Research in the Biological Aspects of Forest Production[1]

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WHETHER we like to admit it or not, forest production is a highly speculative proposition. The degree of speculation in the future will be related to the demands that society places upon the forest potential and the rate at which silvical knowledge is accumulated. One of the greatest deficiencies in the production aspect of forestry today is our general lack of ability to predict the species, form, and volume of the trees that will be growing on a particular area at a given time. This deficiency stems from the fact that we as foresters are working with a wild crop, and we simply do not have the degree of control which permits accurate prediction. Modern industry, the bond between forest potential and society, requires realistic predictions in order to function properly. Ultimately, sound decisions as to production policy must rest upon a firm foundation of knowledge; a knowledge which inevitably will be basically biological due to the inherent characteristics of the forests themselves.

Many problems of forest production have become apparent, although a great number remain to be generally recognized before they can be delineated and rationally approached. Our difficulties seem to originate from two major sources. When one views the first source with an extremely broad perspective, it emerges as the myriad of imponderables involved in the forester's attempt to evaluate the sum total of the reactions between the genotypes of the forest trees and their environments. This is what the forester is trying to do when he predicts the site quality of a wooded area. The second source of difficulties is as specific as the first is general. It involves the factor of time, an element which can be measured precisely and the requirement of which is considerable for the life cycles of most of our native tree species. The influence of time in the biological research of forest production has no parallel in any comparable area of investigation.

Methods of Approach

Research in the biological aspects of forest production can follow several methods of approach.

Experimental.—The one which will ultimately provide the major framework for scientific silviculture is often referred to as fundamental experimental research. Here, elaborate equipment and intricate techniques are employed to break down the physiological processes of plants into their physicochemical reactions, isolate them, and measure their variations under controlled conditions. Control is essential. The major efforts of plant physiology have been devoted to the lower plants and the herbaceous members of the higher plants. The application of similar experimentation on trees creates a whole set of problems of considerable magnitude. The highly trained plant physiologist in this country who concerns himself primarily with trees is rare indeed. One might even say that the science of plant physiology has not developed to the stage where trees as individuals, let alone in the form of forests, can be observed efficiently. One could probably state further that the basic problems related to the reactions of a tree with its environment are not in the hands of the forestry profession as such. This is not an admission of failure on the part of the forester but one of realism, of challenge. Here, then, lies a whole area of research responsibilities, a part of which could be shouldered by the "forest physiologist," if for no other reason than to assist in the recognition and decsription of the basic problems.

Empirical.—Another mode of research is as old as man and is the trial-and-error or empirical method. This manner of learning was largely responsible for the changes wrought in man's existence from one of a gatherer of wild plants and animals to one of a cultivator of domestic crops. Our whole civilization rests upon it. The primary difference between this mode of investigation in silviculture and in agriculture is the time factor that is so strongly in favor of the latter. The agriculturist also has at his command the advantages of over three thousand years of experience with a comparatively few food plants. The silviculturist has as his backlog of experience a few hundred years with a multitude of tree species.

Empirical investigation in forest production has been primarily descriptive chiefly because of the difficulties in achieving an adequate degree of control. Its motivation has been the pressure of practical problems. Plantations and sample plots of differently treated areas generally fall within this realm of research. The value of such research will be related to the manner in which it was originally conceived, and the amount and quality of the observations recorded during the many years of its continuous maintenance. When one considers the complexity of the problems involved, it would appear that a multitude of these projects will produce nothing more than a crop of trees, and many of these at great expense. The trial and error approach is very apt to defy accurate description, interpretation, and duplication.

Historical.—The third avenue to the biological problems of silviculture can be referred to as the historical method. This mode of investigation also has been employed for a long time. It is no accident that the major wheat belt in North

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America occupies the area which only a century ago was dominated by the mid-grass prairies. Trial and error, environmental manipulation, and genetics have altered the boundaries, but the outlines of the original vegetation still are almost intact. In this approach, the plants are considered as integrators of the total environment. Investigators attempt to reconstruct and interpret the expressions or trends in the development of the vegetation in the light of what has gone on before. With an historical background in hand, they can be more intelligent about what to expect in the future. The reasoning is primarily inductive.

Climate has often been defined as the succession of weather. A forest might be referred to as the product of a series of "nature's experiments." In this respect, a forest might also be compared with a technical library. The experiments are not cataloged but they are there just the same and need only to be recognized, interpreted, and evaluated.

One should be very conservative in appraising this means of deriving information. The method is chiefly one of fundamental description. No basic quantitative data regarding physiological processes or facets of the environment will result. The whys and wherefores of plant distribution will not be solved. However, definite facts of presence and absence of tree species will be exposed. Major fluctuations in the environment and the gross expressions of the tree vegetation to related changes can be observed. The time factor, always so influential, can be telescoped by meticulous application of simple techniques and judicious observation. The results of many years of "nature's experiments" can be scrutinized within a comparatively short time. New problem areas can be exposed and subjected to more elaborate experimentation.

The experimental, trial-and-error, and historical approaches to the biological aspects of silvicultural research cannot stand alone. All three, particularly the first, must of necessity take into consideration the principles of genetics. Eventually, all silvical knowledge must have genotypic qualification. Genetics can provide an impetus to forest production. The recognition, selection, and creation of particular genotypes will not only make it possible to grow better trees faster, but also assist in the analysis of the environmental complex.

Silvics, commonly defined as the biological foundation of silviculture, is in its embryonic stage of development. It is destined to become a science of synthesis, dependent upon the contributions of the allied disciplines for its foundation. The nature of the problems demands the application of the experimental sciences for ultimate solutions. As a result, answers will be a long time in coming. One might rationalize the situation by considering experimental research as the long-term approach, and descriptive research in the form of trial-and-error and historical methods as short-term approaches. Of the three, the historical is perhaps the least time-consuming. When one considers the present status of the development of silvics, the complexity of the problems, and the importance of time, it would also appear that the historical approach could be employed to the greatest advantage *now* toward the contribution of partial solutions for the silviculturist in the woods.

Application of Historical Approach

For a period of two years the historical approach was applied to an area slightly less than one acre, situated on the Harvard Forest in Petersham, Massachusetts.

The original objective was to trace the development of the vegetation to precolonial time, about 1730. The area was chosen because it supported a stand of trees, and it was accessible. The first procedure involved the construction of a 10-foot grid which permitted the accurate location of any observation one cared to record.

A series of maps was constructed to the scale of 10 feet to the inch which described:

1. All stumps, dead tree boles and large fragments of wood lying on the forest floor.
2. All live tree elements to a minimum d.b.h. of 1½ inches.
3. All live tree elements ranging from 1½ inches in diameter to the smallest recognizable seedling.
4. Contours of the forest floor to an interval of 6 inches.
5. Boulder concentrations on the surface of the forest floor and all individual boulders to a minimum diameter of 6 inches.
6. Present forest canopy.

Along with map construction other procedures were as follows:

1. Specimens of all the stumps and wood fragments were collected for identification and age determination.
2. As the tree elements less than 1½ inches in diameter were described, a section for age determination was removed from the base of each coniferous seedling and from the base of the stem and primary root of each sprout hardwood.

The 6-inch contours vividly delineated the microrelief of the area which included over 60 mounds and pits created by the uprooting of trees. The next major effort concerned the mounds and pits exclusively. Each was sectioned at right angles to its long axis, to depths of from 2 to 5 feet. Ten sections, the ages of which could be most closely determined, were profiled to the scale of one foot to the inch. Only the gross aspects of the sections were observed: color, consistence, texture, and arrangement of horizons. The remaining sections were diagrammatically profiled to the same scale and described. Coincident with sectioning, specimens were collected of buried wood from the trees that had been uprooted, buried organic layers of the predisturbed forest floor, and charcoal. The wood and charcoal were collected for identification, as was the pollen content of the organic layers.

The final stage in the field consisted of clearcutting the area. Sections for height and diameter growth reconstruction were removed at 4-foot intervals from each tree. So much for the general procedures except to say that the laboratory analyses involve a terrific volume of labor. Approximately 10,000 individual specimens were collected.

Findings

One of the first facts to be revealed was that in spite of at least two major logging operations, four periods of wind disturbance, and fires, the area had supported trees continuously since precolonial time. This fact has a significance which perhaps is so elementary that its real meaning is forgotten: that in this general region of the United States the developmental trends of the vegetation are climaxed by trees. This is the basic premise upon which our present-day silviculture and forest management are founded. The concept of plant succession was derived from the discipline of plant ecology, and provides the forester in New England with the basis for a reliable prediction: that any area in New England—those of obvious environmental extremes excluded—will produce a crop of trees if given enough time.

The majority of the trees whose uprooting had caused mounds and pits had been alive and quite large when uprooted. The individual characteristics of the mounds and pits indicated that at least four major periods of wind disturbance had occurred over approximately the last 500 years. Recently I had the opportunity to travel over 5,000 miles to the Cumberland and Smoky Mountains, south through the Piedmont Region, then west across the Mississippi Delta to the Quachita and Boston Mountains, and back to Massachusetts. Practically everywhere one looked mounds and pits of uprooted trees were found. One has no difficulty finding the same phenomena in New England. The evidence on the ground is substantiated by accounts in the literature of innumerable storms of varying intensities since colonial time. I have come to the conclusion that the mound and pit microrelief is as much a characteristic of the forests as the trees themselves. The question that I am forced to ask myself is: how does disturbance of this magnitude and frequency affect the climatic climax concept of vegetational development, a concept upon which much of our silvicultural and management practices are based? The climatic climax concept is founded upon a degree of stability that appears never to have existed in many forested regions. What adjustments do we have to make in our silvicultural reasoning to accommodate the influence of uprooting, of instability? Can the disturbances be predicted with reliability? Can the regions most affected be mapped?

The insertion of a disturbance or instability concept forces one to ask the same question about the development of soils. On the area under investigation it is possible to ascertain three different ages of soil surface within a horizontal distance of 20 feet. Over the area in general it is impossible to select one profile that can be designated as "typical," "normal," or "mature." The influence of instability upon soil genesis would appear to be an important consideration.

The stem analyses vividly revealed the height growth of the trees as individuals and of the stand in general. The hardwoods of one age class showed a period of pronounced decrease in height development. Further observation indicated that about 70 years ago the crowns of this age class were mechanically damaged. A severe ice or glaze storm was probably the agent involved. Regions of frequent and severe glaze storms are recognized by the electric power companies throughout the United States. So aware are they of this phenomenon that critical areas have been mapped, and in these regions adjustments have been made in the equipment employed to accommodate the weight of ice accumulation. What influence do ice storms have upon tree height growth and consequently upon the development of clear log length? Is clear log length actually limited by ice in certain regions? Can the frequency and occurrence of ice storms be predicted?

Had a forester cruised this particular area periodically every hundred years starting in 1650, his tally sheets would have shown quite different totals in regard to composition, dominance, and, of course, volume. The chances are that he would have assigned a different forest type designation to the stand that he found there each time. Which one of these "forest types" was real? Which one represented the true biological potential of the area? One might ask the same questions concerning the many different forest types now recognized in New England.

I have attempted to describe my concept of the historical approach to forest production research. I have cited only a few of the gross expressions of the vegetation to its environment and the simple techniques involved in their observation. It would appear that this approach could be applied very advantageously at this stage in the development of scientific silviculture. Its major objectives could be the determination of the "natural" biological production potential of forested areas and the degree of flexibility they present to environmental manipulation. Admittedly, most of the information derived would be descriptive in nature and would undoubtedly fall by the wayside as the experimental sciences came into play. Regardless of the nature of the knowledge, it is needed now, and much of it is destined not only to provide a framework for further investigation but also to contribute to the basic foundation of scientific silviculture in the future.

A basic question involves the degree of accuracy with which one should expect to predict the biological potential of an area. There are innumerable agricultural areas in the Midwest, for example, that have not experienced a crop failure in 50 years. I do not imagine that the proprietors of these acreages would have any difficulty financing improvements through a bank loan. However, move these same areas west near the margin of the 30-inch annual precipitation zone and observe the degree of speculation mount. The inherent characteristics of our forests will never permit the degree of prediction exercised in agriculture. However, a forest industry should be able to undertake a land procurement program with reasonable certainty that the acreage they obtain will meet the demands which are to be placed upon it. A silviculturist should be able to realize the risks involved and the chances of attaining his objectives when he attempts to grow trees with two clear logs of a particular species and size in a prescribed length of time. As we learn to manipulate the environment to coincide with the silvical requirements of a plant, or to adjust the genotype to the environment, we shall be able to predict results more accurately.

Conclusion

In the future, I believe that we should be very realistic about our research in forest production. Not necessarily practical, but realistic. All scientific investigation consists of accumulating observations. The subjects being scrutinized vary tremendously as do the techniques employed. Nevertheless, the first objectives are the same: the recording of accurate observations. Ultimately the data are synthesized. Conclusions are derived which lead to a partial solution. Another facet of knowledge has been exposed, and an additional plane has been established on which further reasoning can be based for an approach to another set of unknowns.

During the initial stages in the development of silviculture, the description and empirical methods of research could probably be employed to the greatest advantage. After these have been exploited to reveal the gross biological phenomena of forests, the application of the experimental method will come into full play. It would also appear that the forester could accept more of the research responsibilities pertinent to the biological aspects of forest production.

A Permanent Plot System of Survey For the Continuous Inventory of Ponderosa Pine Stands In the Southwest[1]

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CONTINUOUS INVENTORY, as it was first conceived and as described by Kirkland (*3*), involved periodical remeasurements of the entire stand to facilitate very intensive management. However, more recently, it has also been used, possibly more loosely, to describe a remeasurement of permanent sample plots at a given interval. This interval may vary with the rate of growth, the length of cutting cycle, revision of the management plan, or most any other stand factor desirable to the manager. It may be applied to strips, blocks or circular plots; but the unit should be definitely established and capable of exact remeasurement. Meyer (*5*) says "The calculation of the periodic increment based on nonpermanent strips will be rather difficult, because the mean error in the estimated volume of the forest is comparatively high. This will cause the error of the increment to be still higher."

Continuous inventory is not a new idea. It originated in France about 1880 as the *Methode du Controle* and was then developed in Switzerland. There have been many papers prepared on the subject. Some authors have advocated the use of the individual tree as the unit. Others have accepted the stand as the unit. Both approaches, undoubtedly, have their advantages and defects.

To the best of my knowledge, Meteer's paper (*4*), in the JOURNAL, has been the only recent report on a system using the individual tree. The method appears to be workable, relatively simple, and readily applicable to experimental and precisely managed stands. It is conceivable, however, that the volume of cards could be too large to be of much use to the manager on most of our larger timber tracts in this country. The cards could be summarized and used as a stand unit, but there would be considerable work in posting, which might be of little value in itself. Also, an individual tree record requires a system of numbering, which entails considerable extra work to maintain.

Buell, Wahlenberg, and Gross (*1, 7, 2*) recommend the total stand approach, with data in a form to permit calculations on the basis of diameter classes. if desirable. By this approach, certainly, the records are reduced; and the basic results and summaries are readily available to the manager.

Forest mensuration in the Southwest has run the usual gamut from ocular estimates, which were later checked with strip cruises and sample plots, through intensive strip cruises by individual G.L.O. sections. The ocular estimates were not sufficiently accurate nor detailed for management purposes and the strip cruises gave no information except the volume and stand composition on the date of the cruise. The cruises were also very expensive. Figures on net growth were very sketchy and it was not known whether or not they were applicable to wide areas of the Region. The Forest Survey has never been extended to the Southwest and thus

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