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ENERGY FROM FORESTS

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There is a considerable body of evidence to indicate that woody plants, particularly trees, constitute one of the world's most efficient biological agencies for the capture of solar energy. Forests now cover approximately one-fourth of the total land surface of the earth, or about 8000 million acres. We can apply factors for volume or space to unit production efficiency in trees, therefore, to produce gigantic figures of quantity. Because forests can, if rightfully managed, be continually regenerated, we can expect to achieve a continuity in the supply of energy not to be found in organic deposits. With these facts in mind, it behooves us to study with great care the productive capacity of forests.

The field of forestry is commonly divided into several parts, each with its subject matter and problems. These parts fall roughly into three groups. The first includes what might be considered the engineering aspects of the field. They are concerned with the evaluation, recovery and utilization of wood. We have seen rapid developments in all of these aspects in recent years, particularly in wood technology. We no longer think of forest products primarily in terms of lumber, paper, fuel and naval stores. We are learning to make a great number of products by the manipulation and rearrangement of wood fibers, or we break down the wood chemically and use its molecules for the production of entirely new substances. A second part of the field of forestry is closely related to the first, and lies in business management. The final decisions regarding wood recovery and utilization, and ultimately with regard to forest policy, are typically business decisions. Allied with them are matters pertaining to private and public administration of forest lands, and to forest taxation and finance. The third part of the field covers most of the biological aspects: the development and management of forests for the production of wood, for the protection of the land and water resources, or for recreation.

A study of the productive capacity of forests could be approached through the engineering and technical aspects of the field. Existing inventories could be tabulated and balanced against new and improved methods of use or the elimination of waste. Most of forestry research, past and current, has been devoted to these aspects. If we consider forests as a basic source of energy, however—a source that can be depended upon to continue for a long time—the problems of sustained long-term production loom as the most significant in the whole field of forestry, for without their solution the planning of long-continued use has no point. It may be necessary for us to develop a silviculture that will approach agriculture in efficiency and scope.

The development of silviculture requires the solution of both biological and economic problems. This paper will consider primarily some of the biological problems involved, though it will be impossible to do so to the complete exclusion of economic and social aspects. No forest exists in an economic and social vacuum, but here will be considered only the biological potential of land for the production of wood. Having discussed in broad outline the existing status of silviculture, some suggestions will be offered regarding the future course of research in this field.

It may be said in general that our knowledge and techniques in silviculture are far from satisfactory. The reasons for this are many and varied. Except in a few parts of the world such as temperate Eastern Asia and parts of Western Europe, civilized man has always lived with a relative abundance of wood. In many parts of the world he has had to destroy the forests in order to make room for necessary agriculture. In this atmosphere of abundance he has not felt the need, or could not afford, to develop an efficient silviculture. In the most densely populated parts of the Far East, forests have been almost completely eliminated, with no provision for their reinstatement. In Western Europe the demand for wood outstripped the natural supply a comparatively short time ago, and silviculture has been raised there to the highest levels known. Throughout most of the world, however, man still depends for his wood supply upon the exploitation of virgin forest or of second growth forest that has had no management. This is primarily the mining of a natural resource which, though it has the capacity for being renewed, is treated as if it were a non-renewable though relatively inexhaustible material such as oil or coal.

Another reason for man's failure to develop silviculture as rapidly as agriculture has been the fact that there are many substitutes for wood, but there have never been substitutes for food.

Further reason is to be found in the nature of silvicultural research itself. It is of necessity slow because of the slow rate of growth of forests. Since the time of Theophrastus and the early Maya there have been at least two thousand generations of wheat and corn, enough to give ample opportunity for the study of the relations of these grains to their habitat, and time and materials for the improvement of cultivated strains. There have been in the same period only ten or twenty generations of our common forest trees. Success with agricultural crops has depended to a large extent upon the opportunity for repeated trial and error experiments with the selection of genetic strains, hybridization, and the manipulation of sites. Such experiments have not been practicable with long-lived forest trees, and progress toward the control of forests in the agricultural sense has been kept to an extremely slow pace.

With such slow development the general rule, methodologies in silvicultural research have never been standardized. We have no body of knowledge and method which can be widely applied outside the region in which it originated.

The present status of silviculture is reflected in forestry education. Silviculture as a subject is taught in all forestry schools, and though it is highly developed in some parts of Europe, it has never been more than a minor handmaiden to American forestry curricula. Our schools and their attendant research organizations are heavily weighted toward the recovery of wood from the forests, its properties and utilization, and toward the protection of the natural forests that still exist.

Before going on to a discussion of the capacity of forests to accumulate solar energy, it would be well to mention some of the basic characteristics of forests as biological entities. The first of these characteristics is geographic position. Forests are made up of species of trees, usually of more than one, and often of many species. Each of the species has a geographic range which can be defined by observation. The range of a given forest complex or type therefore is a composite of the ranges of the species that predominate in it. Examples are the spruce-fir forests of Eastern Canada, the oak-hickory forests of the central Appalachian region, and the various phases of the great coniferous forests of the Northwest. These geographic patterns are relatively fixed by causes that are not clearly known. Alterations in them have occurred, but the time intervals involved in the changes run into long periods, such as thousands of years.

Another basic characteristic of forests is that in spite of the relative permanence of large geographic patterns, natural changes in form, species composition, and density are constantly going on within limited areas. These changes are spoken of as biological successions. They are relatively slow, but many are definable with our present knowledge over periods up to a few hundred years in length. They arise from the fact that the existence of a forest type in a given habitat commonly alters the character of the habitat to such an extent that the composition of the ensuing stand will be changed. If we are to understand and use the forests we must of necessity learn what these trends of development are and how the existing forests fit into them.

Such understanding is difficult to achieve because of another type of change which is exceedingly common. This is cataclysmic in nature and is probably of equal importance to slow successional change. Much of our current silvicultural theory and practice has been based upon a concept of continuity and stability in soils and climates. We have realized the destructive significance of fire and pests, and devote much time and money to preventing them. We have some reason to think that we can control these influences. But no one has seriously considered trying to ward off hurricanes, though we now know that the forests in large sections of the eastern United States have been destroyed by high winds three times in as many centuries. Our surface soils have been so much disturbed by the uprooting of trees that they may as well have been plowed at infrequent intervals. Whatever long-range plans we make for the use of forests must allow for such unavoidable catastrophes.

Because the solar energy captured by trees is converted into wood, it can be measured in terms of the volume of wood produced per unit of area and time. We have elaborate methods for computing volume in existing stands of timber, and for computing the rate of increment in growing stands.

We admit at the outset that with existing knowledge we cannot, by emulating the agriculturist, analyze the habitat or site, apply our analysis to the trees available, and arrive at prediction. We therefore revert to the age-old concept of "plant indicators" in the sense that we utilize the trees as integrating systems. For a given area we speak of "site quality," and attempt to measure it by the performance of the existing trees. At best our predictions of yield are only rough estimates, even in what we think of as normal, fully stocked stands. They are most accurate in even-aged stands, and in forests composed of one or a very small number of species. Usually they do not go beyond the existing stands.

The density of a stand is measured by the number of trees per unit of area, or by the total basal area of cross-sections of the trees taken at breast-height. From these figures and from tree heights we can arrive at volume by reference to tables that have been prepared for various species and regions. By plotting these various figures, usually tree height, against age we get a "site index" which can be compared with other indexes from similar areas. If we are reasonably successful in our computations we have measures of volume and increment that can be balanced against probable costs, and the economic feasibility of operations in existing stands can be predicted.

Production potentials arrived at by these means are of short-term nature and can be misleading. A great many of our estimates of site quality at the Harvard Forest, for example, are based upon measurements of nearly pure stands of white pine. The production of white pine lumber on our upland loam soils between 1850 and 1920 was phenomenal. It commonly amounted to 60,000 board feet per acre in sixty-year-old stands. We now know that these white pine stands were in a sense "artifacts" resulting from the abandonment of upland loam soils previously used for agriculture. In spite of every effort to perpetuate them by economically feasible means, they are being succeeded by the native deciduous trees of the region. In these new forests, as far as our present knowledge goes, the total volume produced, even in eighty years, probably will not be over 30,000 board feet per acre.

Before measurements of production potential can be realistic, therefore, we must be able to place existing stands of timber in perspective with regard to their regenerative capacity, their place in natural trends of development, their relation to past and future cataclysmic changes, and their probable effects upon the productive capacity of ensuing stands. If we are to think of forests as long-term producers of energy, it is necessary to calculate far into the future the production rates computed by present methods. We must learn to go beyond existing stands of timber, and determine the long-term production potential of the land and the forests to produce wood.

Even though our prediction of long-term production potential can be little more than a guess, we must be content for the time being with the potential that exists. With our present knowledge of forests and sites, and within the present or foreseeable economic structure, we do not know how to make any great improvement in the potential. Silviculture can show no such progress in this respect as does agriculture, for reasons that have already been suggested. The agriculturist has no hesitation about trying to improve the site. He removes the natural vegetation, alters the physical, chemical and biological properties of the soil, introduces exotic crop plants, protects them from pests and diseases, and even tries to improve the climate under which they grow. He can do this because the time intervals are short and because, with all his manipulations, he still can predict the outcome with fair accuracy and be confident that the final product will more than pay the costs. The silviculturist has no such control of forest production.

This does not mean that we cannot make some changes for the better in what we recover from existing forests or from potential forest lands. Cleared lands, provided they can be relegated to forests, can be planted to trees. Existing stands can be treated in such a way as to raise the percentage and quality of marketable trees, and perhaps to shorten the time required to produce a marketable crop. By-products of such treatments may be sufficient to pay the costs of the treatments. The total amount of wood actually produced on a given area in a given time is always greater than yield predictions for the final crop would lead one to believe. While the net volume is steadily increasing as the stand approaches biological maturity, a large amount of wood is being lost by the death of suppressed trees. Much of this loss can be captured by properly timed thinnings and improvement cuttings.

Following the harvesting of a mature crop the forest must be regenerated naturally or artificially. European foresters, with their long experience and with relatively simple forests, have been fairly successful at this; but in the New World we have made only small beginnings.

A large proportion of the world's silvicultural activity to date has dealt primarily with the reforestation of cleared land, with the treatment of existing stands for improvement of quality and growth rate, and with the regeneration of existing stands at low cost. These pursuits, and the techniques that have evolved in them, have produced some excellent results and should be continued; but they are badly in need of some fundamental research in the biology and economics of forest production.

In planning silvicultural research we need some realistic point of departure, or "datum plane," from which to begin. The agriculturist finds this in the composite experience of countless generations of his ancestors, wherein it is based upon accumulated knowledge of the behavior of crop plants in relation to soils and climates. In silviculture we do not have such a resource. We are inclined to forget that this great body of agricultural folklore exists and is the real base from which the modern agricultural scientist operates.

Throughout most of the world the harvest of wood is the harvest of a wild crop. We are not far removed from the situation of those ancient proto-farmers who, discontented with having to spend a great part of their time and energy gathering food from wild plants, began to consider how they could concentrate them where and when they wanted them. Nevertheless, we commonly apply modern techniques and assumptions derived from agriculture to our forest problems. We fail to realize that our knowledge of trees and the sites on which they grow will not give us the control that is in the very fabric of agricultural practice. It may be that we should relinquish for a time much of the modern agricultural thinking that tends to invade our research, and revert to the simpler concepts used by our progenitors when they first attempted to domesticate wild grasses. We must find our point of departure in the behavior of natural forests, and our immediate problems center in the rational use of wild populations of trees.

Perhaps we should begin with refinement of our knowledge of the geographic location of forests. We already have the broad outlines of this, but details of sufficient fineness to be usable in actual operations are obscured by previous use or recurrent catastrophe. We must accordingly determine trends of change so that the identity of the natural forests can be unmasked. In practice such a pursuit could be called the ecological classification of forest lands. It should eventually lead to a definition of the natural production potentials which any region affords, for it makes full use of the results of millennia of nature's experiments in adjusting trees to their sites.

Having learned what and where the natural forests are, the silviculturist should utilize all his knowledge and ingenuity to improve the quality and rate of their production of wood. He must learn to harvest them without destroying or decreasing the productive capacity of the forests themselves or of the lands they occupy. If trees are to be planted, species and sites should be brought together so as to give reasonable hope of success. Our landscapes are strewn with fiascos resulting from the hit-or-miss selection of trees and sites for planting. If wood-using industries are to be established, they should be so placed and so organized that their raw materials will be available not only while the present generation of trees exists, but for many future generations. Existing industries should adjust their use of raw materials to the natural production rates of the forests as soon as these potentials can be determined with reasonable accuracy.

These are immediate problems, the solution of which we can hope for with our present knowledge and techniques. If forests are to continue even at the present level in the service of man, however, we cannot be assured that the existing production potential of lands now occupied by trees will be enough. Perhaps we should look forward to the control of forests, in the agricultural sense, on a world-wide scale. Our remote ancestors domesticated their crop plants without knowledge of morphology and physiology, or of actual relations of the plants to water and nutrients in the soil, or of the mechanisms of inheritance. Although our final problems are still of long-term nature, we should be able to make more rapid progress than we would if we had to continue with such limitations as those under which they labored.

First we must learn much more than we now know about the nature of site, and about the ecological relations of trees and forest communities. In modern forestry much of this comes under the heading of "silvics." It aims at the statement of cause and effect relationships between trees and their environments; and most of its research has been in terms of factors of the environment balanced against the supposed requirements of the trees. Its methods have led inevitably to direct attacks upon these factor relationships, and so to a hopelessly complex dichotomy of purpose. We seem unable to put back together again, by taking thought, what we have taken apart with such abandon, for we have no reasoning with which to integrate the multiple variables involved.

We have, however, integrating agencies in the wild trees themselves. We can use them as such provided we are willing to give up, for the time being, our direct attacks upon cause and effect problems. If we can properly define our natural forest types in terms of their species composition and their geographic position, we will have a framework within which to make comparative studies between the behavior of the trees and the factors of the environment. Coincidences accumulated by such studies, interpreted in the light of all the knowledge we possess, will greatly increase our skill in the design and conduct of experiments.

Having thus broadened our understanding of the wild forests we can concentrate more intelligently upon controlled improvement. Such improvement can be approached along two lines: through the growing stock of the forest itself, and through the soils.

The long-term use of good management practices should not only raise the quality of the final crop in the present generation, but should tend to raise it for future generations as well. Good practice aims at the selection of elite trees for the final crop, and if these can be made the source of the new generation after harvest, a selection of the best biotypes for future generations should result. The genetic improvement of the forests can also be attacked by more direct means through the selection, hybridization and nurture of elite trees. It should be borne in mind, however, that this will be fraught with great difficulties until our control of forests is considerably farther advanced than it now is.

Much can be accomplished toward the improvement of forest soils by proper manipulation of the cover, and perhaps of the soil itself, at times of thinning and harvest. We are beginning to know a little about the biological and physical balances that exist in the soils, and we know that they are of great significance to the well-being of trees; but we know almost nothing of their control. The physical manipulation of forest soils may prove to be of first importance. It occurs naturally in the uprooting of trees, in frostheaving, in the mass movement of soils on steep slopes, and as a result of fire. Perhaps we shall have to reproduce it artificially. It may be that we shall come eventually to some kind of fertilization, either by direct application or by the artificial encouragement of species that will enrich the soil.

Our ultimate goal is of course a reasonably accurate prediction of, and improvement in, the rate of capture of the sun's energy by trees. With present knowledge the best hope of prediction seems to lie in the study and use of natural forests, and we can, with continued research, expect to make a small amount of improvement in the quantity of energy we can capture in the wild forests. Large improvement can come only when we cease to be dependent upon wild stands, and when we can say that we have domesticated our trees.