THE PRACTICE OF SILVICULTURE

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SEVENTH EDITION

The continuation of a work published as a first edition in March 1921, by Ralph C. Hawley

1962

John Wiley & Sons, Inc., New York · London

Library of Congress Catalog Card Number: 62-16244

Printed in the United States of America

PREFACE

This is the first time that an edition of *The Practice of Silviculture* has not appeared under the authorship of Professor Ralph C. Hawley, who has turned his attention from the guidance of communities of trees in the forest to those of human beings in the desert. Perhaps the most important premise of all previous editions has been his contention that silvicultural practice is based on economic as well as biological considerations; this philosophy is pursued still further in this seventh edition.

When the sixth edition was written, a deliberate attempt was made to leave no statement unsupported by at least an inkling of the reasoning behind it. The accelerating developments in forest science and American practice during the last eight years have made it possible to proceed with such analysis to an extent which gratifies as much as it whets the appetite for more. This line of attack is based on the belief that the most powerful tool of forestry is the analytical reasoning of its practitioners.

The book is intended primarily for use in North American forestry schools and in courses integrated with those others that comprise the normal curriculum of instruction in professional forestry. Therefore, an attempt has been made to elucidate the principles of silviculture, which are really independent of geography, almost entirely in terms of American practice. A secondary purpose is to provide the harried practitioner of forestry with a synoptic review of recent developments in silviculture.

The lists of references at the ends of the chapters are designed mainly to provide the reader with points of departure for the kind of further inquiry that is a necessary antidote to the sweeping and infectious generalizations that are diseases of textbooks. The references chosen are usually those deemed most likely to be accessible to the student and thus come more from the recent American literature than from older material or that published abroad. Consequently there are many instances in which the original sources have not been credited.

I am indebted to Professor Hawley for the wealth of ideas and material expressive of them that has been inherited from the forty-year history of this book. Thanks are due Professor David R. M. Scott for reviewing the chapters on thinning, and Messrs. Ernest A. Kurmes, D. Peter Loucks, and Edward J. Dimock II for critical editorial assistance. The opportunity to make selections of illustrations from the collections of the U. S. Forest Service, American Forest Products Industries, and other organizations credited in the text has been invaluable. Finally, I am humbly grateful to the host of foresters on whose thoughts, experience, and investigations this book is based.

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New Haven, Connecticut
June, 1962

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CHAPTER 1

Silviculture and its place in forestry

Silviculture has been variously defined as: the art of producing and tending a forest; the application of the knowledge of silvics in the treatment of a forest; the theory and practice of controlling forest establishment, composition, and growth. The subject matter of silvicultural practice consists of the various treatments of forest stands that may be applied to maintain and enhance their productivity. The duties of the forester with respect to silviculture are to analyze the natural and economic factors bearing on each stand under his care and then to devise and conduct the treatments most appropriate to the objective of management.

Silviculture occupies a position in forestry somewhat analogous to that of agronomy in agriculture, in that it is concerned with the technical details of crop production. Like forestry itself, silviculture is an applied science which rests ultimately upon the more fundamental natural and social sciences. The immediate foundation of silviculture in the natural sciences is the field of silvics, which deals with the laws underlying the growth and development of single trees and of the forest as a biological unit. In silviculture, information from silvics is applied to the production of forest crops, and technical procedures are developed for the scientific tending and reproducing of these crops.

In a broad sense silviculture is often regarded as including both silvics and its practical application. The present book, as its name *The Practice of Silviculture* implies, does not include the field of silvics. However, it is taken for granted that those who read this book have already acquired some grasp of silvics.

It is in the practice of silviculture that much of the growing store of scientific knowledge about forests is applied. As Muelder (1959) pointed out, knowledge derived from formal research can be put to effective use only by practicing foresters who are alert to new developments and understand them. The efficient practice of silviculture, whether it be crude or elaborate, demands as much knowledge of such fields as ecology, plant physiology, entomology, and soil science (to name but a few) as a forester can acquire. If it were otherwise, there would be scant need for college-trained foresters.

The competent forester must maintain contact with forest science and the results of formal research. He cannot, however, depend upon these sources for ready-made solutions to silvicultural problems. Skillful practice itself is a continuing and informal kind of research in which new ideas are constantly applied and old ideas tested for validity. The observant and inquiring forester will find many of his questions about silviculture answered by the results of accidents of nature and earlier treatments of the forest.

The practice of silviculture is concerned with the economic as well as the biological aspects of forestry. The implicit objective of forestry is to make the forest useful to man. Since all management of the forest is, therefore, aimed at economic objectives, it is almost impossible to separate the biological aspects from the economic. The mere fact that the silviculturist grows trees so that they will be useful rather than merely vigorous from the physiological standpoint automatically introduces an economic purpose.

The Purpose of Silviculture

Silviculture is normally directed at the creation and maintenance of the kind of forest that will best fulfill the objectives of the owner. Returns from silviculture are generally thought of in terms of timber production, although it is not uncommon for owners to have other goals. The growing of wood may, in fact, have low priority among these objectives or none at all. The essential thing is that the objectives should be clearly defined and the treatment shaped to their attainment. In this book greatest emphasis is placed upon the production of wood crops because this is the most common objective and also because the treatments involved are better developed and ordinarily more intricate than those aimed at other goals.

The forester should work for the good of the forest as an entity, not for the sake of the forest itself, but to ensure that it will remain a permanently productive source of goods and benefits to the owner and to society.

Improving on Nature through Silviculture

The most magnificent forests that are ever likely to develop in North America were present at the time of settlement and grew without assistance from man. Furthermore, under reasonably favorable conditions, forests may remain productive even after long periods of mistreatment. Therefore, it is logical to consider why foresters should attempt to direct any of the powerful natural forces at work in the forest. The reasons are economic and mainly involve attempts to produce more useful forests than nature can and to do so in far less time.

The purely natural forest is governed by no purpose unless it be the unceasing struggle of all the component plant and animal species to perpetuate themselves. A purpose not existing in nature is introduced by human preference for certain species and for individuals thereof that have particular useful characteristics. Examination usually shows that whenever forests of highest utility have developed in nature it was the result of a fortuitous set of circumstances followed by a long period of growth.

The time required for growth was not a factor in utilizing virgin forests because no one had to pay any costs of holding land while the trees were growing. In managed forests the rate at which value is produced, and not the final value, is the important factor. Unmanaged or mismanaged forests, like poorly treated farm lands, do not yield products of the kind, amount, or value that might be grown. The forester increases the rate of production by properly tending the wild forest and establishing new forests on vacant areas.

The managed forest is more productive than the unmanaged or mismanaged forest because of the advantages gained through attainment of the following objectives of silvicultural practice:

Control of composition. Inferior species appear in almost any forest. One objective of silviculture is to restrict the composition of a stand to those species that are most suited to the location from the economic as well as the biological standpoint. This almost invariably means that the total number of species in a managed forest is less than that which could occur there under purely natural conditions. Since the inferior species flourish at the expense of the desirable, every reasonable effort should be made to keep them in check. The primary means by which species composition can be controlled is through regulating the severity of cuttings and the characteristics of the seedbeds during periods when new stands are being created by natural regeneration. In this manner environmental conditions can be adjusted to favor development of the stages of plant succession most nearly dominated by the desired species.

Regulation of natural succession by itself is not always enough to provide adequate control over stand composition. It is frequently necessary to supplement this approach by direct attack on the undesirable species. Cutting, poisoning, controlled burning, or regulated grazing may be used to restrict the competition and seed production of undesirable species. The desirable species can be favored in more positive fashion by planting them.

Crooked, misshapen, and defective trees (even though of valuable species) are apt to accumulate in the forest not under silvicultural treatment and retard the development of better individuals.

Control of stand density. Improperly managed forests are commonly too densely or too sparsely stocked with trees. If timber production is an objective, both extremes are detrimental and have the final effect of reducing the value of the crop produced. Deficient stocking is most prevalent in the early life of a stand and results from inadequate provision for regeneration; the unoccupied spaces are unproductive and trees in such stands are often too branchy to produce good timber. Excessively dense stocking causes the wood production of the stand to be distributed over so many individual trees that none can grow at the optimum rate. One should seek to provide and maintain just enough trees to stock the area properly at each stage of the life of the stand.

Restocking of unproductive areas. Without proper management many areas of land potentially suited to growth of forests tend to remain unstocked with trees. Fires, destructive logging, and ill-advised clearing of land for agriculture have already created many large, open areas that can be put back into immediate timber production only by planting or artificial seeding. Temporary, but nonetheless important, reductions in production can result from poor cutting practices that produce conditions unfavorable to immediate natural regeneration and resumption of growth.

Protection and salvage. In unmanaged stands, severe losses are commonly caused by such damaging agencies as insects, fungi, fire, and wind, as well as by the loss of merchantable trees through competition. Substantial increases in production may be achieved merely by salvaging material that might otherwise be lost. Proper control of damaging agencies can result in further increases in production. Forest protection often involves modification of silvicultural techniques in addition to more spectacular direct measures. Adequate protection should be extended to all forests, even the poorest, because fire and insect outbreaks developing in relatively worthless stands often spread into valuable adjacent areas.

Control of length of rotation. In any given situation there is an optimum size and age to which timber should be grown. Premature cutting is a common type of mismanagement in which trees are harvested before they have reached their optimum value. Trees allowed to grow beyond optimum size decline in value because of decay or difficulty of handling, or merely because further increase in value ceases to provide an acceptable rate of return on the investment represented by the value of the trees. Under proper management, the optimum size or age is carefully determined and the trees harvested accordingly. The period of years required to grow a crop of timber to this specified condition of either economic or natural maturity is known as the **rotation.** Proper regulation of stand density can shorten the rotation by making the crop trees grow to the desired size at an earlier age.

Facilitating the harvesting, management, and use of the forest. In the unmanaged forest timber, like gold in the hills, is where one finds it; the greater the amount extracted, the more difficult and expensive it becomes to find and extract more. In the managed forest it is possible to plan the growth of stands so that any use of them is on a more efficient, economical, and predictable basis. It becomes possible not only to produce good stands but also to have them so located and of such composition by species and age classes that the cost of transporting products from them is kept under control. The recent tendency of some forest products to be priced off the market has taken place in spite of the introduction of all kinds of labor-saving machinery for harvesting. It is due in part to the necessity of going to ever less accessible unmanaged forests to find timber of ever dwindling quality. The vicious cycle can be halted only by growing good stands on sites readily accessible to convenient harvesting.

Protection of site and indirect benefits. Proper management of forest lands often provides benefits that have little to do with production of wood. In fact, many forests are managed primarily for other purposes, although wood production is rarely inconsistent with these objectives. The techniques employed for improving the habitat of wildlife and grazing animals in the forest are essentially silvicultural. To a more limited extent, the same is true of measures designed to maintain the aesthetic beauty of forests used for recreation.

The relationship between silviculture and watershed management is coming to be of primary importance. Interception of precipitation by dense, untreated forests can, on the one hand, cause appreciable reductions in the water yield of an area. Excessively drastic treatment may, on the other hand, induce erosion or compaction of the soil which in turn reduces the capacity of the forest soil to store water. The resultant irregularities of stream flow and siltation can have a variety of disastrous consequences downstream. The damage done to the forest soil by erosion and compaction can also cause well-nigh irreparable reductions in the growing capacity of forest lands.

Silviculture as an Imitation of Nature

Silviculture is usually a combination of improvement upon and limitation of natural processes of forest growth. If knowledge of both economic and natural factors were perfect, it would always be possible to determine how far to move from the purely natural toward the degree of artificiality exemplified by intensive agriculture. Since one is not clairvoyant enough to know all the economic consequences of natural laws or to foretell all future fluctuations of the economy, there is bound to be uncertainty about how far to depart from nature. Some departure is certain; even a so-called wilderness area that is imperfectly protected from fire and used for limited recreational purposes ceases to be wholly natural. If the forest were created for the express benefit of man and natural processes reacted to his changing demands, it would be advisable and require no great silvicultural effort to follow nature closely.

Some silvicultural measures depart very far from natural precedent. These usually involve the introduction of exotic species or the creation of communities of native species unlike anything that might come into existence naturally. Departures of this sort cannot be condemned out of hand but should be viewed with reservations until they have been tested over long periods. Otherwise, most of the choices can be thought of in terms of the degree to which natural succession is accepted or arrested, pursued or reversed.

Preoccupation with natural plant succession has sometimes led to the erroneous assumption that sound forestry consists entirely of presiding passively over the majestic progress of succession. According to this philosophy, the primary goal of silviculture should be to encourage the development of stable, climax types that are held to be, by their very nature, superior to earlier successional stages. The importance of thorough knowledge of the natural succession on a given kind of site lies in the fact that it shows how fast and in what manner the composition of existing stands is being or may be altered by natural processes. With this information the forester can determine whether and by what means he can control the succession. The fact that he must know the course of natural succession does not indicate that he should necessarily allow it to proceed.

Economic factors ultimately decide the silvicultural policy to be followed on any given area; the objective is to operate so that the value of benefits derived from a forest exceeds by the widest possible margin the value of efforts expended. The most profitable forest type is not necessarily the one with the greatest potential growth or that which can be harvested at lowest cost. One must also consider the silvicultural costs of growing the crop and the prospective losses to the damaging agencies. In fact, it is usually the inroads of insects, fungi, and atmospheric agencies that ultimately show where silvicultural policy has run afoul of the laws of nature. The majority of the best choices are imitations of those natural communities, not necessarily or even commonly climax communities, that have grown well in nature.

It is not entirely safe to accept the success of modern agriculture as justification for highly artificial kinds of silviculture. The environment of a cultivated field is much more thoroughly modified and readily controlled than that of a forest stand. Furthermore, forest crops must survive winter and summer over a long period of years while most agricultural crops need survive only through a single growing season. One disastrous year harms the production of but one year with an annual crop but can destroy the accumulated production of many years in a stand of trees. Any silvicultural application of refinements borrowed from agriculture must be combined with *all* the kinds of measures appropriate to the intensity of agriculture imitated. Forestry can profitably borrow much more than it ever has from the science on which modern agriculture is based, but there is little place for uncritical imitation.

Many of the unpromising kinds of deviation from nature can be eliminated simply by exercise of knowledge and reason. The residue of uncertainty can be resolved only by trial and error, cautiously and objectively conducted. Any departure from nature that still looks good at the end of a rotation is probably sound.

The best approach to the matter is to determine which stage of successional development is most desirable in a given situation. In the Pacific Northwest, for example, the forester must often decide whether to perpetuate pure stands of Douglas-fir or allow them to be succeeded by western hemlock. In the Lake Region, he may have to choose between the pioneer aspen association and later stages like the spruce-fir association. In the South, he must determine whether to let old-field stands of loblolly pine revert to hardwoods. Several generalizations of wide, but not universal, application may be introduced at this point.

In the first place, the most valuable commercial species in any region tend to be relatively intolerant trees representative of the early or intermediate stages in natural succession. Such species as pines, Pacific Coast Douglas-fir, yellow-poplar, and ash definitely fall in this category. It is no coincidence that species of this kind are important commercially because they are the ones most likely to lose their lower branches through natural pruning. It is also significant that some of them are adapted to reproduce mostly after major disturbances that occur infrequently. If they are to survive from one major disturbance to another they must be long-lived; as a result they are likely to develop the economically desirable attributes of large size and resistance to decay or other relatively minor sources of damage. Late successional forest types, characterized by species such as hemlock, true firs, and beech, are frequently composed of branchy trees which produce less valuable wood. Because of their shade tolerance they can reproduce almost continuously so the ability of individuals to endure for long periods is not so crucial in the survival of the species. Of course, many pioneer species have even less capacity for individual survival; however, they usually exhibit good natural pruning and the necessity that they grow rapidly to seed-bearing age is an economically desirable attribute.

Natural succession proceeds most rapidly and vigorously on the better sites, that is, on soils that are both moist and well aerated. Here it is sometimes impossible to resist natural succession without expensive silvicultural treatments. Furthermore, such sites are, at any stage of succession, hospitable to the growth of such a large assortment of species that silvicultural treatment becomes complicated and difficult. These considerations have the paradoxical effect of making silviculture most profitable on sites of intermediate quality where uncomplicated stands can be maintained without strenuous effort. In fact, on poor sites it may occasionally be virtually impossible for succession to proceed beyond an intermediate stage, which is sometimes referred to as a **physiographic climax.** For example, stands of both jack and red pine occasionally represent valuable physiographic climaxes on certain dry, sandy soils in the Lake Region.

It has also been claimed that late successional types may be more resistant to, and more cheaply protected from, fire, insects, fungi, and atmospheric agencies than earlier stages. This advantage results more from the diversity of species and age classes in a climax type than it does from position in the successional scale. Similar advantages can prevail in mixed stands with a variety of age classes that are still typical of earlier successional stages.

The point is often advanced that natural communities are in a stable and favorable equilibrium with the physical and biological environment. Actually any kind of stand is in dynamic equilibrium with its environment. Perfect stability and complete favorability do not exist, so one must think in terms of relative degrees of each quality. For example, the balance achieved by long-continued natural processes, operating more or less at random, is not necessarily more favorable to the trees than to the organisms that feed upon them. The more artificial equilibrium produced by prudent silviculture is likely to be less stable but ought to be more favorable from the standpoint of the integrated effect of all economic factors relevant to the particular circumstances. If the dynamic equilibrium created by treatment ultimately balances at a condition of economic disaster, the silviculture was hardly prudent.

The naturalistic doctrine of silviculture did not arise from any clearly demonstrated disadvantages of early stages of natural forest succession. It developed largely from disappointments with attempts to create unnatural types, particularly with exotic species or those not indigenous to the sites involved. The most extreme manifestation of this viewpoint is, in some respects, merely an unwarranted extension of a sound observation.

The classic example of violation of the ecological principles of silviculture is the widely cited and frequently misinterpreted "Saxon spruce sickness" which appeared in the lowlands of east central Germany early in this century. In this region the financial charms of spruce pulpwood had induced foresters to convert degraded stands of hardwoods to pure plantations of Norway spruce. The first crops were excellent, but successive crops commonly grew less and less vigorously. All kinds of explanations were proposed, and a widespread impression developed that pure stands of conifers in particular and tampering with natural succession in general were universally responsible for "deterioration of the soil." However, a thorough analysis of the difficulty [Krauss et al., 1939] has shown it to be neither mysterious nor the basis for sweeping generalizations.

In the first place, spruce was introduced into the lowlands from the moister and cooler climate of neighboring mountains. Furthermore, the decline in vigor occurred only on very heavy, clay soils. After the old root canals of the hardwoods had closed, internal soil drainage became very poor. The soils were then so moist and poorly aerated in the spring that the spruce became even more shallow rooted than normally. Therefore, during the summer, when the low rainfall was further reduced in effectiveness by interception, the spruce suffered from drought. The situation grew progressively worse as more of the old root canals became closed. In other words, this particular difficulty was not mysterious and was confined to soils rich in clay; it could not even be said that planting of spruce was out of the question on all sites in the locality.

The famous experience in Saxony has an important lesson for foresters everywhere but not to the extent that one may say that "they have found in Europe that repeated crops of pure conifers cause site deterioration." What it does show is that proper aeration of the soil is necessary for good growth of trees and that shallow-rooted species allow internal drainage to deteriorate on soils with a high clay content. The little leaf disease of shortleaf pine on badly eroded clay soils on the Piedmont Plateau of the Southeast (Zak, 1961) is a more spectacular example of the same sort of thing in American experience.

The important thing to note about this illustration is that such problems can eventually be explained in terms of definite ecological factors. It is far better to base practice on available knowledge than to ignore it and proceed on a mystic philosophy founded on vaguely suspected influences of unknown agencies. Where lack of knowledge hampers practice there is clear need for the critical observations essential to both formal research and intelligent practice. Knowledge is, after all, a cheap commodity when compared to the values wasted when operations are conducted in ignorance.

The Field of Silvicultural Practice

The subject matter of the practice of silviculture is logically divided into three parts defined as:

Methods of reproduction, treatment of the stand during the period of regeneration or establishment. (See Fig. 1-1.)

In every stand the time comes, sooner or later, when it is desired to harvest all or a portion of the timber and to replace the trees removed with others of a new generation. The act of replacing old trees, either naturally or artificially, is called **regeneration** or **reproduction** and these two words, which are entirely synonymous in this usage, also refer to the new growth that develops. **Advance repro-**

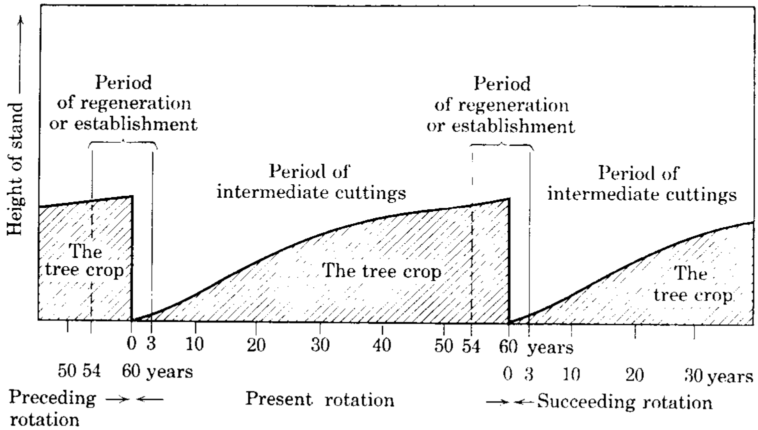

Fig. 1-1. The relationship between the period of regeneration and the period of intermediate cuttings for a sequence of even-aged stands managed on a 60-year rotation according to the shelterwood system.

duction or **regeneration** is that which appears before any special measures are undertaken to establish new growth. **Reproduction** or **regeneration cuttings** are made with the two purposes of removing the old trees and creating environmental conditions favorable for establishment of reproduction. The period over which they extend is known as the **regeneration** or **reproduction period.** Reproduction cuttings range from one to several in number, and the regeneration period may extend from less than 5 years to more than 50 years. In truly uneven-aged stands, handled under the selection system, regeneration is always underway in some part of the stands. The period of regeneration begins when preparatory measures are initiated and does not end until young trees have become established in acceptable numbers and are fully adjusted to the new environment. The **rotation** is the period during which a single crop or generation is allowed to grow.

Intermediate cuttings, treatment of the stand during that portion of the rotation not included in the period of regeneration. (See Fig. 1-1.)

After a new stand is established, a long period ensues during which the crop grows and passes through various stages until it is mature and ready, in its turn, to be harvested and replaced by a succeeding generation. The various cuttings made during development from the reproduction stage to maturity are termed **intermediate cuttings.**