preserves all over the area an unbroken cover. In reality, woods never quite attain to this degree of perfection, which, however, is frequently taken as the standard = 1, and the divergence from it is expressed in decimal fractions. To be normal, the canopy of the whole wood must be so perfect that absolutely no direct sunlight can reach the forest floor. As such woods—at least, of light-demanding species—do not exist, the wood's condition may be more precisely determined by a comparison with the "normal" state given in the yield tables.

If the quality of a locality be known, and the age of the wood, one may, by means of yield tables, estimate what quantity of timber can be produced on such an area, during any given period of years.

The amount of the increase in volume duly arrived at, it is easy to calculate the *mean annual increment* as being the volume increment evenly distributed over the period. The rate of volume growth is, however, by no means uniform. Most generally, during a wood's earliest youth, the yearly accretion is slight; it then becomes accelerated, reaches its maximum, and ultimately decreases—at first slowly, but later rapidly. The ordinary course, the so-called *current annual increment*, is occasionally interrupted by storms, the occurrence of seed years, and the troubles of insect, fungus, or other attack. The true current annual increment of a tree or wood is very difficult to determine, and it usually suffices to take the average increase over a short period—say from five to ten years—and consider this as being accurate for each of the years within the period.

The mean annual increment follows a course very similar to the actual yearly increase. At first it is even lower than the latter; it rises gradually, and culminates later than does the current increment, its maximum being also lower; the decrease from this point is less fast in the average than in the current yearly increment. The mean annual increment reaches its maximum when it is the same as the current annual increment; previous to that it is lower, subsequently higher than the latter.

Besides the *quantity* increment dealt with above, it is also necessary, for the purposes of forest management and valuation, to take into account the *quality* and *price* increments. Quality accretion or increment follows from the increase of value per cubic foot, which is associated with increased age and dimensions of the trees in a wood. With additional volume, there is a more than proportionate increase in price per unit of measurement; hence the need of this factor being duly noted. It has nothing to do with the price of timber in the general tendency of the market, which receives consideration under the term "price increment." Price increment denotes the change in value (positive or negative) which may be occasioned by economic circumstances, most of them beyond the control of the forester. Thus prices are influenced very greatly by the shortage or superabundance of the supplies of imported timber, and locally by the formation of new roads or railway lines.

All three forms of increment (volume, quality, and price) may be conveniently expressed as percentages.

As the sum of these three values (volume, quality, and price increments) represents the actual increase in the value of the forest, it is not difficult, after the three items are known, to ascertain the return on the invested capital.

The value of a wood is judged from the present worth of its timber contents, T; that of the land, L; and a sum must also be named to cover the costs of management, M, which will include working expenses, taxes, wages, and so forth. If the volume, quality, and price percentages be called respectively *a*, *b*, and *c*, then from these variables, which determine the amount of the forest capital, may be derived the interest on the working capital $(T + L + M)$.

The relationship may be stated as follows :—

$$(T + L + M) : T\frac{a + b + c}{100} :: 100 : p_i;$$

$$\text{or, } p_i = \frac{T}{T + L + M}(a + b + c).$$

This per cent., p_i, has been called the "indicating" per cent. (Pressler); it is useful as showing the return yielded by a forest at any desired period, and it seeks to determine the financial maturity or most profitable rotation of a wood.

Collection of Data for Working Plan

Previous to the regulation of forest management and control of the woods by means of a working plan, the total area of a forest property is divided into suitable compartments, and measurements are taken after the manner described above. The results of such a survey and all relevant matter are brought together in a statistical or descriptive report. The two large divisions of this document are termed the General and the Special Reports. The former concerns itself with the prevailing conditions of the forest area *as a whole*, and deals with such questions as ownership, public rights or servitudes, the area occupied by forest growth, the sylvicultural systems adopted, the character of the soil and situation, marketing facilities, means available for transport of produce, data regarding the quantity of timber hitherto utilised and the monetary returns, notes regarding the executive staff, etc.

The Special Report is a detailed description of each division or subdivision of the forest. In it the quality of the locality, the nature of the existing crop, and proposals for future management take the foremost place. The first of these, the locality, is judged from the soil's physical and chemical condition, depth and degree of moisture, the altitude, slope, exposure, and general relations to climatic influences of the situation, the natural weed growth on the soil's surface, etc. Where trees have already occupied the ground the value of the site is more easily estimated than where there is no guide from forest growth. In the former case the condition is judged from the development in height of the trees for the respective ages.

For certain methods of regulating the utilisation of a forest, not the actual average-sized area, but a so-called "reduced" area, is taken. This is necessary, because the productive quality of the areas usually varies; and if it be desired to divide a forest into sections of equal yield capacity, it follows that the poorer situations must be of greater extent than the rich. In order to arrive at a proper balance, reducing factors are employed. The best quality may be called 1, and inferior grades expressed by decimals of this, or the average quality may be selected as the standard unit. From the above it is evident that the soil and situation of each wood ought to be appraised with care.

Coming into consideration along with the locality is the quality of the crop. The species of which the wood is comprised must first be stated in the written account; mixed woods may have the kinds of trees indicated in the proportion in which they occur. Thus, for example, a mixture of Beech, Oak, and Ash might be stated Beech ·6, Oak ·3, Ash ·1. Then the age is noted, and the natural period to which the wood may be assigned is given. Terms such as "thicket stage," "pole forest," and "timber forest" describe the stage which a wood has reached even better than a mere numeral giving the years of its growth. Anything remarkable about the trees, as affecting the quality of the timber, should be included in the statement. The degree of density may be represented by a figure, the "normal" condition being called 1, and the less perfect being denoted by decimal fractions. Whether the crop be "blanky," "open," have a "fairly good canopy," or what its general state is, should be expressed in words as well as by figures. The method of formation of each wood must be given so far as it is known, and its sylvicultural treatment in the past as regards thinnings, etc., explained. The volume of older woods requires to be assessed in order to fix the proper quantity of timber shortly to be utilised, and it is usually necessary to ascertain the forest's increment or rate of volume accretion.

After the facts indicated above have received due consideration, the most important points to be observed in the future treatment of the woods are collected into a short statement. Such matters are dealt with as instructions for the filling in of blanks which have occurred in recently formed woods, mode of carrying out thinning operations, the process by which regeneration should be brought about, and much else of like nature.

As far as possible the mode of management should be represented upon maps or plans. Working first with only a rough sketch of the area, the forest surveyor defines the boundaries of the compartments and subdivisions, determines the direction of roads, etc., until gradually the finished map is evolved. Usually, at least two kinds of maps are prepared: (1) The "Detail" map, in the scale of perhaps twenty-five inches to a mile, showing boundaries of the property and the forest working sections—a map of much value in the event of change in ownership or management. (2) The "Stock" or "Plantations" map, which represents the character of the woods, particularly as regards species, distribution of age-classes, and the manner by which the plantations have been allotted to the periods of the rotation. Very often the scale of six inches to a mile is found to be suitable for this. Contour lines and the road system are occasionally depicted on a separate plan, or they may be included upon the Stock map.

The survey and division of woodlands proceed simultaneously in practice. The disposition of the divisional areas is determined after an examination of the ground, together with plan or map measurement. The division is thus the result of work done partly in the office and partly on the spot. The measurement of the forest is effected according to the recognised methods of land-surveying which are based chiefly on trigonometry.

The Normal Forest

The laws of nature make it impossible for us to take away annually from each individual tree its yearly production of timber. This must be allowed to accumulate till the tree has reached a useful size, and then, on felling it, the accretion of years is at once harvested. In a forest consisting of sections equal in number to the years of the rotation, the oldest section should represent the year's increment for all the forest; upon its removal the quantity this represents is realised. Yields from thinnings are here not taken into consideration.

A forest permanently placed under sylvicultural control is under rules regulating *sustained management*. It is the foundation of systematic forestry to secure to the proprietor continuously (annually or periodically) a regular yield or income. When the timber output is approximately equal every year, it is the most positive evidence of sustained management. This is possible only in the so-called "normal forest" (see Fig. 30, p. 138), of which in its simplest form the following is true. With a rotation or felling age of r years (for instance, 100 years) a forest has r acres (say 100 acres) divided into a number of sections, the ages of which are graded evenly from the youngest to the most mature (gradation 1......r years). Immediately upon felling the oldest wood, matters may be represented as 0......$(r-1)$, because the newly felled area is not restocked, and the ninety-nine-years-old wood requires one year before it reaches its full rotation period. Under such conditions the volume of the r-years-old section is exactly equal to the annual increment amassed during the last growing season over the whole forest area, and does not vary from year to year. The stock of timber in the normal forest is called the *normal growing stock*.

The amount of the normal growing stock, apart from the size of the forest, depends upon the species, the quality of the locality, the sylvicultural system, treatment, and length of rotation. With I representing the normal increment, and r the number of years in the rotation, the normal stock S is found from the equation—

$$S = \frac{rI}{2}.$$

The quantity of timber that may be taken each year under normal conditions is called the normal annual yield. Corresponding to this in practice is the actual produce available for use without interference with the permanent revenue of the forest.

If the increase of the growing stock exceed the amount calculated as being the normal yield, the surplus may be allowed to accumulate to form a *reserve*. Reserve stock may consist of specified woods which, as a provision against accident, are not included in the estimate for the income, or the returns may be calculated at a figure below that which the forest is known to be capable of yielding.

Factors determining the Course of Future Management

The survey of the forest, the estimate of the volume and increment, and the detailed description of the woods, furnish the information on which the course of future management is based. It is necessary first to consider the object the owner has in view in maintaining the woodlands. In strictly economic forestry, some financial calculation is necessary to decide when it will be most profitable to harvest the crop. This may be reckoned by either the *highest forest rent* or the *highest soil rent* theory. The former represents the difference between the average annual income and expenditure; but it does not take into account the time occupied in the realisation of this. In the second case, the effort is to earn the highest *rate of interest* on the capital invested—represented by the soil and standing crop. To obtain this, the management must realise the maximum "expectation value" of the soil; in fact, the rotation chosen must be that which promises the greatest financial return. For this purpose, that rotation which furnishes the highest *net soil rental* should be selected.

The peculiar nature of forestry, especially as regards the time element—the long interval between formation and realisation—which the production of timber entails, makes it possible to arrive at only approximate results in any computations of this kind.

It is interesting to note that for the last forty years there has been a literary strife between the advocates of the two methods of calculating the financial rotation which have just been mentioned. This has resulted in an ultimate decision in favour of the soil-rent principle, in spite of the uncertainty of the premises upon which the reckoning is necessarily based. In practice deviations must frequently be made to suit local circumstances—more especially is it desirable, in many cases, to keep the felling age well within the date indicated theoretically.

This preliminary question concerning the aims of the forest being fairly settled, the following matters in connection with the management of the woods must be decided upon:—

(1) The selection of the sylvicultural system. High forest (in any of its various forms), simple coppice, or coppice with standards.

(2) Choice of the species.

(3) Determination of the most suitable felling age. Under the financial arrangement of the highest soil rent the felling age is earlier than where the largest forest revenue is the motive. But when all the factors concerned are judiciously weighed, the difference is not nearly so great as speculative literary controversy would suggest.

(4) Arrangement regarding "working sections" according to the species, rotation, and character of public rights where such exist.

(5) General principles upon which future operations should be conducted.

As the whole course of management has its foundation in the above subjects, their importance will be readily appreciated. The conclusions arrived at are embodied in the Working Plan report.

Methods of Regulating the Yield

Various methods are employed to regulate the amount of produce that may annually or periodically be taken from a forest without diminishing its permanent stock or reducing the productivity of the soil. The simplest of these consists of the division of the total forest area into sections, corresponding in their number to the number of years in the rotation. These *annual felling coupes* may be either of equal size, or else they may vary in extent according to their yield capacity and degree of complete stocking. In this their acreage is determined in inverse proportion to their productive value. It is evident that smaller areas of dense woods are equivalent to greater areas of thin crops or poorly grown woods, and the allocation can be arranged accordingly. The plan of making the divisions of equal or nearly equal size is suitable for coppice woods and for woods worked on the Selection system.

Of more general applicability is the method of allotting the woods of a forest into *Periods*. The number of the period classes and the time occupied by each, depend chiefly upon the length of the rotation, but intervals of twenty years are frequently found to be suitable.

Division of the forest into Periods takes place according to *area* or *volume*, or regard is had to both of these factors, and a method of partition by *area and volume combined* is resorted to.

Allotment by Area. By this system approximately like areas are allotted to separate periods in the rotation.

For example, if a forest of 12,000 acres, worked on a rotation of 120 years, be treated in Periods of 20 years, there will be 6 Periods, in each of which 2,000 acres will be dealt with—that is to say, an average of 100 acres per annum.

If differences in the quality of soil or situation occur, the areas may be reduced to one common quality standard.

The advantage of the allotment system is that it is more elastic than mere division into fixed annual coupes. Under the system of "Periods," the wood manager is at liberty within limits to determine the area of the year's felling.

Allotment by Volume. The method of allotting the woods into Periods by volume is made according to the anticipated yield (growing stock and increment), so that the total quantity of produce from each Period may be nearly the same. The system of volume allotment has found but little support in practice, owing to the difficulty, and indeed impossibility, of determining the yields far into the future with sufficient accuracy.

Combined Method. An improvement upon forest regulation by volume alone is found in the "combined method," by which the areas receive more consideration, and due importance is given to the arrangement of the age classes.

First of all, a suitable distribution of the areas into the several Periods is effected, then the volume returns are calculated (at least, for the first one or two Periods), and, so far as appears necessary for the equalisation of the returns, shiftings of single areas are made.

The estimate for determining the amount of the yield which may safely be taken is sometimes confined to the next ten years of the rotation. This practice, which originated in Saxony, is gaining favour. A selection is made of the woods which it is necessary to take in the course of the coming decade, and the fellings are distributed as evenly as practicable, so that the supply is made nearly constant. The woods most urgently requiring removal are those whose increment has sunk or is sinking below that which is profitable; but in the removal of such woods, due regard must, of course, be given to the sequence of the age classes.

Regulation by Comparison with Normal Stock. Wholly differing from the allotment system is the method of regulating the felling accounts by calculating with formulæ. This consists essentially of a contrast between the *actual* and the *normal* stock. In the Austrian formula method, which is the oldest of its kind, and still practised in that country, the underlying principle is as follows: A normal growing stock produces a normal increment, the amount of which, in mature timber, should be removed; but forest crops which show a growing stock greater or less than the normal should be more largely exploited or more carefully conserved, as the case may be. If a surplus be present the formula is—

$$Y = Ir + \frac{Gr - Gn}{r},$$

where Y is the annual yield, Ir the normal increment, which is taken as equal to the final mean annual increment, Gr the actual growing stock, Gn the normal growing stock, and r the number of years in the rotation.

Forest Working Plans

The object of the working plan is to regulate the time and manner in which the utilisation of the forest produce should take place; and as a necessary accompaniment to this, for the assuring of a "sustained yield," particulars concerning all operations about to be undertaken are here brought together in methodical fashion. The plan or scheme is capable of differentiation into three divisions:—

(1) The General or Chief plan.
(2) The Periodic plan.
(3) The Annual plan.

The first of these indicates the lines upon which the management is to be conducted. Its prescriptions extend over the time occupied by the rotation; only occasionally, when the condition of a forest is very abnormal, its scope is provisionally shortened. If more than one series of age classes ("working section") exist, each must be managed on a distinct rotation. One may, for example, have woods of Alder coppice in the midst of a Scots Pine forest; but as their methods of treatment are fundamentally different, each is given a suitable felling age and working section.

The General working plan deals with all that concerns the control of the forest. It is the basis of the whole system of management, and special emphasis is given to directions regarding fellings and regeneration, regulating the way in which the woods will pass gradually from one Period to another. It consists partly of tabular statements, partly of a written report. In former times schemes of regulation were prepared to control detailed work, even in the distant future. Such laboriously constructed plans are, however, quite unnecessary, as, in the course of very long periods of time, changes intentional and accidental are certain to occur. It has therefore now become customary to state only the aims and guiding principles of the work, with particular reference to the operations in the next ten or twenty years. The areas of the more remote Periods have their places in the working plan allotted to them in such a way that a permanently equal yield is assured. By noting these in the general scheme, a survey is given of the whole of the proposed course. As has been already mentioned, however, the selection of the woods for allocation is occasionally made with regard only to the next decade.

In drawing up the General working plan attention is given to the arrangement of the succession of the fellings and the formation of what will be the cutting series of the future. Regard must also be paid to these important matters at the time of the subdivision of the forest area.

The order in which the fellings are made, influences the restocking of the cleared ground. The direction which the fellings take in following one another is largely dictated by the dangers which locally threaten the forest. Amongst these, the lessening of damage by windstorm should be given first consideration; but also insect attack and destructive forest fires may in great part be combated by a suitable disposition of the cutting series. As a rule, the successive fellings should be carried on in a direction contrary to that of the prevailing wind, and the felling areas should then take the form of broad strips at right angles to that line.

Cutting Series. Each apportioned part of a working section for which a complete succession of fellings is arranged forms what is called a *cutting series.* There may be only one cutting series in the working section, the age gradations being so planned that fellings proceed straight forward in unbroken sequence, as shown in Fig. 30. The "coupes" in such a

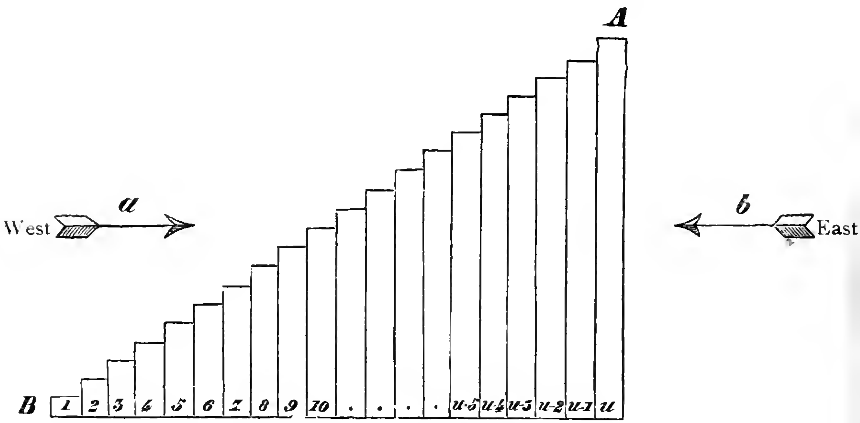


FIG. 30. FORMAL ARRANGEMENT OF AGE-CLASSES
Cutting would proceed from east to west

regular series as this equal in number the years in the rotation. But though possessing the advantage of simplicity, and usually suitable for coppice woods, long cutting series of this kind are not always desirable. In the management of high forest it is a general rule that no part be cut over until the recently cleared area adjacent to it has been fairly established. To obtain this, and yet continue the annual utilisation and restocking, it is necessary to carry on operations at several different points in the forest, and to return to these for the continuance of the fellings, not annually, but at stated intervals. The formation of small cutting series, giving many of these centres or points of attack in exploitation, is therefore to be recommended. Many dangers to which regular age-gradations, when too closely associated, are prone are thus avoided, or at least considerably reduced.

Formerly the data determining the quantity of timber to be felled were also recorded in the General plan. Now, however, since it has become customary to reckon the volume and increment only for the first Period, or even only for the first ten years, it has been found most suitable to give the figures regulating the yield in the Periodic plan. This latter, following the principles laid down in the General plan, deals in a detailed manner with the necessary fellings and regenerations. The woods which require to be entered in the scheme of fellings as those first to be taken in hand are the following: (1) defective old woods which are improperly stocked, being blanky or too open; (2) odd corners which have arisen in the course of laying out the system of roads, and whose age, species, or character suggest alteration; (3) areas to be cleared between divisions of the forest as Severance fellings in the interests of the cutting series; (4) the removal of parent or shelter trees from regeneration areas, where such trees are no longer desirable.

If, after such woods have received attention, the felling budget allows of still more being utilised, parts of the forest where the yearly accretion has become unsatisfactory should be dealt with. Where the "indicating per cent." (showing the interest yielded by the forest capital) has not been ascertained, the condition of the woods and of the cutting series must decide the woods' position in the Periodic plan.

The volume of wood on the area to be cut over during one Period, along with its increment up to the time of cutting, is the measure of the Period's "final yield." The quantity divided by the number of years in the Period gives the *annual* yield. To this must be added the intermediate yield from thinnings extracted from woods belonging to later Periods. As the amount of material which these yield is apt to fluctuate, one seeks to arrange the woods for thinning by taking a certain proportion *by area* in hand each year. All woods requiring thinning must be visited at least once in ten years. The yield which may be expected from these intermediate cuttings is estimated from figures given in yield tables. The tables consist of carefully prepared averages of measurements taken from a large number of cases.

Then there is the so-called *Annual* plan of management, which has for its object the arrangement of the actual works of felling, sowing, planting, etc., for the ensuing season, in accordance with the instructions contained in the General and Periodic working plans. It is not in itself a working or regulation plan, but is simply part of the executive work.

Execution of the Working Plan

For reasons already stated, schemes which define in detail the management for a whole prospective rotation are impracticable if the rotation be at all lengthy. Indeed, the working plan should never be considered as something fixed and unalterable. In order to maintain its efficacy, it is essential that it be subjected from time to time to revision and renewal. Revision is a check on the accuracy of the work of the original document; it has due regard to changes in the objects of management, and, in short, by re-examination, the whole scheme gains in reliability and usefulness. In the event of very extensive damage by windstorm or other depredation, the existing plan may be so interfered with that the preparation of a completely new one becomes a necessity. Of the utmost importance to the accomplishment of the aims of the working plan is a proper system of book-keeping. Records must be kept to show how the various operations have been carried out in order to construct a history of each wood. Accounts are therefore necessary to show the yield in material and money on the one hand, and every item of expenditure on the other. The method of entering the required particulars varies with circumstances; but the following books and statements may be mentioned: (1) a register of all changes in the area and boundaries of the forest; (2) a statement giving the volume and value of the returns from the fellings, both in the aggregate for the whole forest, and for each compartment or division; (3) a report of the work of regeneration, of road-making, draining, fencing, etc.; (4) notes on matters of importance for future reference, *e.g.* the occurrence of seed years, of windstorms, insect attack, and so forth.

A revision of the working plan should take place at least once in twenty years—usually at the end of a Period; very frequently, however, it is desirable to have it at a much shorter interval. In Saxony, working plans are customarily examined each five years. The longer the interval between the revisions, the more thorough must they be; the amount of work entailed, depends on the changes that have occurred, and the suitability, or otherwise, of the system at first adopted. Sometimes a revision is as laborious as was the preparation of the original plan; under other conditions it may occasion very little trouble indeed. When circumstances have not altered, it consists of merely closing the books of one Period, and opening accounts, as it were, for the next, along with the preparation of a new Periodic working plan.

CHAPTER IX

FOREST FINANCE

Valuation and Rate of Interest

FOREST valuation consists in estimating the financial value of woodland property. As far as mere calculation is concerned, forest valuation is fairly simple; but a distinct difficulty is found in determining the absolute values to employ in the formulæ made use of. The time element which forestry has to face makes any approach to perfect accuracy impossible. The management of a single crop of trees extends, as a rule, over a very lengthy period, and it cannot be expected, for example, that we can at present estimate with much confidence what the yield and value of a wood will be a hundred years hence. No less uncertain is the task of determining the rate of interest to be charged for capital invested in forestry, though, owing to the length of time during which the capital is lying untouched, the accuracy of the basis of this estimate is of great importance. Again, the financial calculation rests largely on the supposition that the future management will proceed upon definite lines, which, however, it may be necessary to depart from—for example, the length of rotation may have to be changed, the exact time at which thinnings will be required is not known, and the yield from them cannot well be forecast. In the narrower sense, at least, the computation of the receipts and expenditure does not come into the work of forest valuation, these matters being held as part of the forest management—especially is this the case with the more important forest areas.

Questions which materially affect the making of the estimates are the future price of timber and the rate of interest chargeable. Both of these are uncertain quantities; but statistics show that the tendency is for wood to rise in price and that the rate of interest is sinking. This is true, of course, only as regards the general tendency throughout long periods, temporary fluctuations being beyond our power to forecast. As the value and rate of interest tend to move in opposite directions, the best course to adopt is to base calculations on present prices, and reckon with a low rate of interest—say 2½ or 3 per cent.

Amongst other arguments in favour of the use of a moderate interest rate, it may be said that land, even in a good agricultural district, yields but a low net return to the owner, that for a permanent investment forestry is accounted very safe, and that there is a feeling of pride in the possession of forest property that is to be reckoned amongst the returns of capital so invested. These advantages render this form of investment particularly attractive and suitable to large capitalists. If storms or insect plagues occasionally cause damage, there is to be remembered, on the other hand, the comparatively small expenditure required in forest maintenance.

Sale Value, Cost Value, and Expectation Value

Various more or less useful formulæ have been constructed for the calculation of the value of the forest soil, and the growing stock, and for these two—soil and growing stock—taken together under the comprehensive term "forest." For each of these there is a *sale value*, an *expectation value*, and a *cost value*; and for the forest there is, in addition, a so-called *rental value*.

The **Sale Value** represents the market price of the object for sale; no mathematical formulæ are needed to determine it; but, instead, the price is estimated by comparison with lands, woods, etc., previously sold under like conditions.

In calculating the value of a forest the selling price enters largely into the calculation in the case of mature or nearly mature woods. It is different with young woods; their timber may not be readily marketable, and to attempt to sell anything more than a small portion of it might have a very bad effect upon the price. The same consideration holds good in estimating the returns and rental value of the final yield wherever rotations are shortened, that they may give an increased supply of a certain size of material temporarily scarce.

With forest soil the selling value is in many cases capable of being very exactly fixed, especially when the area has been cleared of trees or when it appears suitable for tillage.

For extensive forests, owing to the diversity of the points under consideration, the sale value should be used only as a general guide.

Expectation Value is the present value of all yields which may be looked for from an estate, minus the present value of all estimated expenditure to the date of realisation. It is employed chiefly when estimating the value of the soil, and it forms the best standard for judging the profitableness of the forest's management. It also affords a means of gauging the respective merits of different systems of tree raising, of agriculture combined with forestry, and so forth. Only rarely is the expectation value used for calculating the sale value of the forest.

The **Cost Value** of a forest property represents the present value of the outlays for formation and maintenance to date, less the present value of all receipts. It is chiefly used for estimating the value of younger woods. Of the cost value of the soil one can only speak when the land has been reclaimed from an unproductive state by the expenditure of money. The sum spent, along with interest, then constitutes its cost value. Examples of this may be found where peat bogs have been redeemed, or drifting sand permanently fixed.

By the term **Rental Value** is meant the capitalised rental that a forest is able to yield. The organisation and treatment being all that they should be, the rental value forms the best standard of valuation. Where proper attention has not been given, however, its employment in the sale of forests often proves unfavourable to the interests of the vendor.

In practice it is always best to choose the method of calculation for which the most reliable data are available; thus for young woods the cost value should generally be chosen, and for middle-aged woods the expectation value.

CHAPTER X

FOREST ECONOMICS

In its scientific sense forest policy may be defined as the representation of the economic position which forestry occupies in the affairs of the State and the people. That which is briefly discussed here, however, is simply the relationship which exists between the State and forestry. State administration consists, on the one hand, in the protection, care, and management of the forest in the public interest; and, on the other hand, when the forest as a lasting source of supply is endangered, administration may assume the form of restriction of individual action for the benefit of the community at large.

State Ownership of Forests

The attention given to forestry in a country depends very largely on the nature and manner of treatment of the State forests. Whenever one finds laxity of management or non-conservative treatment of Government reserved forests, one also finds the privately owned woods in an unsatisfactory condition. Similarly in lands which do not possess any considerable area of regulated national forest, the fact is there reflected in the poor development of sylviculture. In short, State woods teach through their example—being of first importance as an educative power.

About the close of the seventeenth century, and the beginning of the eighteenth, there arose a movement in France and Germany in favour of the alienation from State ownership of forest lands, it being held, in accordance with the economic theories of the time, that the State should not be directly interested in any particular industry. Owing to the financial distress that prevailed, the agitation led to measures being taken in pursuance of this policy. Almost at once, however, it became obvious that a mistake had been made. In private hands the forests were mismanaged in nearly all cases. Not only was the elementary principle of a sustained yield and the production of the highest soil rental quite neglected, but too often the public good was sacrificed to private advantage by deforestation. Consequent on the withdrawal of the forest cover, the soil was unduly exposed; in many parts barren wastes were formed, there was much destruction by the washing away of soil by mountain torrents, and, in other districts, great damage was occasioned by drifting sand. It is the *time element* that singles out forestry from all other commercial enterprises. The advantage or necessity of continuity of ownership and management is felt in nothing so much as in forestry. Much time, large areas, and regularity of action are necessary to its most effective working. The permanence and resources of a nation make the State the most suitable custodian of forest property. With the realisation of this fact the tendency now is to extend State ownership; one sees the policy active not only in such countries as Germany and Austria, but also in the United States of America.

The management of State woods differs in its method according to its aims; a distinction may be made between (*a*) forests which, independent of all else, are treated for the production of revenue, and (*b*) forests which are maintained for a definite protective action in the interests of a district or locality. In the latter case, financial profit may be interfered with or entirely foregone in obtaining the desired effect.

From what has already been said, it will be evident that the chief object of State-owned woods is usually the realisation of the highest soil rental from the forest, having regard, however, to all interests, particularly to the fostering of commercial industry. In accordance with this principle, it is not consistent that a rotation should be suddenly shortened in order to take advantage of an unexpected demand for produce of a particular size, or to specially favour a certain species simply because its timber has, for the time being, shown an advance in price. In fact, anything prompted by mere speculation is out of place in State forest practice.

Many countries which have a system of Protection impose a tax upon imported timber. So far as Germany is concerned, the incidence of taxation has led to neither afforestation nor deforestation. The imposition of an increased duty in 1885 and the lowering of tariff charges in 1892 were alike without effect on the continued increase of imports over exports. Between 1882 and 1896 the imports into that country nearly doubled in quantity and trebled in value. Since 1896 imports have risen still further. It is obvious that the German forests are inadequate to meet the requirements of the country. To do this, the quantity of timber exploited would have to be increased by about thirty per cent., which, of course, is out of the question.

Technical Education in Forestry

On the continent of Europe forestry is a recognised branch of the civil service. This fact, together with the opportunity for the pursuit of game which life in the forest invariably offers, attracts a very excellent class of men to the work of forest administration. Even though the service is not specially lucrative, positions in it are at all times much sought after.

In Germany the State forest service recognises two distinct grades of officials, whose social position as well as technical training is clearly defined. In both cases candidates pass through a lengthened period of careful preparation. The course followed varies slightly in different parts of the country; but the following account indicates the character of the educational system :—

Higher Grade. A candidate aspiring to an ultimate position of control in the State forests is required, first of all, to produce a certificate from one of the higher public schools, where he must have passed certain examinations. In Prussia from six to twelve months are then spent in the woods in practical training under the supervision of a district officer. In other German States this portion of the work is taken at a subsequent period. Leaving with a testimonial on which is stated exactly what his work has been, the student repairs to a Forest Academy such as that at Eberswalde or Tharandt. Here he studies for two and a half years; the course being of a thoroughly scientific nature, illustrated by demonstrations and excursions to the forest.

From the Academy the student proceeds to a University for one year, where he occupies himself with Jurisprudence and Political Economy. Before he can go further with his course he is required to pass a very severe test. Amongst the subjects with which he must show himself familiar may be mentioned the management of woods, their formation, regeneration, treatment, utilisation, valuation, and protection; forest history, applied mathematics, surveying, physics, chemistry, geology, zoology (with special attention to entomology), and botany. Passing this examination, he is styled "*Referendar.*" For at least two years he is engaged, without salary, in various forest districts; part of this time he is required to take the place of a forest guard or keeper in the woods, thus ensuring experience in the details of practical work. One year also is passed in compulsory military training.

After the *Referendar* has gained the necessary knowledge, he again presents himself for examination. On this occasion matters of a technical kind are dealt with, relating chiefly to forest management. The greater part of the examination takes place within the forest, and relates to the actual processes connected with the systematic treatment of woods. The successful candidate then assumes the title "*Assessor*"; but for many years (usually about eight years, though it may be much longer) his salary is only from five to nine shillings per day. This is a period of probation; when it is ended, his name, for the first time, receives consideration for election to the post of "*Oberförster,*" or district officer. Only then does he enter on any work of forest control; he receives but a modest salary, and later advancement is generally slow; "*Forstmeister*," or conservator, is the next stage—should he reach it. The training is long and severe; but, as already indicated, applicants are not scarce. The profession is a much respected one, and the social standing of the higher officers is good.

Lower Grade. Posts, in some ways comparable to the forester's position in Britain, are also filled by men specially trained for the work. A beginning is made by spending two years in apprenticeship on a conservancy. During this period no wage is received—indeed, sometimes a small premium is exacted. An examination is passed, and some years—the number varies in the different States—are spent in general education and in gaining an elementary acquaintance with science. In Bavaria this instruction is given in special schools ("*Waldbauschulen*"); in Prussia and Alsace-Lorraine it is taken in conjunction with the duties of military service. All must join the "*Jaegerbataillon*," or corps of sharpshooters or scouts. This period passed, their knowledge is again tested, and they become "*Hilfsjaeger*" for about eight to ten years. Once more they present themselves for examination, and if successful they attain the rank of "*Förster*," or "forester." The status of the Förster somewhat resembles that of the head gamekeeper in Britain, but in State forests he is a Government official, and may retire with a pension after long service. For wage he receives about £80 per annum, a free house, and some acres of agricultural land.

In Austria and Russia there is, in addition, an "intermediate grade" of training. This has an advantage in that the private proprietor can more easily select a forest manager who has the technical education necessary for any particular requirement.

In order to aid in spreading a knowledge of the elements of sylviculture, some countries, including Austria and Switzerland, have successfully inaugurated short courses of lectures that extend over a few weeks or months. In Germany, also, such work has grown in a marked manner in recent years.

Communal Forests

Distinction is made between the various classes of forest property according to ownership. Communal forests are those in the corporate possession of a town, village, or association. Reference has already been made to the gradual subdivision of property that took place in Germany from the time when the forests belonged either to the princes and lords on the one hand, or to communities of peasants on the other. This movement lasted till well into the nineteenth century. The economic conception prevalent at the beginning of the nineteenth century was more in favour of individual than of collective ownership. This policy was successful with agriculture, but destructive to forestry. The reasons why the latter is less adapted to treatment on a small scale than on extensive areas have already been discussed, and need not be repeated here. Dismemberment led to very poor results; systematic management of the small piece of forest which became each man's lot was impossible. Even where any effort in this direction was attempted, its effect was too often nullified by the pests that spread from the woodland of a careless neighbour.

The fallacy of dividing forest lands has been exposed, however, and the present trend of forest policy is decidedly towards combination. Communal forestry is encouraged, and much is being done to promote the co-operative working of forest properties previously separated.

Protection Forests

One of the most difficult questions, and at the same time one of the most important, in connection with forest policy, is that which deals with the treatment of protection forests. By the term "protection forest" is understood a forest which from its situation, or the nature of the land which is enclosed within it, is of importance to the cultivation not only of the soil on which it stands, but also of neighbouring land or even of land at a distance—as, for example, when the latter is liable to suffer from floods.

The protective action consists mainly in binding the soil. This may take the form either of checking the erosive effects of very heavy rains which wash away the soil, or of preventing the drifting of sand.

Even though descriptions of the nature of land which ought to be treated as protective forest are carefully circulated, it is still found that if the matter be left to private action the results are almost invariably unsatisfactory. This experience has led to State intervention. In many countries qualified Government officials inspect the threatened areas, and forest courts are held. Should these declare the forests in question to have a distinctly protective function to perform, the areas are at once brought under definite laws, restricting the freedom of use of such land. In Prussia and Austria investigation with a view to State restriction or control, is made only as occasion demands; but in Switzerland, Italy, Russia, Würtemberg, and Hungary inspection of the country for this purpose takes place periodically at regularly appointed intervals. The former system is the more desirable.

In order that a protection wood may realise the end in view, it must always be maintained in good condition and be managed with particular care. The better to accomplish this, certain rules are drawn up, to forbid clear-felling, the entrance of grazing stock, the extraction of tree stumps, etc.; but, naturally enough, the specific treatment necessary for each case must vary with the circumstances.

As will be readily appreciated, the enforcement of the regulations for the treatment of this class of woods is effected only with greatest difficulty, more especially as the single owner often suffers in the interests of the many. In consequence, the procedure usually adopted is a transference of the endangered areas from private hands into the possession of the State.

This may be done by negotiation and purchase, should the sellers be willing to part with the land, otherwise expropriation must be resorted to. The acquisition of such lands by Government has been largely adopted in France—the country most famous for its successful works of land protection by means of forest growth.

In some countries it is found necessary to have laws compelling private owners to restock land that has been cleared of trees. Compulsory afforestation of areas not previously wooded is never attempted, however, except when the areas are put under charge of the State. Indeed, the usual preliminary action in such cases is the purchase of the land by Government.

Government Supervision of Private and Communal Forests

As regards the method of management adopted in private woods, the State is chiefly concerned with protection forests. So long as the public interest does not suffer by the action of the private owner, State intervention is unwarranted. In Germany Government supervision of private forests is practically confined to the south and central districts, where the character of the country demands that precautions be taken. Seventy per cent. of Germany's private forests are entirely free from interference by the State.

The success of restrictive measures is not very marked, due partly to the fact that the staff provided is generally inadequate for the quantity of work to be done, and partly because, on the other hand, means of circumventing the law are readily found and taken advantage of. Modern forest policy, as adopted in several countries, tends therefore to confine interference on the part of the State to those woods whose existence is of actual necessity to the public good or safety.

Measures for the encouragement of forestry have proved much more effective. These consist mainly in providing for land-owners and their agents opportunities for technical instruction in forest treatment, in giving advisory assistance, or by supplying plants, granting loans of money at a low rate of interest, allowing abatement of taxation, etc.

With forests belonging to public bodies the matter is different. In them the State has a much more direct interest, and over them it has a greater power. The woods form part of the yearly income of the communities, and it is a duty of Government to safeguard this source of revenue. To obtain a permanent yield, proper methods of cultivation require to be instituted, and exploitation must be duly regulated according to production. The financial and even social interests involved are considered to be of very great importance to a country's well-being, and worthy of the attention of the State.

In most European countries the Forest Department has been empowered to assist in the control of municipal forests, and to this end the following systems of supervision are found in operation :—

1. The State may only exercise a general control over financial dealings in order to render difficult the sale or alienation of the land, or the burdening of it with debt. Partition of the forest among its shareholders is forbidden, and the utilisation of the land for purposes other than timber production is subject to the sanction of the Government forest authorities.

This is in vogue in only six per cent. of the communal forests of Germany. It is less satisfactory in its results than either of the following systems.

2. In addition to the above-mentioned control, corporation woods may be placed under supervision as regards their technical management. For their administration, proper provision is then made for the protection and skilful treatment of the woods by a thoroughly well-qualified staff. Almost universally the woods are placed under the systematic direction of a working plan prepared by the higher grade forest officers of the State.

In Germany this method obtains in close upon half of the communal forests.

3. By the third system of State control, the forests are simply transferred to the care of the State forest officers. The treatment then resembles in every way that accorded to the Government forests.

Of the German communal woods, nearly forty-five per cent. are managed in this way.

The action of the commoners is, of course, limited most of all by this last-mentioned system, but it certainly gives the best economic results, and is in every way advantageous to the community when administered with due discretion. The community pays a certain sum to the State in lieu of management expenses, but, as a rule, this does not compensate for the actual costs. The system is, on this account, the most expensive to the Government—a fact which has in many parts militated against its more extended adoption.

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