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SOME ASPECTS OF FOREST BIOLOGY[1]

By Professor A. W. BORTHWICK

UNIVERSITY OF ABERDEEN

In forestry the long period which must elapse between the establishment of a crop and its final harvesting at maturity makes it imperative that we should use every endeavor to secure the best types of trees suitable for the concrete conditions of the localities in which they are to be grown. If a wrong species is chosen at the start—that is, a species unsuited to the soil or climate—and in mixed woods, if a wrong combination of species is adopted in their formation, then no amount of skill, care and attention on the part of the forester can remedy the defect or make full use of the productivity or growth factors of the locality. In cultivating his crops the forester must always keep in mind that the ultimate success of his efforts is determined by rate of growth combined with the usefulness and volume of the timber produced. This again brings him into close contact with the botanist. Among species of trees, apart from varieties and sports or mutations, no two individuals are absolutely identical, in spite of all outward resemblance. There are differences in rate of growth; commencement and duration and finish up of seasonal vegetation; flower, fruit and seed production. All these may vary in time from a few days up to as much as one or two weeks. These differences may occur in all soils and in all climates. In both the artificial and the primeval forest it can be detected among trees of the same species, growing side by side on the same soil and sprung from seed of the same parent tree. Individuals from the same seed may show differences in stem quality, branch formation and crown balance, due to some internal

[1] From the address of the president of the Section of Botany, British Association for the Advancement of Science, Aberdeen, 1934.

impulse, which is independent of soil or climate. Some individuals produce straight cylindrical stems, others bent, twisted and crooked stems; some have an inherent tendency to fork and produce double leaders —accident to the end bud of a leading shoot may cause double leaders, but that is a different thing; in some the branches ascend at an acute angle, in others they tend to spread horizontally at right angles. Forking leaders and spreading branches result in defective crown formation.

Another individual defect is the tendency to produce water shoots or epicormic twigs. Unfortunately this individuality does not seem to be hereditary, otherwise we could with greater certainty avoid such in selecting our growing stocks, but even if this were possible we would still have to face the fact that defect in stem, branch and crown and rate of growth is not due to individuality alone. Although the characteristic individuality remains constant throughout the life of each single tree, it does not follow that its seedlings will all possess the same characteristics: each seedling will have inherited an individuality, but not necessarily the same as that of the parent tree. Nevertheless, rate of growth and tendency to late or early vegetation become apparent early in the life of the seedling. It is then that the first choice can be made in the selection of growing stock. But no matter how perfect the young tree may be, it is still subject to the influence of external growth factors, and climate, soil and silvicultural treatment can influence its form and growth. A plant with individual tendency to slow growth in the colder limits of its distribution will be stimulated to more rapid growth in the warmer climate; and, on the other hand, a rapid-growing individual of the warmer climate, if transferred to the colder climate, will suffer check to its rate of growth, and individuals of normal growth will show the same tendency. Keeping these facts in mind, it is easy to see how readily false conclusions may be drawn in regard to the actual and relative rate of growth of different species.

In a community of trees of different species growing on the same soil and in the same climate, some may be in their optimum, while others may be on the colder or warmer limits of their natural habitats, and the soil may suit some species better than others. If such an experimental plot were established by planting, allowance would have to be made for the time taken by different species to get over the check stage and to become completely established in their new quarters. Some species are quicker to reestablish themselves than others. That is, they are more easy to transplant. Then again, trees are not uniform in their rate of growth at all ages. We must, therefore, be careful in coming to conclusions regarding the growth behavior of trees. We must seek the aid of plant physiology and plant geography if we wish to arrive at reliable and useful conclusions. Climate is after all the main controlling factor, and each country must collect its own data. Hitherto, in forestry, we have had to rely too much on data applicable to the continent of Europe. But with a well-selected series of representative sample plots established throughout Britain by the Forestry Commission, the arrears of our knowledge in this respect are being made good rapidly.

Let us now consider the importance of these fundamental biological facts to silviculture. For convenience let us divide the life of the forest into three stages—the juvenile stage, the pole or stage of most rapid height growth, and the adult or tree stage; and, in order not to obscure the main points by unnecessary detail, let us assume that the trees have been artificially planted. In all recent plantations there is bound to be competition by weed and grass growth; it may be also woody scrub, stool shoots or interloping and unwanted light-seeded invaders. Cleaning and weeding must not be delayed. Careful tending of the young trees should begin early. Too often plantations are left to look after themselves until they are supposed to have arrived at the thinning stage, when they may yield something in the way of returns for the cost of thinning. But by this time irreparable damage may have been already done to the growing crops. Not only is weeding and cleaning necessary during this period, but now is the time to remove and replace trees of inferior growth habit, which they begin to show at this early stage. Trees which naturally tend to fork can not be improved by pruning off one of the leaders: forking will be repeated later on, as this natural individual tendency persists throughout the life of the tree. The same thing applies to all trees with faulty stem and crown formation.

Among all species, but more especially among broad-leaved trees and in particular the beech, it is these heavy-branched, spreading-crowned, short-stemmed trees which may forge ahead and become predominant in the mature stand, at the cost, it may be, of smaller but better-formed and more valuable trees. Therefore by the timely removal of such individuals, so-called wolf trees, much future trouble, cost and loss will be avoided. A certain amount of thinning may be advisable before the pole stage is reached, but such operations should be confined to completely suppressed, back-going and dead trees and aggressive, malformed wolf trees. For various species under average conditions the period of the pole stage falls between the twentieth and the fortieth year. This should be the time of greatest density in the life of the stand. The trees have reached the stage of their most rapid annual growth in height, and this is further stimulated by the density of the stand, which also leads to lateral branch suppression and the cleaning of the stems. The density must not be too great, otherwise the trees are liable to become too long and attenuated to carry their own weight. It is here the skill of the forester is put to the test. Now is the time, and indeed the best opportunity, during the whole life of the stand to encourage length, form and cleanness of stem. Growth in height is dependent upon crown room and light; and cleanness of stem is dependent upon crown density and shade. These two opposing conditions must be so balanced that the one will not defeat the object of the other. The thinnings during this period will depend upon the planting distance originally adopted and the amount of care and attention which has been given to the young growth until the branches meet and establish cover or canopy when the thickest stage is reached. The maintenance of pole stage density is prolonged until the side branches have been killed off, by side shade, up to the desired height on the stem. Subsequent drying, decay and fall is merely a matter of time. Up to this stage, which will occupy as a general rule the first half of the rotation, the main endeavor is to secure a good growing stock of tall, straight, clean-stemmed trees.

In the second half of the rotation, which we have called the tree stage or adult stage, the problem in tending should resolve itself into obtaining the greatest volume production and quality of timber by encouragement and control of diameter increment. The quality of timber depends to a large extent upon uniformity in breadth of the year rings and the texture and fiber of the wood. This can only be obtained if the growth of the tree itself is uniform and sustained. Hence in this latter half of the rotation attention must be directed to the crowns and roots of the trees. A gradual removal of certain trees and opening up of the canopy gives the crowns of the remaining trees more light and room to expand, and this means increased food production. These cuttings may be called "light increment cuttings," in contradistinction to "thinnings," from which they differ in regard to their influence on the biology of the stand. The more open growth under light increment treatment means fewer trees at maturity, say 160 per acre, but individually they are of greater volume and collectively of not less volume than would have been produced by a larger number of trees in closely crowded crown competition. The more open stand necessitates the retention of some kind of undergrowth or, more commonly, underplanting for soil cover and preservation. This method has been successfully practised in Denmark in the case of beech, oak, pine and spruce. Under the old system of dense canopy preservation, the intermediate yield in thinnings was about 25 per cent. of the final yield. Under the light increment treatment the thinnings may amount to 20 per cent. and the light increment cuttings to 50 per cent. of the final yield. That means in the latter case we have 75 per cent. against 25 per cent. in the former; and if we assume, as we are entitled to, that the value of the material removed in light increment cuttings is greater per unit of measurement than that of thinnings, and at the same time if we keep in mind the fact that the volume of the final yield is the same in both cases, with the balance in favor of quality in the case of light increment treatment, it will be seen that the treatment increases the yield per acre by well over 50 per cent. The material removed by the light increment cuttings, from the fiftieth year onwards, would be clean grown and straight, and would yield all sizes required for telegraph poles, for which the demand has always been high. The trees of the final crop would easily be of sleeper size—that is the most all-round useful and valuable size for mature timber. If this can be done in Denmark, why should it not be possible in our equally favorable if not more favorable climatic and soil conditions?

All the problems which arise in regard to the care and treatment of young, middle-aged and maturing stands of trees are subjects of the study of stand biology, and that system of silviculture which makes the fullest use of the external factors of growth, in combination and individually, will achieve the best results in the end. The old system of preserving dense, uniform, unbroken canopy was unnatural and made it impossible to utilize to its full advantage the important growth factor, light.

In the primeval forest, loss and replacement is constantly going on. As each veteran disappears it is replaced by hundreds of seedlings which strive and struggle among themselves and against surrounding hindrances to reach the light. The struggle is a prolonged one, and many seedlings and saplings are killed off in the process. Still, nature works cheaply if slowly, and if we can make use of the free gift she offers in the way of natural regeneration, it would be an obvious gain. Nature has produced and maintains the forest for her own purposes. On the other hand, man exploits the forest for his comfort and well-being, but if he oversteps certain limits in his treatment of the forest for the sake of extra gain or profit to himself, nature revolts, with the result that man defeats his own ends.

If we are to make use of nature's free gifts, in the natural regeneration of the forest, we must study the natural biological laws under which the process can take place. As we have seen, nature works slowly but surely in her conservation of the primeval forest, irrespective of what the utility and value of the species may be to man. Man's idea is to grow certain species only in massed, even-aged assemblages, in order to obtain the maximum amount of timber of the kind, size and quality he wants, and if he expects nature to help in the quick and certain regeneration of these artificial woods, at the end of what he considers the most advantageous age or rotation, he must make certain provisions in accordance with natural laws. This can be done by appropriate silvicultural treatment. The trees must be of a suitable seed-producing age, the forest floor must be in a suitable condition for the reception and germination of the seed, and the conditions of light, moisture and temperature must be suitable for the future growth and development of the seedlings. These three things are of fundamental importance. In most of the mature and maturing woods which have been treated under the strict artificial rules of so-called forest management, the question of quick and certain natural regeneration often presents insurmountable difficulties.

At the time required by the working plan the trees may not be in a suitable condition for flowering and seeding; the forest floor, under light demanders, may be long past the best conditions for the reception and germination of seed, owing to weed growth, and under shade bearers an over-abundance of humus, especially raw humus, is equally unfavorable. Many years are required to bring the trees and the forest floor into a suitable condition for natural regeneration, and if this is attempted over a whole compartment simultaneously, the result is seldom satisfactory. In dense-canopied, even-aged stands a series of preliminary fellings, called preparatory fellings, must be gradually carried out to allow more light and room for the selected seed trees, in as even distribution throughout the stand as possible, and also gradually to prepare those trees for their more isolated conditions and resistance to wind. Under shade bearers this opening up of the canopy leads to the disintegration of over-abundant humus by allowing more direct access of precipitations and light, and also by increased aeration due to the freer circulation of the air. Under light demanders it means costly artificial surface and soil preparation. In either case, when the soil is in its most suitable condition a further felling is made either immediately before or during a seed year, if one should happen to occur at the right time; if not, it means delay and the soil gets past its best condition for seed germination. Even if a seed year should occur at the right time, there are many climatic and weather conditions which may prevent complete and uniform regeneration over the whole area: only patches of seedlings may occur here and there. This means waiting for a second seed year, which may be five or ten years hence, meantime further deterioration in soil conditions and risk of storm damage to the seed trees which were isolated so late in life.

The only alternative in such cases is to complete the process by clear cutting and artificial planting, and this is what generally occurs. If, as sometimes happens, by good luck the regeneration is sufficiently complete to provide a new crop, then the old trees are gradually removed in a series of falls, called the final feelings. But the whole process known as the uniform or compartmental system is slow, uncertain and risky. To lessen the risks of failure and loss by opening up large areas at one time, numerous modifications have been introduced into the practise of forestry. The underlying idea was to confine natural regeneration to smaller areas, in the shape of groups or strips, with peripheral extensions of these as they became regenerated. By selecting the shape, breadth, line and direction and sequence in time of the strips, a considerable amount of success has been achieved. Strips or groups may be clear felled or a certain number of trees may be left to provide seed and to protect the young seedlings. In the former case, protection is supplied by the adjacent stand of mature trees, and seeding takes place from the side. Various and numerous combinations of the uniform, group and strip methods have been tried, with more or less success, under certain favorable locality conditions.

The main trouble is that in the past the woods have not been managed with a view to natural regeneration; under light increment treatment, the more open canopy and crown room enables the trees to respond almost immediately to the influence of the seed felling. The under planting which has kept the soil in a favorable condition for seed reception can be dealt with easily, and after the seedlings have appeared, the old trees may be removed at one felling instead of gradual removal over a protracted series of years, as a certain amount of undergrowth can be left to provide shelter and protection to the young trees.

The biology of the large pure stands of timber must obviously differ from that of large mixed stands, consisting of two or more species, as generally prevail in the primeval forest. To establish artificially or to regenerate naturally a mixed stand of timber which will have the desired ratio of species at maturity involves much labor and cost, and the attempt is not always certain of success, except perhaps under the selection method of treatment. To get over the difficulties associated with single stem mixture, other forms have been tried, such as planting the different species in alternate rows, bands, strips, clumps and groups, but still this does not quite solve the problem. It is all right for the trees in the center of the group or strip, but those on either side at the contact margins are apt to become bent and branchy; further, each of these numerous units requires individual attention, and this is not compatible with economic management. It is possible with certain light-demanding and shade-bearing trees to form mixtures in which the crowns of the light demanders form a kind of upper story, with those of the shade bearers beneath; but such mixtures are very difficult to bring through the pole stage of growth unless the light demander happens to find itself in its optimum conditions.

The problem may now be stated: How are we to manage and develop our woods so that the demands for different species of timber, sorts and sizes of the highest quality possible, may be met, and adequate provision made for the regeneration of these woods, without loss of time and without deterioration to the productive capacity of the soil, and at the same time make as full use as possible of all growth factors, without interfering too much with the natural laws of forest growth? This is a big and important question, and in my humble opinion the solution suggested by Professor Heinrich Mayr, of Munich, seems to fulfil all these requirements. His suggestion was to compromise between the economic objects of man, the user, and the natural laws which govern the designs of nature, the producer. He suggested that the forest should be made up of small compartments, 1 to 8 acres, each compartment to consist of one species. These small pure compartments would be scattered as much as possible, so that adjacent compartments would differ in age and species. We would thus have a forest of mixed small compartments differing in age and species. Due attention would be given to assigning each species to its most suitable soil and exposure. Where conditions were such that only one species would grow satisfactorily, owing to physiographical conditions, such as in the mountains, pure sand, wet soils, cold climate, the compartments may be larger, about 14 acres, if desired, and the same species may adjoin each other, but the age difference between adjoining compartments should be varied.

The present division of the forest into large compartments need not be done away with, but each large compartment should be subdivided into sub-compartments—small compartments—which would become permanent units of management. Each small compartment treated from its earliest stages with a view to natural regeneration would, under later light increment treatment, always be in such a condition that natural regeneration could be imitated without long and costly preparation. The process could be completed within five years, and the risks of failure would be small compared with those of large contiguous areas, where ecological and biological conditions vary. In the small stand, the more open stand of the trees under the light increment treatment and the shelter afforded by adjacent stands would eliminate the necessity of the risky and lengthy preparatory fellings—a seedling felling and one final felling would suffice. Thus, as Professor Mayr claims, natural regeneration could be made easier, speedier and safer. The danger and risks from wind, fire, insect and fungus epidemics would be lessened; the varied demands for different kinds, sorts and sizes of timber could be more easily met. The forest community as a whole would approximate that of the primeval or natural forest, and the productivity of the soil would at least be preserved, if not improved.

To turn now to another aspect of the forest as a living community of plants and animals. The forest is perennial and less subject to seasonal changes than other forms of massed vegetation. The tree stems raise their crowns of branches, twigs and leafy canopy high above the forest floor, and this has a marked influence on the light, temperature and moisture conditions within the forest. Light is subdued, but temperature and moisture are both increased, and this, combined with a relatively still atmosphere, render the conditions within and under the crowns of the trees quite different from those of open country. Under the leafy canopy the soil surface vegetation consists mainly of shade-loving shrubs, herbs, ferns and mosses. The leaf fall from the trees and the general organic remains, along with that of the undergrowth, produce a soil covering of disintegrating organic matter, generally referred to as the humus layer. This layer acts like a mulch and ameliorates and conserves soil moisture and temperature. The tree roots penetrate more deeply into the substratum than most forms of other vegetation, this increasing its aeration, permeability and water-holding capacity. Although it has not been definitely decided whether forests increase the rainfall or not, it can be claimed with every justification that the forest is of great importance as a conservator of water and as an equalizer in the drainage of the land. Where no forests exist in the upland or collecting regions of watersheds, the rain falls unhindered, beating the surface hard or eroding it down to the bare rock. There is nothing to check the downward rush of water, which collects into mountain torrents which gush unbridled into the main rivers and streams, causing them to become swollen and flooded. These in turn race through the fertile valleys to their outlets, tearing down and overflowing their banks. The damage done by severe and sudden floods to roads, bridges, agricultural crops and stock, including human habitations, is well-nigh incalculable. Nor does the matter end there: millions of tons of valuable soil are washed away in these turbulent floods, and deposited as barriers in the river beds or in the sea at the river bar. Harbors and docks at the outlet of our main rivers become silted up with mud and debris: this in turn—apart from the loss of soil—involves costly dredging operations to keep the navigation channels clear.

Where forest exists in the upland districts or collecting ground of the water, rivers are more uniform in their flow, year in year out, and carry much less silt and debris. The crowns of the trees break the force of the falling rain; the humus layer on the forest floor has an enormous water-absorbing capacity, and when saturated it allows the water to percolate slowly into the deeper loosened layers of mineral soil, from which in turn it gradually finds its way into springs and watercourses. Further, the influence of the forest is such that the melting of snow is more gradual and water is slowly absorbed and held, thus again avoiding floods. The forest regulates the off-flow of water after heavy rains or melting snow. This water is fed into springs and watercourses more gradually throughout the year, thus preventing floods at one season and equally serious drought at another. As regards the influence of the forest in lessening the destructive effects of cloudbursts, we have it on the authority of Fernow that: "The forest litter, the moss-covered leaf-strewn ground, is capable of absorbing water at the rate of 40,000,000 to 50,000,000 cubic feet per square mile in 10 minutes, water whose progress is delayed by some 12–15 hours after the first effects of a heavy freshet have passed." I do not claim that afforestation or forest conservation in the high ground and valley slopes will entirely prevent floods and drought, but what the forester is doing or leaves undone in the remote hinterland will go a long way to check or ameliorate the evil effects of both. I have referred to these facts because the biological influence of the forest is so important and wide-spread in regard to drainage and water supplies.

As a form of vegetation which rises high above the surface of the ground, the value of the forest in breaking and tempering the effects of the cold winds has long been recognized and appreciated by the agriculturist. An adjacent sheltering strip or even clump of trees exercises a marked influence on farm crops and pasture lands; stock also thrive better in the shelter afforded. The trees afford shelter and at the same time exercise a very marked influence on the rate of evaporation of moisture from the surrounding area; this influence, in lessening the surface velocity of the wind and rendering it more moist, may be noted up to between 300 and 400 feet from the trees, but the distance varies with the height of the trees. In spring the pasture is earlier and more abundant, while in the autumn it remains longer green. The question of a reasonable balance between forest and grazing land is one of considerable biological and economic importance.

In the time available it is obviously only possible to refer to a few aspects of forest biology. I would have liked to say more about the importance of plant geography, but probably enough has been said to indicate how important this branch of botany is to forestry. Plant physiology and ecology are also of the highest service in the applied science of forestry. Plant anatomy is likewise of great value in wood technology, timber identification, seasoning, testing and preservation, which are all very materially helped by a knowledge of wood anatomy. It is needless to say that without help of the botanical systematist the forester would frequently find himself in serious difficulties, while the mycologist is equally indispensable.

Many biological problems of first-class importance in silviculture have still to be tackled, and it is to botany that the forester must look for their ultimate successful solution.

SCIENTIFIC EVENTS

THE TRAINING OF PHYSICIANS IN SOVIET RUSSIA

IN a special cable to *The New York Times* Walter Duranty, correspondent from Moscow, describes the training of physicians as an important feature of the Second Five-year Plan of the USSR. Mr. Duranty writes:

The plan provides for a great increase in the number of medical students. In 1928, at the beginning of the First Five-Year Plan, the total number of students was 26,000. On January 1 of this year it was 48,000. The plan provides for the admission of 15,000 additional students this year—beginning this month—24,000 more next year, 30,000 in 1936 and 33,000 in 1937.

Whereas 5,400,000,000 rubles was spent on the hygienic needs of the Soviet Union—which include rest homes and physical culture as well as hospitals, medical schools and the like—the Second Five-Year Plan's hygienic budget amounts to 19,600,000,000 rubles. The number of hospitals in the cities will be increased by 44 per cent. and in the rural districts by 98 per cent.

The Bolsheviki assert there is no branch of the na-