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Forestry:

An Elementary Treatise

HERMAN H. CHAPMAN

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Forestry:
An Elementary Treatise.

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FACULTY OF FORESTRY
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No. 26.

Forestry

An Elementary Treatise

BY

Herman H. Chapman, M. F. 1874 -

Assistant Professor of Forestry,
Yale Forest School.

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FORESTRY.

BY HERMAN H. CHAPMAN.

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I. GENERAL DEFINITION.

To the question so frequently asked, "What is Forestry?" it would be difficult to give a concise and satisfactory answer, for forestry is a union of many elements as widely different in character as those which enter into the activities of a city like Chicago.

But the foundation of forestry is the growing of trees as a crop to be cut and used. Everything else hinges on this principle. The mere growing of trees is not forestry, for they may be intended as shade trees or for ornamental purposes. To cut them for the wood they contain would be to destroy their real usefulness. So the planting and care of shade trees is not forestry. The forester should know about these things, but they are a side line, the specialty of the landscape gardener who does not need to know anything about true forestry.

Nor is the mere cutting and marking of timber, true forestry. Too often the lumberman cares nothing about the growth of his timber, or the possibility of ever getting a second crop from the land which he is stripping. Destructive lumbering and forestry are at opposite poles. Lumbering is in reality a very important department of forestry, but the distinguishing feature remains, as before, the actual growing of the timber.

In recent years, with increasing public interest in forestry, lumbermen are becoming more anxious to be known

as practicing forestry. It stands to reason that no lumberman can be practicing forestry who does not definitely intend to cut a second crop of timber from his land, after the first cutting. And at least part of the value of this second crop should be obtained from the growth, or increased size of the timber he leaves at the time of the first cutting. At present it is the almost universal custom of lumbermen to cut every stick of merchantable timber and then sell or abandon the land. If a second cutting is obtained it has usually been because at the time of the first cut it did not pay to take out small, knotty, or defective timber, or timber of certain species was not saleable. As the value of all timber became greater, the lumberman found he could return and conduct a second operation profitably. Often, when considerable time elapsed between the first and second cut, the small timber had really grown much larger and more valuable. But the chief increase was always in the price. This may be forestry, but it is not intentional, and does not in any way cause the lumberman to depart from his working principle, which is, to remove every stick of timber now, provided it can be done at a profit. When the timber owner holds forest lands to profit by the actual growth of the timber, or logs it in such a way that he deliberately and purposely leaves an investment of seed trees or young timber which must grow to give him returns on his money—then and not till then, can he be said to be practicing forestry.

The truest conception of forestry is that of devoting land permanently to forest production. Successive crops of trees are grown upon the same land and these crops are either cut clean and replanted or are made to reproduce themselves naturally by seeds or sprouts. In European states, where forestry has been thoroughly established for a century, there has grown up a very definite classification of lands into forest land and agricultural land. Upon the forest soils, considered too poor for agriculture, can be seen

all stages of forest crops, from the seedling up to the mature timber in the process of removal and reproduction.

This conception of forestry has only dimly begun to take root in the public mind in America. Too often, forestry means only forest preservation. The cutting of timber is fiercely opposed on general principles. In the conception of such persons, public forests are merely public parks, to be preserved as such. This view is at total variance with the treatment of forests as crops of timber, and where it prevails, the practice of forestry becomes impossible.

II. RELATION OF FORESTRY TO GOVERNMENT.

But while timber is a crop, there are many features which put it in a different class from the agricultural crops. The latter are harvested annually and produce a constant and regular income. Their production can be left entirely to individuals, and the only relation which agriculture has with the government is in the indirect efforts put forth by experiment stations and through publications intended to instruct farmers in better methods of cultivation. Could the growing of timber be carried on exclusively by private parties, to the complete satisfaction and safeguarding of the interests of the public, the two occupations would be very similar, and forestry might truly be regarded as merely a branch of agriculture.

But universal experience proves the absolute contrary. Whenever the management of forest lands has been left entirely in private hands, the public interests are entirely ignored and a short sighted, often ruinous policy of forest destruction has been the rule, ultimately forcing the public, through their governments, to interfere for their own protection. And in regions and countries where governments have been unable or unwilling or not wise enough to interfere, the final results have often been almost complete ruin and depopulation of the country.

From the public standpoint, the interests are several. The product, wood, is almost indispensable in many important lines of industry. Substitutes are being continually forced into service by the increasing scarcity of wood, but for many uses they are not so satisfactory. New uses are appearing for wood, and the demand along established lines shows constant increase. The growing of wood will not only secure a continuance of the supply of a multitude of essential articles which enter into our everyday life and comfort, but the industries which are now engaged in the manufacture of wood products, and the logging and marketing of wood will continue to employ men and distribute wages. Then comes the public interest in the protection of soil and waterways. Private owners can and do ignore the possible effects of forest removal on the flow of streams, the erosion of soil and the welfare of their neighbors further down. Just to the extent that these results are injurious, is the government called upon to prevent them in the interests of common justice.

The relation of the government to forestry is greatly strengthened and the ability of private owners to grow timber crops much lessened by the long periods of time which must elapse before trees reach sizes large enough to furnish profitable crops of timber. Fence posts may be grown on rich agricultural land in 10 to 15 years, but timber grown on true forest soils, takes 40 to 100 years to mature. During the time the crop is growing the owner gets very small returns if any, and his expenditures for planting, protection and taxes roll up at compound interest to a large sum. If to this certain expense, is added the uncertainty that he will live long enough to receive any benefit from his exertions, beyond the satisfaction of leaving his estate to relatives or descendants, we can understand the chief barriers to private forestry on a large scale. Even corporations, which are looked upon as fairly permanent, cannot plan too far into the future, since they

must earn regular dividends and manage their holdings for present rather than future revenue. None of these drawbacks apply to state or national governments, whose interests are perpetual.

Enough has been said to show that the raising of timber crops is a matter which ultimately concerns not merely individuals as such but the whole public, as acting through the government. Even the private efforts to grow timber need the encouragement of the government, both in educational lines and in protective measures, such as fire laws.

III. THE SCOPE OF FORESTRY AS A PROFESSION.

A study of forestry or the training of a professional forester will include all the main aspects of forestry. These are—

1. Political and economic.
2. Technical.
3. Business.

The political and economic side deals with the relations that forests bear to the public. The amount of standing timber and forest areas, the uses of timber and possibilities of using substitutes are studied. The actual relations of forests to climate and water are investigated. The laws bearing on forests and forest protection, and the policy of governments, must be understood. Without a firm grip on the essentials of forest policy, the forester is poorly prepared for this work, especially in a country such as ours, where so much remains to be done, the forester's chief duty may well be to secure proper laws and a progressive and stable forest policy before he undertakes much along the line of timber production.

The technical side of forestry calls for the application of scientific and practical knowledge of the growth of trees, the knowledge of how to get results and avoid failures. A crop failure is a more serious matter when the growth of

50 years may be destroyed or be of inferior quality, than if but a single season's product is damaged. Beginning with Forest Botany or Dendrology, in which he learns the distinguishing characters of tree species, the forester becomes acquainted with the structure of the woods and with their different qualities and the uses to which they are best adapted. Then the factors of soil and climate must be understood since trees, having a long life, show great variations in their demands on soil, moisture, and heat, and produce very different results in different situations. Silvics teaches us the different traits and peculiarities of the tree species, seed production and germination, the conditions under which the seed will grow, the demands of the seedling for light, the ability of the tree to win out in competition with others, its form, its power of resistance to enemies and injuries, and the real value of the species for different localities and conditions. Silviculture applies this knowledge in the form of definite plans and methods, by which the largest and most valuable crops of timber may be raised on any soil in the shortest possible time. Added to this, the forester must know the dangers which threaten his crop, and how to anticipate and avoid them. This applies both to the mature timber and to the young seedlings. Fire, wind, and fungus or insect enemies threaten the growing trees, just as storms, weeds, insects and fungi injure the farmer's crops. Finally he must know how to get his crop to market. The art of lumbering is a trade in itself, and considerable knowledge and skill is required to conduct a logging operation with the least cost. But the forester must be able to modify old established customs of lumbering, to persuade or force lumbermen, contractors, and laborers to do unfamiliar things, such as burning brush or taking care not to destroy young trees. He must, therefore, be enough of a lumberman so that his recommendations will be practical and capable of being carried out. The subject of road building is of great importance, for the

biggest problem of forestry is the transportation to market of the bulky and heavy products, and whether this be done by wagon, railroad or stream, on ice or on dry ground, the forester must understand his problem and be able to choose the cheapest method and lay out his roads so they will most efficiently perform their office.

The third branch of knowledge demanded by foresters is the business side of forestry. No matter whether forests are managed by private parties or by the government, it means that large tracts of land are devoted to the production of timber crops, which must be cared for and sold. To carry out all the work required on such a tract demands orderly business methods, and a knowledge of costs and returns. If forests require such long periods of growth it is important that different stands be established not all of the same age, so that if possible, there may be timber ready to cut every year and a steady revenue be possible. We must know something about the probable size and value of the timber and to get this knowledge we depend on Forest Mensuration. Mensuration is not in this case a study of abstruse mathematics. It is rather the intelligent application of a few simple methods to get at the facts, and it is much more important to understand natural laws of growth of trees and stands than to attempt to apply refined mathematical calculations to stands which refuse to grow in conformity with them. A higher branch of forest management discusses the best ways to bring a forest into the condition where it can be maintained permanently, producing a regular yield each year of wood. The organization of a force of men to do the work on a forest, or on larger areas of forests, such as might belong to a nation or state, calls for a knowledge of the amount of labor necessary for efficient results and the proper division of work and responsibility. In nearly all respects, forests are more economically cared for when the areas are fairly large and compact, than if split up into small tracts.

IV. AMERICAN FORESTS.

American forests are noted for their large number of valuable species. The forests of Europe, compared with ours, are monotonous. In northern Europe a single species of pine, *Pinus Sylvestris*, is the only representative of its genus, supplemented in the south by two others. In America we have over thirty different species, and no large region is without at least three. Other conifers are usually represented more numerous here than in Europe, especially in the forests of the Pacific coast, where in addition to numerous firs and representatives of the cedar, yew, larch, spruce, incense cedars and cypress, we have two genera not found at all in the old world—the Douglas fir or *Pseudotsuga taxifolia*, and two species of big tree, the coast redwood and the big trees of the Sierras. The sugar pine, largest of the white pines, grows in the Sierras. The sequoia, or big tree groves, have most unfortunately passed largely into private ownership, but through the generosity of one or two men some of the finest timber has been deeded to the national government and is secure from destruction. Even aside from these giant trees, which surpass in grandeur any forests ever known, the size and value of the coast redwoods and of the Douglas fir stands in Washington and Oregon, are greater than any known forest in Europe or the tropics.

Just as the west coast excels in conifers, so the eastern portion of the country is first in her array of valuable hardwoods. The Appalachian region is the central home of these hardwood species. Europe has two oaks of commercial value, America has nearer forty. Beech, for lack of anything better, is made much of abroad. Here we may grow ash, hickories, maple, birches, elm, basswood, yellow or tulip poplar, chestnut and a long list of other trees of greater or less importance each of them possessing some particularly valuable qualities, or else showing capacity for growth on

situations ill-adapted to more valuable kinds. This profusion of species is in a sense a drawback, for German foresters with only two or three important trees to study, soon perfected their systems of cultivation and built up an orderly scheme of management. We must adopt new plans for every species and every region and the knowledge gained in one locality will not necessarily apply elsewhere.

V. SILVICS.

The Forest versus the Single Tree.—A forest must be studied from two standpoints—first, the individual trees and their characteristics, and second, the attributes of the forest as a whole. Trees growing singly not only follow different laws of growth and development than when crowded together in a forest, but the effects of a forest upon the soil are not secured unless the trees cover practically the entire surface. An illustration of tree growth which does not properly constitute forest growth is found in orchards or in shade trees. Each tree is allowed full crown space and develops a symmetrical form with a short trunk, branching near the ground. No two species assume the same form, even when open grown. White oaks will send horizontal branches to great distances and grow into hemispherical shaped crown. Hard maple takes an oblong or elliptical shape, while the white elm always develops the umbrella shaped crown which makes its presence so desirable as a shade tree overhanging roadways and lanes.

Such large and well-developed crowns mean a correspondingly large root system, which is secured by the absence of competition with other trees. The size of the crown is an indication of the freedom of root growth. It often happens that old trees in city streets die as a result of interference with the roots, through the laying of pavements impervious to water. Trees which are found in a thriving condition when growing entirely alone, have usually de-

veloped from small sizes, under the same conditions, and have adjusted their root system to the moisture supply and their boles and crowns to the exposure to wind and abundant light. The ground about such trees may be baked hard by the wind and sun, or covered with a dense sod, but the tree will resist these drying influences since it has always had them to contend with, and its roots have spread out and struck deep, insuring abundant moisture. At the same time, the trunk at the base has swelled into a strong buttress, and the crown lies low on a tapering bole, so that the form and strength of the stem are ideal for resisting the sudden onslaught of a fierce wind. Competition with other trees is eliminated, and the tree easily masters the opposing forces of the elements.

The Struggle for Moisture and Light and its Effect on the Form of Trees.—But in the forest, single trees grow so closely together that there is a struggle between them for the necessities of life, light and moisture. Plant food is taken up by means of water, always in solution, and the amount of moisture present is of more importance in its effects on tree growth than the richness of the soil in chemical food supplies. This struggle for light and moisture gives the forest its distinctive form. Wherever there is sufficient soil moisture to support a full stand of trees, the competition is fiercest for light. But in many places the moisture is very scant, and then the struggle becomes wholly one of root competition for water. The form of a forest growing on dry soil is necessarily open. Trees are spaced at considerable intervals, and their crowns have room to develop. But investigations show that the stand is really as dense as the soil will support. Young seedlings which may spring up, die out in a few years, because they are unable to get moisture. The roots of the old trees, larger and more vigorous than the seedling, and penetrating deeper, suck up all the water, and the seedlings perish of drought. Such stands are true forests, although they may

resemble the orchard form of the growth, since the struggle is taking place underground, and the trees influence each other only through their roots. In extremely dry regions such scattered trees will have all the attributes of open-grown shade trees, including the buttressed and swelling roots, but since the supply of moisture is so small, the crowns will be correspondingly scant and open rather than full and dense. Such forests are common through the drier portions of the West.

When the rainfall is sufficient and the soil retentive, as is largely the case through the eastern half of America, the struggle is transferred to the crowns, and becomes one for the possession of light. As many trees will grow on an acre as can secure light enough to live. In a forest stocked with the full number, the crowns touch and throw almost complete shade. The growth of the trees in height is stimulated, and their sidebranches are killed by the shade of their competitors. Those which grow fastest in height survive. The form of such trees is strikingly different from the same species grown in open places. The first live branches are much farther up the bole, and in old trees, most of the lower branches have not only died and fallen off, but the scar has closed over completely, giving the trunk the appearance of having never possessed those lower branches. What crown there is, is confined to the top, where it gets the light from above, or, if one side or the other happens to be exposed to the light, we find the crown abnormally developed on this side. The bole is slender and holds its size well, approaching a cylinder in form and not tapering rapidly until the live crown is reached. The base does not show a large swelling, although some is always present. Such a tree, protected by its neighbors from the force of the wind and from excessive evaporation of soil moisture, has not developed the extremely resistant form of the open grown tree. If the stand is cut away, leaving it alone and exposed, several things may happen. If the species is

shallow-rooted, it will probably blow over in the first big wind. If it is exacting in its demands for soil moisture, the roots will dry out and the tree will die. This often happens to species which habitually grow only under the shade of other trees. If it is a young tree with thin bark, the bark may sun-scald badly, causing wounds which give entrance to spores of fungi that will cause the tree to rot. But if the tree is naturally deep-rooted, fairly stocky, with thick bark, it will survive the change and will at once begin to strengthen its base against the unusual wind strain, at the same time enlarging its crown and roots. The growth will probably increase and the tree will begin to bear seed in great abundance.

The forest form of the species is therefore not as well adapted to sudden changes as the open grown tree, but it is vastly more useful in the production of material. The taller and more cylindrical a tree is, the greater will be the per cent of its volume that can be used. The fewer branches it has and the sooner these fall off, the more valuable will be the products.

Left to themselves, trees will always form forests in regions with sufficient rainfall to support tree life. This fact, and the immensely greater production both in quantity and value of material when trees are grown in forests, makes it necessary to consider the forest stand as the real unit in forestry, instead of the single tree.

The Early History of a Forest Stand.—The development of a stand of trees is best illustrated by taking the example of an area which has been seeded to a single species all about the same time. This occurs with certain pines, as for instance on an abandoned field. Such natural seeding is never uniform, but the seedlings occur in groups, and many small openings are left, while in other spots a dense mat of seedlings may spring up. But on the whole the stand may be fairly uniform and the trees within a few years of the same age. The open spots not occupied by

seedlings may be filled with grass, weeds, or shrubs, and with these the seedling must compete both for moisture and light.

As the seedlings grow in height, their crowns spread and interfere more and more, casting a shade which first kills out the grass and weeds and many of the bushy plants, and then begins to cause the death of the lower branches of the seedlings themselves. Almost at once, in the more crowded portions, the weaker seedlings or those which did not get so early a start as the others, begin to die out through the competition of their more vigorous neighbors. As the trees grow in height, more and more of them are killed in the struggle. This diminution in numbers is natural and inevitable. There is not room for more than a very small per cent of the original stand, and the strongest are best able to appropriate the growing space. A stand of seedlings fully stocked, may have from 5,000 to 20,000 plants per acre. The same stand at maturity may not retain more than 100 trees. As long as the growth in height continues there will be a correspondingly rapid reduction in numbers. After the trees have attained their principal height growth, the numbers still diminish, but much more slowly.

The Forest Floor and its Effect on the Soil.—As soon as a complete cover is formed by the crowns the soil is shaded and grass is killed out. This very much reduces the evaporation, since grass and weeds use a much larger amount of water from the surface soil than woody plants, a fact which gives them their strongest hold in competition with tree seedlings. The annual fall of leaves or needles begins to accumulate and soon forms a mat of litter which still further checks evaporation. Since the agencies which harden a soil are sun, wind and rain, while opposed to these frost and the growth of roots tend to make soil loose and mellow, we find soils protected by a forest cover and a leaf litter, becoming soft and capable of rapidly absorbing the

water which falls upon them. The hardening influences are overcome by the protection of the forest. This capacity to absorb water is increased by the fact that dead leaves, fallen branches and even the stumps of standing trees tend to obstruct the flow of water and give it a chance to soak into the soil. This increased absorption and water-holding capacity of the soil improves its condition and results in a better growth of the trees. It is one of the chief ways in which the forest creates favorable conditions for its own existence. As the litter increases it begins to decay, and finally disintegrates into a dark material known as humus in which the structure of the original leaves and twigs is no longer noticeable. This humus has a high value both as a sponge to hold water, and for its chemical and physiological effects on the soil. The mineral food contained in the vegetation is made available for use again and the presence of humus promotes both the chemical disintegration of the soil by which new portions of plant food are released and the bacteriological activity which plays an important part in the activity of roots.

The stand may be said to reach its maximum vigor about the time that the trees have attained nearly their full height. Height growth in some species continues slowly until death, in others it ceases almost altogether long before the tree has passed its prime. But in all species the greatest vigor in height growth comes in the first half or third of its existence. When about completed, the stand is composed of a much reduced number of trees, whose crowns are well developed and throw a dense shade. There is almost no underbrush and the litter on the forest floor has accumulated and decayed until it forms a heavy layer of humus partly blended with the soil below.

The Differentiation of Crown Classes.—During this early struggle, culminating with the completion of rapid height growth, the trees have not grown at the same rate in either height or diameter. A slight advantage at the

start, either in age, or location, enables some trees to take the lead. This once obtained gives the tree a start over its slower and smaller rivals which it never loses until with increasing size and spread of crown it comes into competition with trees of its own class, when the struggle begins again; and again the larger and thriftier tree is bound to win. Those overtopped in growth, first endeavor at all costs to maintain their height growth, but lose most of their side branches and become much reduced in size of crown with a total height only slightly less than the stronger trees. Later on, they lose more and more ground and the crowns of the neighboring trees begin to close above them. Soon afterwards these trees die from loss of light. Thus we find the trees in an even-aged stand classified by their crowns, which are a sure indication of the thrift and prospects of the tree. Those trees which overtop their neighbors in height and have a well-developed crown, are known as dominant trees. The crowded trees which still maintain their struggle for light by keeping up their height growth, are the intermediate class. The overtopped trees which are about to die are in the suppressed class. It almost never happens that an intermediate or suppressed tree becomes dominant in such a stand. This could occur only by the destruction of the dominant trees which are crowding it. Since the numbers constantly fall off, it is always the intermediate and suppressed trees that disappear. Trees are continually dropping out of the dominant class into the classes below, as they fail to keep up their initial advantage.

The Old Age of a Stand.—From the period when height growth ceases, the history of the stand is quite different. Trees continue to drop out, but most of those remaining are able to hold their own and may be regarded as victors in the struggle for existence. The trees as they grow older need more light, and the branches in the lower crowns die faster. The crown becomes thinner and when a tree dies

or is destroyed the neighboring trees no longer spread out eagerly to close the gap as before. Sunlight gets in and filters through to the ground, which begins to dry out. Shrubs and grass come in again and with them, groups and patches of young tree seedlings. If the old timber is not cut, it will disappear in time, either suddenly by being blown down, or gradually by loss from decay. The older the trees get, the less able they are to resist the attacks of fungi, and the structure of the trunk becomes finally so weakened by rot, both in the bole and in the stump and upper roots, that it falls or is blown down. It is in this decadent half of the life of the stand that the forest will reproduce itself naturally.

These laws of development best illustrated in the case chosen, where stands are of a single species and even-aged, apply to almost all forms of forests, but are not always so evident. Under natural conditions, large clearings, on which stands of even age should spring up, occur only through fire, or extensive windfalls. If a stand of any species were left entirely undisturbed by such agencies, the old trees would drop out one by one or in small groups, and their places be taken by groups of either the same or different species. Finally the forest would be broken up into small groups of trees of different ages and sizes. The conditions are further modified by the large number of species which may be competing for space in the same stand. Yet the two laws, that of the reduction of numbers with growth in height and that of the survival of the most vigorous trees, will always apply, no matter what the conditions.

Silvical Characteristics of Tree Species.—Both the form and the composition of a forest will depend, first, upon the quality of the site and its fitness for tree growth; secondly, upon the tree species in the region and their needs and, thirdly, upon the history of the forest in that locality, such as the occurrence of fires, insect ravages or other destructive incidents.

Effect of Heat on Distribution of Trees.—The site or locality determines the species of trees which can grow there. The climate has a profound effect upon the range of tree species. The total amount of heat in the growing season diminishes with increasing latitude and with elevation. The effect of increased altitude on the total heat is especially noticeable and in mountain ranges is chiefly responsible for the distribution of trees in distinct zones, corresponding to the altitude. Species which grow well in a climate with a certain average and total heat, would perish in a warmer or colder climate. The northerly range of a species is limited by its ability to withstand frost and to ripen its wood in the growing season. Early fall frosts destroy the shoots of slow maturing species and extreme winter cold combined with evaporation and the deep freezing of the soil causes the death of species not acclimated to such conditions. The southern range of northern species is limited by excessive heat which stimulates the activities of the plant beyond its natural capacity, and causes rapid production of weak and coarse wood, and early decay and death. But the real factors which limit the range of a species are those which prevent its natural reproduction. Seedlings are always more sensitive to extremes of heat, cold and drought than mature trees. So it often happens that if trees are artificially planted and protected they may grow much farther north or south than their natural range. But even then they will not be as healthy and vigorous as when they grow within the range to which they are acclimated. So ingrained are these characteristics of climatic requirements that it is not possible for a species to thrive much beyond its natural range, and the acclimatization of a tree species involving a change in the heat requirements of the species, has never been successfully accomplished. Seeds or seedlings may be brought long distances and thrive, as for instance natives of Japan such as the Ginkgo tree, which grows well on our eastern coast,

and the white pine which is proving one of the best trees for planting in Germany. But in these cases the amount of heat is very similar in each locality and there is no real change in the demands of the species itself.

The local range of a species is affected by heat, chiefly in a mountainous country not only through altitude, but by the difference in the exposure on slopes facing to different points of the compass. A south or southwest slope is much warmer than a north or northeast exposure. Toward the northern portion of its range, a species will favor south slopes and low altitudes while at the southern limit it will only be found on the north slopes and toward the tops of the mountains.

Examples of such distribution are found in the pines of the United States. The white pine is normally limited to the Lake States, Pennsylvania and New England, but in the Appalachian range it extends southward into North Carolina where on the high summits of the great Smoky Mountains at 5,000 feet elevation it comprises over 50 per cent of the stand in some places. On the other hand even the most hardy of the southern yellow pines, the shortleaf, confines itself to the plains and foothills, and is never found further north than New Jersey, while the longleaf pine is found largely below Virginia, and its cousin, the Cuban pine, is only met with along the gulf coast.

Soil Moisture and its Relation to the Life of Trees.—While heat fixes the general range of a tree, the demand for moisture in the soil has a far greater influence locally in determining which of several different species will survive in a struggle. Water in the soil not only enables the tree to dissolve, with the aid of weak solutions of acids, the plant food it needs, and absorb it by osmosis into the root cells, from which it is slowly conducted upward until it finally reaches the leaves, but it is vitally necessary to the existence and functions of the leaves themselves. The constant supply of water makes good the loss by transpira-

tion from the pores or stomata and evaporation through the cuticle. It enables the green and delicate tissues of the leaf to maintain their rigidity. The loss of too much water is shown by wilting, and if not supplied, the leaves would die. The elaboration of food from the carbon dioxide of the air by the aid of the chlorophyll bodies requires water, and the food or carbohydrates thus formed as starch is redissolved for transportation in solution to other portions of the tree where growth of wood occurs. Thus the water supply of the roots is of the first importance. There can be too much water in the soil. Roots need air as well as water, and cannot perform their functions properly in a soil constantly below the water level.

The Characteristics of Soils Affecting Soil Moisture.—Swampy soils are not as favorable for trees as better drained soils. The most favorable sites are the well-drained loamy soils which will hold a large amount of water by capillary attraction, and are elevated far enough above the level of the underground water table so that the roots at the same time have plenty of air. The mechanical composition of soils is important, since it determines very largely their behavior toward water. The larger the soil particles the less water the soil will hold. The series used in such soil classifications is gravel, sand, loam, silt and clay. There is a disadvantage in a clay soil since the particles are so finely divided that the water is held tenaciously and the soil remains cold and wet, while if it does dry out it bakes hard and cracks. Loamy soils, with particles about midway in size between sand and clay, allow a free movement of water, retain it in sufficient quantities for tree growth and allow a proper circulation of air.

The depth of the soil of course affects its moisture holding capacity. A shallow soil over a rocky ledge is a dry soil since there is no storage room for water. But a very deep soil, if sandy, may be still drier, since the water rapidly percolates through it to depths where even tree roots

cannot follow it. Deep accumulations of silt, washed down from slopes into gullies or on flat benches, and supplied with underground seepage from above, make ideal conditions of soil moisture, since the storage room for water is large, the supply is continuous and the drainage prevents too great a surplus. Aside from the depth and consistency of the soil, and the amount of rainfall it receives, the water content is determined by the topography and the drainage. If the water has no chance to run off or seep away underground, swamps are formed, in which the water stands constantly at or near the same level, filling all the pores and drowning the soil by exclusion of air. In other places underground water comes to the surface, making marshy spots, even on hillsides. The water in a swamp may not necessarily overflow the surface at all times, but the distance down to the average water table will have a profound influence on the character of the swamp vegetation.

The Effect of Soil Moisture on Competition of Species.—The difference in the requirements of tree species for moisture is very marked. Some distinctly prefer swampy soils, and have adapted themselves to them. The Bald Cypress of the south has pushed this adaptation so far that it develops special growths on its roots in the form of upright conical excrescences known as knees, through which the roots receive the necessary air. The white cedar and tamarack of the Lake States are swamp trees. But most of these species are found to grow much more rapidly when they obtain a foothold on soil which is elevated above the level of the swamp. They have undoubtedly been forced to occupy these wet soils by their inability to cope with species better able to fight for room on well-drained soils. Having become inured to an excess of moisture they would probably suffer severely from drought if they should accidentally get started on soil not supplied with constant underground moisture.

At the other extreme we find trees occupying soils so dry that many species are killed by drought and cannot grow in such places. On the dry, rocky ledges in eastern states the red cedar finds its natural habitat, while on the dry, deep sands of the Lake States the Jack pine has a clear field against all competitors. Other species like Norway pine and scarlet oak, come in on soils too dry for white pine which, in turn, needs less moisture than hard maple. Species which grow only in dry soils are almost never found in swamps. Norway pine, for instance, will not grow where water stands in the soil. They are affected by rot even when they grow in moist ground. It is evident, as in the case of the true swamp species, that they are so accustomed to their habitat that a permanent change in the water content does not agree with them. They can no more stand excessive moisture than swamp trees can stand dry conditions. But on the best sites, well-drained soils with a good supply of moisture, most of these hardy trees will do much better than on their usual site and grow faster and larger.

The only reason that they are not found on better soils is that other species are stronger and crowd them off, leaving them the alternative of dying or taking the poorer sites.

Strong species, then, are those that can capture the most desirable soils and secure for themselves the best and most uniform supply of soil moisture. These species are usually found to be hardwoods, such as the hard maple, chestnut, white oaks and hickories.

The Struggle for Light as Affecting Competition of Species.—But in what does the strength of such species consist?

The ability to capture soil moisture simply means that the tree from some quality or other, is able to grow faster than others—or survive its competitors. Where there is enough moisture for all, it is not moisture but other factors

which decide the contest. Chief of these is the struggle for light.

A species may secure its foothold and light in one of three ways. It may grow faster than others, in which case with an even start, it is sure to win for the time being. It may get along with less light than others. Or by reason of small windblown seeds, it may be able to distribute its seeds in accidental openings in advance of other species. All these methods have their advantages. The kind which relies on its ability to grow rapidly is not sure of surviving beyond a single generation. The critical time comes in the reproduction and the establishment of seedlings. If the competing species, which needs less light, has come in under the shade of the original stand, or along with it, the seedlings of the first species will be unable to grow in this shade, while those of the other will easily survive. The old trees might die with no survivors, and the site will belong to the competitor.

Tolerance.—This ability to grow with less light is known as tolerance. Just as in the case of moisture, it is not beneficial to be deprived of light, but the less of it a tree needs, the greater advantage it has in the struggle for existence. Trees needing a great deal of light are intolerant.

The tolerance or light requirements of different species are hereditary, and species may be classed according to their relative ability to endure shade. But it is not true that the same species always requires the same amount of light for vigorous growth. All other factors which increase the vigor of a tree tend to decrease the need of light. For this reason we find that young trees are more tolerant than old, the need for light steadily increasing as the tree grows older. The life vigor of a plant is largest when it is a seedling—it will do more on less food and less light than at any later time. This conforms to the general laws of life development of all animals and plants. The chance

of survival of the seedling is increased by its tolerance, and later in life with increasing need of light, the increased size gives it the chance to secure this light. Tolerance is also increased by favorable sites. If a species is growing in a climate whose temperature is most favorable to it, the vigor of growth is at its maximum and it needs less light than it does when growing at the extreme limit of its range. The relative tolerance of two species, therefore, may not be the same in different regions, for a tree is always more vigorous when near the center of its range. In spite of these differences, tolerance is so marked a characteristic of different species that the trees in any region may be roughly classified in order of their needs for light.

A general list, given by Dr. B. E. Fernow, for northern trees, will illustrate such classification. The most intolerant trees, or those needing the most light are given first, and the trees grouped together are of nearly equal degrees of tolerance.

{	Aspen	{	Soft Maple
	Cottonwood		White Pine
	Black Locust		Hickory
	Honey Locust		White Oak
	Pitch Pine		Black Oak
	Norway Pine		
{	Tulip Poplar	{	Sugar Maple
	Elm		Beech
	Basswood		Balsam Fir
	White Birch		Spruce
	Black Cherry		Hemlock
	Walnut		
{	Chestnut		

This is a fairly good list, since it does not attempt to state which of two similar species is the most tolerant.

A very tolerant tree like the beech, hard maple, or spruce, will start as a seedling under heavy shade and grow slowly, in a state of suppression for many years under the old trees. Finally, the old timber falls or dies and the small tree takes on new vigor and grows as rapidly as if it had never been held back in early youth. This capacity for survival and complete recovery from long periods of shading and suppression give the tolerant trees their chief weapon of attack in the struggle for moist sites.

Indications of Tolerance in the Form of Trees.—The demands of a tree for light are indicated by its form and crown. The best place to study tolerance is in crowded stands, where the struggle for light is most severe. Tolerant trees may be recognized first, by their dense crowns, with many successive layers of leaves, most of which are partially shaded; secondly, by their presence under the shade of other trees and their survival in such situations. Intolerant trees will have leaves only on the outer portions of the crown, arranged so that each leaf gets plenty of light, and small trees will be entirely absent from shaded places. It follows, too, that the more intolerant a tree is, the shorter will be its length of crown compared with a more tolerant tree.

The Formation of Forests of Tolerant Versus Intolerant Trees.—If a tree is not only tolerant but capable of living to a great age and attaining large sizes, it is well equipped to survive. In some sections, forests are almost never destroyed over large areas at once, either by fire or wind. Such a region is seen in portions of the Adirondacks. It is here that extremely tolerant trees like the hard maple, beech and spruce have taken absolute possession of the forest, forming a dense stand composed of trees of all ages and sizes. This is the final result of such a struggle when not interfered with by the elements of destruction. But to a much greater degree and over much

wider areas, our forests are either periodically burned up or blown down. This may not occur in the same place oftener than once every 100 years, but since the life of most trees is much longer than this, it gives many species a chance to perpetuate themselves indefinitely which would otherwise be crowded out by more tolerant trees. So widespread is this condition, that many of our most valuable timber trees, especially the pines, are found over wide areas in stands which are practically even-aged, and must therefore have come up after such natural clearings.

Two things, then, favor intolerant species: their rapidity of height growth, and their ability to distribute seed to great distances. Some tolerant trees can also distribute their seed in the wind, as hemlock. But this tree grows very slowly in height. Take the case of white pine and hemlock forests. In a windfall, the seeds of the white pine and hemlock get a start, probably in company with aspen and white birch—if any seed trees of these species are near. The aspen and birch grow rapidly and the pine, which is somewhat tolerant, holds its own in the light shade cast by these species, or fills the openings in the stand. The hemlock seed is also scattered but on the bare soil these seedlings are apt to dry out and die, or fail to take root at all. But as soon as there is some shade cast, the moisture in the soil increases and hemlock seedlings take root. Long before they reach any size, the poplars are almost mature, and the pine is thrifty and making rapid growth. At 80 years the aspen begins to die out. It has reached its old age and the pine is overtopping it. At 120 years the white birch follows the aspen, leaving the white pine in possession, with an understory of hemlock now attaining a fair size. These two species live together until they both reach old age. Should the pine be cut out, the hemlock will usually die from undue exposure to drought. If the forest is burned, the whole

process is repeated. But should the soil be rich, and nothing happen to the stand, the hemlock, and probably certain species of hardwood, would eventually survive the pine, which could not come in as seedlings in their shade. There are other tolerant species which do not do as well as the hemlock in holding their own, but exist usually as a secondary tree under the crowns of more rapidly growing and less tolerant species. Such trees are the dogwood, and hornbeam, and in the Lake States, the balsam fir under white pine.

Duration of Life of Trees.—Once established, a species whether tolerant or intolerant, has a great advantage if it is long lived. Short lived trees will die out of a stand, leaving the more enduring kinds in control. The duration of life of different species varies from 70 to 80 years in the case of Jack pine and aspen, or even less, up to the almost miraculous ages attained by the sequoias, or big trees of California, which live to be over 2,000 years old. It is hard to explain these differences, but they are specific, and as much a part of the tree's characteristics as its growth and tolerance. With old age, a tree simply loses vitality. The power to heal up wounds in the bark is lost. The roots seem to lose their grasp of the soil in some species and are no longer able to resist the pressure of strong winds on the large and heavy body of the tree. Sometimes insect enemies in the form of bark beetles attack these old trees and kill them. But more often the spores of fungi enter through open knot holes or broken limbs, or upwards through the roots, and the body of the tree rots out until the strength is gone. Ultimately the tree is blown over. Old woodsmen have often observed the peculiar phenomenon of a tree tottering to its fall on a still day, with apparently no reason for causing the fall at that particular moment. The longest lived trees are apt to be rather slow in growth. White oak which reaches greater age than other oaks, does not compete with them

in height growth, but by its tough wood and resistance to decay, it survives them. It is, therefore, more numerous in old virgin forests than in those which have been cut heavily and grown up to second growth since such a condition favors the more rapidly growing oaks which are shorter lived.

Reproduction of Trees and Stands. The Seed.—The most important feature of the struggle of species, is the ability of the trees to reproduce themselves, and the conditions affecting reproduction determine the composition of a stand. Seeds are borne by some species every year abundantly. Such trees are always ready to seize an opportunity if offered. Others only produce seed at intervals of two to seven years. Many conifers have this habit. Spruce seed trees are five to seven years apart. The seed borne in the intervening years is so small in quantity that it is usually all destroyed by birds, animals or insects. In seed years the abundance of the seed insures a surplus over the ordinary ravages of such pests, and a crop of seedlings, if conditions favor them.

Distribution of Seed.—In the distribution of seed, the light wind blown seeds of the aspen will travel for miles. As each seed is supported by a thistle-down tuft of hairs, a few trees will seed up large areas. This is the chief advantage which such a species possesses. All conifers have wind blown seeds, and the distance to which they will blow depends on the lightness of the seed, the size of the wing, and the position of the tree and strength of the wind. Spruce seeds will travel half a mile down hill. But the heavy seed of the longleaf pine will only fly to a distance about equal to the height of the tree. Many hardwoods—as maples, elms and birches, have winged seeds, and can capture seed spots at varying distances from the parent tree.

Of the trees which do not depend on the wind, some produce berries or fruit, which is eaten by animals and

birds and may be carried long distances, escaping uninjured by the digestive processes and ready to germinate. Red cedar berries will not germinate at all until submitted to such a process. The fire cherry of the Lake States, which springs up abundantly on old burns is literally planted by robins and other birds. The nut trees do not have this advantage. Occasionally squirrels carry nuts into an opening and bury them. Almost always, these animals, in a good seed year, will plant large numbers of acorns and other nuts and never return for them. But the rapid reproduction of large spaces at any considerable distance from the old trees cannot be depended on in the case of nut bearing trees.

The Extension of the Forest onto Abandoned Pastures. —The growth occurring on abandoned pastures in New England affords the basis for an interesting study. Grass usually forms a dense sod at first drying out the surface and preventing the germination of tree seeds. The first species to get started are the red cedar, carried in by birds, and the grey birch, blown by the wind. Both trees need full sunlight and can spring up in dry places. It takes ten to forty years to form a thick stand of these trees. But the shade cast by them finally kills out the grass and the seeds of occasional oaks or chestnuts are carried in by the rodents, and grow rapidly, forming bushy crowns. These trees will then, after 50 or 60 years, begin to seed up the ground about them. Dogwood, black cherry and others sometimes get started. But it is all a matter of accident, how long it takes for the stand to work back to its natural form, in which the forest is composed, not of weak slow growing, intolerant species like cedar, but of the strong species which originally held possession. The great extension of the cedar over such old pastures shows how quickly a species takes advantage of opportunities afforded by clearings either natural or artificial, when it relies more on seed distribution than on either growth

or tolerance. Such species are forever on the move. Aspen almost never succeeds itself, unless the old stand of aspen is burned off. In the spruce regions, much of the spruce on mountain slopes gets started under aspen and birch which are the first trees to spring up on burns, and this birch and aspen grows old and dies, leaving the young spruce, almost as old as they are, to live for 200 years longer. But in the meantime another burn or blow down has occurred within a mile or two, and is at once seeded up to aspen from the first stand.

The Seed Bed and the Seedling.—Many times we find seed trees and seed, but very few seedlings. There is always a reason for this to be found in the condition of the seed bed. The seed will not germinate without moisture, and it must be able to take root. Very dry soils, exposed to the sun, prevent the starting of tender seedlings like hemlock. Hard-baked soils make it impossible for the root to penetrate, and we find acorns with a long radicle, rolling about on the surface, and soon drying up, while amongst leaf litter they find easy access to the soil. But pine seeds cannot grow at all on leaf litter, and very seldom in grass, which holds the seed up off the soil and dries it out. So it is an accepted fact that for most pines we must burn the ground in order to get good reproduction of seedlings. Some such considerations always explain the lack of seedlings if seed is present. But the mere starting of seedlings does not insure their survival. Here is where the needs of the species for light come into play. Many more seedlings die for lack of light under old trees, than survive. A seedling will live a year or two in shade, but if this shade continues, it will succumb. Trees begin to bear seed at ages varying from 6 to 7 years in the case of Jack pine to 50 and 60 years and the seed is always borne most abundantly by the trees with the greatest opportunity of distributing it to good advantage—the open grown trees or those on the edges of stands, or over-

topping the stand. In this way, the species extends its territory.

But the seed which falls under the old trees, while it may germinate and form seedlings, usually requires more light to grow than it receives. A full stand of any species throws too dense a shade for its own seedlings, although the seedlings of a more tolerant species may grow there without difficulty. So that with most intolerant trees, the forest cannot renew itself on the same ground, until it begins to go to pieces from old age, and we will get a succession of crops of trees of an even-aged form.

Reproduction by Sprouts.—The production of seed is not the only way in which a tree can renew itself. All hardwood species, if cut or burned, can sprout again and these sprouts will form trees almost as tall and large as the original trees. The conifers, as pine, spruce, etc., cannot do this, and with them a fire or a cutting destroys the trees, and, if seedlings are not already growing and survive, it puts an end to the forest for the time being. But with the sprouting hardwoods, it takes a succession of fires to completely destroy the trees. Some hardwoods sprout vigorously and to a great age, as the chestnut. But most of them lose the power of sprouting when they reach middle age, from 70 to 120 years old, and all trees sprout best when young. Of the few conifers which sprout, the pitch pine of the Atlantic coast produces the longest lived sprouts, while certain western forms of juniper are known to survive fires by sprouting.

Sprouts appear in greatest numbers from the base of the stump next the ground, or root collar. If trees are cut in summer, after most of the growth for the year is formed, they may not sprout at all, since at this period all of the reserve food of the tree has been used up in forming new growth, and there is nothing upon which the roots can draw to put forth the new sprouts. But at any time after the tree has had time to renew this reserve, it is

safe to cut it for sprouts. The best season is from late fall till before the growth starts in the spring. The stumps should be cut low, with slanting surfaces, to prevent rapid decay. A great many sprouts start, their number being an indication of the vigor of the tree. In a few years these are reduced by natural competition to 8 or 10, and only two or three will mature as a rule.

Forest Types.—To sum up, the composition of a forest is determined by the conditions of heat, exposure, soil and moisture; by the hereditary qualities of tree species which enable them to compete for these sites, and by the destructive forces of nature and man combined, which modify natural conditions. The accidental combinations of these three elements give rise to the infinite variety which we find in our woods. But as a rule in any given region, the same set of conditions will produce the same kind of forest. There will be certain characteristic associations of species, which are able to grow together, or compete with each other. These associations are known as forest types, and are sometimes divided into permanent types and temporary types. Permanent types are found in regions where the forest is never destroyed violently by fire, wind, insects, or lumbering, and where, during many centuries, the struggle has gone on until only the most enduring species, usually very tolerant, have survived. The Adirondack hardwoods, of beech, hard maple, and scattered spruce, are the best illustration. The forest floor is covered with an accumulation of litter and humus sometimes two feet deep, showing entire absence of fires, and these trees seldom blow over except singly here and there. Starting with such a type we might construct a series, in which accidental destruction played a stronger and stronger role—until we come to types which are of such purely temporary character that they are sure to be succeeded by other species. Following the so-called permanent types, come the types formed by most of the hardwoods, such as

oaks and other nut trees. These trees form types which are more or less subject to injuries, and may vary from century to century in composition, but still will maintain their general character. The great hardwood forests of the Appalachians and the original hardwoods in southern New England belonged to this class. Upon the best soils, with perfect drainage and plenty of moisture, we might find a type marked by white oak, beech, hickories and chestnut. On soils a little more moist, and sometimes too wet, these species would be handicapped, and weaker kinds not able to compete in growth or tolerance, but capable of surviving a slight excess of moisture would form a type differing very decidedly in composition from the first. White ash, white elm, sour gum, red maple and others would form such a type.

Next in the scale of permanence would come types found in rather dry soils. Such soils are either shallow or loose and sandy, and in either case they are exposed to both wind and fire to a much greater extent than better soils. Consequently, fires and blow downs occur as a regular feature. The species best adapted to such sites are the pines, and we find all sandy soils occupied by some species of pine, if they are not too dry to prevent the growth of pine altogether, as in deserts.

Very often small oaks come in under such species as white pine and, owing to their inability to sprout, the pines may fail to renew themselves when cut or burned. This leaves the oaks, which grow into a scrubby forest, and the type has changed. So apt is this to happen that it is a common belief that pine will not succeed itself. Yet it is one of the first principles of forestry that the trees which will thrive best in any locality are those which have grown best on that site in the past. Under natural conditions, if fires are not too severe or widespread and pine seed trees survive, pine will come in again after fire or windfall, as at first, and the type remains the same. It

is a temporary type only because reproduction occurs at irregular intervals depending on accidental conditions, and this reproduction may not be of the original species.

The types which are most truly temporary are those formed by short lived species with seeds wind blown or carried by birds, and which cannot hold their own if any other species can reach the same area with seeds. For this reason cedar in old pastures or aspen stands on burned lands are true temporary types.

Types are of the greatest use to the forester. They indicate the quality of the soil and the kind of wood materials which it will produce, and determine the species of trees which he should try to raise in the future. It is useless to attempt to grow trees on any soil which is not suited to the demands of that species, and there are always kinds which are adapted to it, and will make as good growth as the site permits. No greater fallacy exists than that any tree found in a region can be successfully grown for wood products on any site in the region. Mistakes can be made which will not become evident for many years, and the only sure guide for the forester in planting or management of forests is the evidence constantly before his eyes of the natural types, representing the survival of the fittest. From such types he can gain the knowledge necessary to decide what trees to plant on vacant land, or to recognize a purely temporary type, and know whether a better species might not grow there if given a chance. For instance, white pine would ordinarily grow well in old pastures, if planted there, when for lack of seed trees, it might not be present at all under natural conditions.

The Basis for Distinguishing Types.—Types, being the result of a number of influences, are not usually bounded by sharp lines, except where artificially produced as in clearing. They grade into one another and their boundaries are somewhat arbitrary. Nor is the composition of a

type constant especially when several species grow in mixture. In some parts, one species will predominate, while a different one will be in the majority in an adjoining area. Out of a constantly changing forest, types are chosen by deciding upon the general features of sufficient importance to justify a division of the whole forest to conform with the differences noted. Minor differences are neglected. The basis for such divisions, or types, are usually broad topographic features such as bottom land, swamp land, south slopes, ridge tops, and the types so determined are named from the topography. Where the type depends less on topography, and more on accidental distribution of species, it is named from the prevailing species or mixture, as white pine type, Jack pine type, poplar type. Differences in age do not form a basis for making different types. A spruce slope type is the same type whether the trees are seedlings or veterans. But if the old stand is destroyed and is followed by a different species, the type is changed. Thus types are recognized solely on the basis of the dominant trees, which make up the bulk of the stand and will produce the crop of wood.

Forest Enemies.—The worst danger to a forest is from fire. There is no region in this country free from fires, and so profound is the influence of fire on the forest, that the forester is forced to consider this danger before everything else. The leaves and needles shed by trees form an inflammable litter, which in dry times burns readily. Some forests grow on such wet land that they seldom burn over. If a swamp becomes so dry that fire runs through it every tree is killed. Forests on rich soils throw a heavy shade, and this with the resultant damp condition of the litter prevents fire except in bad droughts. But on the drier soils less shade is cast, and there is a long season each year when the slightest spark will start a blaze. Sandy pine lands in the South are burned over every year, and if

by chance the fires do not run for several seasons, the accumulated debris may cause such a hot fire that a great deal of damage is done.

Resistance of Trees to Fire.—The amount of damage done to the trees by a fire varies from total destruction down to almost nothing. This depends first, on the nature of the fire, and second, on the resistance of the tree. The living tissue of the tree is its cambium, between the bark and the wood. If this is heated beyond a certain point it is killed. If the cambium around the entire base of the tree is killed, the tree is girdled and dies. The cambium of one tree is probably just as sensitive as that of another, but these cells are protected by the bark and it is here that differences exist. Bark is composed of corky substance which is a non-conductor of heat. The more bark there is and the more corky its consistency, the better will be its protection against fire. Seedlings of all species are very sensitive to fire, and the slightest ground fire will kill most yearling plants. But in two or three years, they begin to develop thicker bark, and some of them may survive a light fire. The seedlings of the southern longleaf pine develop thick bark and at the same time the needles of the crown turn down around the stem, affording additional protection, so that it is no uncommon sight to see these seedlings starting to grow after fires which scorched off every vestige of foliage. But with most pines, fires occurring every two or three years will absolutely prevent young seedlings from getting started. Such conditions are found on nearly the whole of the cut-over pine lands of the Lake States. The old forest has been cut, and fires, by preventing the growth of the new crop, have produced a treeless waste. Many of these stump wastes have been cut for 40 or 50 years, in which time a second crop of pine would have reached merchantable size. Yet today there is nothing and 100 years from now there will still

be nothing if the fires continue to burn. Upon such soils, a considerable quantity of grass and weeds springs up, which forms food for such periodic fires.

Hardwood seedlings are just as sensitive, on the whole, as conifers but they possess, almost from the start, the capacity for sprouting, so will come up after a fire. The older a tree gets, the more severe must a fire be to kill it, so that in regions of frequent surface fires, the mature timber stands from year to year apparently uninjured. This apparent freedom from injury may in some cases be actual. The bark is so thick and the fires so light that the tree continues sound. Even in such a case, all the natural covering which preserves the moisture of the forest floor is burned up and it is probable that growth is interfered with by the excessive exposure of the soil. But once let the bark be burned through anywhere and the succeeding fires each eat out a little larger hole until the tree may burn completely off. Some pines, as the Norway pine of the Lake States, and the Longleaf pine, show this capacity for fire resistance in the face of repeated small fires. With many trees, both pines and hardwoods, the fire may kill the cambium on only one side. This is usually the side opposite to the direction from which the fire is coming. The fire forms an eddy and licks the face of the tree—burning a strip of bark sometimes 6 to 10 feet high. If young, a tree may heal such a wound completely, so that it cannot be noticed until the tree is felled, when the old scar will be seen, with the annual layers of wood formed since the fire each closing in across the gap until it is finally bridged. The younger the tree, if not killed outright, the greater is its chance of recovery, provided a second fire does not keep the wound open. But this is not the end of the damage. The spores of fungi often find lodgement in such fire-scars, and develop rot in the heart of the tree, so that the damage done from this source may in a few years exceed that caused by the fire itself.

The Nature of Forest Fires and Their Effect on Forests.
—Fires severe enough to cause the death of large timber only occur in prolonged dry spells, and on windy days. In regions commonly free from fire, where the vegetable accumulation is deep, fires at such seasons burn in the ground itself, and, killing the roots, destroy the largest trees. Complete protection is the only safeguard for such timber. In pine regions a strong wind sometimes causes a fire to burn up into the crowns of the trees and to travel through the crowns. Such fires are rare exceptions, but since they only occur in severe droughts, they do tremendous damage. The great forest fires of history have been of this nature. That at Hinckley, Minnesota, in 1894, caused the death of over 400 persons. The wind carried fire brands over lakes to distances of over half a mile. Not a single pine survived over great areas. Traces of similar fires may be found elsewhere in Minnesota. One, the Ely fire, burned a distance of 40 miles and laid waste from 12 to 15 townships of land, which is now after a lapse of nearly 40 years, covered only with poplar, birch and some Jack pine, the original white and Norway pine timber surviving only on one or two islands in the center of large lakes.

Fires in hardwood regions are less severe, since crowns of hardwoods are not inflammable. Hardwood ridges act as checks to bad fires in pine woods. But many species of hardwoods are badly injured by fires, since the bark is thin. So it frequently happens that a severe surface fire will kill an entire stand of such species as chestnuts. Stands of pole size, if killed, sprout readily, but the fire-killed poles decay and fall over, creating a dangerous fire trap. The second fire is almost sure to occur, again killing the young sprouts. The stumps sprout a second time but there is no limit to the number of fires that may occur, while the capacity of the stumps for recovery is soon exceeded—and after each fire less stumps

recover. Finally scrubby and worthless shrubs like bear oak—which can sprout annually for indefinite periods—take the place of the chestnut and valuable oaks, and the area can be classed as non-productive. Large districts of this character can be found in parts of Pennsylvania.

Perhaps the most common source of fires is the burning of the tops left after lumbering. Both in pines and hardwoods, when logging is very heavy, the inflammable nature and great quantity of the debris created, coupled with the increased exposure of the soil to the sun and wind, causes a very hot fire. This fire is almost sure to kill chance seed trees left because of some defect, and to wipe out all traces of seedling and sapling growth. A condition is created which is favorable to future fires, and the causes for these are not far to seek, in a region where no effort is made to suppress them, and the resultant damage is not appreciated. Forest fires are said by good authority to have destroyed as much timber as the lumbermen have cut. But a far greater loss than this is represented in the seedlings burned, and the absolute prevention of future growth over almost all of our pine forest area.

Other Forest Enemies.—Of the other natural enemies which threaten the forest, none are of such a nature that they form a serious and universal menace. Occasional fungus diseases occur, such as the chestnut blight, which at present threatens this tree in the southern New England region. The trees attacked are killed by the girdling of the cambium through the operation of the fungus. Dry seasons probably give rise to such epidemics by weakening the naturally resistant trees, and such a condition will correct itself. Of the fungi which attack the heartwood, there are several kinds but all of these operate only upon trees which have some injury in the bark. Danger of premature decay from this source may be reduced in a well-managed forest by removing the fruiting bodies of such

fungi, when they appear on infested trees, or by cutting out the trees. Insects are sometimes fatal to trees. They work either by defoliation, or by boring in the bark or wood of the tree. The defoliating insects are occasionally serious, since a tree cannot live without leaves. The mature tamarack throughout the East was practically all killed by a sawfly within the last twenty years. The imported gypsy moth and the brown tail moth may, if not controlled, kill most of the trees in regions which they infest, and the state of Massachusetts has for years employed an army of men to combat them, not altogether successfully. Ordinarily, insects are kept in check by their natural enemies, which are insect parasites and birds. But the parasites of imported insects are not always imported with them.

Bark beetles often do great damage to standing timber, killing all the trees over wide areas. These beetles are ordinarily found only in weakened trees. But when in great numbers, they attack healthy trees, choosing the larger and older rather than the small trees, since the former are really not so vigorous. The most disastrous attack of beetles of recent years was the recent visitation in the Black Hills of South Dakota, where over 200 million feet of pine were destroyed. As in other instances, the beetles suddenly disappeared, killed probably by a fungus disease. But such plagues can always be controlled if taken in time, by cutting the infested trees and burning the tops, the logs being either removed or put in a stream and the beetles drowned. When only a few beetles exist, woodpeckers and other enemies keep them within their natural limits.

VI. SILVICULTURE.

The Relation Between Silvicultural Operations and the Value of Wood Products.

Silviculture is the art of growing tree crops. In this country it requires a working knowledge of our native species, and an ability to recognize conditions, both in the woods and in the markets. One can hardly consider the production of timber without taking the cost into account. The lumberman holds standing timber either because he has more than he can cut at present, or to profit from an increase in the value of the stumpage. It is his intention to convert the investment into cash by the cutting of the timber and sale of the land for farms if possible. The production of timber means a definite intention to profit by growth. Whatever gain comes from the increase of stumpage value is merely an additional incentive. The ideal of the forester is to produce the largest crops of the most valuable material in the shortest possible time, and at the least possible expense. Since forest crops are not obtained for many years after they are planted or started from seed, the only way to calculate returns on investments is by means of compound interest. The longer the period, the more rapidly this accumulates. For this reason all expenses connected with the production of forests must be kept as low as possible if one is to receive a reasonable return on his investment. But ideal methods of forest production call for a great deal of work in the forest during the growing of the crop. To produce the largest crops of the most valuable materials, each tree should have room to develop, yet be crowded sufficiently to enable it to clear itself of its lower limbs. In European countries this result is obtained by first securing a dense stand of seedlings and then making frequent thinnings, in which small material is taken out allowing the remaining trees to grow freely. But no-

where is such work done when it does not pay to do it. The cheapness of labor and scarcity of wood in continental countries enable foresters to actually sell brush and twigs for enough to cover the cost of removal. Every stick of material produced has its value—and thinnings instead of being an expense, are a source of actual income. In our country there are wide areas where it does not even pay to sell cordwood, since the cost of cutting and transportation more than equals the price received for it. In a few localities near large cities, small material can be sold for various uses, chiefly fuel, but over the greater part of our forest domain a tree must not only be of a valuable species, but must reach a size where it is fit for lumber, railroad ties or other important commercial use, before it can be cut at a profit. To cut out material which is not salable, would be to incur a large expense for which the final yield might not give an adequate return. This necessity, which is universal, of limiting the expense of their operations in conformity with the market, makes it very difficult for American foresters to do many things that they would like to do otherwise, but true forestry is to make the best and most profitable investment in the forest and not to sink money in fancy operations, which will never be returned. This necessitates more extensive operations. Instead of managing a few acres with the greatest care, the American forester is forced to care for many thousands of acres as well as he can with a small annual expense, and depend very largely on nature to produce the crops of trees.

Planting.

Artificial planting is therefore not as widely applicable in the United States as in Europe. But it is one of the surest ways of securing the largest and best crop from an acre of land, and in the East and on farmland is being quite extensively practiced. It is a safe quick

way of reforesting a tract devoid of trees. The better the soil, the simpler the operation. Mistakes are made in choice of species and in methods of planting, chiefly in going to too great an initial expense. Plant material for forest planting if obtained from nurserymen, is sometimes held at prices more suitable for ornamental planting. Plants are bought which are too large for the needs of the planter. White pine if planted should not be over three years old, at which age, if transplanted once, it is not over 6 or 8 inches high at most, and should cost not more than \$5.00 or \$6.00 per thousand. In planting, the spacing is quite important, as it determines the number of plants per acre, upon which hinges the cost. Closer planting than 6 by 6 feet is now universally condemned in this country. It requires too many plants and the stand grows up so dense that at an early age the growth is checked by crowding. It does not pay to thin the stand for such small material hence there is a decided loss instead of a gain from the crowding in spite of double the initial planting expense. Spacing as wide as 8 by 8 feet is sometimes urged, and should succeed if care is taken to secure a full stand, and the soil is not too dry. If the roots of conifers are allowed to become dry at any time during transplanting, the seedlings will be killed. But after planting they should not be watered as this will cause their death. Needless to say, the watering of large plantations would be an impossibility in any case. The operation of planting does not require much labor—a hole is made by the insertion of a spade, or with a mattock, big enough to receive the roots, and the earth is firmed about them with the foot. Two men can plant 1,000 trees a day in sandy soil, and the cost depends on the price of labor. To produce the seedlings, special care is required. They are raised in seed beds, and protected by lath screens during the first season, and by a slight mulch over winter. The best plan is to sow broadcast in the seed bed,

since a full stocking of plants may be secured that will crowd out weeds. But where seedlings can be had at reasonable figures it is best to purchase them. Upon farm lands, there is considerable interest in the planting of trees to produce fence posts. Where such small materials are desired, the trees could be set a little closer than 6 feet, since thinnings can be made for fuel and posts are useful at small sizes. Some species, as hardy catalpa, have been advocated for universal planting, when experience shows that they succeed only in a narrow range. Catalpa thrives only on the best of soils, and on sandy land, or dry soils, does not grow as well as other species. Many experiment stations are testing the growth of native species, and numerous bulletins may be had from the U. S. Forest Service on trees suitable for planting in different localities, so that there is very little excuse for committing serious blunders.

But planting affects the larger problems of the management of forest tracts only in a very small way. Most lands that will be devoted to forests are already forest lands, wholly or in part covered with trees, or else burned and cut over. If there are seed trees of any description near enough to seed up the burned or logged areas, some kind of tree growth will come up. It may not be very valuable now, but there is a possibility of its becoming so with rising values for wood of all kinds. In case of large burns, following logging, where practically no seed trees remain, planting would be the most sensible means of restocking, provided the funds can be obtained for the purpose.

Cutting the Old Timber to Secure Reproduction.

A second general plan to secure a new crop of seedlings can be applied if the land is put under management before the old timber is removed. This timber is producing seed, and can be cut in such a way that the seed will

be distributed and the seedlings have a chance to become established before the last of the old trees are gone. There are many modifications of this plan in use in Europe, but all have the common feature of leaving part of the merchantable timber standing after the first cut, to be removed later on. This, to the American operator, means increased expense.

Silvicultural Systems.

Strip and Group Systems.—One plan, known as the strip system, is to cut strips through the forest, whose width does not exceed the distance to which seeds will be blown from the adjoining strips which are not cut. This plan has been used in Montana in lodgepole pine with some success, in a region where it was possible to sell all the small material removed by clear cutting. A modification of this system of clear cutting is to cut in groups or patches leaving the surrounding timber for seed and protection. Species which are shallow rooted and require considerable protection from drought as well as wind are reproduced best by this plan, which is being practiced in the mountains of Colorado on the Engelmann spruce.

Clear Cutting with Seed Trees.—A still further approach to clear cutting is the removal of almost the entire stand, leaving seed trees to secure the second crop of seedlings. On the Minnesota National Forest it was specified by law that 5 per cent of the merchantable timber should be allowed to remain as seed trees. The species were white and Norway pine, both of which come up best in clearings. The important point in this method is the selection of seed trees. In ordinary logging, if any trees are left it will be the defective or rotten trees which the lumberman does not see a profit in handling. Such trees will produce seed, and the seedlings will be vigorous. Even if the seed trees are crooked or stunted it does not necessarily mean that the seed produced will have

inherited these undesirable qualities. The seedlings will be very certain to produce trees which have the general characteristics of the old stand, and not of the single tree. Only in case all or most of the trees in a vicinity are stunted, crooked or otherwise defective, will the seedlings of any one tree inherit these qualities since in such a case it is evidently the general conditions which have produced these qualities.

The real objection to leaving rotten seed trees purposely is that they can never be utilized and are a dead loss. With increased value of wood, there are very few trees that it will not pay to cut and use at least in part. But by the time a second cutting comes around, such trees will have blown down from weakness, due to rot and old age. The best plan is to select sound, young, thrifty trees which are old enough to produce plenty of seed. These trees will increase greatly in size, remain sound, and form a valuable part of the next cut. The chief danger in using this method is from windfall. Trees suddenly exposed on all sides to the wind are apt to blow down before they have time to adjust their roots and stump to the new strain. The older the tree is the greater the danger. In selecting trees it is possible to choose trees which are as exposed as possible, since such trees have already become adjusted to wind strain. The species which lend themselves most readily to this method are strong rooted trees, which ordinarily grow in somewhat open stands, as the western yellow pine or the southern yellow pines. Shallow rooted trees like spruce would be almost sure to blow down, and even white pine in the mountains of Montana, on shallow soil, was found to be unable to stand when left singly.

Selection System.—The opposite extreme to clear-cutting for reproduction is found in what is known as the selection system. Under this plan, only the oldest and largest trees of a forest are removed, leaving most

of the stand intact. Cuttings would be made at frequent intervals on the same ground, but there would always be a forest cover. Such a plan is suitable for very crude operations in forests composed of many species, of which only a few are merchantable. The selection of valuable hardwoods such as cherry or walnut, or of large white oaks for stave material, bears a resemblance to this system of cutting. But such a method in a mixed forest soon exterminates the best kinds of timber, leaving only the poorer varieties. It is not possible to do anything else when markets are so poor that only the best quality and kinds of wood can be sold at all. Hence it has been the prevailing system of logging over most of the hardwood forests in inaccessible or pioneer localities. As markets improved, a greater number of species became merchantable, and much smaller sized trees could be cut. Logging operations then began to take on the form of a clear cutting but without any regard for future crops or the protection of young trees.

A systematic application of the selection system by foresters differs very widely from the hit or miss selection by woodsmen. The forester chooses this method only when the species is one that succeeds best when the young trees spring up under almost complete shade and protection of the old timber. The European silver fir is sometimes managed in this way. At intervals of a very few years the whole forest is cut over, a small portion being cut each year, but the only trees taken are the oldest and largest. Before the next cut, a few more trees have reached the proper size. There is in such a forest, only one or two species, and every age and size is represented on each acre, so that the form of the forest stand is the extreme opposite of an even-aged stand, where the crowns of the trees form a canopy of about the same height. When the forester attempts to apply the selection system to forests which are irregular in the distri-

bution of their age classes, and are composed of many species, some of which are not valuable, he is sometimes forced by market values to do just what he ought not to do, that is, cut the best kinds and leave the poorer. But the difference between his operations and the lumberman's would be, that he would make every effort to cut out and get rid of as much poor material as he could sell, even at a very small profit, and save as many of the more valuable trees as he could, both to grow and to act as seed trees. The form of a forest cut on these principles is bound to be very irregular and patchy. But most of our native woods, especially our virgin stands of hardwood, are of this character, and it would not be possible to at once bring them into the condition when the stands are comparatively even-aged. There is young timber in scattered bodies all through the forest, which has been growing for 10 to 50 years, and this must be allowed to mature. But on the whole, the aim of the forester in most cases should be to work for even-aged stands rather than to try to perpetuate a selection form of many-aged stands indefinitely. Greater yields are produced by the even-aged form, and the expense and difficulties of logging are much reduced.

Changing a Selection Forest to an Even-Aged Form.

—A good example of the choice between these two extremes is to be found in stands of western yellow pine. This tree is so nearly fireproof and wind-firm that it is hardly ever destroyed. The old trees die singly and groups of young trees take their place. The whole form of the forest is open on account of the dryness of the soil. It would be perfectly possible to apply a selection system of cutting here, removing a few old trees each year. But the reproduction of the tree would take place just as well over large cleared areas if seed trees were present, and the expense of logging is such that it is absolutely necessary to cut as much from each acre as the

welfare of the stand will permit. So the forest is cut in two operations. In the first cutting, about two thirds of the mature timber is taken. All the old, over-mature trees and those damaged or rotten or otherwise defective, come out in this cut. The trees which are not taken are marked either with paint or by blazing with an axe. They comprise all the young rapidly growing trees, sound, with good crowns, capable of producing plenty of seed. If the stand is all over-mature, seed trees are selected as well as possible from these trees. A much larger per cent of the stand is left than in the seed-tree method previously described. The result of the first cut should be an even-aged stand of seedlings over at least half the area. After an interval of 30 to 40 years, the remainder of the stand may be cut. There will be a great irregularity still, but the stand will be reduced roughly to two age classes, which is a great improvement over the original form. This scheme is being put into operation very widely on National Forests in the Rocky Mountains.

Reproduction of Even-Aged Stands by Successive Cuttings.—A more advanced system of reproduction by making several cuttings, is practiced in Europe with hardwoods, such as beech, where the young plants must spring up under the old trees. The forest has in the past been brought into an even-aged form. When the stand is ready to cut, a few trees are first taken out to give light. The seedlings at once start up. Then more of the old timber is removed and after three or four cuttings on the same area, it is all gone, leaving a dense and thrifty young even-aged stand in its place. Many of our trees could be handled in this way if the time ever came when we could, with high markets for all classes of wood products and cheap labor, afford to cut any kind of wood at any time, and thus finally bring our mixed forests to the condition of pure or nearly pure even-aged stands. Heavy

seeded trees like oaks, chestnuts and others, if they are to be reproduced from seed, must be managed by gradually opening up the stand, so that there is light for the seedlings and the seed trees will not be too far off. But anything like the system used in Europe will not be possible here for many years.

The Sprout System.—The simplest method of reproducing a forest, and one which has been unintentionally applied over vast areas, is to depend upon the sprouts. As all hardwoods sprout, we have only to be sure that the trees are young enough to retain this power, and to cut them at the proper season, that is, the dormant period of the tree's annual growth, and the second crop starts at once. These stands are even-aged if the area has been clear-cut. It is usually far better to make a complete cut than to select the best trees and leave part of the stand, if this method of reproduction is to be used. Some of our best species, as chestnut, are rather intolerant of shade. If many trees are left, the sprouts from a chestnut stump soon become too shaded for good growth, and lose their upright form, spreading out sideways for light. Finally they may die and the productiveness of the stump be ended.

Sprouts from trees which were originally seedlings are vigorous and apt to be sound. But in many places in New England, these sprouts have again been cut, giving rise to a second generation of sprouts. A third and fourth cutting may be made, but with each crop, the sprouts grow more slowly, reach a smaller size and are more apt to be rotten, since they frequently become infected from the rotting stump to which they are attached. One of the most difficult problems of the forester is to renew such depleted sprout forests. This should be done by establishing seedlings in the place of the old sprouts. The European method is to allow the stand to grow to an age at which the stumps have lost their sprouting vigor. It

is then a simple matter to produce a crop of seedlings by gradual cutting in the old stand. With us, the same method might be adopted, but in stands containing a great deal of chestnut it is found that this tree sprouts at ages exceeding 100 years. Sprouts always grow much faster than seedlings, and suppress them, so that it is difficult to establish seedlings in competition with sprouts, no matter how poor the latter may be. Our general plans would have to be the same as in Europe, that of allowing the stands to reach as great an age as possible, saving the large trees until last, and thus killing out the larger number of the old stumps by shading. To sum up, the systems of silviculture in this country are, planting; clear cutting with reproduction from adjoining stands, by strips or by groups; selection cutting with a tendency to establish even-aged groups; removal of the stand in two cuttings on the principle of selection and seed trees; clear cutting with the reservation of a few seed trees, and clear cutting for sprouts.

Unwise Legislation Regulating Silvicultural Methods.

—A great deal is said about cutting forests to a diameter limit, and saving all trees below this limit. Laws have been recommended along this line. In a very rough way, such regulations might be applied to forests which could be cut on the selection plan, but for all other forests, it would frequently prevent the proper method of cutting necessary to secure reproduction. Even in the selection type, there are frequently stands growing in poor soil in which the trees never reach a large size and must be cut. It is not possible to embody such technical requirements in laws with any success, when the proper measures differ so greatly with the forests and the markets.

The Nature of the Investment Demanded by Silvicultural Operations.—In carrying out any of these systems in the woods, it is found necessary to modify the old methods employed by the lumberman. Saving of waste in log-

ging is not so difficult to secure. Any operator will cut low stumps, and take small logs from the tops as soon as he can be convinced that it pays him to do it. But all silvicultural systems call for the actual investment of money in the forest, in various forms. The portion of the stand, which is left, reduces the present cut, and since it costs just as much to build roads, the relative cost per unit of product is higher. The timber must be felled so that it will not injure any more young trees than necessary. This may not entail extra expense except in increased supervision and friction between the boss and the crew. But the disposal of the tops and limbs is always an open question. The danger from fire is in most districts so great that if this rubbish is left to dry out, there is almost sure to be a fire that will ruin most of the remaining stand. The tops can in some cases be burned either in piles, or as they lie, without much damage, if done at the right season. On the Minnesota National Forest much of this burning was done in winter as the logging progressed, with great success. The rest was burned as soon in the spring as the piles were dry but before the ground dried out. For every 1,000 feet of timber scaled, it cost from 12 to 25 cents to pile and burn the tops. But the resulting condition of the forest was more than satisfactory, and it has been a comparatively easy matter to keep fires out of the cut-over area. In spruce sections it is recommended that instead of burning, the tops be cut down to lie flat on the ground, where in about two years they will decay and cease to be a menace. In portions of the southwest it is thought best to let the tops lie, and not to burn them, since the shade is beneficial to seedlings and owing to the scattered condition of the tops, the increase in fire risk is not very great. Local conditions will always determine what disposition to make of the tops.

VII. FIRE PROTECTION.

It is always necessary, and often far more important, to keep fire out of a cut-over tract, either after the brush burning or altogether. Reproduction will surely be destroyed by fires and the most favorable opportunity to secure tree seedlings will be lost. Other kinds of vegetation, as grass, weeds and worthless brush, at once come up in clearings, and these will, by sprouting seeds and root growth, survive fires while the seedlings will not. A plan for fire protection must be adopted as the most vital measure in any attempt to grow timber. State laws are a great help in securing the prevention of fires. But the methods of protection consist of employing men to patrol tracts and of constructing fire-breaks. Of the two more can be accomplished at less expense by a patrol. Most fires are started carelessly, and the presence of a paid ranger whose duty is to inform persons crossing the tract, of the necessity for caution in the use of fire, will reduce the risk greatly. Again, fires under most circumstances start slowly, and the prompt discovery of a blaze by the patrol gives a single man a chance to put it out without help. Should one get beyond his control, the ranger is able to summon help. Telephone communication is almost indispensable on large tracts where help is scarce. The whole purpose of the work should be prevention and suppression of fires before they have time to get beyond control.

Fire Fighting.

In fighting a fire, tools are a necessity. A man without a weapon of attack is helpless. It is possible to cut brush and beat out a blaze, but this is a very insufficient substitute. In loose soils the long handled shovel is best. With this, sand can be thrown on the fire. Rakes, in open flat forest, or hoes on rough brushy or rocky ground, are

used to scrape out a path in front of the blaze, over which it cannot burn. These methods will work in fighting a fire burning along the surface in leaf litter. Such a fire does not travel very fast. Water is always useful, but is seldom available when wanted and cannot be carried any great distance over rough ground. When a fire is so situated that wagons can be driven in to it, water can be used best by dipping cloths or brush into pails and beating out the fire. A pail of water so used goes a long way, while if thrown on the fire it is wasted at once. Sometimes fire extinguishers can be used with good effect. They hold about two gallons and are a good load for a man. About 100 to 150 feet of blaze can be put out by one charge, so their use is limited to emergency calls, when a fire can be reached at once, and is apt to get beyond control. Fires burning in tall grass or dry brush sometimes travel as fast as 5 or 6 miles an hour, and it is not possible to fight them by direct attack. Such fires must be checked by back firing. To start a back fire, some line must be found along which it is possible to set a fire that will burn against the wind toward the approaching blaze. A stream, an old road—even a foot path, may be used. If none of these is present, an artificial line must be constructed, and the fire set along its edge. If the back fire can be prevented from crossing the barrier, it will put an end to the blaze. Even in smaller and less dangerous fires it is often more sensible to rake out a line at a little distance from the fire, and start a back fire toward it than to exhaust the men in beating out the main fire, where they will be bothered by heat and smoke.

Fire-Breaks.

But there are some places where the danger from fires is very great, because of accumulations of inflammable debris or long grass, and at the same time the property

to be protected is quite valuable—as for instance, plantations of young pine. It is not safe to trust to the ability of a patrol service to be on hand with sufficient force to stop fires. Here artificial fire-breaks should be constructed, not so much with the idea that fire cannot cross them, as to give the rangers the best possible chance to set back fires and control the oncoming fire. Most of the mistakes in building fire-breaks have arisen either from the supposition that the fire-break must be wide enough to prevent fires from crossing or in forgetting that such fire-breaks, once constructed, do not stay clean, but grow up to inflammable grass and brush if not tended. Fire-breaks should be wide enough to check an ordinary fire, and to make it safe to set a back fire against a fire traveling on a strong wind. But a wind will blow a fire across almost any fire-break in the absence of a back fire, hence the absurdity of constructing very wide lines. In sandy lands, lines may often be plowed, and a fifty foot wide fire-line is more than sufficient. In most conditions, a break as wide as this not only means great expense in clearing, but the line soon becomes a jumble of briars and young growth and ceases to be a barrier to fire. In such cases, if old timber is standing the line should be run through the timber and consist of a well-cleared strip, perhaps not over ten feet wide under the crowns of the old trees, which will keep down the young growth that would otherwise spring up. The main point is to clear the ground of leaf litter, dead logs and brush, and expose the mineral soil. In many places strips 3 or 4 feet wide, literally paths, serve the purpose of fire-breaks. Such lines have been constructed in southern pine regions to check the small annual grass fires that destroy the seedlings. The most difficult problems are in regions like the Adirondacks where a fire-line is not complete without a trench dug through the accumulated duff down to soil one or two feet below. Such lines have often had to be

constructed hurriedly in the two dry summers of 1905 and 1908, to stop fires from traveling underground. At least one estate has now begun the building of such a fire-line along their boundary to be in readiness in case they are threatened again. This line cost \$250.00 a mile for clearing a space 16 feet wide and trenching two feet wide in the center.

The expense of fire protection should not exceed 5 to 10 cents per acre annually. This sum will not permit of much outlay on small tracts. A ranger should patrol from 3,000 to 10,000 acres of land. In the west they are required to guard far greater areas. It is this limit to the expense which prevents the construction of many fire-breaks, but there are often locations where it will evidently pay to construct one especially along borders of forests. On the Angeles National Forest near Los Angeles, Cal., over 100 miles of fire-breaks have been made along the foot hills and the crests of the lower ridges. In the mountainous region a fire-break should be placed either at the very bottom of a slope—or at the crest of a ridge. There is very little chance to make an effective fight mid-way up a slope.

Fire Laws.

So important is fire protection to the success of forest production that states have developed fire laws, and systems of state fire wardens, to aid in securing the desired result. Practically the first forest legislation in any state has been laws providing penalties for setting fires in woodlands. But like all other laws—to be effective they must be enforced. The duty of arresting offenders, and of extinguishing fires must be placed upon definite persons. The state of New York was first to pass a fire law of this character, and this was brought about mainly by the demand of the public that state lands held as forest reserves in the Adirondacks be properly protected from fire.

The original form of this law has been greatly changed, but other states copied the provisions and have in some cases retained the weak points. Minnesota is such an instance. In 1894, after the Hinckley fire, this state passed a law creating the office of Chief Fire Warden, and imposing the duties of town fire wardens upon the supervisors of each town. They were required to proceed to all forest or prairie fires and extinguish them, could appoint deputies, and employ men to aid in fighting fires, and submit accounts for such services to the county commissioners who were to pay the bills and collect one-half from the state. A summons to fight fire was obligatory and refusal to go was punished by a fine. The warden could arrest anyone on sight who was caught in the act of setting fires, without stopping to procure a warrant. Most of these features are necessary to a good fire law. But it was found that town supervisors with the duties of fire warden thus foisted upon them by statute seldom took any interest in putting out fires and often ignored their duties altogether. In the organized towns of New York outside the state reserves, and in southern Maine, the same system still prevails with the same result. It is tolerated because in such agricultural regions there is not much danger from fires, and no one cares who is the warden. But where it was really necessary to secure protection, a new plan was soon adopted which was a great improvement on the old system. The local fire wardens were appointed instead of having an elected officer serve *ex officio* as fire warden. In New York, the Commissioner of Forestry received the power of appointing wardens in towns within the forest reserves.

These men were naturally selected for their fitness for the job, and were retained in office by reappointment, as long as they gave good services. This resulted in a great improvement in the efficiency and diligence of the wardens. Later on, New Jersey, after experimenting with

the old plan of making town officials serve as wardens, changed her law so as to require these same officials to appoint a fire warden for the town, which choice must be approved by the state fire warden. Connecticut and Massachusetts both passed similar laws, in which while the town supervisors appointed the warden, the state forester had to approve of the appointment. A feature of all good fire laws is the office of state fire warden. Local wardens need the presence of some higher authority both to educate and stimulate them in their duties, and to have the power, at least, of removing them if they are incompetent. Conservative states like Massachusetts did not wish to take the power of appointment away from the town, but allowed the state warden enough authority to accomplish the desired result of impressing the town warden with his responsibility to the state official.

Fire Patrol.

But the state and town fire wardens, however efficient, cannot control fires without the aid of public sentiment and the active support of land owners. Up to within very recent years, the sole duties of such officials were to extinguish fires that were already started. But the proper way to keep out fires is to prevent their starting. To do this requires a fire patrol, which means the employment of men by the week or month, and paying them wages while so employed. Town fire wardens were in some states required to patrol their territory, and could appoint men for this purpose, but usually nothing of the kind was contemplated. The obstacle has always been the cost of establishing an efficient system of patrols. Taxpayers do not appreciate the necessity for it, and will not vote for the appropriations. It is not until there is a lively demand for such service that the funds will be forthcoming to secure it. The increased effectiveness of paid patrols over town fire wardens has been demonstrated

whenever the system is used. The State of Maine has for several years maintained a system of state fire wardens in the unorganized wild lands of the northern portion. These lands are divided into districts over which a deputy fire warden presides, who can employ rangers. As but \$10,000 was appropriated for this purpose, the land owners offered to pay the expense of rangers if the state would appoint them and a great deal more was spent by associations of owners in wages than the total state fund. But as each warden has the authority of the state behind him, the whole plan was satisfactory. A system was developed of building watch towers on high hills and establishing one of these wardens as a lookout with telephone connections, to report the first sign of fire. This plan was found to have great merits, as long as the fires were kept down, but with a smoky atmosphere the watch towers were no longer useful. The plan has been adopted in the West using mountain tops as stations.

The idea of allowing owners of land to pay for men to patrol their lands, and secure state co-operation by having these men appointed as state fire wardens, was adopted on the Pacific Coast, in the states of California, Oregon, Washington and Idaho. Timber holdings of immense value were here constantly threatened by fire. Under state laws, associations were formed which now employ hundreds of rangers and at a cost of from 1 to 4 cents per acre have reduced the losses from fire to a small fraction of the former loss. This seems to be the fairest and simplest way to secure patrol on private lands. But it is not easy to bring it about except where lands are held by large owners, as corporations. An instance in Pennsylvania where the same principle is effective is the Pocono Protective Association, consisting of a large corporation interested in protecting the head waters of streams for water flow, and a number of proprietors of summer hotels and parks. The law of Pennsylvania as it stands pro-

vides that town constables shall be fire wardens, and in many sections it is a dead letter. But this association has secured by petition, the appointment of special constables to serve as fire wardens, and pays them a salary to patrol this district. Rewards are offered for the capture of persons setting fires and a campaign of education has been waged against the habit, formerly common, of burning the ground over annually. As a result fires have almost ceased in this vicinity. In many cut-over districts the annual fire is not thought to do any harm, and land owners are indifferent to its occurrence. Under such circumstances no system of laws or wardens will stop the fires. State wide fire protection is an impossibility in many states until a much greater amount of interest is roused in the possibilities of our forest lands. This must be brought about by owners of lands who are willing to set the example of growing trees and to a large extent furnishing their own fire protection, with the assistance when needed of town fire wardens and state laws.

VIII. TAX LAWS.

Aside from proper fire laws, states can do more to encourage private forestry by wise systems of taxation than in any other way. Forests are now taxed as real estate is taxed. As long as trees are regarded as so much lumber on the stump, waiting to be cut, the policy will be continued of taxing this material as long as it is there to yield a revenue, with the knowledge that once cut there will be no further income to be derived from it by the local government. But this policy is only a part of the vicious system of destruction which is laying waste lands that should be kept in a productive condition forever. Since the returns on young timber are deferred until it reaches merchantable size, the longer the owner defers the cutting the more taxes he has to pay, and the less will his ultimate profit be. Such taxation stimulates and even com-

pels forest destruction. Attempts have been made to exempt plantations from taxation for a term of years, or to give rebates on taxes for the preservation of small tracts of woodland in connection with farms. But these laws have not effected any improvement in the general situation and are mostly unoperative. The principle which meets with most favor among reformers is to tax annually only the land, on the basis of wild or unproductive lands in the vicinity, and to tax the timber at the time it is cut. If this can be done, lumber will bear a fair but not undue burden of taxation, and timber may be cut or held at the owner's convenience. The private owner who desires to devote otherwise worthless land to growing trees should be assured of the protection of the state, to his investment, instead of as at present being left at the mercy of local tax assessors.

IX. FOREST MENSURATION.

Since forestry is a business as well as an art, it is important to know what returns will be received from the use of land for tree production. The growth of trees in size, and their age, can easily be measured in all temperate zones, since the trees have a seasonal growth, and lay on annual rings which are usually quite distinct, although much more so with some species as pines and oaks, than with others as maple or basswood. Sometimes two rings will be joined in the same year, due to interruption in growth by reason of drought or defoliation by insects. But the extra or false ring can often be detected by its not being complete around the whole circumference of the tree. Since the age of a tree can be found by counting the rings on the stump, the measured volume, in board feet, or cubic feet, gives the average rate of growth of tree during its life. If the stump is high, it may have taken the seedling two or three years to reach that height, in which case this period must be added to the age of the stump to get the

true age of the tree. The volumes of trees are measured by foresters at $4\frac{1}{2}$ feet from the ground, or breast high, to avoid the swelling of the stump. This swelling is not regular in different trees of the same diameter at breast high, and the volumes are more consistent for diameters at the latter point. By measuring a large number of felled trees, the average contents may be determined. If the trees are classified by height as well as diameter, and the contents of the different classes found, these values may be tabulated, giving us a volume table based on the diameter and height.

Timber Estimating.

Such tables are very useful in determining the contents of standing timber. The work in the field consists in measuring the diameters of trees and enough heights to determine the average. The volume of an average tree is found from the table, and multiplied by the number of trees of that diameter. If the diameter of every merchantable tree can be actually measured, and a volume table is available, an accurate estimate of the standing timber can be obtained. But in most cases, time and expense do not permit of so much labor. Professional timber estimators resort to many short cuts to get at the result. The shortest and least accurate is to guess at the total, which can sometimes be done quite accurately by experienced men, or a strip is traversed on which all the trees are counted to a definite distance, say four rods on each side. In this way the estimator, or timber cruiser, seeks to get an average which will give him, without actually counting them all, the total number of trees on the tract. The volume of his trees is also gotten by an average, the cruiser merely guessing at the contents of the average tree. Each man may have a different method, but experience is the basis of them all, and the more painstaking men attain an accuracy greater than could be expected by the use of such

rapid methods. It is not uncommon in pine timber for a single man to estimate a half section or 320 acres of land, in a day.

The method most used by foresters has been to measure the diameters of all trees on a strip four rods wide run on compass courses straight through the forests. This is known as a valuation survey and gives the forester a good opportunity to make a map of the topography and types of timber during the running of the strips.

Determining the Growth of Stands—Yield Tables.

While the volume of standing timber may be quite accurately measured if time enough is devoted to it, the prediction of the growth of a stand is more difficult. The past growth of a single tree is easily studied, but this will not show what a forest or a single stand will produce. The laws of the growth of stands differ from those of single trees, for the number of trees in a stand is constantly diminishing with age. The average tree of a 50 year old stand will not be the average at 100 years, but may be crowded into the suppressed class or may even be dead. So the yield of a stand at 100 years of age is best found by measuring stands of that age, to find how many trees survive, and their total contents. If stands of all ages can be found, a series of plots is obtained which will show directly in terms of stand per acre, the results that can be obtained by growing trees. European yield tables are so constructed. In America the chief difficulty in obtaining such data is the irregular and poorly stocked condition of our forests. The stands actually present may not be more than half as heavy as the forest is capable of producing owing to damage from fire, and unregulated competition of poor species. Tables of this kind can only be made for even-aged stands composed largely of a single species and are used to predict the yield of plantations and of densely stocked stands.

Current Growth of Stands.

But it is possible to determine the present rate of growth or current growth of any stand. To do this the present stand is measured, to find the number of trees in each diameter class. Then the width of the last ten rings should be measured on several trees of each class. This can be done by making a slight notch in the tree or by the use of an instrument designed for the purpose, known as an increment borer. This will give the size of the tree ten years ago, at breast high. The volumes of the present tree and of the tree ten years ago, can be taken from a volume table, and the difference gives the growth in ten years. From this the growth of the whole stand in that period is easily determined. One way of overcoming the difficulties of predicting growth for long periods is to measure the crown space occupied by a dominant tree, and find its age and volume. We can assume with some degree of safety that an acre will grow as many trees of this size as there is room for the crowns. So difficult is the general problem of prediction of growth for long periods in our wild forests, that very few reliable figures exist which give yields per acre.

Growth of Individual Trees.

Most of the studies of growth have been made to show how fast the trees of a given species grow in diameter. Growth studies of this kind bring out many interesting facts if trees growing under different conditions are kept separate. The comparison of the rate of growth of spruce in old fields where it has full light, and the spruce growing under poplar, shows an astonishing difference in favor of the old field spruce.

Most figures on growth are shown by means of curves in which the increase in size, either diameter, height or volume, appears graphically by plotting the quantities on

cross section paper over the corresponding ages. The curve may serve the purpose of getting a better average from figures which do not run evenly since the irregularities may be evened out, and new values read from such a curve.

This method is commonly used in preparing tables of volume and of growth.

X. FOREST VALUATION.

When regular crops of trees are produced from forests which have been under management so long that the stands are even-aged and are producing the greatest possible amount of wood, the yield can be predicted with some certainty. The market value of the product cannot be foretold except that it will probably be more valuable than the same class of product is at present. The expenses of planting, protecting the stand from fire and insects, thinning, and other care, and the probable amount of taxation can all be closely approximated from actual experience. From these data European foresters have calculated the financial returns from forest crops basing their profits on the margin left after paying all the expenses of the crop from its inception until it is cut, with compound interest on every item, at a fixed rate of interest. Such calculations cannot be employed in America except for similar conditions. For a plantation it is possible to compute the probable returns if we can assume the costs, yield and sale value. Such figures can always be made conservative so that we may be sure that the indicated profits will probably be exceeded.

The most profitable time to cut a stand of timber is shown by these figures, which is, of course, the age at which the largest rate of interest is earned on the money invested. Stands continue to increase in yield to an advanced age. The value of each unit of wood also increases as the trees grow larger and produce clear timber, and there is a probable increase in general prices for wood independent of

quality. But it will not pay the private owner to wait too long, even with this three-fold source of increase. The interest on his expenses, with no income to offset them, is compounding at a rapid rate, and will soon offset the increasing value of the crop. The practice indicated for such owners is to cut the crop as soon as it has reached merchantable size without waiting for the production of large material.

The principles of compound interest and discount, when applied to forest finances, show exactly what one can expect from forestry as compared with other investments in which the money would be tied up without returns for the same length of time. This knowledge not only prevents us from making wild statements about the profits to be derived from growing trees, but emphasizes the need of economy in all expenses. The best returns from white pine plantations in New England are 5 to 6 per cent compound interest, and in many localities with slow-growing kinds and poor markets the returns would at present be as low as 1 per cent or might not yield any margin over the taxes and other expenses.

XI. FOREST POLICY.

The interest of the private owner of land in forestry must remain largely one of financial profit, and the dangers to which his investment is exposed, from fire, taxes and unforeseen accidents, when combined with the extremely long periods he must wait for his crop, will discourage many owners, from lumbermen down, in attempting it. But as it was hinted at in the introduction, these drawbacks do not apply to forestry by states or the national government. Here interests which affect the welfare of the whole community must be considered. Wherever it is conclusively shown that public interests will suffer if the forests are left in private hands there is sufficient reason for urging the government to undertake the work of caring for such lands.

The Influences of Forests on Climate.

The subject about which there is the most dispute is the effect of the forests upon the climate and rainfall. Popular interest is easily aroused on this theme. But a great many statements made for or against the beneficial effects of forests are not proven. A long series of records has been kept at European experiment stations established for the purpose of finding out the facts, and from such conflicting data, some points have been proved. The total amount of rainfall over a large area for a number of years is probably not perceptibly increased by forests, though it is almost impossible to prove this. Nor do forests have much influence on storms of a general character. They may, and probably do, slightly increase the number of summer showers. The influence of forests upon the air under the crowns is to moderate extremes of temperature, both hot and cold. They are very effective in checking strong winds, so that not only within a forest is the air almost still on a windy day, but the effect is felt for a long distance on the lea side. Single rows of trees are planted as wind-breaks in prairie countries. Both by checking the wind and cutting off the rays of the sun, forests check evaporation and tend to preserve the moisture in the air and in the soil. The effect of moisture in the air is to check undue loss of heat by radiation and to dispel the direct heat rays of the sun. This largely accounts for the modifying influence of the forest on extremes of temperature. But taken as a whole, we cannot prove that the presence or absence of forests increases the rainfall or modifies the climate to a great degree, though all the evidence points for rather than against the theory. Nor is it possible to establish any connection between the destruction of forests in one region and changes of climate in an adjoining region separated by 20 to 200 miles in distance. Whatever influence the forest has

must of necessity be local, and will be felt, at most, only a very few miles from the forest borders.

Influences of Forests on Streams and Soil Erosion.

But when we consider the influence of forests upon the behavior of the water which falls as rain, and its influence on the soil and on streams, the facts are indisputable. Rain falling on bare soil hardens it by impact and decreases its absorptive power. In heavy downpours, the water, unable to sink into the soil, rushes off in surface streams which soon wash out gullies. The more exaggerated these conditions become, the more rapidly will the rainfall be drained into streams, causing sudden freshets, which destroy bridges and wash out or cover bottomlands with sand and boulders. Any influence which retards the flow of rainwater and increases the amount absorbed by the ground, will tend to equalize the flow of streams. This to a marked extent the forest accomplishes. The force of the rain is broken by the branches, while the leaf litter and other rubbish impede the flow of the water. The litter and humus cover, not only take up water in large quantities, but keep the soil porous below. Much of the water so absorbed appears as springs and it is everywhere noted that the destruction of a forest cover causes springs to dry up. In many places, the retarding effects of forests on runoff have been compared by actual measurements and found to be very pronounced. Soil thus protected cannot wash. It is in mountainous regions that these effects are most noticed and here the need of forest protection is greatest.

Government Regulation versus Government Ownership.

For these reasons it is not safe to allow owners to remove timber from steep mountain slopes, and in many countries laws are enforced regulating such cutting. But even in European states whose citizens are used to being interfered with by the government, it has not been easy to

compel them to properly manage forests which must be protected. A better plan almost universal there is for the state to acquire the ownership of such lands, and with it the right to manage them wholly for the good of the dependent communities. In the French Alps, following the revolution, timber was cut on mountain slopes, which had previously been protected. The effect is historical. Torrents formed and destroyed the fertile land in the valleys. The population dwindled to a remnant of the original numbers. The government finally began the work of controlling these streams by means of brush dams and forest planting, and has been wholly successful as far as the work has proceeded. But in every case the title to these lands was first obtained by the state and under such management a repetition of the catastrophe cannot occur. It will be found that the movement for government and state management and ownership of forest lands has made the most rapid strides in mountainous regions. There is but little opposition to government ownership of forests on high mountains whose chief value is for protection. In such forests there is seldom any cutting done, and if at all, it is managed under a system of selection which keeps the forest cover intact.

History of National Forestry in United States.

The movement for governmental forestry in America did not gather force until quite recently, and has reached its greatest development in the West. This was due to two facts. The national government still owned vast tracts of mountainous and forest-covered land there, and there existed a man who had the breadth of insight to see the future needs of the nation, and the strength of purpose to achieve his ends. Gifford Pinchot became the chief of the government forest service in 1897. The first large forest reserves were proclaimed in 1891 and had been much increased in size and number by President Cleveland in 1897. It was easy, after the proper legislative authority had been

obtained, to declare government lands set aside as forest reserves. But it was not easy to bring about their proper management, and to make them useful to the people. This has been the work of Mr. Pinchot. The first task was to formulate regulations permitting the cutting of timber under restrictions, opening the reserves to legitimate mining and stock grazing, and protecting them from fire and trespass. The next forward step was the transfer of their management from the Land office of the Interior Department, to the Forest Service of the Department of Agriculture, where they would come under the direct charge of foresters educated to understand both the objects of the reserves and the methods of accomplishing them. The third and final stage, which is still in progress, was the education of the people of the West to the necessity and significance of government control and regulation of the use of the forests, water, and grazing rights, for the benefit of all. The policy of the Forest Service has been clearly defined from the start. The settler and home builder receives first consideration, and this is most effectively accomplished by distributing grazing rights on the basis of residence rather than influence. The title to water power is retained, for the benefit of the public, and a strong fight is waged constantly to prevent the passage of legislation tending to give these rights in perpetuity to power companies. Timber is sold to lumber companies, but the lumbermen on a National Forest can no longer neglect the future of the stand. Before any cutting is done, the needs of the forest are thoroughly worked out, and the logger is then allowed to cut only such trees as are marked, and must remove all merchantable timber, fell defective trees, and use them if possible, and take whatever measures to clear up the tops and rubbish as are considered necessary by the forester. Settlers are allowed free use of timber, under permit, for fuel and building, and in every way the forest areas are made to contribute as much as possible to the prosperity of the West. Not

the least of these benefits is the protection which the forests afford to the water sheds from which are drawn the waters for irrigating the numerous valleys whose cultivation is wholly dependent on this water. Much strong opposition has been met, rising partly from ignorance of the aims and methods of the service, but more often from selfish interests desiring undisputed possession of grazing, and other resources, and a chance to acquire timber and cut it as they pleased. In overcoming this opposition, Mr. Pinchot has shown the qualities which Americans most admire, honesty, fearlessness and common sense. National forestry is, under his guidance, making rapid strides toward the attainment of the purposes for which it was designed. But the government has not yet committed itself to the policy of purchasing lands for forest reserves, no matter how pressing the apparent need. The only national forests in the East are found in Florida, Michigan, Minnesota and Arkansas, where public lands existed that could be set aside as national forests without purchase. A determined and well-sustained fight has been waged to bring about the purchase of mountain lands in the Southern Appalachians but without success.

State Forestry.

It is probable that in the East, forestry will be more extensively practiced by state governments than by the nation.

Already several states have inaugurated the policy of buying lands for forest reserves. New York, the first state to do so, now owns in the Adirondacks and Catskills 1,655,000 acres obtained largely by purchase. Pennsylvania has bought, or is under contract to buy, 967,000 acres of forest land around the headwaters of the streams flowing into the Atlantic, and can spend annually \$300,000 for this purpose. New Jersey, Connecticut and Massachusetts are

spending small annual appropriations of from \$3,000 to \$10,000 in purchasing lands for state forest reserves.

But states do not always establish reserves solely in mountainous land. Wisconsin has no mountains, yet she set aside all of her public lands in the northern third of the state as forest reserves, totalling over 260,000 acres. Michigan has made a beginning with 37,000 acres in the midst of a flat, sandy plain. These reserves must be justified by something more than the effect of forests on the runoff or erosion.

Agricultural Soils versus Forest Soils.

There are two arguments to favor these reserves, neither of which is as yet accepted by the public as a whole. The first is that land may be too poor for agriculture and should therefore not be farmed, but devoted to forests, for which it is entirely suited. The second is that the state can go into the business of producing timber and succeed better than the individual, yet without injury to the interests of those individuals who wish to raise timber. As to the first proposition, could the truth be clearly set forth it would convince the most skeptical. Sandy land without a clay or compact subsoil will not retain either moisture or fertility. They are easily tilled but soon exhausted and even clover fails to maintain their fertility. Except when located in the near vicinity of large markets where truck crops can be grown, and the land heavily fertilized artificially, it is not possible to earn a good living on such lands. Areas of this character exist in Michigan, Wisconsin, and Minnesota, and in each state, it is found that such farms are usually abandoned after a more or less protracted struggle with adverse conditions. Were this the final result, the question would be solved. But land speculators are able to obtain such lands very cheap, and by means of flaring advertisements, which may be read every day in the press, they attract from the city inexperienced victims who pay

them ten times what the land has cost them, and in addition give a mortgage which they are never able to pay off. If the original settlers failed, these later victims are sure to, and such lands become a sponge to extract the savings of land hungry purchasers. The only possible relief is for the state to acquire such lands and, by devoting them to forestry, not only put an end to this disgraceful swindle but aid in restoring such regions to a fair degree of prosperity which the presence of forests on the poorer land would insure.

The State as a Producer of Timber.

As for the state going into the business of producing timber, which is considered un-American in principle, it can be shown that in every way this will encourage individual effort along the same lines. It has always been true of wood products that the greater the quantity of a certain species produced in a restricted locality, the more profit there was in handling it. Operations could be planned on a large scale and all the costs of logging and marketing reduced, while at the same time the product became known and accepted as a staple article in manufacturing lines. So great will be the scarcity of wood in the future, and so comparatively little will be raised, unless the movement for reforesting waste lands proceeds much faster than now, that the combined efforts of state and individual will fall far short of the demand, and if wood is not to cease to be an article of trade, it is necessary that enough be raised to make it worth while to rely upon it in the future for manufacturing and other uses. State timber will help maintain the market for private timber. But in other ways state forests will benefit private forestry. Where states have established forest reserves, it is their policy to protect them from fire and to plant trees. The example and encouragement thus given to individuals makes it much easier for the latter to carry out plans for forest production. Some

states, like Connecticut and Massachusetts, put this as the primary object of such forest reserves. But in the final analysis, it takes permanent ownership and a settled policy to bring success in raising trees on a large scale. Private owners die and their estates are sold, or they change their minds and cut the timber and there is nothing to prevent these things. With states or the nation as owner, and a policy once strongly intrenched by popular support, the best possible opportunity is given to the forester to grow the timber which will supply our needs in the future. Real progress in forestry in any state will be largely measured by the extent to which the state itself is interested in forest lands.

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