AMERICAN FOREST REGULATION

WOOLSEY

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BY

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TO

JAMES W. TOUMEY

IN RECOGNITION OF HIS SERVICES

AS A TEACHER OF FORESTRY

IN THE YALE SCHOOL OF FORESTRY

PREFACE

"American Forest Regulation" is intended primarily as a textbook on the theory and application of regulating the cut. It may also serve as a guide to forest administrators who must solve broad regulation problems at a reasonable cost. Emphasis has been placed on the discrimination and choice of material, rather than the collection and elaboration of a multitude of methods—many totally unsuited to American conditions. Forest management in the United States cannot be successful until it is definitely recognized that the cutting on all forests held for permanent production must be controlled by working plans based on sound silviculture, local economic requirements and rate of yield.

Not the least perplexing of the problems encountered has been the question of terminology. The author, a member of the Committee of the Society of American Foresters, which recommended standard terms* and definitions, has followed the Committee's report, except where it departs from well established common usage. "Working circle" has accordingly been substituted for "working unit." The student who is assigned additional reading or study in the works of other authors, cannot help but be confused by a varying use of terms. For example, "working group" may be termed "working section" by one author, "working figure" by another, and "working circle" by a third. The "working unit" of the S. A. F. again may be described as "working circle" by Sir William Schlich**, thus further perplexing the student. The writer felt that no personal preference for terms should enter into this new book on American Forest Regulation but that "working circle," widely used in the United States, was preferable to "working unit." On the other hand, the new term "management plan," largely used by the Forest Service in place of the term "working plan" (adopted for generations by English speaking foresters), has not been adopted.

To simplify study, the regulation of cut methods in Part I have been treated systematically, as follows: (1) Definition, (2) Discussion, (3) Illustration, (4) Class room questions or quiz. This plan has not been rigidly adhered to, yet so far as the subject matter lends itself to this form of treatment, it is used throughout. Formulae have first been stated in English (instead of in "formulae equivalents") because the writer found they were more readily grasped by the student. A special feature is quite complete foot-note references to American Literature on each subject.

A rather theoretical discussion of soil-rent (after Endres) has been given, notwithstanding the fact that it is likely that a large proportion of the best American forests will eventually be owned or controlled by the public, and consequently need not necessarily be managed strictly on the basis of the

* Published 1917 in the Journal of Forestry, Vol. XV, No. 1.
**Schlich, Sir William, Manual of Forestry (Forest Management, Vol. 3, p. 273).

highest soil-rent. Yet this financial side may eventually be of weight in planning the management of many private American forests, where business reasons may usually be foremost. Because of this considerable space in the appendix has been given to a frankly Germanized explanation of soil-rent, and to Endres' discussion and illustration of its application.

The contrast between French and German text-book methods is evident even to the casual reader. The German is apt to treat the subject exhaustively; he will describe twenty different formulae, each varying from the other ever so little, while the French writer will perhaps narrow the formulae down to three fundamental and radically different methods, and omit the others. This book (with the exception of soil-rent) has been written from the French rather than from the German viewpoint, and, consequently, may err in its simplicity rather than in the complexity of subject matter. Commenting on this very feature of German thoroughness and complexity, Sir William Schlich states :*

"Of the seventeen methods described several have only an academic interest, if so much, and all of the others have for their object to secure a sustained yield by gradually producing such a proportion between the different age classes that each shall, as nearly as possible, occupy about the same area, whether they are found on different areas or scattered over the whole forest . . . . there is not nearly so much difference in the several methods as their inventors believe."

This viewpoint explains why the author of this volume has omitted the usual elaboration of textbook methods and formulae which differ from each other in some minor degree.

Rather than include data on American working plans which are untried and preliminary in character, the writer has omitted the usual treatment of this phase of organization. In Appendix A—E some "working plan" data have necessarily been included so as not to mar a complete translation of a portion of Martin's Forsteinrichtung.

Acknowledgment has been made in the foot-notes for material borrowed directly from other sources, but necessarily many of the ideas and much of the data included, have been absorbed and adapted from text-books on the same subject, especially from Volume III (Fourth edition) Manual of Forestry by Sir William Schlich; from Lehrbuch Waldwertrechnung and Forststatik by Max Endres; and from Volume III, Economie Forestiére by G. Huffel. The description of regulation in the various German states and in Austria given in the appendix is translated from Martin's Forsteinrichtung. Acknowledgment is also due C. E. Carter (of Australia), Yale School of Forestry, 1922, T. S. Hansen, Yale School of Forestry, 1917, T. T. Munger, U. S. F. S., E. J. Hanzlik, U. S. F. S., E. Koch, U. S. F. S., and M. H. Wolff, U. S. F. S., for a review of and a critical comment on the manuscript of Part I.

When the original plan of February 1, 1917 of publishing under joint authorship with Professor Chapman had to be abandoned, the following acknowledgment was agreed upon:

"This manuscript was (largely) written in 1917, with the consent and coöperation of H. H. Chapman. The technical order and arrangement followed the Yale lecture notes

of Prof. Chapman, but the American and European details and references and scheme of treatment, are original with the writer. The manuscript was revised and completed by the writer in 1920 (1921). While Prof. Chapman assumes no responsibility, whatsoever, as to technical details, the writer wishes to acknowledge his very great indebtedness to him for the use of his notes as a guide. Those who took his lectures at Yale will recognize just how great this indebtedness is."

In 1920 Prof. Chapman kindly agreed to contribute Part II on "Correlation of Regulation and Growth in Extensive American Forests," with the understanding that the book would be immediately published under my authorship. The slight duplication of Part I in Part II is an advantage rather than a detriment and Chapman's comment on the correlation of growth and regulation is invaluable.

When chief of silviculture in the Forest Service, District No. 3, the need for regulating the cut of timber on National Forests was very apparent. After giving the courses in management at the Yale School of Forestry, 1916-17 (when Professor Chapman took my place in the West) I was convinced that regulation had been misunderstood and neglected in the United States and that, therefore, there was an immediate need of a thoroughly Americanized edition on this essential and important phase of forest management. The opportunity of service with the A. E. F. in France explains the four years delay in publication, but I am certain that the need for such a book to-day is all the more acute.

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New Haven, Conn.
    December, 1921.

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SYMBOLS USED

	Equivalent
Gn	Normal growing stock.
Ga	Real or actual growing stock.
n	Normal.
r	Rotation.
r′	The difference between the age when the tree reaches merchantable size and the rotation age.
s	Age when tree reaches merchantable size.
i	Increment (c. a. i. and m. a. i. are symbols for current and mean annual increment).
N	Number of years.
Yn	Normal yield.
Ya	Real or actual yield.
x	Number of years within which to distribute the surplus or deficit.
M%	Mortality per cent (M is the symbol for German marks in appendix A).
M ft.	1,000 feet board measure.
cc	Cutting cycle.
Res.	Timber reserved after cutting.
F$	Final yield (in dollars).
I$	Intermediate yield (in dollars).
E$	Expenditures (if annual, symbol is AE$) capitalized.
C$	Costs (initial).
a, b, etc.	Yield table figure for yield at 10 years, 20 years, etc.
A	Area.

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INTRODUCTORY

By B. E. Fernow

The question is sometimes raised—even in professional circles—whether silviculture or forest regulation (organization) is the more important subject. To raise this question is like inquiring whether the shelves in the library are more important than the books, the implements used in raising a crop more important than the crop itself. Nevertheless as suggested by Æsop's noted fable on the quarrel of the members, forest regulation (organization) is absolutely essential for a well conducted forestry business, just as the systematic management of a factory is all important to the success of that business.

In applying the various methods of regulation, the needs of silvicultural operations must necessarily produce modifications of the mathematics involved in regulating the felling budget. How far these silvicultural considerations are to influence the economic considerations will depend upon the character and the interests of the owner. For instance for forests under State ownership the interests of the future could and should dominate and more economic or financial sacrifices may be justified in attaining the normal forest than is the case in private ownership. The conditions for an economic sustained yield may be more rapidly attempted by the former, while the latter may be satisfied with a mere *silvicultural* sustained yield, i.e., keeping the land in forest. Conditions vary so greatly that it is impossible to lay down principles. Compromises will be necessary which depend upon the financial ability and other modifying circumstances of the owner.

The forestry business has an advantage over most other businesses in that it has its ideal formulated, namely in the normal forest (with its normal growing stock, age class gradation, and distribution, and normal increment), consciously and expressed or unconsciously and unexpressed. As with all ideals, practical considerations and conditions keep us from attaining them fully, and the problem for the forester is always how far he will sacrifice present advantages to this ideal of the sustained yield forest.

It should be borne in mind that the European methods of regulation represent a historic evolutionary series, each one having acceptable features which are borrowed by the next. With modern means of transportation, the need of making any small forest completely normal has become less imperative and has permitted the freedom of handling it à la Judeich. Moreover the extensive application of the division and allotment methods had brought about the existence of suitable age classes when the stand method became practicable.

Although only one state (Baden) has adopted the Karl Heyer (see paragraph 85) method of regulating the forest, I am inclined to consider this method the most practical in attaining a normal forest condition without too much sacrifice *if carried out in Heyer's spirit*. It will also be applicable in the United States in many cases.

The effort of investigating the applicability of European methods and of developing American methods, as attempted in this volume, is one which is worthy of all praise.

B. E. Fernow.

December, 1921.

PART I

POLICY AND THEORY OF REGULATION

CHAPTER I

INTRODUCTION TO FOREST REGULATION

1. Definition and Significance of Forest Regulation. Forest Regulation* (syn. organization) is that *branch of forestry which concerns itself with the organization of a forest property for management and maintenance, ordering in time and place the most advantageous use of the property, with the aim of securing a sustained yield.* The broader term forest management includes all subjects dealing with the inventory, condition, and proper and systematic development of forest resources, and the organization and administration which will secure their continuous productiveness. *Regulation* aims chiefly at *continuity of productiveness* but also at utilizing to the fullest extent the resources under forest management; *the normal timber capital is property held in trust, while the cut constitutes the owner's returns.* It is the most important ultimate goal of the forester to bring his forest property to a sustained yield so as to produce a nearly equal annual or periodic return. It is only by systematic regulation that permanent economic production can be secured. This principle of sustained yield is of importance to the individual and to the nation. It is customary for the private owner to require equalized returns on his investments and the wood industry of the nation also requires fairly sustained annual production in order to keep wood-using industries in full operation. Serious depression, when industrial production is curtailed, may warrant a corresponding diminution of output from public and private forests. On the

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* It is important to differentiate clearly between forest economics, forest economy, forest finance, forest management, forest mensuration and forest regulation.

Forest Economics (syn. *Forest Policy*). A comprehensive term including all matter referring to the position of forests in public affairs.

Forest Economy. A comprehensive term including all matter dealing with the business aspects of forest management. (See also Fernow, B. F., Economics of Forestry, p. 103, 5th edition, New York.)

Forest Finance. That branch of the science of forestry which relates to the forest as an investment. It includes two distinct subjects, Forest Valuation and Forest Statics; the first concerning valuations of soil and growing stock, increment, and damage; the second with a comparison of the financial results of different methods of treatment and other questions of profitableness and financial effects.

Forest Management. The practice of the application of forestry in the conduct of the forest business.

Forest Mensuration. That branch of forestry which deals with the determination of the volume of stands, trees, logs and other timber products, and with the study of growth and yield of trees and stands.

other hand, in times of stress, as was evidenced in France during the War, a nation is fully justified in over-cutting its public and private forests for the good of the state.

Of the technical factors which lead to an assured annual yield, the most important is the age of the different stands. For it is evident that if all the timber in a forest is immature, there can be no production of sawtimber until these individual stands ripen. If, however, all the timber is mature, the problem of securing a continuous yield of sawtimber may be assured, provided the owner is willing to make certain sacrifices, often obligatory when part of the decadent and overmature timber is held without cutting for long periods.

Russell and Roth (see § 12) have pointed out the hiatus in national timber production which is sure to follow our present era of destructive lumbering. Our national timber resources are largely composed of virgin stands* of mature and decadent timber and of idle cut-over land, much of it barren or only partially stocked with valuable species; aside from woodlots there is but little forest land today in the United States stocked with middle-aged timber; therefore it is easy to visualize what will happen when our virgin stands are destroyed; the nation surely will be confronted with a shortage of timber land stocked with merchantable timber. Our publicly owned forests will be insufficient in area to supply national demands. Even if we wake up to the need for permanent forest production before all our virgin timber is gone, we cannot now repair the damage in time to avert a serious shortage, because it takes from 60 to 120 years or more (see chapter IV-V) to produce *saw-timber* as contrasted with *cordwood*. Even if every acre of potential forest land were fully stocked with valuable immature timber, when the last of the virgin stands disappears, many sawmills must shut down until these areas of immature trees ripen. We would be in much the same situation that England was when the demand for ammunition overran the supply. Factories capable of enormous production were being built but had not yet reached the production stage. Fortunately, in the industrial world such a shortage can soon be relieved, but in forest management we must face squarely the hiatus in production sure to occur if there are no middle-aged stands ready to grow into merchantable timber that is certain to be required by our rapidly increasing population.

The owner of merchantable timber when deciding upon the proper cutting policy to adopt has three alternatives:

(1) In anticipation of higher prices due to the predicted timber shortage he may carry his timber as a speculation;

(2) He may rapidly convert his stumpage into money and realize on his forest investment. High taxes and heavy carrying costs on forest and plant investments have induced practically all American lumbermen to follow this course; or,

(3) He can make a compromise between (1) or (2); but after the owner

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* Of course virgin stands contain young and middle aged timber but this is usually all destroyed by "destructive lumbering."

has decided not to hold his timber as an investment against higher prices or to realize on his forest, there is still the important decision, *how much to cut and when.* This question must be answered by applied regulation, which should always aim at a sustained yield of timber and permanent production. It goes without saying, as Dr. Fernow has emphasized in his Introductory Note, that regulation cannot be successful without sound silviculture, nor are the two incompatible. *Re-growth,* ordinarily by natural regeneration, will always remain the *sine qua non* of successful forest management in the United States.

2. **Conception of Regulation in Europe.** It is instructive to see what the European idea of regulation is in the exact words of great foresters. Huffel,* the foremost French authority says: "The management (or regulation) of a forest includes all operations which aim at systematizing the cut." He argues that public forest owners have only the right to *income* from properties and must pass the *principal* on to the future generations unimpaired; that this is the fundamental idea of forest regulation. He admits, however, that the private owner should be given more freedom in the use of his property according to his individual needs. All owners are, however, benefited by systematic forest working plans, "which indicate for a definite period, (1) the date, (2) the method, (3) the location, (4) the extent (degree) of all fellings which will be made in the forest."

The German and Austrian definitions** emphasize profit, orderliness and continued yield: Judeich (Saxony) says:

"The object of forest management is the most profitable use of soil or land for raising timber........ The task of regulation is to order in time and place the entire management or business of the forest, in such a manner that the object of the management is accomplished as fully as possible."

According to Martin (Prussia and Saxony) forest regulation,

"comprises the measures necessary to conduct an orderly forest management........ Regulation forms the most important subject of instruction in the business of management of the forest........ The most important task of regulation is to direct the order or progress of the harvest or cut and removal of the several stands of timber........ The most difficult and yet the most important task in the preliminary work is a suitable division of the forest into permanent sub-divisions."

Von Guttenberg (Austria) defines regulation as,

"that part of the science of forestry (and particularly of forest management) which attempts a well planned order and arrangement of the entire management of a forest, and especially the regulation of the cut in order to assure the most profitable and sustained yield or income from the property."

Stoetzer (Saxony) also bears on the sustained yield idea and adds other details to his definition of what regulation is:

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* Huffel, G., Économie Forestière, Tome Troisième, 1907, pp. 4, 7, 8, 12.
** Adapted from the appendix of F. Roth's Forest Regulation, pp. 203-218.

"........It maintains order in the management of a forest; it regulates particularly the manner and time of cutting........; it plans to restock the land with new stands of trees, and it determines the amount of timber which may be cut each year without diminishing the wood capital or endangering the continuance of such a cut for the future........ The provisions of forest regulation are not employed for individual stands of timber, cut at intervals of many years, but apply to forests where a yearly cut of timber is possible and is demanded."

3. **Scope of Regulation.** As a matter of fact, the correct regulation of cut on a forest requires a complete and detailed study of all local and general conditions. Regulation depends on correct answers to the economic, business and technical problems presented. It is most intimately linked with (a) Stock taking and growth, included in mensuration (Business group), (b) Policy and history (Economics), (c) Forest finance (Business), and (d) Silviculture, protection and lumbering (Technical). But the more the following diagram (after Chapman, page 4, Forest Mensuration, John Wiley & Sons) is studied, the clearer becomes the interrelation between forest regulation and the parts of the physical, mathematical and human groups:

RELATION OF REGULATION TO OTHER SUBJECTS IN FORESTRY
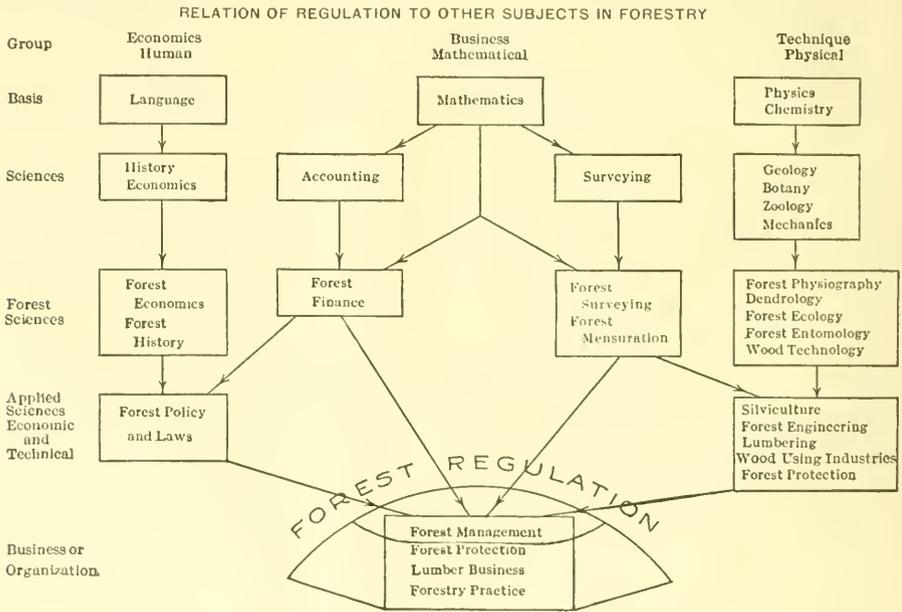
Fig. 1.

4. **Land Classification, an Initial Step.** As our industrial development continues, land originally classified as chiefly valuable for forest production may eventually be devoted to other uses. But before regulation can be intelligently planned, it is obviously necessary that the land classification must clearly differentiate for the time being between agricultural and forest soils. If the estimate of permanent production is based partly on stands growing on agricultural land soon to be cleared, the whole arrangement will

be disrupted if this land must be withdrawn from the forest for purely agricultural uses.

5. **Details Must be Systematized in Working Plans.** Forest Regulation or Forest Organization is therefore the systematic and orderly presentation of the business* of Forest Management usually embodied in a formal *working plan* which is:

> *The plan or plans under which a given forest property is to be continuously managed.* **Annual** *or* **periodic** *plans may be based on the general working plan and may refer to any specified class of work, as the annual cutting, planting, protection, grazing, or administration and improvement plan.*

> *Such annual plans may be either mere schedules or may contain more or less detail, explanations, estimates of cost and results, as seems desirable.*

Details of forest management must be systematized to avoid waste. The past and the future policy upon which forest management is based must be clearly presented to the manager and the basic local economic data** concerning the area must be collected so the forest can be divided to suit the system of silviculture and intensiveness of treatment. Then the essential regulation of cut—the soul of forest regulation—can be determined and the time to cut each compartment decided upon. In American forest regulation *silviculture will usually take precedence over the mere dictates of forest mathematics,* but the two of course should be correlated.

Without system, the work of one manager is lost to his successor. The manager who "carries the data in his head" is the forester of the past generation; he is the sort of man who is eliminated by the modern board of directors who insist on constructive business efficiency.

6. **Progress of American Regulation in Early Working Plans.** The progress of Forest Regulation in a country is a sure indication of the intensiveness of forest administration. Every annual report in British India catalogues *the area under working plans,* because this is considered a criterion of advancement. But in the United States, curiously enough, while the initial work of trained foresters was early centered in the preparation *and publication* of working plans for private timber lands, yet today there are few plans for public forests, although the regulation ideal has never been lost sight of. But judging from the interest in management that has arisen during the past year (see appendix E), the present lack of really effective National Forest plans will soon be remedied.

> The earliest published plan*** set the standard for private working plans and originated diameter limit methods* of regulating the cut which were blindly followed in other plans without regard to type, or character of cutting and silviculture. A method which might give passable temporary results in the tolerant spruce forests of the Adirondacks

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* Chapman, H. H., Working Plans (P. S. A. F., Vol. X, pp. 376-383, 1915).

** Chapman, H. H., Forest Mensuration, John Wiley & Sons, New York, 1921.

*** Graves, H. S., Practical Forestry in the Adirondacks (Bureau of Forestry Bulletin, 1899).

* Moore. Barrington. Working Plans: Past History, Present Situation, and Future Development. (P. S. A. F., Vol. X, pp. 217-259.)

naturally failed when applied without modification to almost clear cutting in the intolerant pineries of the South.

According to Olmstead,*

"The yield to be expected from cutover lands shows a high return from the capital invested in them . . . . cutting to . . . . twelve inches breast high (fourteen inches stump) . . . . with stumpage at two dollars (now one fifty), land at one dollar per acre . . . . the annual interest represented by the future crop on cutover lands for a period of forty years, is nearly nine per cent . . . . The lands which have been cut over will be producing timber, which at a conservative estimate represents an income of 8.8% on the capital invested in them."

This calculation applies to short-leaf and loblolly pines in the South, but Fernow** says, "The real interest which the above quoted example will give is about 5½%. This is considerably different from 9%."

The reason why working plans for private lands were so important a part of the work of the Bureau of Forestry (prior to the establishment of the Forest Service on February 1, 1905) was that these were but a means to an end—a useful method for advertising forestry, a propaganda which proved entirely successful in enabling a technical bureau to assume charge of the National Forests (then termed Forest Reserves). The technical failures of these early plans according to one writer,*** were due to putting future interests ahead of the present, a failure to understand that the lumberman's wanton destruction of forests was dictated by economic factors; this latter shortcoming was because they had not received a proper business training. These plans attempted the impossible and copied too closely the European counterpart. Where less was attempted, a greater measure of success was secured.* This early activity in working plans was under the artificial stimulus of a propaganda campaign. A measure of technical success it is true was attained in the woodlot plans because here the main emphasis was placed on silviculture (and especially on the immediate execution of sample thinnings) rather than on regulation.

7. **Stock Taking by the Forest Service Preliminary to Regulation.** When on February 1, 1905 the Bureau of Forestry was given the National Forests to administer, the problems of organization, fire protection, grazing, improvement and the sale of timber occupied the attention of those in charge. Sporadic attempts were made to draw up *preliminary* working plans but the main expenditures during the next decade were on mapping and estimating. These data were for timber sales and for rough purposes of regulation—to prevent overcutting. Generally speaking these early estimates have proved too inaccurate for the modern timber sale appraisal unless corrected by comparing them with the results of cutting in timber sales—and even then the results are not wholly satisfactory. All of the rough estimating eventually will have to be done over again. This was to be expected and it can safely be said that as a policy a rough estimate for every forest was entirely proper because it cost perhaps but a cent or two an acre. As a result of normal economic development more accurate estimates will be justified later on. Forest history certainly justifies the rough timber survey of a forest area as

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* Olmstead, F. E., "Working Plan for Forest Land Near Pine Bluff, Ark." (Bureau of Forestry, Bulletin 32, 1902, page 44.)

** Fernow, B. E. (Forestry Quarterly, Vol. 1, page 32, note).

*** Ibid., pp. 221-222.

* Foley, John. Conservative Lumbering at Sewanee, Tennessee. (Bureau of Forestry, Bulletin 39, 1903.)

an initial step in regulation. Only high stumpage prices and intensive markets justify costly and intensive estimates. Preliminary regulation requires not only a knowledge of the resources but equally important, systematic data on the marketing, manufacture, and utilization of the product and basic information on silvicultural practice. During this initial period of development no satisfactory or practical regulation scheme was developed, notwithstanding a number of attempts. According to the 1919 Forest Service Manual (Reg. S-2), the limitation of cut is now as follows:

"The Secretary of Agriculture will prescribe from time to time, upon data furnished by the Forester, the maximum amount of matured and large-growth timber which may be cut by years or other periods, on each National Forest or other unit."

In many countries the annual cut is fixed by the Secretary (the ranking official) since the technical services in principle should not establish the allowed cut for the forests they supervise. Probably more effective results would be obtained in the United States if the limitation of cut on National Forests were checked and correlated by an independent forestry advisor *actually serving* in the office of the *Secretary of Agriculture*. At present the limitation of cut figures are prepared by the Forest Service and the Secretary's approval is purely perfunctory. But such a plan of re-organization will probably not be adopted because of the additional cost.

Today efforts are continued to systematize estimating and mapping, since accurate regulation of cut as a vital problem by itself can only follow reliable estimating which in turn is dependent on appropriations; until very recently estimating on National Forests was frankly based chiefly on timber sales demands but now the policy has been changed so as to give more emphasis to obligatory regulation.

8. Regulation on Privately Owned Property. Strictly speaking, there has been no regulation on private, state, or institutional lands.

On the Vanderbilt property near Asheville (now Pisgah National Forest and Game Preserve) silviculture dominated the early cutting policy, but today the forest is being heavily culled prior to its being turned over to the United States. On the Whitney and Webb tracts in the Adirondacks the regulation of cut has been made subservient to a good business showing. Yale has managed the forest property of the New Haven Water Company,* but systematic regulation has not been commenced because good silviculture demanded the removal of diseased chestnuts, and a formal working plan has thus far been deemed unnecessary. Improvement thinnings and planting rather than regulation was what the forest needed. Similar conditions have dictated the policy at Sewanee, Tennessee and at Syracuse, N. Y. (State College of Forestry), where important school forests are being successfully managed. Of college forests the Harvard Forest alone has been really regulated during the past ten years.

Silviculture must come first, to be sure, but during the initial period, it appears only too easy, even for technical forest schools, to minimize the need for systematic mandatory regulation. It is predicted that regulation will come into increasing prominence during the next decade. For without a systematic attempt to regulate the forest for continuous production in accordance with correct silviculture, forest management cannot be put into effect.

9. Quiz. What is the distinction between forest regulation and forest finance? forest mensuration?

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* Hawley, R. C., Bulletin 3, Yale School of Forestry, 1913.

What are the essentials of a definition of regulation?

In what particulars do different authors vary in their definitions of regulation?

Why were working plans made for private timber lands prior to 1905?

How was forestry benefited by this?

Why did these plans fail technically?

Why were calculations of profit too high?

Why are working plans now being developed for National Forests?

Why were rough timber surveys justified?

What restrictions as to timber sales are now made by the Forest Service?

Which should come first, silviculture or regulation; should the two be correlated?

What replaces regulation on privately owned forests and why?

BACKGROUND OF A REGULATION POLICY
AND SUSTAINED YIELD

10. Basic Conditions. Gifford Pinchot, in an address delivered in 1921, declared that the United States must have a National forest policy for the conservation and regulation of forests. More than half of our original timber has been cut and burned away. We are cutting what remains more than four times faster than it is being reproduced. Three-fourths of what we have now will be cut within twenty-five years. When our own timber is exhausted, neither in Canada nor in Mexico nor elsewhere in all the world can we get the kinds and quantities of timber that we need. The supply of timber indispensably necessary to keep our agriculture, mining, manufacture and transportation productive and prosperous is the greatest and most far reaching economic question now before the people of the United States.

One-fifth of the timber of the United States is in State and National Forests (almost wholly in the latter). Four-fifths is in private hands, and is being destroyed as rapidly as ever. If we are to mitigate or escape the timber famine which is now clearly ahead, forest devastation on the privately owned commercial timberland must stop. Already more than eighty million acres of forest lands in America have been so completely devastated that they produce nothing, and the lumbermen are extending this devastation every year over a total of new land as large as the whole State of Connecticut.

A National forest policy, to be effective, must put a stop to forest devastation, control or prevent forest fires, and provide for raising at home the timber without which the United States cannot even exist as an organized community, to say nothing of the safety, prosperity and comfort of our people.

The forest policy of the United States, Mr. Pinchot points out, must be nation-wide for many reasons. Already more than three-fourths of our people live in the states whose forests are unable to supply their own needs for lumber. All of our greatest agricultural and industrial communities are in the thirty-three timber-importing states. The timber-importing states are rapidly increasing in number and the timber exporting states rapidly diminishing. The timber-importing states contain four-fifths of our agricultural values, and nine-tenths of our manufactures are produced in them. Seventy per cent of the lumber used in America is consumed outside the state in which it is cut. Half of the timber left in the United States is in the three states of Washington, Oregon, and California, which contain but five per cent of our population. How to get lumber is a far more pressing problem for the states which do not have it than for the states which do. It takes more wood used in more ways to feed, clothe, and house the city dweller than the farmer or the mountaineer—the people far from the forest than those who live in or near it. The only way to prevent control of lumbering on

privately owned timberlands from imposing unfair and unequal burdens is to make it National and, therefore, uniform throughout the Nation. The only control that can be impartially enforced is National control. The only control that can be kept free from politics is National control. National control can be adapted to local conditions fully as well as state control. The only organization prepared to enforce control, with full knowledge, long experience, and undisputed character and ability, is the United States Forest Service, which has been doing with marked success in the National Forests almost exactly what National control would have it do on commercial timberlands. National control through the power to tax is simple, easy of enforcement, and in accordance with our way of doing things, and would require little or no machinery beyond that already in existence. So run the facts and arguments in Mr. Pinchot's address.*

11. **Basic Studies.** Since forest lands cover one-fourth the area of the United States, their development and use will become increasingly important as this shortage of forest products develops. This development and use will depend: (1) On the policy of the owner; (2) on the economic conditions that affect values; (3) on the exact silvical knowledge available. This third condition is fundamental, because policy and values are so closely linked with thorough knowledge of growth and silviculture. The study of volumes and growth are important branches of forest research, but all research, directly or indirectly, aims at the solution of the problems underlying forest regulation. To be sure, there must be a balance between policy, economic conditions, and the results of research; but research is often so *all important* a problem that it may come first. At present there is a tendency to give economics too much prominence. Shall timber sales sway absolutely forest regulation? Or will regulation influence the business of lumbering? This general question must be decided in each case on its merits, but the true ideal of forestry is unquestionably to put sound regulation (based on research) first.

12. **Curtailment of Production.** Recent attempts to curtail normal *government* timber sales on the Pacific Coast so as to relieve the private owner of competition, are needless and unwise; and yet recently a forester proposed that the regulation of the *private* timber resources in the South to prevent too rapid exhaustion might demand assigning a cut to that region with the

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* An interesting proposal is made by Roth and enlarged upon by Watson (J. of F., Dec., 1921, pp. 817-835, "Sustained Annual Yield as a National Policy of Forestry") to organize and plan for forests cut by any accepted method, but to protect the actual growing stock by allowing only the cutting of one-third the basal area per forty acres every twenty years. This would certainly tend to stop forest devastation and would prolong the cut but like rigid diameter limit systems is too artificial to be generally applied throughout the country to all types of stand. Watson is, however, on the right track when he states (in the article cited above) that: "It has been shown in the previous pages that neither satisfactory fire protection, silviculture, nor a system of taxation of private lands can well be established until the forest properties of the United States, private as well as Federal or State, are brought under a form of continuous forest production . . . . some form of forest regulation is needed . . . . in a mandatory fashion."

object of forcing some owners there not to cut more than a certain amount. This amount could be gauged by the potential productivity of the soil, and would be dictated by the future danger of a timber shortage. This is a bold plan, but indicates how regulation may sway the economic problem of production. With the laying waste of forest lands owing to overcutting, such as has taken place in the *Lake States,* how long will it be before soil values can be restored? Unquestionably it will be years, and the expense will be many times the cost of cutting more conservatively in the beginning. This truism is fundamental of good forestry.

Watson* figures the *possible* annual growth from all timber lands in the United States at about the amount now used, but before the *possible* annual growth can be secured, from fifty to a hundred years must elapse. In other words, past overcutting means a hiatus in our *national* sustained yield (see § 1).

13. **Continuous Forest Production.** In a broad sense the policy of holding timber lands on the basis of continuous forest production means: (1) Stabilizing the lumber industry, (2) the adoption of a true and sound forest policy, (3) a solution of important land and forest labor problems of the country; (4) provision for permanent cheap transportation in the forest. As soon as timber lands, both public and private, can be placed on the basis of permanent forest production, the greatest advance will have been made in national conservation—the first step towards the termination of forest destruction.

14. **Early Western Land Policy and Its Results.** Conditions in the West** during the past half century have led away from systematic regulation rather than towards it. First the Government tried to dispose of its land for revenue and railroad development; then for the benefit of settlers, and throughout the application of the public land policy, there were always frauds which involve astounding values in public property. In the West, too, frequently the citizen endeavored to beat the United States, and to see how he could get around the law. The laws, themselves often impractical, encouraged this viewpoint, and there was unbridled exploitation of resources with no regard for the future; (a) in agriculture (where the soil was "cropped"); (b) in land speculation; (c) in forest devastation; (d) in extravagant methods of mining; (e) in illegal fencing; (f) in the free disposal of water-power and water-power sites; (g) in survey frauds; (h) in swamp-land frauds; (i) in the profligate disposal of railroad land grants; (j) in homestead commutation.

The Public Lands Commission reported:

"Detailed study of the practical operation of the present land laws, particularly of the desert land and commutation clause of the Homestead Act, shows that their tendency far too often is to bring about land monopoly rather than to multiply small holdings by actual settlers . . . . The settler is at a marked disadvantage in comparison with the shrewd business man who aims to acquire large properties. There has been spoliation and illegality due to the weakness in laws, speculation and corruption of petty officials appointed for political reasons."

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* Russell Watson (J. of F., 1921, pp. 390-393).

** Hill, Robert Tudor. "The Public Domain and Democracy" (Columbia University, 1910).

According to Hill,* "The situation seems partially to reduce itself to this:

(1) Exploitation of natural resources has produced waste, and future social interests have been disregarded.

(2) Frauds against individuals and society at large represented by the Government, have been encouraged and perpetrated on a large scale, and private and public dishonesty has ensued.

(3) Public estate has been used for private interest on a large scale. It takes time for social ideals to change. Social disapproval has been extended far enough to prevent the individual from holding himself superior to law." The paragraph numbers have been inserted to give force to Mr. Hill's conclusions.

Thus, as a background to forest regulation in the West, we have the doctrine of individual liberty, the opening of the public domain to give away the natural resources which were fast disappearing.

One of the** troubles with the early western administration, was that business principles were needed just as if the public domain were a private estate. When an efficient administration of the National Forests was commenced, misunderstandings of policy and objections to the rules and regulations were prevalent. The mining interests were afraid that they were going to be unable to proceed unmolested and unrestrained, and that they would not get timber at a reasonable cost. The grazing interests were afraid that restricted grazing would mean confiscation of their stock, and before the repeal of the lieu land-selection law, all the public feared that the large owners would denude their land and then exchange it for script. Such objections, which were most potent in northern California, found some vent in other parts of the West.*** These fears have been disproven.

15. **Effect of Economic Lumbering on Forest Management.** A study* of the lumber industry by the Forest Service has shown clearly that

"forest conservation is affected by economic conditions in manufactures whose raw material is wood. Demoralized lumber markets affect the value of timber, the stability of its ownership, the degree to which it is wasted in exploitation, and the possibility of carrying out any far-sighted plan of forest renewals," the need for broad gauge regulation is all the more important.

According to Greeley, ". . . . the main problem of the lumber industry is a forest problem. It is a problem which has grown out of quantities of cheap timber acquired from the public domain."

Greeley shows that the West has a surplus of saw-mills and logging camps, that there has been speculation in timber, that owners have over invested, that mill capacity has been excessive, and there have been poor methods of finance, and low efficiency in manufacture and in salesmanship; that competition has been destructive. And yet unquestionably, as Greeley shows, "the public is vitally interested in the prosperity of the lumber industry in

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* Ibid., page 215.

** Woodruff, G. W., "The Disposal of Public Lands." (Proceedings S.A.F., March 10, 1904, page 53.)

*** Potter, Albert F. "Objections to the Forest Reserves in Northern California" (P. S. A. F. Vol. 1, 1904, page 50).

* Greeley, W. B. "Some Public and Economic Aspects of the Lumber Industry" (part 1, Secretary of Agriculture, Report No. 114, 1917).

regions where it is the dominant factor in the economic life of the community." Unquestionably there is need for

"a more suitable kind of forest ownership . . . . the extension of public forest ownership . . . .. is needed. Private ownership has shown itself ill fitted to the task . . . . private coöperation in taxation and fire-protection . . . . reasonable public regulation of the handling of private lands will unquestionably find a place in working out the problem."

The conclusions are that within the next two decades there will be local timber shortage, hastened by over-production due to the wrong kind of ownership. The answer to all these evils which Greeley has enumerated in his study of the lumber industry is unquestionably broad gauge forest regulation, which primarily must be based upon the study of growth because, as already emphasized, without knowledge of the rapidity of timber production per acre, the regulator of forests has little chance of giving correct answers to the various problems.

The public must coöperate with the private owner to make a regulation of cut a practical business. There are people today who fear regulation of cut and the curtailment of lumbering operations and the consequent restriction of local development. We have simply reached another stage in the management of our national forest wealth,—the obligatory regulation stage,—*and this does necessitate some present day sacrifices for increased future benefits.*

According to an unpublished paper by Zon,

"Another persistent fallacy is that forestry cannot be profitably practiced unless stumpage prices are high enough to raise timber to maturity on a bare tract at a profit above all costs including compound interest. If we are to allow our forests to be turned into deserts and then expect to reclaim them by planting, the chances for having in this country any forests at all, are very slim indeed."

If forests are completely wrecked, it will take a century or so to repair the loss. According to present estimates, private owners have fifty to sixty years of supply at the present rate of cutting. There is an annual demand of approximately one hundred billion feet a year, forty billion for lumber, and sixty billion for ties, poles, fuel, and fencing. To supply such an enormous demand there is need of young age classes to grow the forests of the future. According to Zon,

"If all our forests were placed at once on a sustained yield basis, they would absolutely produce the annual supply of wood needed in this country."

But today the lumberman is afraid of regulation. Under present conditions there has been over investment by the lumber industry. Owing to the high cost of capital, the incentive to destroy the forest investment as soon as possible in order to reduce the carrying charges has predominated.

16. **Possible Solutions; Restricted Private Control, or Public Ownership?** There are two possible solutions to this problem; control of the private individual, and restriction as to how he shall use his forests, or, ownership by the public. Because of American Democracy the viewpoint that the public must own most of the forests, is, in many ways, logical, but a large proportion will of necessity remain in the hands of the individual. Toumey* says,

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* Toumey, J. W., Who shall Own the Forests (Yale Review, Oct., 1913, p. 156).

"Can you look forward to the time when at least one-half of our permanent forest area will be publicly owned? If not, our private forests must come under governmental control, with prescribed methods of management. Future development in American forestry must be in one or the other of these directions. The writer believes public ownership is far more in harmony with American instincts, and more acceptable to the great body of American people."

If the private owner, notwithstanding carrying charges imposed by taxation and interest on his investment, desires to own forest land, and yet refuses to adopt conservative methods of treatment, what is the solution? With a situation such as this, an ex-appropriation of at least those forests which cover erodable slopes and water-sheds will unquestionably be forced in the interests of the public. For forests in level country, that are merely supply forests, perhaps conservation has not advanced far enough in this country to justify at once federal or state control. Time will tell. Fernow* in discussing the control of small owners says:

"The former may be largely left to the free exercise of private enterprise, and this will probably be the answer to the regulation problem so far as it touches the small owner; he will not brook control, and so long as he is willing to fight it, probably he will have his own way."

Kirkland** argues that public ownership is not necessary even to secure a sustained annual yield; that it would be practicable to put the forest industry on a permanent producing basis by establishing a central association of American forest industries which should classify, finance, organize, and standardize the business of the members, and most important of all regulate output and prices.

"The only effective maintenance of price must be one through limitation of the quantity placed on the market. The only sound limitation of the amount to be marketed annually is that imposed by what this resource will produce continuously. Bad as that forestry is which overcuts any given producing unit, that which undercuts is still worse because it neither furnishes revenue to the owner nor supplies the consumer with product."

Fernow for one does not believe in the practicability of Kirkland's plan nor does the writer, unless this suggested association of private forest owners is under National control—an association of private owners and producers under the guidance of the Forest Service would undoubtedly work efficiently and may be the solution of preventing the present devastation.

17. **Policy and Definition of Sustained Yield.** Granting that there must be public control of forests, we have then to answer the question, Shall the cut be according to the principle of a sustained yield or shall economic conditions and fiscal expediency gain the ascendency in the decision as to "How much must be cut"?

Sustained yield is the yield or cut of timber from a forest which is managed

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* Fernow, B. E., Economics of Forestry, New York (5th Edition, p. 271).

** Kirkland, Bert T., Continuous Forest Production of Privately Owned Timberlands as a solution of the Economic Difficulties of the Lumber Industry. (Journal of Forestry, Vol. XV, 1917, pp. 15-64.)

in such a way as to permit the removal of an approximately equal volume of timber annually or periodically.

It is argued* that a sustained annual yield gives the best social results, the best investment, the safest management. In Europe there can be no question but that forest workers, with permanent work in their local valleys, are better off than they are in temporary logging camps of the United States.

18. Comparison with Conditions in France. According to Huffel, the foremost French authority,** the arguments in favor of an *annual* yield are summarized as follows: most wood products will not stand long distance transportation so that it is better to cater to local markets which are often dependent upon an annual wood supply for their prosperity; a sustained cut is better for lumberjacks and teamsters as well as for wood using industries; an annual revenue is best for the owner of forests; it is of less moment to the state but a necessity for many communes and individuals. This annual yield should not be too unequal because of the drawbacks to labor and local industries dependent upon a supply of wood. For this reason and on account of the dictates of good silviculture, increases or decreases in growing stock should be gradual. But the divergence between the intensive forests of France, for example, and the working circle of the Pacific Coast is so great that it is very confusing. In the one case (France) the working plan may regulate a working circle of but a few thousand acres; in the other case perhaps it takes two hundred thousand acres or more to form a circle that will yield a large enough cut to justify the maintenance of the local timber-using mills and industries. In France, for example, the valley is tributary to a small group of saw mills; here the unit of sustained yield is smaller, simply because of its more advanced state of forest development, and because of the local labor and market conditions which demand an annual cut, and an annual cut convenient to the homes of the workers. One does not find in France the large scale railroad logging of the United States. Wagon roads permit easy hauling at any point; each little hamlet has its constant annual wood and timber needs; the social and economic conditions are absolutely different, and therefore working plans and regulation in the two countries must be built on different lines. Often the principles are the same, but the application of methods in the Western United States must be broader, and must be changed to conform with the different problems that are to be solved. Perhaps in some localities on National Forests fire protection must come first, and strict regulation of timber must be retarded for another decade or two. Perhaps for a time the pressure for timber sales may lead forest administrators to adopt a policy of giving precedence to timber sales examinations over areas which should be cruised for management reasons; whether due to low appropriations or not, this is unfortunate and is now being modified on some National Forests; but under existing conditions may for a short time continue to be a necessary economic result. Without permanent efficient transportation owned by the forest proprietor the present temporary large scale logging camp, uprooted when the locality is cut, is a natural consequence of economic conditions. The forest workers must suffer; the social evils attendant to a shifting population are proverbial; what is more familiar than the wastage and extravagance after a winter's work in the woods! Yet in the Eastern United States after two centuries of logging these conditions still exist because large scale logging is so customary. With *permanent* sawmill industries and local workers (with families) different social conditions would come logically and naturally as in Europe.

19. Financial Aspect of a Sustained Yield. Usually investments yield semi-annual or quarterly returns and recently attempts have been made to

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* Kirkland, Bert T., The Need of Working Plans on National Forests and the Policies Which Should Be Embodied in Them (P. S. A. F. Vol. X, 1915, pp. 341-371).

** Huffel, G., already cited, pp. 9-12.

popularize monthly dividends.   To meet the minimum demand for an annual income sustained yield production of forests is necessary.   The recent studies of the lumber industry* indicate that better financial results (because of over-production under existing methods of wrecking the forest property) can be brought about only by,

"A more stable kind of forest ownership, divorced from manufacture to a larger degree than now, must come about before the ills of the lumber business can be permanently cured . . . .   Private ownership has shown itself ill-fitted to the task, at least in the larger forest regions."

Legitimate demands for timber must be met, but forced sales** should be discouraged.   Then too, it is generally recognized that present methods of taxation*** are an incentive to over-production, since the operator must try to create a demand for his timber rather than to hold it for permanent production.   It is interesting to bear in mind that a 15 per cent tax on the final yield of private stands would yield about the same revenue on the Pacific Coast, as is at present received by the communities from the 25 per cent tax on current production of all timber cut from the National Forests.

20.   **Sustained Yield on Public Forests.**   Even as early as 1905 the government has idealized a sustained yield.   In an early working plan* for private lands it was argued:

"The object should be to get a sustained yield from as small an area as possible, provided this does not materially interfere with, or increase the cost of present operations.   The smaller the area the smaller the invested capital and the yearly tax list, and in the long run this means the saving of a considerable sum of money."

The public naturally expects the National Forests to be models of permanent forest production.   Why then has not a sustained yield management been adopted?   The answer** is:

(1)   That there are physical limitations that are now insurmountable owing to inaccessibility and lack of transportation.   "*** . . . . primary transportation must precede any kind of forest management."

(2)   Competition with private stumpage more conveniently located would necessitate reducing prices below the danger point if national timber sales had to be forced.   "A sustained annual yield presupposes a sustained market," which is rarely available.

(3)   The National Forests are a great resource which cannot be depreciated or forced on a market which is glutted with cheap private stumpage.   Yet as is pointed out,*** ". . . . management with or without the sustained yield principle is totally unrelated to the policy followed in pricing stumpage . . . .," according to the appraisal system now in force on National Forests.

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* Greeley, W. B., Studies of the Lumber Industry, Part I (U. S. Dept. of Agriculture, Report No. 114, 1917, p. 4-5).

** Ibid., page 95.

*** Hutton, G. W. and Hapham, E. E., Forest Taxation as a Factor in Forest Management.   (P. S. A. F. Volume 13, 1916, pp. 50.)

* Chapman, C. S., A Working Plan for Forest Lands in Berkley County, S. Car. (Bureau of Forestry, Bulletin 1905, p. 50).

** Greeley, W. B., National Forest Sales on the Pacific Coast (P. S. A. F. Vol. VII, pp. 42-50).

*** Greeley, W. B., Working Plans on National Forests (P. S. A. F. Vol. XI, pp. 84-85).

Moore* argued that sustained yield is not necessary "where the community forming the natural market for the timber is not dependent on National Forest material,—that is, where material can be brought in from the outside as cheaply as it can be produced locally,— . . . . where there is no local market for the timber, ... and where . . . . the possible annual sustained yield is too small to warrant the building up of a community dependent solely on lumbering."

The writer agrees that during the development stage of forest management there will be innumerable instances where a sustained yield (either annual or periodic) will be at present out of the question for practical reasons. One must bear in mind that after the first few periods there can still be *permanent production* even if a strict sustained yield does not commence until after the first improvement fellings have removed the overmature and diseased timber. In virgin forests often good silviculture and a theoretical sustained yield *during the first rotation* do not go hand in hand. One reason why there has been so much divergence of argument regarding sustained yield is that it has been idealized and its practical limitations** not sufficiently appraised.

21. **Sustained Yield Objectives and Difficulties in Practice.** The policy of the owner and his objective in managing the forest is always the first consideration in forestry, and will ordinarily determine the whole course of unrestricted management. The private owner may put financial returns first. The public owner may not desire to manage the forest from a strict dollars and cents standpoint, but may wish to preserve the stand, so as to conserve an important water supply, or keep the forest as a recreation ground for the public. In any event, the forest resource must be maintained in a state of maximum and continuous production. Hence the principle of sustained yield enters in, because the ideal of management is the maintenance of the largest possible continuous yield. A continuous yield is just as important in forestry as in any other kind of business. It is more difficult in forestry than other forms of business, because of the length of time required for crop production. These difficulties necessitate special plans to accomplish a sustained yield, which can rarely be attained during the initial years of management.

22. **Summary of Limitations on a Sustained Yield Policy.** In arguing for a sustained yield one must not overlook certain limitations; the principle of sustained yield may be correct but it may not be practicable for a number of reasons:

(1) It is fundamental that the land must be chiefly valuable for forest purposes. Obviously it would be shortsighted to plan for permanent production on any area, without first inquiring whether the soil itself was *now* chiefly valuable for agriculture.

(2) Transportation facilities may not permit. If there is poor transportation, this may prove a practicable argument towards cutting more than the amount warranted on the basis of permanent production, in order to meet large and temporary transportation charges incident to the construction of expensive logging railways. Such a situation is unfortunate.

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* Moore, Barrington, Methods for Regulating the Cut on National Forests (P. S. A. F., Vol. VII, 1912, p. 12).

** Woolsey, T. S., Jr., Forest Service Silviculture Plans (P. S. A. F., Vol. XI, 1916, pp. 1-17, especially pp. 15-16).

(3)   The market for timber products may be insufficient to utilize the entire amount or the quality of timber produced. Perhaps there are accessible and readily salable bodies of timber which are being wrecked, in order that the soil may be used for agri-culture, which will for the time being, compete with the owner who desires ultimately to adopt the sustained yield principle. This condition is typical of extensive forest conditions where a final land classification has not been made, and where economic conditions governing the sale of forest products are unsettled.

(4)   The silvicultural needs of a forest may necessitate the rapid removal of over-mature timber. Perhaps large areas of mature age classes demand the installation of mills whose capacity cannot possibly be supplied when once the excess growing stock has been reduced to normal.

(5)   The demand for timber products may fluctuate according to the development of cities, mines, or other chance local development, with profitable export of only the higher grades of lumber.

(6)   Acts of Providence will always exert an influence against the successful adoption of a sustained yield. Fire, insect attacks, disease, windfall (and perhaps war) may all tend to derange the application of an exact sustained yield. For example, even in well regulated forests abroad the variation in the annual yield is considerable. In the Forest* of Retz (France) the cut in 1863 was fixed at 987,671 cubic feet; in 1877, 1,218,055; in 1887, 996,535; in 1896, 1,241,736, and in 1902, 1,014,319. Such variations in a regulated forest under intensive economic demand indicates how much greater these variations will be under American conditions.

(7)   Of less importance, but withal to be reckoned with, is the personal factor in forest administration. From forest history we know that the tendency of administra-tions is to overcut or undercut. Some administrators (British India is an example) desire to make a good financial showing; consequently, they may be led to cut more than the forest produces, unless they are restrained by working plans based on a clear knowledge of forest production. Other administrators (as evidenced by France) may undercut the forest, sometimes with poor results, because it means the accumulation of over-mature timber and consequently increased danger from disease, windfall, and insect infestations. Changes in regeneration methods may disarrange for the time being the regulated cut.

(8)   One of the greatest obstacles to a sustained yield is the character of the forests themselves; the fact that so far the cut has generally been from virgin forests often of mixed species, instead of from second growth or grown as even-aged stands free from suppression. (See paragraph 108.)

The sustained yield management ideal is thus something to steer by. It is not so unattainable as the normal forest, but nevertheless there are many pitfalls before it can be reached. The administrator and student of forest production must bear in mind that permanent production is safeguarded by frankly acknowledging a sustained yield policy for working circles of reason-able proportion. The working plans officer must be enough of an idealist to combat the every day arguments of the opportunist administrator, who desires to give practicable considerations too great weight when solving the vital problem of permanent forest production.

23. **Quiz.** What will future forest development depend upon?

What is an important aim of research?

Should preference be given regulation aims or the dictates of local business require-ments?

Discuss permanent forest production and conservation.

* Fisher, W. R. (Quarterly Journal of Forestry, 1910, pp. 285-286).

Why do past methods of disposing of the public domain in the West make conservative management difficult?

What were early objections to the national forests?

What is the matter with the lumber industry?

How can it be improved by regulation?

What are the solutions of national regulation of timber cutting?

What does Kirkland suggest? Is it possible?

Discuss sustained yield and the worker, the investor, the forest, taxation.

Why cannot a sustained yield management be adapted at once on national forests?

When is it claimed to be unnecessary?

Summarize the sustained yield problem—advantages and limitations.

How exact can an annual sustained yield be: (a) in France? (b) on our national forests?

What are some of the difficulties in the United States?

CHAPTER III

MANAGEMENT AND ADMINISTRATIVE SUBDIVISIONS

24. Definition of and Size of Subdivisions. In order to intelligently systematize the location of cuttings at the proper time, and in order to determine the area of forest to be cut over and volume of product to be removed the land must be suitably subdivided into practicable *subdivisions* which are defined as *a larger or smaller part of a forest property segregated with a view to making units for purposes of administration, protection, organization, and management.* The size of the subdivisions will depend on the intensiveness of management and administration. Where the conditions are intensive, as in New England woodlots, the size of subdivisions will obviously be much smaller than on the Pacific Coast. In New England the cordwood, poles, posts, or ties are usually marketed by the owner. This is facilitated by established wagon roads. Thus if desired small tracts can be managed on a sustained yield basis under one working plan. On the Pacific Coast the conditions are essentially different because railroad marketing of saw logs demands a large area of timber so that the annual cut may be sufficient to *maintain* the investment. Still another factor—the progress of silviculture— enters into the problem. With virgin forests, management subdivisions will always be larger than where silviculture has been intensified. In the initial years of management there will be fewer distinctions in methods of cutting and in rotations. It stands to reason that the size of administrative subdivisions will vary in like manner. The forest in Europe under the control of one man may be limited to 10,000 acres because of the detail incident to administration. The typical national forest of the Western United States today perhaps averages a third of a million acres and is as efficiently managed in a relative sense as is the 10,000 acre tract in Europe. There may be no thinnings, but few sales (and these are centralized), and no forestation; instead the manager's time is centered on fire protection, grazing control and the broad problems of administration. It is important to grasp clearly the differences in the conditions which indicate intensive or extensive subdivisions, which are of two kinds: (1) Management and (2) Administrative.

25. Definition of Management Subdivisions. Management subdivisions aim at the orderly location of all data on forest resources so that this knowledge can be applied to all timber operations within the forest and the results recorded so as to preserve an accurate history of past cutting. These subdivisions are divided into working groups and working circles for the regulation of yield.

Working group may be defined as an organization or working plan unit, comprising an aggregate of compartments or stands to be managed under the same silvicultural *system and rotation.* (Syn: working block; working section; management class. G., Betriebsklasse. F., Serie D'Exploitation.)

Working circle may be defined as an **economic** *forest area managed under one*

plan. It may or may not coincide with the administrative unit or with the working group. (Syn: working plan unit, working figure. G., Wirtschaftsganzes.)

There appears to be more variation in the use of words for working-group and working circle than with other terms of current use in regulation. According to Schlich,* the working section (corresponding to working-group) is "a number of compartments . . . . grouped together into cutting series, ... a number of the latter form a working section." Moreover, according to the same author, "if a working circle" (our working circle) "consists of only one series of age classes, it is identical with a working section" (our working group). A working circle (our working circle) is, according to Schlich, an "area which is managed under the provisions of one and the same working plan." Other terms have also been introduced. Recknagel** used in his first edition the term "working figure" for "that unit which is to be managed with the idea of a sustained yield." He stated "But in America the unit of regulation, the working figure, must be the market unit." To simplify the unit of regulation he omits the distinction between working group and working unit. Roth*** uses working section for group and does not distinguish working circle as a separate term.
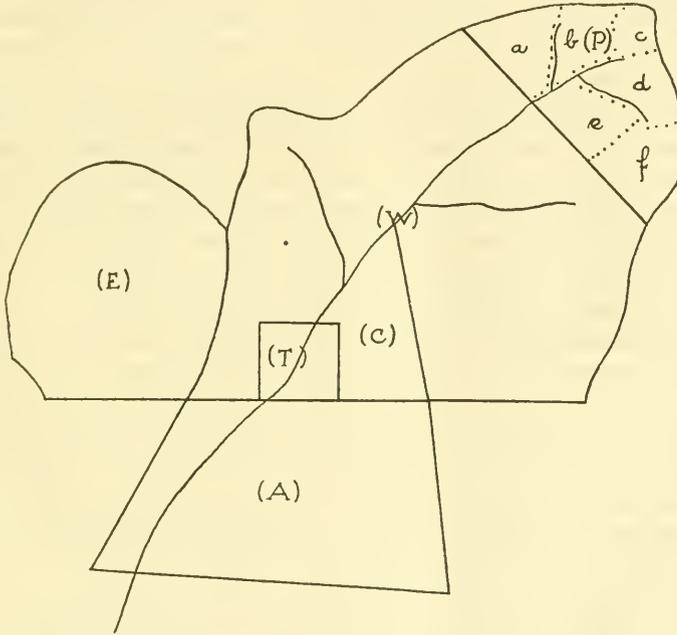
Fig. 2.—Diagrammatic Sketch Map Illustrating the Distinction between Working Group and Working Circle (Syn., Working Unit).

26. Discussion of Management Subdivisions. The distinction between working group and working circle is illustrated by Fig. 2.

Here is represented a central town, with established sawmills and associated industries, surrounded on the south by (A) agricultural land, on the

* Schlich, Wm., Manual of Forestry, Vol. III, 1911, pp. 273-285.
** Recknagel, A. B., The Theory and Practice of Working Plans, 1913, p. 20, p. 33.
*** Roth, Filibert, Forest Regulation (Vol. I, Michigan Manual of Forestry, pp. 1-203).

west by a pure (E) Englemann spruce forest managed on an eighty-year
rotation for paper pulp, on the north and north-east by a large watershed
stocked with (W) western yellow pine, where clear cutting is followed by
planting on a one hundred and twenty-year rotation. Directly to the north-
east of the town is a simple (C) coppice of scrub oak managed on a twenty-
year rotation; further up on the mountain is a city watershed, held chiefly
as (P) protection forest with natural regeneration. The rotation here is one
hundred and fifty years, and the mixed conifer stand is cut over by light
selection fellings on a cutting cycle of twenty-five years. In the case cited
the local industries of the (T) town were entirely dependent upon a sustained
yield from the combined watersheds. Under these circumstances a separate
working group would be established for each of the four stands (E. C. W. P.);
since these four stands are tributary to this one town, it would be entirely
practicable to have *one* working circle include the four working groups. If,
on the other hand, instead of four different stands with four different systems
of management and varying rotations, the entire area had consisted of western
yellow pine with a hundred and twenty-year rotation, followed by clear
cutting and planting, *but one working group would have been established,* and
this would have coincided exactly with the working circle; whereas under
the conditions cited in Fig. 2, there are four working groups, because of
varying types, silvicultural system and rotation. A further complication
might have been introduced had the area (W) been so large that it could
not have been conveniently handled under one working group. In such a
case mere size might have dictated the formation of additional groups. It
is therefore important to bear in mind that the working group is a smaller
and narrower management (silvicultural) subdivision than the working circle.
The working group is determined by type, *silvicultural system,* rotation or
size, while the working circle would be determined more by transportation,
market, and business and not by silviculture. Fernow naturally considers
"working circle" the broader term, judging the aggregation of stands from
the administrative yield and market point of view, and "working group" the
narrower term, based mainly on *silvicultural management* as a unit.

27. **Factors that Justify Formation of Working Groups.** The formation
of separate working groups may thus be dictated by the following factors:
(1) forest type, (2) silvicultural system, (3) rotation, and (4) size of area.

(1) Forest type. Types differ according to the kind of product yielded,
silvicultural system of cutting and reproduction. They may demand a differ-
ent rotation; therefore, whenever types cover such a large area or differ
sharply in products yielded, rotation, method of cutting or reproduction,
that they cannot be worked as one group for the regulation of the yield, it
is necessary to establish different working groups.

(2) Silvicultural system. Suppose that on one watershed there is clear
cutting followed by planting, while on another the forest of yellow pine is
managed by selection cutting; here separate working groups would be indi-
cated. If these stands could be managed under the same silvicultural system,
probably no distinction into two working groups need be made.

(3) Rotation. Where two entirely different rotations are necessary, separate working groups must be established. This is not always the case, however, because in a mixed stand, frequently species with different rotations are managed under an average rotation in but one working group. But if the types were entirely separate with widely varying rotations, then different working groups would be essential.

(4) Size of area. A single working group must have eventually, if it is clear cut, a complete series of age classes, and these age classes must be as small as is consistent with economy in logging, so as to reduce the danger from fire, windfall, fungus and insect damage. It is a fundamental maxim of silviculture that large even-aged stands endanger the forest; therefore with a very large working group, excessively large age classes could not be avoided if a clear cutting system were practised. Consequently, more than one working group might be necessary in order to reduce the size of the age classes.

28. Working Circles. The working circle (as contrasted with working group) is, in theory at least, dependent chiefly on the market, but under modern methods of rail transportation so typical of American lumbering, the market may not be the primary factor except in the case of small local market units where rail transportation does not enter into the problem. Rail markets draw from a wide territory, and therefore a working circle may, under exceptional circumstances, be composed of several forests so far as the market is concerned, but restricted in size because of administrative or management grounds. Ideal conditions for a working circle, where a sustained yield is desired, consist of a complete market, complete transportation facilities of a permanent character, such as drivable streams, or a permanent system of forest roads. If temporary roads, railroads, or flumes must be built by the operator and paid for by him from the operation of cutting the timber, then these apparently unavoidable economic conditions make the attempt to regulate the annual cut more perplexing. In some cases it might mean that there was not enough timber locally to permit of a sustained yield until later rotations, and it must therefore be cut off rapidly in order to make a practical logging chance. An economic woods operation would be secured at the expense of the sustained yield—an objectionable feature.

Under extensive conditions such as exist on the Pacific Coast, working circles are laid out in territory logically tributary to manufacturing centers by existing or possible transportation. This basis, under these conditions, fits in with the objective of a permanent industrial center and should have more weight than topographic or administrative conditions, which are here of secondary importance. Another problem met with under extensive conditions is whether to take into consideration land under private ownership when establishing national forest working circles. The policy should unquestionably be to give due consideration to the private timber which will probably come into the market, since this will help to maintain the industrial center just as surely as the cutting of public stumpage. Allowance on the other hand must be made for timber land, which may be chiefly valuable for other purposes, since such areas will not contribute to the support of the economic working circle after the first crop of timber is removed.

29. Policy of Small or Large Working Circles. Really effective regulation and a future sustained yield can best be obtained by securing reasonably small working circles (working plan units) today. Very large working circles, such as have been planned for some of our western forests, will preclude the possibility of moderate sized local sawmill industries, because if virgin stands are cut heavily on a watershed (with the idea of moving operations to another watershed of the working circle later on), there will be no local merchantable timber for cutting after several decades. Where possible the plan advocated by Wolff* of having working circles coincide with natural main drainage areas is certainly logical, the intensification of administration, the fire danger, the bodies of overmature timber in immediate need of disposal and the sale of some of the less accessible timber are problems which can be adjusted and overcome. Small working circles will encourage permanent local industries, stable labor conditions, more permanent improvements, diversification of sales, better silviculture and protection. It is "the safe conservative course"; and the development and maintenance of logging communities is certainly desirable.

30. Definitions of Block, Compartment and Lot. To build up suitable working groups and working circles it is convenient to first divide the forest area into smaller subdivisions in keeping with the intensiveness or extensiveness of management. The smaller the division, the easier it will be in after years to segregate management data according to new and more intensive lines made necessary by a change in economic conditions.

Since forest regulation is the arrangement of operations as to place, time and quantity, subdivisions are for the purpose of making convenient and possible the location of all operations, as follows:

(1) On the ground, so that operations can be conveniently conducted in the forest.

(2) In the office, in order that records may be systematized by tabulations or by means of maps or graphics; these essential records include (a) an inventory of estimates and (b) the record of future operations.

In American forest regulation three subdivisions may be distinguished:

(1) *Block—A major division of the working circle, intermediate in size between the working circle and a compartment. A block is usually based on topography and comprises a main logging unit or group usually based on topography and comprises a main logging unit or group of logging units. A single block may contain many thousand acres.*

(2) *Compartment—An organization unit or small artificial subdivision for purposes of location, administration, and silvicultural operation.* (G., Abteilung, Jagen (Prussia). F. Parcelle.)

(3) *Lot—A small silvicultural subdivision of a compartment, differing in composition, age, or character, requiring different treatment from the main body of the compartment; temporary if due to accidental, permanent if due to site conditions.* (Synonyms: subcompartment. G., Unterabteilung, Abteilung (Prussia).)

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* Wolff, M. H. (Journal of Forestry, 1920, pp. 486-497).

31. **Discussion of Block, Compartment and Lot.*** In figure 2 (P. W. C.) would probably form one block including the entire watershed but excluding the townsite (T).   Area (P) would be divided into compartments a, b, c, d, and e, as indicated by dotted lines.   The lots would probably not be necessary in a protection forest.

(1) The boundaries of the block will ordinarily be topographic features such as watersheds, where the block would correspond to the logging unit rather than artificial subdivisions such as townships.   The block should assist in the general location and classification of estimates and forest descriptions, but for larger areas than for compartments.   Whether the topographic boundary will be a stream or ridge will depend on the local method of logging. If the block is based on natural logging units, the estimates will be convenient for small timber sales.   If larger sales, comprising many thousands of acres, must be made because of market conditions, the estimates of a number of blocks can be conveniently grouped where each block corresponds to a logging unit.

Care should be taken to clearly distinguish block and working group since the two may frequently coincide.   The working circle may even be identical with the working group and block if the area under a sustained yield in a working plan happens to have the same boundaries as the group or block.

(2) The compartment for some time to come will be the smallest permanent subdivision in the West with boundaries clearly marked.   These boundaries may be artificial survey lines (corresponding to the western section lines), rods, or preferably topographic features, such as ridge crests or streams. In our western mountains compartments are really small secondary logging units.   The formation of compartment lines, *especially in highly intensive management* should, if possible, conform to type, broad lines of quality and age classes.   Where compartments can be made to include uniform quality, type or age, it is obviously an advantage to do so, but age, type or uniformity of stand cannot be the governing factor.   In the United States, compartments in surveyed fairly level country will ordinarily be six hundred and forty acres, and in unsurveyed country considerably larger *depending on the topography*.   The size must depend finally on the intensiveness of management.   In New England the compartment may be less than one hundred acres.

(3) The lot (often termed sub-compartment) is always a subdivision of a compartment, coinciding with distinct stands or descriptive unit.   Since compartments cannot recognize differences in age or quality, the lot may be mapped and described separately if intensiveness of management justifies. Its boundaries are usually not permanently marked in the field but even under the extensive conditions existing in the Western United States, the lot may be justified in level country (except in mere protection working groups) because of the ease of recording intensive estimates by 40-acre subdivisions. So far as practicable the compartment and not the lot should be the unit

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* The term lot, adopted by the S. A. F. Terminology Committee in preference to the English term sub-compartment, should not be confused with the local use of "lot" in New England and in government surveys in the West.

of description in extensive timber surveys. The separation into lots may be dictated by a change in quality and type, provided this will not necessitate dividing the forest into such small units as to be impracticable of description; or age classes, if distinct enough to map. The lot as a silvicultural subdivision without demarcated boundaries will always be of value as an intensive unit for timber surveys. In New England the lot may be separated in the forest.

32. Definition of Administrative Subdivisions. Administrative subdivisions are district, forest, ranger district or range, patrol district or beat. These are defined as follows:

District—Generically, any administrative unit; specifically, an aggregate of administrative units or forests for control and inspection purposes.

Forest—An administrative unit, as national forest, state forest, or municipal forest.

Ranger District or Range—Part of a forest, an executive unit under care of a ranger.

Patrol District or Beat—An executive unit for protective purposes, under a guard or patrol.

Administrative subdivisions thus comprise the entire system of national forests, districts of forests, one forest, a ranger district within the forest or the beat for the guard within a ranger district.

33. Discussion of Administrative Subdivisions. Administrative subdivisions are made to facilitate *administration* rather than the regulation of yield and forest management. The entire system of national forests may be distinguished from other public lands, or from forests managed under a separate bureau or department. For example, Indian forests, which are managed for the benefit of the Indians, may be segregated from national forests, or state forests. For convenience of administration these national forests have been divided into administrative districts* in order to facilitate the administrative control of the individual forests under supervisors. Each district is under the direction of a district forester assisted by a staff organization, divided in the United States according to lines of work, such as silviculture, operation, lands, and grazing. The forest is a distinct or connected unit or aggregation of units under a forest supervisor, who has immediate direction of the administration** under the direction of the district office. The forest is divided into ranger districts, which are in charge of a district ranger. Where necessary to facilitate administration or protection, the ranger district may be divided into beats, each in charge of a guard.

34. Quiz. Define subdivision.
What does the size of subdivisions depend upon?
What kinds of subdivision are there?

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* For a discussion of administrative organization problems the student is referred to Forestry Quarterly, Vol. XIV, pp. 188-236, Forest Service Revenue and Organization, by T. S. Woolsey, Jr.

** It will be useful to give the student definite acreage figures on administrative subdivisions for Western and Eastern conditions.

What are management subdivisions?

Define working group, and working circle.

What is the distinction?

When do working group and working circle coincide?

What determines working groups?

Discuss how working groups are affected by type, silvicultural system, rotation, size, market.

What determines working circle?

Define lot, compartment, and block. Discuss boundaries, size, value, and distinctions of each of these three units.

How does block differ from working group? from working circle?

When would they coincide?

What effect will topography have on compartments and working circles in the West?

What are administrative subdivisions?

When would a guard's beat correspond to a block and to a working group?

CHAPTER IV

ROTATIONS—TECHNICAL, SILVICULTURAL, AND ECONOMIC

35. Definitions of Rotation (and Felling Age). *By rotation is meant the predetermined time or period during which it is intended to cut over a working group; the predetermined approximate felling age of the stands. Rotation refers to the forest as a whole and is usually expressed not by a definite year, but to the nearest decade. Felling age refers to the actual age of the stand when cut.*

The length of rotations depend partly on the object of the owner and are also determined by technical, silvicultural, economic, or financial considerations as limited by silvicultural possibilities. According to Fernow a rotation is "the time through which the crop is allowed to grow normally until cut and reproduced."

The view-point in India, as expressed by D'Arcy,* is contrary to the European conception of rotation (except in selection forests in France), namely, "........the exploitable age of a forest crop is the age at which the individual trees furnish the kind of produce most wanted."

According to Endres,**

"By rotation period or rotation is meant that time which elapses, under normal conditions, between the planting and the utilization of a stand. In the case of the working group the rotation is the average time of growing merchantable material which is the fundamental consideration in working plan calculations."

Variations from the normal may be due to unusual silvicultural, financial or economic conditions.

36. Not to be Confused with Cutting Cycle. Rotation is not to be confused with cutting-cycle in selection forests, which is the period elapsing between cuts on the same area. Obviously in selection forests the length of the cutting cycle has an important bearing on the amount removed, and the frequency of cut also has a direct bearing on the amount that is lost through decay; consequently, there is a tendency with intensive management to short cutting cycles of from five to eighteen years. With extensive management longer cutting cycles are at present unavoidable. In Oregon western yellow pine a cutting cycle of 50 to 60 years has been tentatively adopted; this will be decreased when the market and permanent transportation is established. A cutting cycle of 100 years for western yellow pine in Arizona certainly must be reduced as soon as possible. In France*** under most intensive conditions the cutting cycle is five to eight years; under less intensive conditions, nine to eighteen years, and rarely more than this. The

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* D'Arcy, W. E., Preparation of Forest Working Plans in India, Calcutta, 1898, 3d Edition.

** Endres, pp. 220-221.

*** Woolsey, T. S., Jr., Studies in French Forestry, Chapter IX, John Wiley and Sons, 1920.

cutting cycle* is usually a sub-multiple of the rotation; obviously the longer the cutting cycle, the greater the cut.

37. **Conception of Length of Rotation.** The tendency is to have too narrow an idea of what length of rotation means: for example, if five-year-old transplants are used for a plantation (after clear cutting) which is allowed to grow one hundred years, the rotation in this case would be one hundred years (the length of time the forest soil is used) and not one hundred and five, the felling age, that is the age of the trees, since the time the transplants were in the nursery would be omitted in the calculation of the rotation. Yet it is of course recognized that the length of the rotation is shortened by the use of well formed transplants simply because the stand matures sooner. Similarly frequent and early thinnings are of the utmost importance in reducing the necessary rotation because with thinnings the stand will mature earlier than if left unthinned. Efficient thinnings not only enable the forester to grow timber of a specified size in fewer years, but they increase seed production and promote earlier seed crops; they decrease the date of the culmination of mean annual growth, and, as Endres puts it,

"The greatest benefit is felt where the highest soil rent is maintained . . . . It is recalled that large, early yields produce large soil rent and vice versa . . . . A stand that has been thinned up to the "n" year will have higher value than one that has not been thinned."

It must be born in mind that while the forest as a whole may be managed according to specified rotations yet individual stands may be cut before or after the rotation age because of accidents, market conditions, etc. Still another point, worthy of emphasis, is that it is usually sufficient if the rotation can be established to the nearest decade; it is splitting hairs to figure to the exact year when computing the rotation.

Biolley in a recent treatise cautions against placing too much stress on age in considering rotations.

". . . . they persist in confusing the age and the size of trees . . . . The age or time is only one of the factors of the result sought for (and not the principal one) . . . . The other factors are: the suitable rôle for each tree . . . . and especially the "savoir-faire" of the silviculturalist, the quality of treatment by means of which he utilizes and improves these factors . . . . The result sought for can only be *production.* The age is only an accessory."

What Biolley** wants is really a flexible rotation to be modified by the silviculturalist so as to give the best possible production according to the demands of each group of trees, site, or local conditions of stand. "The Gurnaud idea........consists above all in experimenting with the treatment........" Such ideas are based on too intensive a treatment to be applicable for the United States, and it may often be unwise to give the officer in charge of a forest *too much* leeway. Regulation implies systematized control.

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* Refer to the discussion of cutting cycles in "Studies in French Forestry," already cited, pp. 226-228; also see chapter X, Part II of this volume for a more detailed discussion of cutting cycles.

** L'Aménagement des Forets par la Méthode Expérimentàle at Spècéalement La Méthode du Controle. Attinger Fréres, Paris, par H. E. Biolley, 1920, p. 15.

According to Blascheck,* in India economic conditions necessitate an annual felling area; an average tree best suited to the objects of the management; sufficiently heavy fellings to insure regeneration; and, of less importance, a felling cycle which shall be a sub-multiple of the rotation.

38. Basic Policy for Rotations. One of the chief difficulties in computing rotations (and especially *financial* rotations) is that the forester must use present statistics or the *trend* of present statistics for calculations which pretend to answer management problems on the basis of unknown or roughly approximated conditions a half century or a century hence—obviously impossible to fathom. But the proper regulation viewpoint is that the problem should be solved for the present on the basis of the best available present data with the assumption that when the working plan is systematically revised, these calculations will be recomputed and brought up to date. The fact that a revised and altered answer to the rotation problem will be certain is no reason for not doing our best with available statistics. As a matter of policy it is often safe to also estimate future conditions, based on the trend of economic conditions, rather than to follow blindly present stumpage prices, present cost values, present current interest rates and market requirements for forest products. The best regulation implies some attempt at fathoming the future. We know from past history that forest conditions will change; therefore to follow *blindly* present conditions, we will arrive at the least accurate predictions. There is a via media between following today's data on the one hand and on the other of making unwarranted guesses at the future. Moreover we must realize that our calculations are at best approximations and therefore the minutiae may often be omitted with profit and propriety. American foresters, in striving for details, are apt to lose sight of the goal.

39. Mean Rotations for an Entire Stand. The forester must (in theory) distinguish in intensive regulation (as for example in parts of New England) between the rotation for a particular stand and the rotation for a working group which is composed of a number of stands of varying quality, but in the West (in Northern Arizona for example) a rough general average rotation for portions of an entire region, will usually be a sufficiently close approximation for conditions prevalent while National Forests are being organized. Even in a selection forest such as Chamonix the French prescribe one technical rotation for Norway spruce and larch based on a rough proportion of the length of time it takes to grow the two species, and weighted according to the aggregate volume present. This rightly emphasized the futility of minute mathematical calculations for the solution of a problem which only demands an approximate answer.

40. Kinds of Rotations. The following kinds of rotations are of value in the United States and are listed in the order of extensiveness:

(1) Technical, maximum of material for a certain purpose and size.

(2) Silvicultural, based on limitations of species to reproduce or to resist decay.

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* Blascheck, A. D., "The True Selection System" (Indian Forester, 1913, pp. 427-430).

(3)   Economic, maximum average volume production gauged by culmination of mean annual growth of stands.

(4)   Financial, divided into:

a.   Maximum forest rent or highest mean annual net money income (disregarding interest).

b.   Maximum soil rent or highest returns per dollar invested (with compound interest).

41.   Definition and Discussion of Technical Rotations. *Technical rotations attempt to produce the maximum of material suitable for a certain purpose and of a given size, such as railroad ties, mine-timbers, or saw-logs.*

Technical rotations in the United States are of more than mere historical interest. A technical rotation, especially under conditions existing today in the West, might give the correct answer. Take the case of a watershed which is most suitable for producing railroad ties, because railroad ties alone could be floated down a drivable stream, the sole means of transport; here a technical rotation based on the length of time it took to grow ties of given dimensions, is clearly indicated. The exact length, in this case, would depend on the most suitable period for growing the quality of tie which yielded the largest net return on the investment, not taking into consideration compound interest charges* unless the data for financial calculations were available.

In French Government selection forests technical rotations are usually chosen so as to produce the kind of material most in demand by the public, and to support local industries vital to the economic life of the locality. This kind of rotation, under the conditions existing in the Vosges, Jura, or Alps, where large sized saw logs are required, has been severely criticised by certain German foresters because of the financial losses usually involved; but with public forests it is usually better policy to put national needs above narrow conceptions of financial gain; so it is held that for National Forests the French policy is fully justified. A somewhat broader German viewpoint, as expressed by Endres,* is as follows:

"Were we to apply the technical rotations to even-aged high forests, producing mainly large timber, great financial losses would take place. However the policy of bringing about a mixture of species in order to meet market requirements or demands is apparently correct . . . . It is in keeping with sound forestry because it also maintains soil fertility . . . . The technical rotation may also be used by the state for social and political reasons . . . . but the technical rotation can only be recognized when production costs . . . . are of no consequence to the owner."

42.   Illustrations of Technical Rotations. One of the earliest examples of technical rotations, for use on national forests, is that for western yellow pine, established in 1909. According to Woolsey,**

"If only timber of the lower grades is produced, export shipments will suffer. It is therefore particularly essential, on account of the long hauls and consequent heavy freight rates, that a fair proportion of higher grades be supplied . . . . The best rotation cannot be predicted until after regulated cutting . . . . Tentatively, a rotation of 200 years is recommended."

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* Korstian, C. F., Manuscript Report, files of Forest Service, District III.

** Woolsey, T. S., Jr., Western Yellow Pine in Arizona and New Mexico (Forest Service Bulletin 101, 1910, pp. 48-51-52).

Overmature stands of this species are from 250 to 400 years in age. At 200 years the average tree is about 21 inches in diameter and it is argued:

"All available figures indicate that it will take 200 years to grow saw timber. It will be seen . . . . that diameter growth begins to fall off at from 100 to 160 years, and that height growth declines from the mean annual from 170 years. . . . . this is certainly the minimum size (21 inches) that can be estimated to yield timber of fair quality that will justify shipment. With thrifty, well thinned stands, however, it is hoped the growth will be greater."

Obviously such a long rotation will be reduced with more intensive conditions, but even an author, such as Schlich, agrees that with extensive conditions and slow growth maximum rotations prevail. The rotation in question was preliminary in character, and merely facilitated the use of rough formulae methods of regulating the annual cut, advisable at that time, crude though they may have been. Judging from Table 19 of the Bulletin,* on the basis of maximum mean annual growth a rotation of but 70 years might have been indicated, obviously impracticable, under the conditions enumerated.

As a contrast to the preliminary technical rotation of 200 years for the production of western yellow pine saw logs, the following specific rotation problem arose on the Pecos National Forest in Northern New Mexico and is instructive:

The** rotation and cutting cycle will be adopted which will yield the product having the highest monetary stumpage value, involving a combined technical and financial rotation."

It was found that the greater the per cent of hewn ties in the final cut, the greater the stumpage value. Consequently, a rotation to produce this result was recommended and the problem was to find out from growth studies the size when western yellow pine (and other local species) produced the largest number of the most profitable sized ties. It was found that 14 and 15 inch trees were the optimum tie trees, because "trees less than 14 inches yield no square ties and no firsts." There was a wider margin of profit on the firsts than on the seconds. With this data as a basis the rotation established was the approximate number of years it takes to grow a western yellow pine tree 14 inches in diameter breast high—in this case 120 years. An average rotation was established on the basis of the dominant species, since it was considered impracticable to have separate rotation for different trees. The conclusion was also reached (as was to be expected) that "the shorter the rotation, the freer will be the forest from disease." (See also Silvicultural Rotations.)

The factor of the size and quality of boards in the determination of rotation must be considered. For example, in the case of loblolly pine, 20 to 30 years would be a sufficient rotation, if round-edged box boards are desired; 35 to 40 years if part of the product must be a fair grade lumber; and 50 to 100 years if a considerable per cent of lumber of the best grade is to be produced.***

Short technical rotations may be chosen for the production of cordwood, mine props, pulpwood, fence posts, telephone poles, box boards, and such classes of product which can be grown in less time than can large sawtimber.

43. **Definition and Discussion of Silvicultural Rotations.** *Silvicultural* rotations are based on the limitations of the species to reproduce or to resist decay.* If a species produces seed prolifically between seventy and one hundred years of age, and regeneration must be by natural means, it would be logical

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* Woolsey, T. S., Jr., Western Yellow Pine in Arizona and New Mexico (Forest Service Bulletin 101, 1910, pp. 48-51-52). This rotation of 200 years has been confirmed by recent investigations.

**Korstian, C. F., Hewn Tie Versus Saw Timber Rotations ((P. S. A. F. Vol. XI, 1916, p. 315).

*** Ashe, W. W., Forest Management of Loblolly Pine, 1914.

* Termed physical rotations by William Schlich in his Manual of Forestry, Vol. III, 1911, pp. 200-201.

to limit the rotation to within those periods. In sprout forests a silvicultural limitation to the rotation chosen would be imposed by the limit of power to sprout. In case the coppice failed to sprout after it reached an age of seventy years and the treatment had to be simple coppice, naturally the forest would suffer, if a rotation of over seventy years were chosen. In this case silvicultural factors would be an absolute bar to a longer rotation.

According to Endres*

"Some believe it to mean the rotation which would leave the stand with complete reproduction.** With high forest (that time) was when the seed production was largest and when the soil was most receptive. With coppice it was within the sprouting limits of the stumps . . . . Others believed the rotation to mean the time when the stand is silviculturally mature or when the growth stopped."

As a matter of fact if the rotation is an economic or financial one this factor of loss from rot will usually be eliminated because any intensive rotation (economic or financial) will fall before rot is a menace. The danger from rot, however, must be carefully considered when high quality saw timber is grown under a technical rotation or where the rotation is lengthened in protection forests.

There is also the limit placed by decay, but strictly silvicultural rotations are of little real*** importance unless considered in connection with other kinds of rotations. Silvical requirements for reproduction or to avoid decay or other losses must perforce limit all rotations but rarely are the sole determining factor.

44. **Illustrations of Silvicultural Rotation Limits.** As Meineike* points out:

"If a species such as white fir shows an increasing amount of defect after eighty years, a rotation should certainly not be chosen that would necessitate holding stands beyond this period; to do so would court unnecessary loss through decay."

This factor of rot will be found to set a limit to the feasible rotation for other species. With western yellow pine Long** found,

"that during the blackjack period (up to 180 years) the trees are practically free from this rot" (western red-rot) . . . . "while trees over 200 years old show a much higher percentage of rot than the younger trees (blackjack) . . . . It is a fundamental fact that the older a tree is, the more liable it is to be attacked by heart-rotting fungi."

The following table by Zon*** furnishes another excellent illustration of a combined technical and silvicultural rotation:

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* Endres, p. 244.

** Roth, Filibert, in his Forest Regulation terms this a *physical* rotation. He also mentions a natural rotation which "is the natural life of the species, which hardly deserves separate nomenclature or description."

*** Recknagel, A. B., in The Theory and Practice of Working Plans, 1913, New York, pp. 39-40, mentions also a latent rotation which hardly deserves the term rotation; he defines it as "just double the average age of the working figure" (working group).

* Meineike, E. P., "Forest Pathology and Forest Regulation" (Forest Service Bulletin 275, 1916).

** Long, W. H., A Preliminary Report on the Occurrence of Western Red-Rot in Pines Ponderosa (Plant Industry Bulletin 490, 1917, pp. 7-8). The term pathological rotation seems superfluous.

*** Zon, R., "Chestnut in Southern Maryland" (Forest Service Bulletin No. 53, 1904. p. 31).

Kind of product	Trees from seed (age years)	Coppice (age years)
Post	27	14
Tie	41	29
Pole	49	38
Rail	54	43

According to Zon,

"Chestnut (sprout) is not suited to the production of large timber on account of its unsoundness and short clear length when it has reached the desired size. Therefore even if large timber is desirable, chestnut should not stand longer than seventy to eighty years, and coppice will then fill requirements better. Only in exceptional cases, ... should chestnut be left standing ninety years or more."

According to the above table, if the main product is chestnut ties, the rotation, for trees grown from seed, must be at least forty years; but if coppice, only thirty years.

With sprout reproduction, as has been explained, the forester cannot delay cutting until the sprouts are no longer vigorous. Therefore, mean maximum ages can be established, beyond which it would be dangerous to hold sprout stands. For chestnut (prior to the chestnut blight) this maximum age was approximately 75 years; for chestnut oak, 45; for other oaks, 25 to 35 years. As to choice of material, whether cord wood, lumber, ties or poles, it is simply a local problem which must be worked out according to the conditions of haul and stumpage prices. According to the growth studies made by Frothingham,* the average annual growth culminated for chestnut on sites 1 and 2 at 35 years; on site 3, at 40 years; for chestnut oak on sites 3, at 40 years. The general conclusion was reached that for ordinary hard wood sprouts in Connecticut a rotation from 30 to 40 years was advisable, but that (prior to the chestnut blight) chestnut sprouts may be held up to 75 years if lumber is to be produced. This shows the correct application of this technical phase (in connection with other factors) before the decision is reached as to the rotation period.

45. Definition and Discussion of Economic or Quantitative Rotations. *Economic (or quantitative) rotations attempt to secure the maximum average volume production per acre and are based on the culmination of the mean annual growth read from yield tables, and not on the maximum growth of individual trees.*

The point in the yield table, where the mean annual growth** culminates, indicates the economic rotation. This point is readily determined after it has once been established what part of the tree is to be included as volume. Expressed as a simple formula it is as follows: *Final yield + intermediate yield ÷ number of years.* In the United States when the board foot unit is used this culmination of mean annual growth will vary, (1) according to the log rule used, (2) depending on the utilization standards, especially as regards top cutting limits, and (3) according to the class of material which is included in the computations of volume. Because of these complications it is desirable when practicable to use other units, such as the cubic foot.

(1) *Effect of Log Rule.* With a log rule which gives large volumes for small sized trees, the tendency would be to shorten the rotation because with such a rule the mean annual growth would culminate earlier. With a rule

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* Frothingham, E. H., Second Growth Hard Woods in Connecticut (Forest Service Bulletin, 1912, p. 45).

** See Forest Mensuration, H. H. Chapman, for the curves of current annual and mean annual growth.

that put proportionately small values on small logs and too generous volumes on large logs, the culmination (other factors being equal) of mean annual growth would be retarded and consequently the rotation would be lengthened.

(2) *Utilization Standards.* The smaller the top cutting limit, the shorter would be the indicated economic rotation because with a larger top cutting limit a longer time must elapse before an appreciable proportion of the tree is merchantable.

(3) *Class of Product.* If small sized ties are the most desired product, it clearly follows from (2) that the economic rotation will always be shorter than if a larger class of product must be marketed. The culmination of the mean annual growth of small ties (even if expressed in the common factor of board feet) will be earlier than if the culmination in *board feet* is computed on the basis of saw logs. This is a phase which is also present in technical rotations.

According to Munger,*

"It is the policy of the Federal Government to administer the public forest lands in such a way as to perpetuate as forest all the land which is better suited to the production of timber than anything else, and to make it yield for all time the greatest quantity and the best quality of timber."

46. Choice of Economic Rotation with Illustrations. The most satisfactory basis for a choice of economic rotation is the total production of material according to a specified unit of product, such as board feet, for a specified size of sawtimber, cubic feet (or cords) for pulp wood, linear feet of converter poles with a top limit specified, or cords of fuel. Where, as usually happens, the product from the ripe tree must be in three classes, such as board feet, ties and cordwood, the gauge of quantity must be expressed in a common unit which can serve as a basis for the comparison of the standard volume at different ages; otherwise three different quantitative rotations might be indicated, which is impracticable because three classes of product are derived from one and the same tree. In such a case often the most logical procedure is simply to adopt a financial rotation (see Chapter V) since then the common unit of comparison will be the dollar. Endres shows that the culmination of the mean annual growth is earliest on the richest soils and it is well to bear in mind that,

"The rotations on the better sites are often shorter than financial rotations for unthinned high forests where the market conditions are bad."

According to European yield tables** the economic rotations are approximately as follows:

Soil quality	Pine (Schwappach)	Spruce (Baur)	Fir (Schuberg)	Beech (Schuberg)
	—Age in years when mean annual growth culminates—			
I	35	50	55	70–75
II	40–45	60–70	60–65*	80–85
III	50–60	70–80	70–75	85–95
IV	75–80	60–80	85–90	95–100
V	.....	.....	95–105	100–110

* Munger, Thornton T., Western Yellow Pine in Oregon (Forest Service Bulletin, 418, 1917, p. 36).

** Endres, p. 245.

The above figures, however, only serve to illustrate that the rotation which produces the largest amount of wood is not necessarily the best, except perhaps in localities in which coal is scarce and transportation very poor. As Endres puts it,

"In the present age of commercialism, it is no longer a case of the greatest volume but of the highest money return for the best product that is the controlling factor in fixing the rotation."

Whether this will apply to American conditions is a question. If there is a national timber shortage, it would be easy to justify rotations that would produce the greatest quantity of product required by the nation.

Illustrations of economic rotations. The Forest Service (District I) determined that

"The maximum yield for (western) white pine under average conditions occurs at 120 years and the rotation has been fixed accordingly. In the case of lodgepole pine, however, another consideration enters into the problem. It has been determined that at the age of growth culmination the trees are too small to supply the local demand. Hence, a longer rotation than indicated upon a straight yield basis has been established."

This determination of the rotation of lodgepole pine is of interest because the rotation could not be established solely on the basis of maximum mean annual growth, since at that time sufficient merchantable material would not be produced. The objects of management in this case were not only watershed protection but also a maximum sustained yield for merchantable timber of the *most desirable sizes.* According to Mason*

"The length of the rotation . . . . is determined by the rate of growth . . . . and the purpose for which the wood is to be used. Because of the slow growth of lodgepole pine and the necessity of raising large sized ties, a longer rotation must be chosen than would be indicated by the culmination of mean annual growth at 70 to 90 years on different soil qualities. A rotation of this length, however, gives few trees 9 inches or more in diameter and is, therefore, too short."

If the material was cut to 6 inches in the top, the board foot mean annual growth culminated at 130 years, while if cut to 8 inches in the top, the culmination is delayed to from 200 to 210 years. At 130 years only ⅔ of the material produced is 8 inches or more in diameter at the top end, while at 200 years nearly 9/10 of the material produced is merchantable. The author therefore concludes that,

"The mean annual growth in board feet to a 6 inch top is nearly at its maximum at 140 years, when 53 per cent of the scale material is 8 inches or more in top diameter . . . . . Such a rotation is the best for normally stocked lodgepole stands on average sites in Montana."

This is a sound method of analysis, but with thinnings the limitation as to size would probably be largely done away with because there would be fewer trees but with a larger size in the top. There is no objection to basing the economic rotation on the culmination of mean annual growth taking into account *only trees of the most desirable size.*

In a quality I second growth white pine** stand, at 55 years of age the mean annual growth is 1000 board feet; at 60 years it has risen to 1003 board feet and at 65 it is 1002. In this case the quantitative rotation for first quality soil would be sixty years if based on the board foot yield. For the same quality of soil in this table, but for cubic feet, it will be noted that the culmination is at fifty-five years. A still different culmination of mean annual growth would have occurred if the board feet had been computed by a different log rule or with different cutting limits in the type or different standards of utilization. It is therefore evident that in determining a quantitative rota-

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* Mason, D. T., Utilization and Management of Lodgepole Pine in the Rock Mountains (Forest Service Bulletin 234, 1915, 22-3. Special reference is made to table 12, p. 22).

** Reference is made to table 7, page 24, in White Pine Under Forest Management, by E. H. Frothingham (Forest Service Bulletin 13, 1914).

tion it is necessary to give the exact data upon which it is based. Quantitative rotations are never based upon current growth.

According to the Forest Service (District 6),

"In the Douglas fir region we are now operating on a tentative rotation of 100 years. Our overstock, however, is so large that we are not very vitally concerned at present with the length of rotation . . . . In the yellow pine region we have assumed a rotation of 180 years with a cutting cycle of 60 . . . . Until we have more specific data as to the rate of growth after cuttings (making allowance for increased growth, normal loss, etc.) and know more about the silviculturally most desirable method of cutting, I don't see how we can arrive at the ideal rotation and cutting cycle."

Hawley's* conclusions (basis not given but probably economic) as to the proper rotations for intensive forestry around New Haven were as follows:

Hardwood type	60–80 years
Hemlock type	80–100 years
Pine type	50 years

These conclusions are obviously tentative.

According to Chapman's investigations** Ashley County, Arkansas, the shortleaf pine cut on an economic rotation should be grown in 100 to 110 years; probably in the majority of cases the rotation indicated by this local study will be less rather than more.

No mention was made by*** Graves of rotation, but after showing that trees were merchantable for pulp down to five or six inches inside bark on the stump, he analysed the diameter limit of cutting. He showed that if spruce trees were cut to six inches there would be 75 years between cuts of equal size; if to 8 inches, 50 years; while if cut to 10, 12 or a 14 inch limit, there would be a correspondingly shorter interval between equal cuts. He selected 10 inches in this case as the diameter limit because

"The owners wished to obtain the greatest possible immediate return without seriously impairing the productive capacity of the forest and are willing to wait for a longer period for a second cut."

Such a diameter limit corresponds roughly to a rotation of 165 years. This has the character of an economic rotation, but the fallacy and danger of using any diameter limit in irregular stands must be recognized.

The Norway pine mean annual growth culminated at 130 years, curiously enough on all sites. This is probably due to errors in growth data since ordinarily the poorer the soil the later the* culmination of mean annual growth and hence the longer the economic rotation.

According to Mattoon,** rotations depend largely on (1) The age when the mean annual growth is greatest, (2) The kind of material desired, and (3) The total cost of producing the material.

Such a conception involves an economic rotation, a technical rotation and a financial rotation, but this same writer concluded that the most reliable basis is the time when the mean annual production is greatest (i.e., economic rotation). For short leaf pine Mattoon concluded that the economic rotation for site II stands in North Carolina

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* Hawley, Ralph C., A Working Plan for the Woodlands of the New Haven Water Company (Yale Forest School Bulletin 3, 1913, p. 25).

** Chapman, H. H., Prolonging the Cut of Southern Pine (Yale School of Forestry, Bulletin 2, 1913, p. 8).

*** Graves, H. S., Practical Forestry in the Adirondacks (Bureau of Forestry, Bulletin 1899, p. 64).

* Woolsey, T. S, Jr., and Chapman, H. H., Norway Pine in the Lake States (Forest Service Bulletin 139, 1914, p. 26).

** Mattoon, W. R., Short Leaf Pine, Its Economical Importance, and Forest Management (Forest Service Bulletin 308, 1915, p. 32).

was 90 years; for sites in Arkansas, 100 years, but for New Jersey, 45 to 50 years. This is for sawtimber. If the mean annual growth culmination is based on total volume, without consideration of size, then the culmination comes 20 to 30 years earlier than when sawtimber must be produced; on site I, at 50 to 60 years, on site II, at 60 to 75 years, on site III, at 85 years. These rotations would be decreased by 15 to 30 years, with early and frequent thinnings. The specific rotation recommended for conditions on the Arkansas National Forest, where the aim was "to produce the sort of material most needed by the people, which is mostly medium sized sawtimber," is 90 years, which will produce an average tree of 15.9 diameter containing 240 board feet.

47. Quiz. What is a rotation?

Explain cutting cycle.

What affects the length of rotation?

Should the rotation be based on present statistics or on possible future changes?

Discuss intensive and extensive rotations.

Define technical, silvicultural, economic rotations.

What kinds of financial rotations are there? (see chapter V).

How do economic rotations differ from those based on the forest rent theory?

Illustrate when technical rotations are advisable.

Is this kind of rotation best suited to public or private management?

Why do technical rotations sometimes entail financial losses?

Is it safe to base the decision as to the length of rotation purely on technical grounds?

Illustrate a silvicultural rotation?

Is this a safe basis upon which to base a rotation?

How are economic rotations established.

How is it affected by log rule, utilization or class of material harvested?

Would an economic rotation for pulpwood closely agree with the best financial rotation (forest rent)? financial rotation (soil rent)? (see chapter V).

Discuss and comment upon the economic rotations for various species and show how these will be modified in the future.

CHAPTER V

FINANCIAL ROTATIONS

48. Definition of Financial Rotations and Related Subjects. Before defining financial rotations let us repeat the definition for forest rent and soil rent.

Forest rent is the net income from a forest organized for sustained yield without interest charges on the forest capital,—bookkeeper's·balance,—the forest, i.e., soil with a stand or growing stock, being conceived as the forest capital, and the rent as the total interest earned thereon. (G., Waldrente.)

Soil rent is that part of the income (or balance) from a managed forest which remains as interest on the soil capital alone after all expenses with compound interest have been deducted, the soil alone being conceived as the capital. (G., Bodenrente.)

Our definition then is:

Financial rotations aim at securing the highest monetary return. This rotation will vary depending on whether the return is figured on the basis of forest rent or soil rent.

*Financial rotations introduce considerations of cost and attempt at securing either the maximum forest rent or maximum soil rent. The maximum forest rent rotation is that which yields the highest net mean annual net money return without compound interest; the maximum soil rent rotation is that which yields the highest return (at compound interest) per dollar invested.**

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* Before discussing financial rotations let us bear in mind the definitions for capital and value in their various phases (As explained in the preface, the terms and definitions follow the form adopted by the S. of A. F., see J. of F., Vol. XV, 1917, pp. 68-101):

This factor of production in the forestry business is variously figured according to what parts of the investment are referred to and what basis of valuation is applied.

Fixed capital refers to such kinds of capital as are not used up in production, like the soil.

Working or operating capital refers to money capital needed to supply current expenses in operating a forest.

Soil capital refers to the value of the soil figured in various ways.

Stock capital refers to the value represented by the wood material of all stands comprising a forest or working circle.

Forest capital refers to soil capital and stock capital combined.

Base capital may be used following the precedent of Pressler in his index per cent for the combined soil and working capital.

The capitals may be based upon various kinds of values, and to secure a definite meaning, the term must be qualified by the method by which its value was determined.

The following values may be differentiated:

Investment value—the purchase price or the actual expenditures or investments that have been made in acquiring or creating the property with interest, less incomes actually derived from it. with interest. (G., kostenwert).

Sale or exchange value—the market price based on statistics of actual sales: a special kind of sale value is the forced sale or wrecking value that can be obtained by exploitation of saleable parts (see stumpage value) (G., verkaufswert; F., valeur venale).

49. (A) Rotations for Maximum Forest Rent or Highest Mean Annual Net Money Return. This form of rotation is exactly similar to the economic (or quantitative) rotation except that the yield unit is expressed in money with the costs of operation deducted—a common standard of comparison. The cost of establishing the stand is deducted so that the net mean annual per acre income can be figured for each decade. The decade with the largest mean annual return is the forest rent rotation indicated. This is a more intensive form of rotation than the economic (or quantitative) already described but less intensive than a financial rotation based on the soil rent theory described later, where the costs are figured at a definite rate of compound interest and all costs and returns discounted to a definite date so as to have a uniform basis for comparison.

The forest rent formula is as follows:

$$\frac{\text{(Final and intermediate returns)} - \text{(expenditures)}}{\text{number of years}}, \text{ or using the terms listed,}$$

$$\frac{(F\$ + I\$) - (C\$ + A_1\$)}{N}.$$

50. Illustrations of Maximum Forest Rent. As yet there are few examples in American forestry of rotations for the highest mean annual net money return. The following table is from Endres*:

TABLE 2. Synopsis of gross returns, expenditures, and mean annual net returns in dollars per acre for a fully stocked quality III spruce stand.

Rotation years	Gross Returns			Expenditures			Net Returns	Current annual returns	Mean annual returns
	Final	Intermediate	Total	Planting	Administration	Total			
30	$ 48.30	$ —.—	$ 48.30	$8.00	$18.00	$26.00	$ 22.30	$ 5.89	$0.74
40	109.10	4.10	113.20	8.00	24.00	32.00	81.20	8.12	2.03
50	188.00	12.40	203.40	8.00	30.00	38.00	162.40	7.78	3.25
60	259.00	25.20	284.20	8.00	36.00	44.00	240.20	9.31	4.00
70	345.30	38.00	383.30	8.00	42.00	50.00	333.30	11.27	4.76
80	451.00	51.00	502.00	8.00	48.00	56.00	446.00	11.08	5.58
90	554.20	64.60	618.80	8.00	54.00	62.00	556.80	11.19	6.19
100	666.20	77.80	744.00	8.00	60.00	68.00	676.00	9.82	6.76
110	759.40	88.80	848.20	8.00	66.00	74.00	774.20	6.58	7.04
120	821.80	98.20	920.00	8.00	72.00	80.00	840.00		7.00

In the preceding table the maximum forest rent (*mean annual*) falls at 110 years when it amounts to $7.04 per acre per year. The maximum *current* income comes between 90 and 100 years.

Stock or stumpage value—based on sale value of material ready for immediate utilization (Synonym, utilization value) (G., nutzungswert).

Expectancy value—the present worth of all estimated or expected future net earnings (discounted to the present); the capitalized net income value (G., erwartungswert; F., valeur d'attente).

Rent or yield value—a value, determined by capitalizing, with a demanded rate of interest, the yearly or intermittent net return possible to be derived from a managed property. (See forest rent and soil rent) (G., bodenrentierungswert, waldrentierungswert).

* This table was taken from Endres, Lehrbuch der Waldwertrechnung und Forststative, page 233. Marks per hectare were reduced to dollars per acre by dividing by 10. The yield was calculated for spruce, quality 3. This table has been used in slightly different form by other American writers.

Endres* gives another method of figuring what he terms "value increase per cent which is virtually growth per cent expressed in money with expenditures deducted. His calculations are as follows:

$$\text{Value per cent at 110 years} = \frac{100}{110}\left(1 + \frac{\$88.80 - \$8.00}{\$759.40}\right) = 1.006\%$$

$$\text{Value per cent at 100 years} = \frac{100}{100}\left(1 + \frac{\$77.80 - \$8.00}{\$666.20}\right) = 1.105\%$$

"The stand is therefore not ready for cutting because 1.105 is greater than 1.006," as held by the above mentioned author.

$$\text{Value per cent at 120 years} = \frac{100}{120}\left(1 + \frac{\$98.20 - \$8.00}{\$821.80}\right) = .925\%. \quad \text{Here,}$$

"The stand has passed the cutting period because .925 is less than 1.006."

This formula may be expressed as follows:

$$\text{Value per cent} = \frac{100}{\text{rotation}}\left(1 + \frac{\text{Intermediate yields} - \text{planting costs}}{\text{final yield}}\right)$$

This is a formula of technical interest but its use would not be necessary because the rotation is more readily determined by a direct computation of the net mean annual returns for different rotations. Where true per cents are calculated, other factors must enter in.

51. Distinction Between Forest Rent and Soil Rent with Illustrations.
The distinction between forest rent and soil rent rests on the difference between income per acre without interest and income per dollar invested with compound interest. This difference is thus discussed by Endres:

"The manner in which interest accumulates is shown in the following table, figured on a beech high forest (with interest at only 2%):

Rotations	30	40	50	60	70	80	90	100	110	120 years
Forest rent	$0.74	2.03	3.25	4.00	4.76	5.58	6.19	6.76	7.04	7.00
Soil rent	$0.23	1.00	1.56	1.75	1.89	1.98	1.95	1.88	1.71	1.47
Interest on capital	$0.51	1.03	1.69	2.25	2.88	3.60	4.24	4.88	5.33	5.53

"In a beech high forest the largest mean annual forest rent per acre gave a total of $7.04 at a rotation of 110 years. When 2% interest is used then the total of the soil rent (value) in the same year is $85.50, making the annual soil rent $85.50 × 0.02 = $1.71. This equals,

(110 years)
soil rent	$1.71
interest on the accumulated wood capital	5.33
Total	$7.04

The largest soil rent value is figured for a 80-year rotation with $98.80. The mean annual forest rent for the same rotation carries annually $5.58 per acre. This gives,

(80 years)
$98.80 × 0.02	$1.98
interest on the accumulated wood capital	$3.60
Total	$5.58

"*The true "rent" which is possible through the managing of the forest income, lies in soil rent, which is determined by adhering to the rotation of the highest forest rent. The difference between soil rent and forest rent, i. e. the interest on the accumulated wood capital, is nothing more than an expenditure which is necessary to make in producing the soil rent.* The forester has to subtract this from the forest earnings, or, commercially speaking, to equalize expenses incurred on accumulating debts.

"In our example the forester has a yearly income of $7.04 per acre by adhering to a 110-year rotation. If he figures correctly, he will subtract $5.33 as costs of the enterprise and he will actually net only $1.71 (soil rent). By adhering to the financial rotation he earns an average of $5.58 per acre. The expenses demand only $3.60; so he nets $1.98.

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* Endres, p. 234. Since no comprehensive original work has been done in the U. S. on soil rent calculations, it was thought best to give a translation of the best German treatise on the subject.

"The greater profit which the 110-year rotation has over the 80-year rotation is only an *ostensible one.* In reality the 80-year rotation brings the forester a greater *net profit* ($1.98 — $1.71 = $.27) per acre over the 110-year rotation.

"*The yearly loss,* which the forester suffers through the shorter rotation . . . . is equal to the gain between soil rent and forest rent.

"In consequence of the previous facts, it is evident that the *highest income in connection with area is made* in managing for forest rent.

"This is true when we consider forest rent as a clear profit. In reality this is not the case. The greatest part of the forest rent is made up of interest on stored-up wood capital that becomes larger, the longer the timber remains in the woods, i.e., the longer the rotation. This interest, as mentioned before, is no gain to the forester but is enterprise expense or debt that has to be met out of the forest rent.

"In 'Handbook of State Investigations,' III Vol., p. 602, the following explanation is given of managing for forest rent: 'The followers of this idea figure the forest as a box out of which we can take, periodically, a sum of money called rent. How much this will require for expenses causes no worry.' The remarks by Bose, Urich and Baur against this, given in 'Centralblatt,' 1893, are of scientific interest.

"The forest rent thus comes at 110 and the highest soil rent at 80.

"We can also say that by changing the rotations which brought the highest forest rent we change conditions (that existed since the primeval world) since the forest has always been handled under this rotation. The forest owner, whether private or state, will necessarily suffer a clear loss. This is also true in a spruce forest with a working group of 110 acres; using a 110-year rotation will give a forest rent of $7.038 × 110 = $774.20; using a rotation of 80 years gives a yearly forest rent of $5.58 × 110 = $613.25. The net gain in yearly forest rent amounts to $774.20 — $613.25 = $160.95. This gain however (if we consider soil rent) will be more than used up by the interest earned on the stored capital, that had been liberated due to an earlier rotation. This carries $5.33 capital at interest per acre for the 110-year rotation, as follows:

$$\frac{\$5.33}{\$0.02} \times 110 = \$29,315;$$

and for the 80-year rotation,

$$\frac{\$3.60}{\$0.02} \times 110 = \$19,794.50,$$

the excess ($29,305 — $19,794.50) being $9,510.50. The owner has this $9,510.50 as specie (gold coin) drawn out of the forest and can put it in the bank at interest. Should he get only 2% interest, he earns a yearly rent of,

$$\$9,510.50 \times 0.02 = \$190.21,$$

which amount easily makes up the forest rent gain. The actual yearly income gained through shortening the rotation is shown as follows:

80-year rotation, $613.25 + $190.21 = $803.46
110-year rotation, $774.46

Clear gain from 80-year rotation $29.26

Should the forester receive a 3% interest rate on the liberated capital (this rate being quite possible), it will give an interest gain of,

$$\$9,510.50 \times 0.03 = \$285.31$$

and thus the clear yearly gain will be,

$$(\$613.25 + \$285.31) — \$774.20 = \$124.36.$$

Now from the practical side a rotation cannot be changed so quickly in spite of the pecuniary gain on the liberated capital. Besides overstocking the local market, which may be of some importance, we also upset the normal handling and normal conditions of the stand. It is necessary (for such an undertaking) to formulate a definite working basis and allow time for the complete use of the liberated stock (timber). A primary consideration is the proper investment of the drawn out capital. If there is danger of not properly disposing of the capital, then it had better remain in the forest in spite of the fact that it earns no interest . . . .

The fundamental principles of the Forest Rent Management as compared to Soil Rent Management are:

"(a) The forest rent theory is determined by the rotation as based on the area. The fundamental difference between the methods of rotation lies in the fact that the soil rent management discounts the intermediate earnings and costs to a definite period with compound interest, while the forest rent management simply adds and subtracts without considering compound interest . . . .

"(b) The forest rent management . . . . is built up on future earnings and costs. If we want to determine the time the forest rent culminates in a 30-year-old stand, we have to consider the earnings and the costs that are expected to take place at 80 to 110 years, therewith figuring the rotation of the greatest forest rent.

"Therefore the belief that the forest rent theory fixes with more* certainty the rota-

* When the forest becomes a "going concern" the opponents of the soil rent theory

tion period than does the financial (soil rent) rotation is fallacious and the adherers to this belief are misled.

"(c)   The rise and fall in earnings and expenses due to price changes has a pronounced influence on the rotation period.

"An increase in operating costs and rise in stumpage value lengthens the forest rent rotation and vice versa. *An increase of thinnings shortens* rotations, whereas a lessening of thinnings lengthens them. (Read, Loreh's, Handbuch der Forstwissenschft, II, p. 91.)

"It is noticeable that a change in price level has more influence here than in the soil rent theory . . . .   A very small price increase ($0.31) lengthened the rotation from 110 to 120 years.

"(d)   The flexibility of the rotation period with change in price level carries with it the strict adherence to the principle that any excess or defective growth should be disposed of.

"From this viewpoint the rotation of greatest forest rent has no advantage over the soil rent rotation.   The advocates of the forest rent theory put it as a matter of fact that in the state forest operations the shortening of the rotations is done on the principle of highest forest rent.   This assumption is ill founded.   In actual practice the rotation of the highest forest rent is much higher than is usually accepted.

"It is pointed out that Weber argues correctly when he shows that practical considerations must have weight in the choice of the rotation.   Besides one must take into account, the growth of the final stands, the yield from periodic thinnings, average price per cubic meter, relative profit from different species, intermediate costs, cost of administration and supervision, and state and municipal taxes."

Kirkland* argues that if all age classes are present in a forest, it is not necessary to use compound interest in determining profit because,

"Since we are determining the current annual results year by year, compound interest is not involved.   In other words we are working on a forest rent basis; i.e., what will the forest earn each year on the investment?   Particular emphasis should be laid on the fact that today we have large forests, and that any effective forestry work we do must be with these forests.   Therefore, we can best work on the forest rent basis.   Any forestry we do on bare tracts will be insignificant."

This viewpoint does not agree with the best European mathematical theory as has been seen by Endres's discussion of the relationship between forest rent and soil rent.   With the present widespread forest destruction in the United States it would appear that we must deal with bare soil.   For a more complete discussion of the subject see books on valuation.   It should be emphasized however, that in the United States soil rent rotations will usually be rejected for silvicultural and policy reasons and not because soil rent is poor mathematics.

The idea that financial rotations can be based on the growth per cent of single trees has not gained credence in America.   Few would agree that yellow poplar** "can be considered mature financially when their annual rate of increase in value becomes equal to the correct rate of interest on money." No definite number of years is mentioned as the rotation, but instead maximum diameters according to different costs of operation-and different sites.

52.   (B)   **Rotations for Maximum Soil Rent or Highest Returns Per Dollar Invested.**   Here the criterion of profit is the maximum revenue with expenses deducted, but all statistics must be carried at compound interest at an estimated rate.   The customary method of computation is to figure the expectation values for different ages;   the largest expectation value

have more plausible arguments, but as a matter of fact if the forest devastation continues in the United States there will be few forests that are "going concerns."

* Kirkland, Burt P., Continuous Forest Production of Privately Owned Timberlands as a Solution of the Economic Difficulties of the Lumber Industry.   (Journal of Forestry, Vol. XV, 1917, pp. 41-42.)

** Ashe, W. W., Yellow Poplar in Tennessee, 1913, p. 36.

denotes the most profitable rotation or the rotation of maximum soil rent. The following is a complete formula for expectancy or soil value:

Expectancy or Soil Value (see table of symbols) $= \dfrac{F\$ - C\$}{1 \cdot op^n - 1} - (C\$ + AE\$)$

For further details see § 116, page 92 of Forest Valuation by H. H. Chapman.
According to Schlich,*

"The expectancy value indicates the true economic value of the soil for forest culture because it is based upon the productive power of the land when used for the rearing of forest crops."

For practical purposes, if only the rotation is to be determined (and not the actual soil value), the following formula is sufficiently accurate:

$$\text{Expectancy value} = \frac{\text{final yield} + \text{intermediate yields}}{1 \cdot op^n - 1}$$

The reason why this formula is a judicious approximation is that annual expense has no real influence on expectancy value, the cost of formation and soil value almost none, and the yield from thinnings very little. There are two very important factors, namely, (a) rate of interest and (b) final yield.

53. (a) **What Rate of Interest Should Be Used?** The rate of interest is the most important problem and has been made more confusing by the world inflation incident to the Great War. Low interest rates mean longer financial rotations than do high rates. Schlich** shows that (for a Scotch pine forest) if the interest rate was $2\frac{1}{2}\%$ (the rate often chosen for calculations in England), there would be an indicated rotation of 80 years. Increase this rate to 3% and the rotation (based on the expectancy value) would be 70, and if 4%, only 60 years.

Most European authors agree in the theory that a forest which yields permanently the highest net annual income (with interest) is the greatest benefit to mankind, other things being equal. On the other hand, there is a tendency on the part of the individual (and still more so if the state is owner) to forget past interest expense, if by holding a stand to a longer rotation, the gross or apparent net yield per acre is increased. Only when past expenditures constitute an obligation which must be met, and hence earned, will the true financial relation between cost and income (with interest compounded) be the determining factor in the rotation.

As a matter of fact no one would argue that the state should take financial profit as its sole object in forest management, but it is usually admitted that the public welfare *may* be best served by giving proper consideration to value production along with a regard for the obligation to raise the largest amount of product most keenly needed by the locality. The public forests belong to the whole nation and the object of a financial rotation should be the highest possible production of material both for present and *future* generations. One of the main drawbacks to a narrow conception of the necessity of following blindly a short soil rent rotation (untempered by sound silviculture) is that future production might be impaired.

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* Schlich, Vol. III, pp. 127-129.
** Vol. III, pp. 127-29.

According to Roth,*

(1) The "normal" forest of central Europe in ordinary rotations yields two to three per cent on the sale value of the forest.

(2) This per cent is independent of site.

(3) Beech and oak exceed pine and spruce (in rate of interest) on one hundred and twenty-year rotations, because the growing stock is a less important part of the capital.

(4) The rate varies in narrow limits for all reasonable rotations and is little affected by current expenses.

(5) The rate does not materially vary with changes in stumpage value because capital and income are affected in like manner.

(6) Extensive forestry with small expenses and small incomes yields practically as good a per cent as intensive forestry.

(7) It is very doubtful if any business rate over four per cent should be used in forest investments (pre-war conditions).

According to the figures cited by Roth, the per cent yielded by pine, spruce, oak, and beech, under ordinary rotations on four different sites of soil, is shown in the following table:

TABLE 3. Rate of Interest Earned in European Forestry.

Site Class	Pine	Spruce	Oak	Beech	Oak—160-year rotation
I	2.2	2.5	3.6	2.9	2.2
II	2.1	2.6	3.	2.9	2.1
III	2.	2.6	3.3	3.1	2.1
IV	2.	2.7	..	3.	..

It is clear that the quality of the soil does not materially affect the rate of interest earned. The inference that may be drawn from these figures is that the rate used for compound interest calculations should be from 2 to 3%, but there must be periods, such as during 1914 to say 1930, when such rates appear low. But most calculations lead to false conclusions if high rates of interest are employed; any rate over 3½% is doubtful. The length of the rotation is the crucial point.

54. (b) **What is Influence of Final Yield?** The final yield is next in importance. Quality increment of course increases the value of the final yield and hence lengthens the financial rotation.

Because of the lack of yield data and reliable stock figures and statistics upon which to base calculations, the tendency (in American Forest Regulation) has of necessity been to ignore the need for computing financial rotations. For this reason a synopsis of what Endres says on the subject of financial rotations is given (in fine print, appendix A (b)).

* Roth, F., "Business Rate of Interest and Rate Made by the Forest." (Forestry Quarterly, Vol. 14, 1916, page 258.)

55. Illustrations of American Attempts at Calculating Maximum Soil Rent Rotations. One of the earliest intelligent discussions of rotation (with a financial viewpoint) found in American forest literature is by Allen in the western hemlock.*

In reply to the question, "At what age can the second growth stand be most profitably logged and how can the forest be perpetuated?" he showed that small size material "may be cut in 40 years and that in 50 years logs will be produced which would be considered a fair size in the East today." Analyzing the mean annual growth, Allen says that at 50 years 40 board feet per acre per year could be produced; at 60 years, 366 board feet; at 70 years, 471; and at 80 years, 500; i.e., the *economic rotation* already discussed. His conclusion was that "it appears, therefore, that the greatest production of wood can be secured by cutting second growth hemlock when it is about 80 years old." He admitted that other points should weigh in forming a correct conclusion, such as natural regeneration, quality of material and net financial profit. He stated that "the rotation of greatest financial profit still remains to be reckoned . . . . the calculation can only be tentative." but he concludes that 70 years is the most profitable financial rotation and that with $1.00 stumpage per thousand feet, the investment would yield 4½% compound interest yet we must be cautious of advising too short rotations, for building timber is what the world needs.

In an early state** report the conclusion was reached that,

"Whenever this interest (in the financial yield table) falls below the rate which may be earned by the money into which the timber can be converted, the forest should be cut."

The authors conclude that the lower the rate used in the calculation of compound interest, the longer the timber may be left standing. With 4% interest and no quality increase, the time to cut any stand would be hastened ten years. This table, however, simply indicates the maximum age at which cutting should take place and does not determine the exact time to cut, because to answer the second question, we must know the items entering into the cost of production. With compound interest at 4% it was found that for white pine in New Hampshire the net profit would be the greatest between 50 and 60 years of age—with land valued at $5.00, cost of planting at $7.00, protection at 10 cents per acre per year, and current local tax rates on the timber and on the land. In addition to paying 4% on the money with a rotation of 55 years there would be a surplus of $71.26, or an additional profit of $1.29 per acre per year.

Frothingham's conclusions in regard to white pine rotations agree in the main with those (of the New Hampshire report) cited above, and he also agrees that the lower the interest rate, the later the financial maturity will occur. With 4% interest the owner can afford to hold the stand until it is 50 years old. If 6% interest is charged, the rotation must be reduced to from 40 to 50 years or a loss will ensue. He is correct in concluding that financial maturity does not coincide with volume maturity, because the mean annual growth in board feet culminated on site (I), at 60 years of age; on site (II), at 75 years; on site (III), at 90 years. As Frothingham points out, seed years occur every 3 to 7 years, and if the stand is to be reproduced by natural means, it must be cut during a seed year. Therefore, it could rarely be cut precisely when financially mature***; this only serves to illustrate that rotation should be gauged by decades rather than by individual years, and that the final decision must be based on a number of considerations.

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*Allen, E. T., Western Hemlock (Bureau of Forestry Bulletin 1902, pp. 44-48).

** Forestry Commission of New Hampshire, 1905-06, p. 240. Reference is made to table 21.

*** Frothingham, E. H., White Pine under Forest Management (Forest Service Bulletin 13, 1914, p. 36, special reference being made to tables 12 to 17, which deserve careful study).

Ashe* defines rotation as "the most profitable age and size at which to cut," and analyses the rotation for loblolly pine in North Carolina, according to whether the tree is in mixed or pure even-aged stands. In these mixed stands the "most profitable trees to cut can be determined by the rate with (at) which they increase in value." On the basis of these single trees the author argues that "when the rate of increase in value declines to 6%, the tree can be considered financially mature." In other words, his argument was based not on an investment per acre, but on the current income value of the tree, his conclusion being:

"Trees should be cut, therefore, when they are between 14 and 15 inches in diameter, breast high, at which size their rate of increase in value (neglecting increase in price) becomes equal to the current interest rate."

With pure even-aged stands grown for sawtimber, the most important consideration, according to Ashe, is the "largest average per cent of (net) profit," taking into consideration *soil value,* interest, taxes and administration, or in other words, the cost of production. The author admits that the expense of growing timber is variable, but in the calculations made, assumes a soil value of $5.00 an acre and 6% interest. The increase in soil value and stumpage value, he says, "will in part cover the cost of protection and taxes," but to be on the safe side, 1% should be deducted from the profit to cover taxes, protection and administration for the growing period, and he further contends that,

"Since there is no cost of stocking other than protection and leaving seed trees, the initial investment is practically limited to the soil value. The growth of the seed trees, if they are carefully selected, should approximately cover the interest on the initial value."

This is illustrated in the following table:

TABLE 4. Value of Fully Stocked Stands of Loblolly Pine, as Scaled by Doyle-Scribner Rule, at Different Ages on Different Quality Sites and Under Different Costs of Operation; and the Per Cent of Interest on an Initial Investment of $5 an Acre Represented by This Value.

Quality I

Age of stand Years	Operating expenses $11	Rate of compound interest on an investment of $5 an acre Per cent	Operating expenses $13	Rate of compound interest on an investment of $5 an acre Per cent	Operating expenses $15	Rate of compound interest on an investment of $5 an acre Per cent
25	$ 33	8	$ 18	6.1	$ 4	...
30	74	9	42	7.0	10	4.0
40	143	8	87	8.0	30	5.0
50	231	7	158	7.0	84	6.0
60	326	7	243	6.5	159	6.0
70	423	..	336	6.1	249	4.5
80	496	..	406	...	316	...

Quality II

Age of stand Years	Operating expenses $11	Rate of compound interest on an investment of $5 an acre Per cent	Operating expenses $13	Rate of compound interest on an investment of $5 an acre Per cent	Operating expenses $15	Rate of compound interest on an investment of $5 an acre Per cent
25	$ 6	0.8	$ 3	...	$ 1	...
30	31	6.0	17	5.0	3	...
40	80	7.0	47	6.0	14	3.0
50	132	6.5	84	6.0	37	4.5
60	193	6.3	136	5.5	80	5.0
70	267	...	206	...	145	5.0
80	325	...	261	...	196	4.5

* Ashe, W. W., Loblolly or North Carolina Pine (North Carolina Geological Survey, Bulletin 24, 1915, pp. 135-137). It must be admitted that timber production will rarely yield as high as 6% unless there are considerable stumpage increases.

Quality III

25	...	...	...	...	...	...
30	...	...	...	...	...	...
40	$ 27	4.0	$ 15	...	$ 3	...
50	61	5.0	36	4.0	11	...
60	97	4.5	65	4.5	32	3.5
70	141	...	103	4.5	65	4.0
80	177	...	137	4.0	97	4.0

Different results would have been secured had the yield been based on mill run. The conclusion was reached that the less favorable the quality site the later is the age at which the maximum interest rate is attained; this agrees with the conclusion of European foresters. For pure even-aged stands of cordwood there is little, if any, increase in price with increase in size. Therefore, the volume of the stand and the cost of production are the proper bases for the rotation.

"The cheapest cost . . . . . . on all quality sites is when the stand is between 25 and 30 years old." Such short rotations are often veritable nonsense.

The conclusions on the cost of growing cordwood are illustrated by the following table:

TABLE 5. Cost of Growing Cordwood in Fully Stocked Stands of Loblolly Pine at Different Ages on Different Quality Sites on Land Valued at $5 an Acre and Interest at Six Per Cent.

Stem Wood Only from Trees Six Inches and Over in Diameter.

Age of stand Years	Value of $5 compounded at 6% for the period, less the initial investment	Cost of growing a cord of 160 cubic feet, peeled Quality			Cost of growing a standard cord of 128 cubic feet, bark included Quality		
		I	II	III	I	II	III
25	$16.45	$0.50	$0.74	$1.37	$0.26	$0.41	$0.75
30	23.65	.55	.70	1.31	.31	.44	.71
40	56.40	.97	1.34	2.02	.59	.78	1.13
50	87.10	...	...	2.49	.83	1.05	1.45

According to Sterrett's investigations[*] on the ash,

"The financial rotation is lengthened by low yields, low stumpage values, and high initial investments, while the opposite of these shorten it."

It was argued that financial rotations may be altered according to the purposes for which the timber is grown; according to market conditions and seed year occurrence. From the silvicultural viewpoint short rotations are best, and long rotations in pure stands should be practiced only on the best sites, and then the ash should be usually underplanted. Rotations of 30 to 60 years are recommended.

Special reference is made to table 6, which follows:

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[*] Sterrett, W. F., The Ash's, Their Characteristics and Management. (Forest Service Bulletin 299, 1915, pp. 35-39.) The costs of the crop $Vo \times 1.0p^n =$ value of the crop in n years (Vn). When the costs of the crop is less as in poorer quality sites n must be greater where p is constant. See Chapman's Valuation. It should be noted that 6% interest rates in forestry calculations are rarely possible or advisable.

TABLE 6. Interest rates[1] (compound) to be expected on money invested in growing ash, where yield quality I, II, or III stands are secured, calculated for different stumpage values and for different initial investments.

(Blank spaces indicate less than 3 per cent interest.)

Age of stand. Years.	Value of stumpage per 1,000 board feet.	Total initial investment per acre.																	
		$5.[2]			$10.[3]			$15.[4]			$20.[5]			$25.[6]			$30.[7]		
		Compound interest rates (per cent) for yield quality I, II, and III stands.																	
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
20	$5	4.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	7.5	..	..	3.9	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	15	9.6	..	..	5.9	..	..	4.3	..	..	..	..	..	..	..	..	..	..	..
	20	11.1	..	..	7.3	..	..	5.6	..	..	4.1	..	..	3.3	..	..	..	..	..
30	5	6.1	..	..	3.7	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	8.8	4.6	..	6.3	..	..	3.9	..	..	3.2	..	..	..	..	..	..	..	..
	15	10.3	6.2	..	7.8	3.7	..	6.4	..	..	5.4	..	..	4.6	..	..	4.0	..	..
	20	11.4	7.3	..	8.8	4.8	..	7.4	3.5	..	6.4	..	..	5.6	..	..	5.0	..	..
40	5	5.8	..	..	4.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	7.9	5.5	..	6.1	3.7	..	5.0	..	..	4.2	..	..	3.6	..	..	3.1	..	..
	15	9.1	6.8	..	7.3	4.9	..	6.1	3.8	..	5.4	3.0	..	4.7	..	..	4.3	..	..
	20	10.0	7.7	..	8.1	5.8	..	7.0	4.7	..	6.2	3.9	..	5.6	3.3	..	5.1	..	..
50	5	5.3	3.3	..	3.8	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	7.1	5.6	..	5.6	4.1	..	4.7	..	..	4.1	..	..	3.5	..	..	3.1	..	..
	15	8.1	6.6	3.9	6.6	5.2	..	5.7	4.2	..	5.1	3.6	..	4.5	..	..	4.1	..	..
	20	8.8	7.4	4.9	7.3	5.9	3.4	6.4	4.9	..	5.7	4.3	..	5.2	3.7	..	4.8	3.3	..
60	5	4.7	3.0	..	3.5	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	6.4	5.3	..	5.2	4.1	..	4.3	..	..	3.8	..	..	3.2	..	..	..	..	..
	15	7.3	6.2	4.4	6.0	5.0	3.2	5.2	4.1	..	4.7	3.6	..	4.2	..	..	3.9	..	..
	20	7.8	6.8	5.2	6.6	5.6	4.0	5.8	4.8	..	5.3	4.3	..	4.8	3.7	..	4.6	3.4	..
70	5	3.9	..	..	3.2	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	6.4	4.8	..	4.6	3.8	..	3.7	..	..	3.3	..	..	..	..	..	..	..	..
	15	6.5	5.7	4.4	5.4	4.7	3.4	4.6	3.8	..	4.2	3.4	..	3.7	..	..	3.4	..	..
	20	7.0	6.3	5.1	5.9	5.3	4.1	5.2	4.5	..	4.8	4.0	..	4.3	3.5	..	4.0	3.2	..
80	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	10	4.8	3.9	..	3.9	3.0	..	..	..	..	..	..	..	..	..	..	..	..	..
	15	5.0	5.0	3.8	4.7	4.1	..	3.9	3.1	..	3.5	..	..	..	..	..	..	..	..
	20	6.1	5.7	4.7	5.2	4.7	..	4.5	3.8	..	4.1	3.5	..	3.6	..	..	3.4	..	..

[1] Calculated by the formula

$$p = 100 \left[\sqrt[n]{\frac{S+L-A}{F+L}} - 1 \right],$$

where p = compound interest rate, n = number of years or rotation, S = stumpage value at n years; L = cost of land; F = cost of formation; and A = cost of administration and taxes in *n years at 6 per cent compound interest. Five cents per acre annually* is allowed for administration (including fire protection) and *one cent on the dollar (full valuation) annually for taxes.*

[2] $5 cost of land, and no cost of formation of stand.
[3] $5 cost of land, and $5 cost of formation of stand.
[4] $10 cost of land, and $5 cost of formation of stand.
[5] $10 cost of land, and $10 cost of formation of stand.
[6] $15 cost of land, and $10 cost of formation of stand.
[7] $15 cost of land, and $15 cost of formation of stand.

NOTE. As a matter of fact calculations such as these are often misleading.

The Forest Service has used this method of indicating the most profitable rotation on the assumption that money must be borrowed at 6%. At best it is an approximation because it is difficult to answer the financial rotation problem in advance with so many dependent variables. According to the formula used, the equation would work out for 50 years as follows:

$$p = 100 \left(\sqrt[50]{\frac{\$99 + \$5 - \$29.04}{\$5 + \$5}} \right) = 100 \left(\sqrt[50]{\frac{\$74.96}{\$10}} \right) = 4.1\%$$

Here the value of the land is added at 50 years as it is assumed still to be worth $5.00.

Table 7, which follows, illustrates a method of determining the financial rotations* for eastern white pine in common use in the United States. In this case the most profitable rotation is 50 years and the result is more exact, according to the soil rent theory, than in the preceding equation.

* Forest Mensuration of the White Pine in Massachusetts, 1911. (State Forester, Boston, p. 26.)

TABLE 7. The Financial Rotation of White Pine.

(Money valued at 4 per cent; value of land, $4 per acre; cost of planting, $10 per acre.)

| Age of Stand (Years) | Gross Returns (Stumpage Value). | Annual for Five-year Periods. | EXPENSES AND INTEREST. TAXES. | | | | Cost of Producing. | | Total Investment without Interest. | Total Investment and Accrued Interest at 4 Per Cent. | Gross Profit. | Net Profit over 4 Per Cent on Investment. |
| | | | ON TIMBER. | | ON LAND. | | | | | | | |
			Amount paid in Taxes.	Accrued at 4 Per Cent Interest.	Without Interest.	With Interest.	Interest on Value of Land Accrued.	Cost of Planting and Accrued Interest.				
25	$ 40.50	$ 540	$ 2.70	....	$1.50	$ 2.17	$ 6.66	$ 26.66	$ 11.50	$ 35.49	$ 29.00	$ 5.01
30	75.00	1,000	2.70	$ 3.03	1.80	2.90	8.97	32.43	14.50	47.33	60.50	27.67
35	195.20	1,269	7.70	9.32	2.10	3.82	11.78	39.46	19.80	64.38	175.40	130.92
40	262.40	3,498	14.04	18.47	2.40	4.92	15.20	48.00	26.40	86.59	230.00	175.80
45	324.80	4,330	31.53	42.16	2.70	6.25	19.36	58.41	44.23	126.18	280.57	198.62
50	465.00	6,200	53.18	75.76	3.00	7.90	24.43	71.06	66.18	179.15	398.82	285.85
55	505.50	6,740	84.18	127.04	3.30	9.90	30.58	86.46	97.48	253.98	408.00	251.02
60	532.00	7,080	117.88	192.60	3.60	11.35	38.08	100.79	121.48	342.82	410.52	189.18
65	566.00	7,548	153.28	281.32	3.90	15.18	47.20	127.98	163.28	471.68	402.72	94.32

According to Mattoon, the object of management with cypress should be "to secure the highest financial returns from the class of land involved . . . . and the continuous yield of the most valuable species." His conclusion is that a 60-year rotation (with the object of raising poles) would be the most profitable age at which to cut.*

In a recent calculation for Douglas Fir, Quality II, Hanzlik indicates a 70-year financial rotation in the Western Cascades.

TABLE 8a. Soil Expectation Value for Douglas Fir, Quality II Site Western Cascades.

THINNINGS (PER ACRE).

Years from now.	No. Trees Removed in Decade before Final Cut.	Average D. B. H. of Trees Removed.	Contents of Average Tree.	Total Volume Removed as Thinnings in Decade before Final Cut.	Value of Thinnings.
30	200	4	1.5 cu. ft.	300 cu. ft. 3.8 cds.	$0.50 per cd.
40	113	6	6.9 "	780 cu. ft. 9.8 cds.	1.00 "
50	62	8	13.0 "	806 cu. ft. 10.0 cds.	1.50 "
60	25	10	22.0 "	550 cu. ft. 6.9 cds.	2.00 "
70	15	12	180 B.F.	2,700 B.F.	7.00 per M
80	7	13	260 "	1,820 "	8.00 "
90	5	14	320 "	1,600 "	9.00 "
100	2	14	350 "	....	....
110	2	15	400 "	....	....
120	2	15	430 "	....	....
130	2	15	460 "	....	....
140	..	..	..	....	....

* Mattoon, W. R., The Southern Cypress (Forest Service Bulletin, No. 272, 1915, p. 50).

TABLE 8ᵃ. Soil Expectation Value for Douglas Fir, Quality II Site Western Cascades—*Continued*.

Rotation. Yrs.	(Se) Expectation Value Govt. Forest 3% Comp. Int.	Total Value of Final Yield at Various Rotations Per Acre.	Probable Future Stumpage Values.	Average Annual Growth Per Acre Each Decade.	Final Yield Per Acre Each Decade.	Height of Average Tree. Ft.	D. B. H. of Average Tree. In.	No. Trees Per Acre Before Thinning.	Total Value of Thinnings in Each Decade.
30	$11.70	$ 40.40	$ 1.00 per cd.	150 cu. ft.	3,230 cu. ft. 40.4 cds.	34.5	6.3	625	$ 1.00
40	11.68	66.00	5.00 per M	222 "	12,000 B. F.	76.5	8.4	425	9.80
50	23.08	129.00	6.00 "	950 B. F.	21,500 "	90.5	10.6	312	15.00
60	36.08	256.00	8.00 "	1,150 "	32,000 "	100.0	12.5	250	13.80
70	39.28*	373.00	9.00 "	950 "	41,500 "	108.0	13.9	225	18.90
80	38.93	500.00	10.00 "	850 "	50,000 "	114.0	15.0	210	18.00
90	38.78	638.00	11.00 "	800 "	58,000 "	120.0	15.8	203	14.00
100	36.68	792.00	12.00 "	800 "	66,000 "	126.0	16.4	198	14.40
110	31.08	888.00	12.00 "	800 "	74,000 "	132.0	16.9	196	....
120	28.33	1,053.00	13.00 "	700 "	81,000 "	137.5	17.3	194	....
130	25.33	1,125.00	13.00 "	550 "	86,500 "	143.0	17.6	192	....
140	21.20	1,280.00	14.00 "	500 "	91,500 "	148.0	18.0	190	....

Based on present National Forest Practice and Sales Regulations in Douglas Fir Region.
D-6.

Cost of Formation—nil.

Annual expenses—.20 per Acre.

Interest—3% per Annum (comp.).

Tax on Yield—35% of Gross Receipts.

Computed by E. J. Hanzlik, U. S. Forest Service.

Data based on Standard Douglas Fir Yield Tables;

Ms. report by E. J. Hanzlik, U. S. Forest Service.

Rev. in Forestry Quarterly, Vol. XII, No. 3, pp. 440-51.

$$Se = \frac{Yr + Ta \times 1.op^{r-a} + \ldots Tq \times 1.op^{r-q} - C \times 1.op^r}{1.op^r - 1} - E$$

56. Final Choice of a Rotation. The object of the owner will always be the principal factor in the choice of a rotation. This object may vary somewhat according to whether the owner is a state, a company, or an individual.

* Financial Rotation indicated at 70 yrs.

The length of the rotation will depend also on whether this principal object of management is the direct production of timber or the indirect benefits of the use of the forest for recreation or watershed protection. Since the use of aeroplanes has become so general in war, the French attach considerable importance to the value of frontier forests as a screen to the movement of troops. This is but an illustration of the indirect protective value of forests which under exceptional circumstances would influence the choice of a rotation and system of cutting. It is safe to lay down as a general rule that where the indirect benefits of forests are of greater moment with the owner than the mere production of timber, the rotation is usually lengthened. In a forest park such as Fontainbleau, near Paris, or in the famous Wiener-wald near Vienna, the rotation would be longer than a sound technique would permit were the production of timber the sole object. So-called protection forests on the slopes of mountains usually have their rotations lengthened through the mere fact of being managed for protection purposes, aside from the slow growth due to soil or exposure. The silvicultural treatment to be followed has an important bearing; sometimes this is the dominant factor as in the case of a simple coppice of oak where the sprouting capacity fails rapidly after 50 or 60 years. With naturally regenerated oak high forest a maximum limit may be set to the length of rotation because of the falling off in seed production. But if the main object of management is timber production, a rotation based on the maximum income in wood material is indicated if this coincides with the (forest rent) financial rotation. If the two do not coincide as seldom happens, then a compromise must be made by the owner on the basis of the best available data. According to Schlich,*

"In the first place, the financial (soil rent) rotation should be determined as it alone gives a true expression of the economic value of the management; then, it should be ascertained in how far the objects of management demand a departure from the financial rotation; lastly, the financial loss involved in such a departure should be determined, so that the proprietor may have a clear conception of the payment which he is called upon to make in order to realize his special object."

As Schlich well points out, the drawbacks to purely financial rotations in impoverishing the soil must be borne in mind. Quantitative (economic) and financial rotations (which have been discussed at length) depend on more complete yield and market data than is usually obtainable during the initial stages of forest management. It is for this reason that this type of rotation has often been replaced in the United States by tentative technical or silvicultural rotations; an authority such as Endres** refers to these latter rotations as being of mere "historical interest" because of the development in Germany of detailed yield and market data.

57. **Summary of Principles Affecting Length of Rotations.** Let us now summarize some of the principles upon which the determination of the rotation depends:

* Schlich, William, Manual of Forestry, Vol. III, 1911, p. 202.
** Endres, Max, Lehrbuch der Waldivertrechnung und Forstatik, 1895, pp. 220-248.

(1)   The length of rotations tends to increase on poor sites and decrease on good sites.   (Yet in North Germany there are short rotations on pure sand.)

(2)   In financial rotations (soil rent) the lower the interest rate, the longer the rotation allowed by the calculation, but other factors must be considered.

(3)   An increase in the quality of product yielded lengthens financial rotations.   Quantitative rotations will vary according to the utilization in the tops, according to the log rule used, and according to the basic class of product (whether cubic, board feet, poles, ties, etc.).

(4)   When the mean annual growth begins to decrease, the per cent of rot increases; danger from defect limits the length of rotation with such species as white fir.

(5)   Rotations vary according to the ownership and purpose, silvicultural treatment, market and logging conditions, site, species, as well as with the character and condition of the stand.   We must never forget that the world needs building timber.

(6)   With more intensive economic conditions there is always a tendency to shorten rotations; with extensive economic conditions longer rotations are indicated (with long cutting cycles).

(7)   In choosing a rotation technical, silvicultural, quantitative and financial considerations should be summarized before making the final decision.   But the object of the owner must always have the dominant interest in deciding upon what rotation to choose.

(8)   Once a preliminary rotation has been established, modifications are necessary with economic changes.

In the United States Roth advocates a rotation no longer than necessary to produce the kind of material desired and a reasonable income as well as to maintain the fertility of the land.   He believes in calculations to show the highest net financial (forest rent) yield.   He correctly emphasizes that in the future, market sizes will be smaller and rotations will be reduced by thinnings and by efficient planting.   Roth also favors short rotations where open stands may otherwise suffer from insects and fungus.*

** The author dismisses the rotation of maximum volume and the rotation of *forest rent*, the former based on false public economy, the latter because based on false mathematical basis; there remains for discussion only the rotation of maximum *soil rent* and the technical rotation, the latter being defined as that which produces continuously the largest quantity of the most valuable marketable wood under the given conditions of site and market.   These two rotations are in many cases identical (coppice) . . . . The financial rotation depends in the first place on the choice of the rate per cent."

Recknagel first divides the customary European rotations according to whether (1) small or (2) large tracts.   The average rotation for small tracts (presumably intensive forestry) he shows is 10 to 20 years less than for large tracts.   Then he distinguishes between (1) plains and foothills, (2) intermediate mountains, and (3) high mountains; and within each topographic subdivision a further differentiation by species.   But these data are not of real scientific value because the basis for the rotation under the different

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* Roth, Filibert, Forest Regulation, 1914, p. 117.

** Review by Fernow of article by Pilz (Forest Quarterly, Vol. 2, 1904, p. 183).

conditions is not given. In the plains the rotation might be purely on the basis of soil rent while in the mountains perhaps soil protection was of paramount importance in determining when to cut. His averages for small tracts of spruce are (1) 60-80 years in the plains and foothills, (2) 60-100 in the intermediate mountains, and (3) 80-100 years in the high mountains. Roth* says more specifically that the,

"Rotation for largest volume in Germany and for fair to good site (site II) is about as follows: pine 60 years, spruce 90-100 years, beech and balsam 110-120 years. This fits in very nicely with the technical rotation for these species."

The writer agrees thoroughly with Schiffel's conclusion that,

"Today we know that a careful survey and critical investigation of stands as regards their silvicultural condition, a comparative observation of their development, and the proper selection and attention to their growth of species furnishes a much surer basis for securing maximum revenue than Pressler's formula receipts."

Yet especially in American Forest Management, a forester cannot adopt ideal methods, but must weigh the results with the cost. An ideal might be to have complete fire protection, but the ideal may be shattered by considerations of cost. Will it pay?** must be answered before regulation measures are finally decided upon.

It is too early to try to average or classify rotations established in the United States. In the majority of cases they have not been tried out so that they are purely theoretical rather than empirical. Extensive forestry means much longer rotations than will prevail later on because of the extensive conditions sufficient differentiation has not been made. With a possible shortage in the world's timber supply, short quantitative rotations for maximum production are predicted; and quite probably in the tropics under favorable growing conditions the rotations may be one-half to one-third those required in the temperate zone.

58. Quiz. Define the maximum forest rent rotation.

Review definitions of capital and value.

Write and explain the forest rent formula.

How does it differ essentially from maximum soil rent? from economic rotation?

Under what conditions are soil rent rotations preferable?

Why is the answer based on mean annual rather than current annual maxima?

Is this rotation applicable to national forests? to woodlots in New England? to the southern pineries?

What are the difficulties to its wider use?

How would the rotation be affected by the omission of thinnings? by heavy intermediate returns? by natural regeneration? by heavy forestation expenses?

How do large soil values affect the result?

How does price increment and quality increment affect the result?

Write and explain the soil rent formula.

How do you arrive at the culmination of a forest rent and soil rent rotation for given conditions?

Give a simplified form of the soil rent formula.

How important is the rate of interest used?

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* Review by Fernow of article by Schiffel entitled Rev. Reinertragslehre in der Gegenwork. G. A. Schiffel (Forestry Quarterly, Vol. 2, 1904, p. 186).

** Recknagel, A. B., Certain Limitations of Forest Management (P. S. A. F. Vol. 8, 1912, p. 227). Recknagel has done a great deal for American Forest Management by publishing widely on technical forestry, much of it from reliable German sources.

What rate should be chosen?

Of what importance is the final yield upon the result? (The study of the translation from Endres may be made optional.)

Comment on illustrations of financial rotations established in the United States.

What should be the chief factor in the choice of a rotation?

Discuss the choice of a rotation.

What are some rotation variables and axioms?

Cite some rotations established in Europe.

Contrast these with those suggested for the United States.

The student should be given rotation problems to work out in order to fix in his mind the relative length of rotations for given conditions according to whether they are physical, economic, etc.

THE NORMAL FOREST

59. Definitions of Normal Forest, Normal Increment.—*Normal Forest—A standard with which to compare an actual forest to bring out its deficiencies for sustained yield management; the conception of an ideally regulated or organized forest; a forest with normal increment, normal age classes in size and distribution, and normal stock.*

Normal Increment—The best increment attainable by given species on given sites.

Normal Age Classes—The presence of a complete series of age classes as will permit annual or periodic fellings to be made.

Normal Growing Stock or Normal Stock—The amount of material represented by the stands in a normal forest; practically, the contents of the normal age classes as represented in normal yield tables.

The equalization period is the period during which it is planned to attain approximately normal stock conditions. (G., Einrichtungszeitraum.)

60. Discussion of the Normal Forest. The difference between the normality of the normal forest and that of the normal yield table must be clearly understood. The normal forest is merely an ideal difficult to attain, while the yield of the normal yield table is *always* attainable since it is based upon the averages of actual measured stands. Even such a forest as the Sihlwald (cited by Roth) falls far short of being normal even from the sole viewpoint of normal age class distribution. Nevertheless the normal forest will always prove of value as a basis for comparison.

The normal forest requires:

(1) A normal distribution of age classes and a complete cutting series which usually leads to:

(2) A normal increment.

(3) A normal growing stock.

These have already been defined and will be discussed in detail later on.

A forest may be referred to as *under-stocked when it has a growing stock less than the normal growing stock; or over-stocked when it has a growing stock greater than the normal growing stock.*

61. Three Phases of Abnormality. As a matter of fact, forests are usually abnormal in three ways:

(1) *Over-stocked.* A forest past the age of maturity may have more volume per acre than the normal. Therefore, there will be surplus growing stock which must gradually be removed. This surplus may be because there are too many acres of the older age classes (see ⚓ 3 below).

(2) *Under-stocked.* The increment may be more than the average, but the growing stock, because there is too large an acreage in immature stands, will be less than normal. Consequently, the forester may be called upon to economize by cutting less than the increment to accumulate a proper

reserve growing stock. This is particularly true where the yield must be cut in board feet for sawmill purposes, because lumbering trees less than a certain size is usually uneconomic. The accumulation of growing stock to remedy a deficit is often secured by adopting a rotation that is more than the time required to grow the stand or by cutting less than the estimated sustained yield.

(3) *Volumes Normal, but Age Classes Abnormal.* This is the worst form of abnormality because the entire forest may be practically of one age class (the reader should conceive of one age class as allowing a variation of 20 years). This is especially unfortunate because it will necessitate such a long delay before lumbering can take place again. It precludes the maintenance of a sustained yield. It represents the probable situation in the United States when our virgin timber is exhausted by destructive logging.

62. A Normal Distribution of Age Classes. This requires that separate age classes exist which will mature during each year or period of the rotation. These age classes must occupy areas whose yield will equal the same relative per cent of the total yield of the working group for the entire rotation that the year or period bears to the rotation. In theory each of these age classes must occupy areas of equal productiveness so that if they are cut at the proper age, equal annual or periodic yields are obtained. The basis for comparison is the yield from yield tables. If one acre of a forest yields 50,000 board feet at 100 years while another yields but 25,000 then there must be two acres of the latter for every acre of the former in order to have a normal age class distribution. Where the increment of a forest with normal age classes is only half what it should be, its age class form would be normal and it might have a sustained yield because the beneficial results of a sustained yield are not wholly dependent on full increment per acre but on well distributed age classes.

63. Artificial and Natural Factors Influencing Distribution of Age Classes. Unfortunately an abnormal distribution of age classes is the rule because of artificial and natural factors. The *artificial factors* are:

(1) A full cutting series is required. A cutting series is *an aggregation of compartments (stands) in a proposed or actual sequence of cutting areas,* the object being a distribution of cutting areas for administrative reasons, or to secure a final satisfactory distribution or location of age classes, especially to avoid damage by windfall and insects due to uniformity of stand and size of cutting area. It is therefore intended to interrupt a regular sequence of age classes.

(2) The number of age classes hinges on the number of years in each age class (usually 20 years) and on the length of rotation adopted. If the rotation is changed, the number of age classes required is modified, and the forest which was normal in this respect for one rotation becomes abnormal for the next.

(3) The area proper for each age class depends directly upon the total area in the working group and on the rotation and number of age classes. Consequently, areas which are normal for one rotation become at once too large if the rotation is lengthened or too small if it is shortened.

The *natural factors* are even more perplexing. There are always too large or too small areas or volumes present, requiring increases or reductions in given age classes. It is for this reason that the minimum time required for the transformation of a forest to normal age classes is one full rotation, and practical considerations usually call for at least two rotations or more. But as a matter of fact, the ideal is seldom, if ever, attained in age class distribution, but if it is attained and the rotation is modified because of economic conditions, the process of regulation must start over again. Accidents, such as windfall, fire or unusual local demands which must be met, are continually delaying transformation to more normal conditions.

64. Normal Increment. The second requirement of a normal forest is *normal increment.* It is theoretically normal if there is maximum growth on all parts of the area for given species and sites. It is the goal of silvicultural practice. Just as in the case of age class distribution, normal increment cannot be attained until the second rotation, and not even then unless perfect success has been obtained throughout the first rotation—something that is entirely impossible. Normal increment does not serve as the basis for the regulation of the cut in the first rotation, since in this case actual increment is used as a base because normal increment would not apply. Actual increment of normal or ideal stands, or even the average for the stands that are fully stocked, according to local or general yield tables, does not give the forester an idea of the growth on excess stands. The increment on existing stands must be determined in each case, and any attempt to regulate the cut, (based on the removal of surplus growing stock or on enriching the forest where the growing stock is deficient,) must be based on the study of the actual increment and not on the theoretically normal increment.

65. Normal Growing Stock. The third criterion of normality, *normal growing stock,* might be actually attained. But nevertheless it is simply an ideal, which unfortunately is often misunderstood. One writer contended that our knowledge of the forest is so indefinite and the irregularities so unending that a normal condition cannot be conceived, and that normal stock is therefore a delusion.* Often a forest may falsely appear to have a normal stock owing to an accumulation of volume in stands past the rotation age; this phase of abnormality must be recognized especially when a very short rotation has been chosen.

There is nothing in this argument to justify throwing overboard the idea of normal growing stock. It only serves to emphasize the need for bearing in mind that normal growing stock is an ideal to steer by.

The length of rotation is especially important in affecting the normal growing stock, where the forest is to be managed on the basis of permanent production. This is true because the rotation,

(1)   Determines the amount of timber that must exist as forest capital in order to obtain a continuous yield; and

(2)   Indicates whether a surplus or deficit exists in the actual forest under

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* Review by Fernow, entitled Heresies Regarding Normal Stock. (Forestry Quarterly, Vol. 14, 1916, pp. 524, 553-67.)

management and tells whether more or less than the actual increment can be cut.

66. Growing Stock Formulae. To obtain a clearer conception of the normal forest and its normal growing stock reference is made to figure 3.
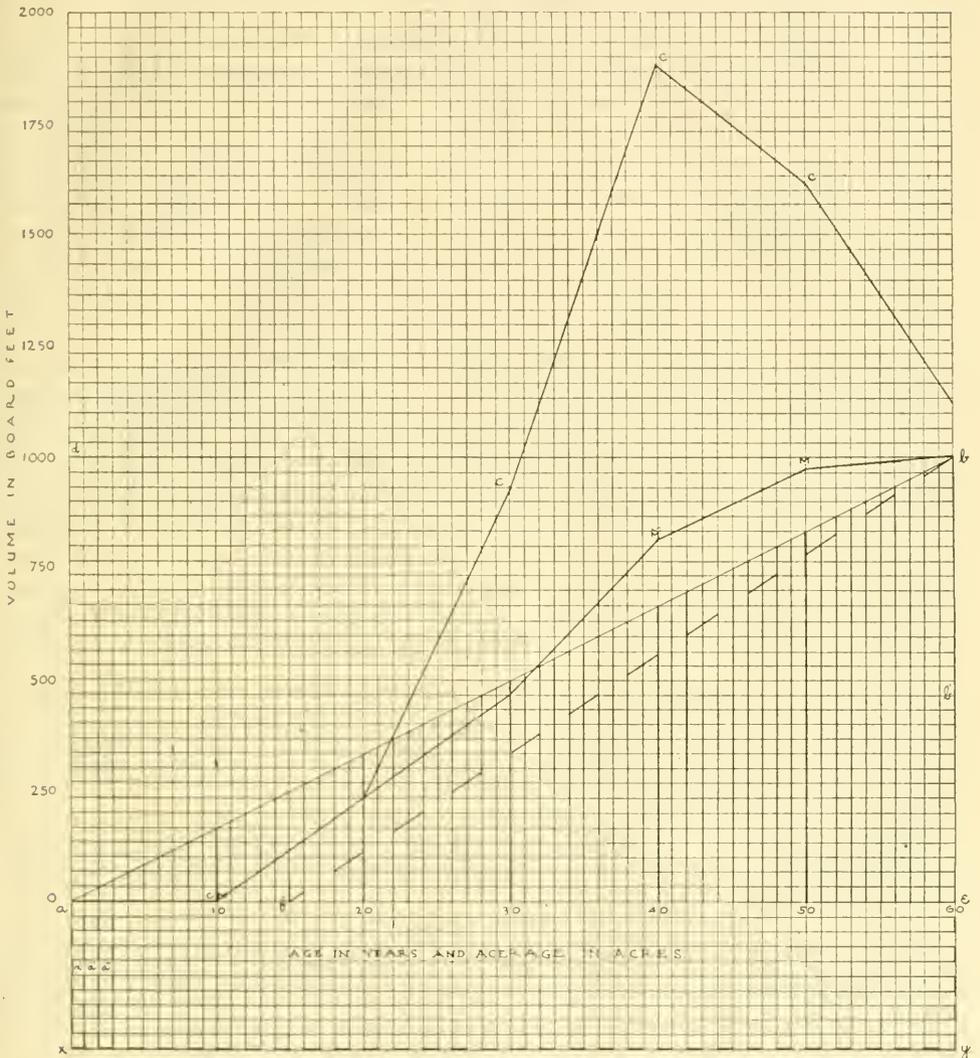
Fig. 3. Diagrammatic Representation of Normal Growing Stock and a Comparison with Mean Annual and Current Growth for a 60-year-old Stand Sixty Acres in Area.

A forest of 60 acres is here represented as being managed on a rotation of 60 years. If the entire forest were very abnormal and contained 60 acres of mature timber, then the volume would be represented by the diagram a-b-d-e. But let us suppose it is normal. Then there will be one acre one year old, one acre two years old,........one acre 59 years old, and one acre

60 years old, or about half what the forest would contain if it consisted entirely of fully mature stands. The column b' represents graphically 60 years growth and the column at the extreme left of the triangle represents one year's growth. From this it is clear that a simple formula for normal growing stock is as follows: $G^n = \text{rotation} \times \text{m. a. i.} \div 2$ or $G^n = \dfrac{r \times i}{2}$

It is customary to ignore the effect of thinnings on the equation.

This formula falsely assumes that current annual growth and mean annual growth remain equal. The author obviously overlooked the fact that growth is not laid on in annually equal quantities, but that it varies according to the age of the tree. The fallacy lies in the assumption that current growth and mean annual growth are the same for all ages. As a result of this false premise, if most of the growth is laid on in the latter half of the rotation, the actual growing stock required is less than that given by the formula, because the mean annual growth or proportional volume is less for the younger age classes. This is particularly true when the growing stock is measured in manufactured products, where it is almost universal that a tree has no measurable volume in board feet until it is 15, 20, or more years in age.

This fallacy of assuming that growth is a straight line is shown diagrammatically in fig. 3, where a-cm-ccc-b represents current growth and a-cm-mmm-b the mean annual growth according to table 8. To correct this inaccuracy of assuming the growth a straight line ab, Moore* (P. S. A. F., Vol., VII, 1912, pp. 15-16) originated a formula which is a makeshift plan based on the disadvantage of the board foot rule but unquestionably it gives more conservative results in the United States than the formula $\dfrac{r \times i}{2}$. His formula is $\dfrac{r' \times i}{2}$, where r' is the rotation minus the age when the tree becomes merchantable. In this case the tree would be (see line fb, fig. 3) merchantable at 15 years or half way between 10, when the yield is 0, and 20, when the yield is 4500 (see table 8).

The use of this formula Moore claims will give a more correct surplus or deficit when compared with the actual stock which includes only the merchantable trees. He states that,

"Where the increment is known to be too low, it is unwise to try to correct the error by using r (the whole rotation) instead of r' (the difference between the age of the merchantable trees and the rotation). The whole rotation will give a growing stock which is actually more correct, but mathematically incorrect and hence uncertain; it may be too large or too small. It will also give too low a cut of increment in the final formula and will not be counterbalanced by a high surplus."

While Moore's argument is sound his substitute formula according to M. H. Wolff is incorrect. The proof of this, and the correct formula, are best developed graphically.

* See Schlich's Manual of Forestry, Vol. III, 1911, pp. 222-227. In intensive forestry it would make a difference in the amount of the normal stock whether it were calculated in spring before growth, in summer after growth, or in autumn after the years cut, but for American conditions this complication can safely be omitted and calculations may be standardized to correspond with the summer when the year's cut is half completed.
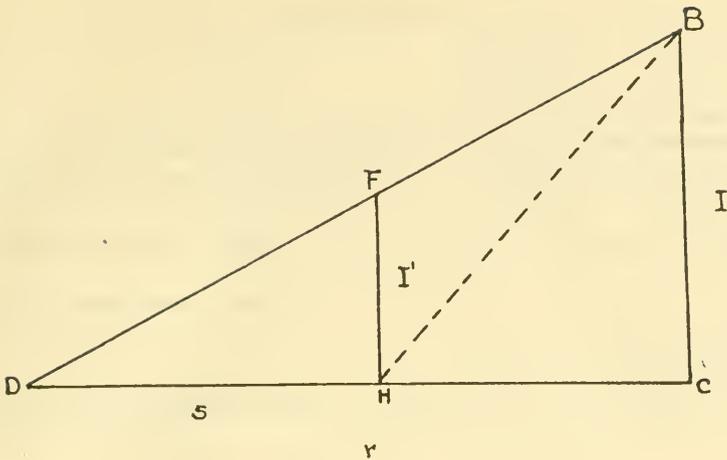
Fig. 3(a)   Proof of Wolff Formula.

Assume the triangle DBC represents the total normal growing stock on any tract including all merchantable and unmerchantable (nonestimable) sized stands, DC being equal to the rotation age (r), and BC being equal to the mean annual increment (I) of the whole acreage. "I" can be more definitely expressed as the mean annual increment per acre (i). times the rotation age (r) multiplied by the total acreage (A) divided by (r).

$$I = (i \times r) \times \frac{A}{}.$$

Assume also that DH represents the merchantable age (s), and that FH is the volume at that age (I') of the annual acreage to be cut over. Volumes below this age are not estimated.

Moore recommends that properly, the normal stock should be figured as $I\frac{(r-s)}{2}$ or in the figure above to $\frac{BC \times HC}{2}$. Diagrammatically this is equal to the triangle BCH. This assumes that volumes at merchantable age commence at zero.

But really the volume at the minimum estimateable age is appreciable. It is theoretically the mean annual growth times the number of years. Thus in our figure the normal growing stock above merchantable age (call it GN for convenience) is the quadrilateral (A trapezoid) FB CH. Hence Moore's suggested formula excludes triangle FBH and gives by that much, too low a figure.

To obtain the correct and most convenient formula for normal growing stock above merchantable age, it is necessary to find the value of the area FBCH, in terms of I, r, and s.

$$I = BC; \quad r = DC, \text{ and } s = DH.$$

(1) $FBCH = \dfrac{FH + BC}{2} \times HC = \dfrac{I' + I}{2} \times r - s.$

(2) $I' : s :: I : r; \quad \text{or } \dfrac{I'}{s} = \dfrac{I}{r}; \quad \text{or } I' = \dfrac{Is}{r}.$

(3)   Substituting for I' in (1)

$$FBCH = \frac{\dfrac{I}{s} + I}{2} \times (r - s)$$

$$\frac{\dfrac{Is + Ir}{r}}{2} \times (r - s)$$

$$\frac{I\ (s+r)\ (r-s)}{2r}$$

$$(4)\quad \frac{I\ (r^2-s^2)}{2r}$$

This is mathematically the correct formula to use, but see table 9.

67. Illustration of Simplest Normal Growing Stock Calculations. The values resulting by the three different methods in any example are interesting to note. Assume $r = 60$ years, and $S = 15$ years (i.e., when tree becomes merchantable). Then by the (a) ordinary method: $Gn = \frac{I \times 60}{2}$ (or $i \times 30$; by (b) Moore's suggested method $Gn = \frac{60-15}{2}$, or $i \times 22.5$; by the method (c) here recommended (after Wolff) $Gn = I \times \frac{60^2-15^2}{2(60)}$, or $i \times 28.125$.

Assuming the mean annual increment at 60 years given in table 8, we have (see table 9):

(a) $\dfrac{1003 \times 60}{2} = 30,090$ feet B. M. per acre.

(b) $\dfrac{1003 \times (60-15)}{2} = 22,567$ feet B. M.

(c) $\dfrac{1003\ (60^2-15^2)}{120} = 28,209$ feet B. M.

68. Yield Table Method of Computing Growing Stock. None of these formulae are as accurate as the result obtained by adding yields from a yield table (see table 8) expressed as a formula; thus,

$$\frac{10\ (a+b+c+d+e+\frac{f}{2})}{r} = \text{normal stock per acre, where } a = \text{the yield}$$

at 10 years, b at 20 years, etc.

10 years	20 years	30 years	40 years	50 years	60 years
(a)	(b)	(c)	(d)	(e)	(f)
0000 ft.	4500 ft.	13900 ft.	32800 ft.	49100 ft.	60200 ft.

Fig. 4. Diagrammatic Scheme of the Yield Table Yields.

Referring to Figure 4, let us conceive of our normal forest composed of six square areas, each 10 acres in extent; with the assumed rotation of 60 years, each square will then correspond to 10 years of the rotation. In computing the normal growing stock formula, it is clear that each yield figure from the normal yield table must be multiplied by 10 to secure the normal growing stock for a forest of 60 acres. Half the yield in square f is taken because cutting is going on in the oldest age classes; consequently all the timber will be standing the first of the decade but none of it at the expiration.

69. Illustration of Calculating Normal Growing Stock from Yield Table. As an illustration of the calculation of normal growing stock by the yield table method, the following is given for site (I), white pine in New Hampshire managed on a rotation of 60 years. The yield assumed is as follows*:

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*Frothingham, E. H., White Pine Under Forest Management (Forest Service Bulletin No. 13, 1914, table 6, page 23).

TABLE 8. Yield of White Pine in New Hampshire.

Year	Lumber yield per acre, board feet		Mean annual increment board feet	Current annual increment, board feet
10	0000 a	(See Fig. 4)	0	0
20	4500 b		225	225
30	13900 c		463 plus	940
40	32800 d		820	1890
50	49100 e		982	1630
60	60200 f		1003 plus	1110
(70)	(69900)		...	970

Adopting the formula we have,

$10(4,500 + 13,900 + 32,800 + 49,100 + \frac{60,200}{2})$ board feet $= 10(130,400) = 1,304,000$ board

feet on 60 acres or 21,733 plus per acre. When a rotation of 60 years is assumed, the normal growing stock formula result may be figured for an acreage equal to the number of years in the rotation.

AGE YEARS
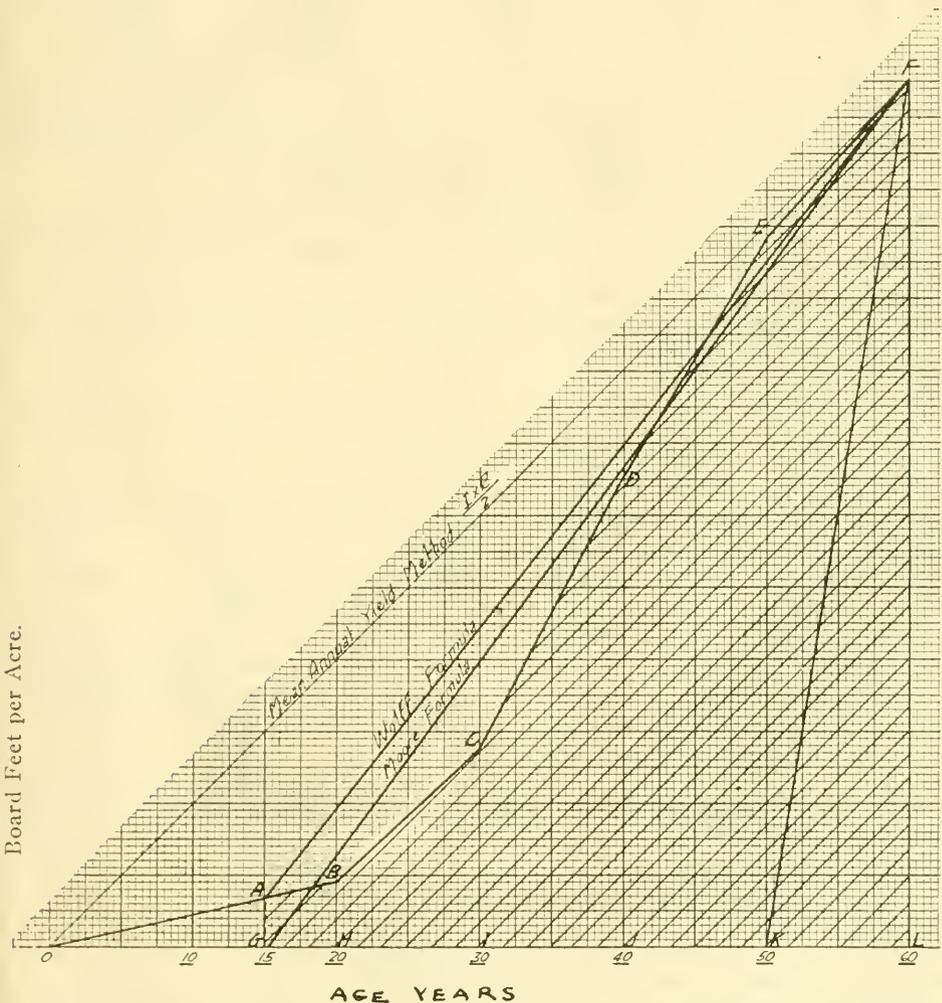
APPENDIX F. Graphic Comparison of Normal Growing Stock Formula (for text, see Appendix F).

70. Comparison of Normal Growing Stock Formulae.* In the following table the normal growing stock has been calculated by the following formulae: column 2, the accurate yield table method; column 3, mean annual increment often inaccurate for board foot units; column 4, mean annual increment, where (after Moore) rotation is taken as total age minus age when tree is merchantable (in this case tree becomes merchantable at 15 years); column 5, same as 4 but using the Wolff corrected formula (§66-67) which should be used instead of 4; it gives higher figures than the Moore formula but is more conservative than 3.

TABLE 9.   Normal growing stock in board feet per acre for rotations of 20 to 60 years by different formulae (figures evened off).

1 Rotation years	2 Yield table method	3 Mean annual increment	4 Mean annual increment (using r')	5 Wolff formula
		(Board feet per acre of forest)		
20	1,125	2,250	562	984
30	3,816 plus	6,950	3,475	5,209
40	8,700	16,400	10,200	14,094
50	15,150	24,550	17,185	22,340
60 .	21,733 plus	30,090	22,567	28,209

From the foregoing it is apparent that the normal growing stock in board feet when calculated on the basis of r' (after Moore) is closer to that given by the yield table method than the result if figured by the usual $r \times i$ formula or by the Wolff modification of Moore's r'. This is discussed at length in Appendix F.

The use of another formula** is advocated for normal growing stock in selection forests, which Munger claims is simpler and perhaps sounder than the formula $\dfrac{r' \times i}{2}$ just (m. a. increment $= i$) described. It is based on the theory that the base ae $\times$ y (figure 3) represents the length of the cutting cycle and the rectangles a', a", and a''', the amount left per acre after a heavy "selection" cutting. Munger uses current increment. The formula is as follows:

$Gn = \dfrac{i \times cc}{2} +$ Reserved timber per cutting area $\times$ number of areas. The following arguments are given in favor of this formula:

(1) It can be applied equally well to cubic feet or board feet.

(2) It obviates the use of the length of the rotation "a very uncertain and meaningless quantity in a forest cut by the selection system."

(3) It does away with the necessity of deciding when a tree is to be *estimated* as merchantable timber which is so vital to the Moore or Wolff formulae.

71. Illustrations of Munger Formula. Suppose** that a virgin stand of western yellow pine averaged 16,000 board feet per acre and that three-fourths of it is cut by so-called "selection" cutting (thus leaving a residue of 4,000 per acre) and that the current annual increment on this 4,000 feet is 100 feet. Let us assume a cutting cycle of 50 years and a rotation of 200 years. Then,

"At the end of a cutting cycle each coupe (cutting area), when ready for cutting, will contain its original 4,000 board feet plus the 50 years of increment (50 $\times$ 100 $=$ 5,000), or a total of 9,000 feet."

Taking 1 as equal to the "annual increment of whole forest (annual increment of each coupe $\times$ rotation)," then applying the formula we have,

* A similar comparison is given in Schlich's Manual of Forestry, Vol. III, 1900, p. 225, but in cubic feet not reduced to a per acre basis.

** Munger, T. T., A Formula for Normal Growing Stock in Selection System Forests (P. S. A. F., Vol. X, 1915, pp. 18-21.

$Gn = \dfrac{5,000 \times 50}{2} + (4,000 \times 50) = 325,000$ board feet on 50 acres or $\dfrac{325,000}{50} = 6,500$ per acre. With $i = 100$ feet the result would be (with the formula $\dfrac{i \times r}{2}$) using of necessity current increment for $i, \dfrac{100 \times 200}{2} = 10,000$ per acre. For a more critical and detailed discussion of this formula, see Part II, Chapter X.

72. Flury's Normal Stock Formula with Illustration. Flury* suggests a reducing factor c (Constant) to read $Gn = c \times r \times i$ instead of the usual $Gn = \dfrac{r \times i}{2}$. This idea is simply to substitute a constant reducing factor for each decade instead of using $Gn = \dfrac{r \times i}{2}$ for all ages.

Recknagel has worked out an excellent illustration** which shows what degree of accuracy can be obtained. But if great accuracy is required, why not use the yield table method to start with, since the calculation takes but a few minutes. Where no yield table was available, the value of c could not be figured; hence the method is not of practical value.

73. A Normal Stock Calculation in Lodgepole Pine. A method of calculating normal and real growing stock in a lodgepole pine forest is illustrated by the table*** which follows:

TABLE 10. Real and Normal Growing Stock and Periodic Annual Increment on the Bernice Division, Deerlodge National Forest, Mont.

Age	Area	Normality	Growing stock		Periodic *annual* increment		Yield at the age of 140 years[1]
			Real	Normal	Real	Normal	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Acres		*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 cu. ft.*	*1,000 bd. ft.*
10 years	1,570	0.67	95	402	9	40	16,662
20 years	9,742	.69	1,815	1,205	121	80	106,476
30 years	5,511	.73	2,203	2,544	121	134	63,448
40 years	7,559	.66	5,687	5,089	284	254	78,920
50 years	1,412	.67	1,731	8,168	65	308	15,058
60 years	4,887	.49	5,747	10,713	136	254	38,000
70 years	1,928	.40	2,267	13,123	42	241	12,215
80 years	2,448	.30	2,468	14,998	31	187	11,633
90 years	2,092	.20	1,582	16,872	18	187	6,628
100 years	3,040	.20	2,481	18,211	18	134	9,631
110 years	396	.20	342	19,283	2	107	1,254
Over 120 (average age 130 years) :							
Merchantable .	17,761	.35	28,671	61,062	57	147	.....
Suppressed ..	4,145	.10	1,890	.....	...	...	.....
Total	62,491	...	57,069	171,670	904	2,073	.....

[1] Normal yield, 15,840 board feet at 140 years on sites of average quality; 78.7 per cent of area overstocked; 20.5 per cent of area understocked; 0.8 per cent of area normally stocked.

* For a more complete discussion, see review by Fernow (Forestry Quarterly, Vol. XIII, 1915, pp. 108-113).

** Recknagel, A. B., Forest Working Plans, New York, 1917, p. 11.

*** Mason, D. T., Utilization and Management of Lodgepole Pine in the Rocky Mountains (Forest Service Bulletin 234, 1915, pp. 36-39). The columns have been numbered to facilitate reference in this text.

The figures for real growing stock (4), the present total stand were obtained by multiplying the normal stand (normal according to an empirical yield table) per acre for each age class (as given in table 9, Forest Service Bulletin 154) by the "normality" (3) or per cent of stocking, a figure which was multiplied by the actual area occupied by each age class. In the case cited in the preceding table the forest comprised 62,491 acres of productive timber land, the rotation was 140 years (divided into 14 periods of

10 years each) so the normal area per age class was $\dfrac{62491}{14} = 4,463.6$ acres.

The normal growing stock for the 10-year age class was then found by multiplying the normal yield (from table 9, Forest Service Bulletin 154) by this normal area. This figures 90 cu. ft. $\times$ 4,463.6 $=$ 94,671, or 95,000 cu. ft. This simple method of comparison is of value under the extensive conditions prevailing in the West.

74. Importance of Normal Growing Stock in the United States. The reason why the computation of normal growing stock is important—even in extensive American forest management—is because of its usefulness in yield regulation by volume formula methods, which may often be sufficiently accurate for early regulation.

This normal forest, which we have been discussing, in theory might be attained on an area of definite size and for a rotation of given length after the lapse of a complete rotation, if all other considerations were sacrificed to the attainment of a proper series of age classes, and provided that all accidents or injury to the forest could be completely excluded from our calculations throughout the entire rotation, and provided further that no change in the existing rotation need be made because of different economic conditions. Because of the impossibility of attaining normal age classes, even if these sacrifices were made, the proper policy is to build up as good an age class series as possible by working groups and let the distribution on the total forest area take care of itself. The gradual attainment of normal age class distribution involves cutting stands before or after the rotation age. This is not so commercially undesirable unless carried to such extremes that serious volume loss results. Such sacrifices are usually warranted to a certain extent in regulation, although it must be recognized that a later change in the length of the rotation requires a rearrangement.

75. Quiz. Distinguish between normal forest and normal yield table.
What must a forest possess to be normal?
How are forests usually abnormal?
Discuss normal age classes: how is the distribution affected by artificial and natural factors?
Discuss normal increment.
Discuss normal growing stock.

Explain the growing stock formulae $Gn = \dfrac{r \times i}{2}$; why is it faulty?

Should growing stock be calculated in spring, summer, or autumn?

Which is the better formula for board feet $\dfrac{r \times i}{2}$ or $\dfrac{r' \times i}{2}$ or $\dfrac{i(r^2 - s^2)}{2r}$?

Explain the formula $\dfrac{i \times cc}{2}$ plus Res. per cutting area $\times$ number of acres.

Why is it useful? Its drawbacks (see chapter X)?

Explain the calculation of growing-stock by the yield table method.
Why is this most accurate?
Why is the yield multiplied by 10 in the formula?

Why is $\frac{i}{2}$ used?

Why in a 60-year rotation is a normal forest of 60 acres assumed?
What is Flury's constant?
How is it computed?
What is its advantage over the yield method?
Why are normal growing stock calculations important even in extensive forestry?

REGULATING THE CUT

76. Definition and Aims of Regulating the Cut. Regulation of the cut in the narrower sense means *the fixation in advance of the annual or periodic cut, which in the normal forest would be equivalent to the annual growth** (G., etats-bestimmung, ertragsbestimmung; F., fixation de la possibilitè).

The broader aim of regulating the cut is three fold:

(1) To cut each stand at rotation age (maturity) and secure the maximum required product. This is largely economic.

(2) To cut about the same amount of material of the most valuable product each year or decade. This is economic and financial and is all important.

(3) To reproduce about the same area each year or decade. This supplements paragraph 1.

(1) If each stand is cut at maturity, it will probably benefit the stand at the expense of the future of the forest because no progress would be made towards a regular yield which ultimately looks for regular age class distribution. On the other hand, if stands are cut when *very* overmature or immature, costly silvicultural sacrifices may result.

(2) If the present volume output is considered of first importance, it will mean a sacrifice in future orderliness for present immediate regularity of cut. For a forest that has been impoverished proper regulation demands that its stock be gradually built up; while a forest with excess stock should have this excess gradually reduced. This may decrease or increase the present cut but need not seriously interfere with *its regularity*.

(3) Unless a reasonably uniform area is reproduced each year or decade the ultimate normal distribution of age classes (and hence of the cut) will be defeated. To reproduce equal areas each year or decade is the *least important immediate object* but the *most important ultimate one*.

77. Basic Policy in Regulating the Cut. The first step in regulation is naturally to take stock and to divide the forest into timber productive and non-productive types as well as into management subdivisions. The next step is to obtain accurate growth data on the productive areas.

Before fixing the annual cut—one of the aims of regulation—the following general principles should also be recognized as basic:

(1) The forest should be managed so as to furnish the maximum quantity of the kind of material required by the owner. Where desired, scenic and protection working groups may be excepted from regular commercial management.

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* In the normal forest the current growth is the same as the mean annual growth. Before commencing chapter VII the student should read "Studies in French Forestry," pages 243-260, so as to have the modern working plan clearly in mind.

(2)   Other things being equal, cutting should be directed to the over-mature and mature stands and age classes.

(3)   Forest management must first provide for the prolongation and per-petuation of the timber supply—sustained *forest* production—needed by industries and for the stabilization of labor, if this can be done without too heavy a sacrifice of technical aims.

(4)   The technical aims of every working plan lead to (3) above and should be: proper distribution of age or diameter classes, normal growing stock, and a proper silvicultural condition ensuring suitable regeneration and a perpetuation of the forest as a whole. Under certain conditions fire or watershed protection may be the chief technical aim.

These aims must be carefully weighed and correlated.* But it must be recognized that no regulation or organization of a forest has the slightest chance of success unless it is based upon sound basic silviculture, because forest regeneration and forest production—both dependent on sound silvi-culture—must be successful or there will be no real forestry.

In our extensive western forests, which must at present often be logged by corporations capable of maintaining and operating large capacity plants with railroad feeders, there is usually presented the following problem which is exceedingly difficult to compromise without serious sacrifices:

(a)   Devastate mature and over-mature timber rapidly to avoid loss from decadence with a consequent heavy cut during the first cutting cycle, a cut which cannot be maintained after the store of ripe timber is harvested. The proper age class distribution will be delayed for a considerable period. This is not forestry.

(b)   Cut off mature and over-mature timber gradually assuming a consid-erable and increasing loss from decadence but aiming at a yield during the second cutting cycle equal or nearly equal to the original cut. The age class distribution will be secured at an earlier date than if (a) is adopted as the fundamental cutting policy. The *actual* losses from decadence are often over-emphasized.

(c)   Compromise between (a) and (b) so as to avoid part of the loss from decadence necessitated by (b) but obviating the serious hiatus of cut required by (a).

This problem must be decided in each case before the details of regulation can be intelligently worked out. Nor must the silvicultural requirements for proper regeneration be lost sight of. With plan (b) certainly regeneration will be surer than with (a) in difficult soil conditions such as often occur in Arizona. The administrator should always remember *that stability of pro-duction* is more important than to save timber that *may* be lost.

Speaking in terms of intensive selection forests in France, Biolley** argues that since the cut depends on the amount of the forest crop, it is better to

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* Eldredge. I. F., says (J. of F., 1920. pp. 284-291) the aims of management plans in the national forests of the Southern States are: maximum production of merchantable timber, permanence of local industries and forest labor, salvage of deteriorating timber, restocking mistreated areas, regulation of cut (by stand method).

** Biolley, already cited, p. 56-57.

decide on the *cut* after it is seen what the *amount* of the crop really is. He says:

> "The growth, which is the fruit of the treatment, can only be known after the product is disclosed; the yield can thus only be a prediction of the harvest (more or less strongly justified) for a very short lapse of time . . . . It is useless and an error to make predictions for a long time ahead; it is even worse to fix a yield for a rotation as is done, even if it is subject to revision every twenty years, for the yield-decree ties the hands of the forester, and substitutes for the worry of the silvicultural aim of the cutting, preoccupation over the volume which it is forbidden to exceed or obligatory to reach; moreover, *the treatment* (the essential thing) gives way to regulation and cannot be the objective."

What Biolley wants is not an *imposed yield* but a *crop proposal*. He desires to emphasize the need for placing more stress on silviculture and less on the regulation mathematics—a policy essentially sound if not carried to extremes. There must always be leeway in applying a prescribed yield figure—silviculture must not be throttled—but this is no excuse for not prescribing, systematizing and regulating the cut.

78. To Attain Regulation Compromises are Necessary. There is thus a conflict between the objects of regulation which entail a compromise. The complete attainment of a single goal (such as a sustained annual or periodic cut) may be sacrificed so as to attain partial progress toward age class distribution, or cutting stands when they are ripe. In another case it may be wise to cut before or after maturity so as to have a more regular immediate annual cut for a local sawmill or to insure better age class distribution during the next rotation. In still another instance more or less than the increment may be cut to attain normal stocking or to allow the development of young stands or prevent the decay of over-mature timber. A point in theory to remember is that under no circumstances would the annual cut be exactly equal to the mean annual increment unless the normal forest had been attained—difficult to attain even under intensive European conditions.

79. Relation Between Increment and Growing Stock. The principle determining the relation between increment and growing stock is normally as follows: one-half the increment will be upon trees cut *within* the rotation and one-half on the *new* crop not yet started. At the *end* of the rotation all timber *now* standing, including seedlings, will have been cut and the growing stock will consist of entirely new stands.

For accurate *regulation* accurate estimates are needed. But these cannot precede the *demand*, and seldom can be *complete* for entire forests because only areas where sales are a possibility can be estimated accurately and intensively. On the other hand, no real regulation is possible till the working group has been *fully* covered by *some* form of estimate. It is for this reason that rapid, cheap and approximate timber surveys are fully justified on areas not accessible for sales for many years to come. But the resulting regulation cannot pretend to be very accurate in detail, nor is this accuracy necessary as long as the cut is fairly conservative. In fact it would be faulty forest management to pay for intensive timber surveys when it was a certainty that the stand could not be cut over for many years. Until there is a market

with transportation to it regulation must be preliminary in character. Thus there is always a creative period when approximate methods are sufficiently accurate for obtaining increment and growing stock. Yet Moore* is exactly correct when he says:

"A thorough understanding of the silvicultural requirements of the different trees and of the methods of cutting which will result in a maximum production of the most valuable ones is the first essential. In the long run it is generally far better to have overcutting under proper silvicultural methods than to have a perfect regulation of the cut with poor methods of silviculture."

If one must choose between two evils, sound silviculture must not be slighted; but this does not justify devastation.

80. **Definitions and Classification of Methods of Regulating the Cut.** General classification of methods of regulating the cut may be recognized:

(1) Normal stock or formula methods, when the amount of cut is determined by comparison of actual with normal conditions and the cut is in part regulated by a volume formula for a rotation or equalization period.

(2) Allotment methods, when a rotation is fixed and for a given year or period of the rotation a certain area, a certain amount of stock, a certain number or size of trees is allotted to be cut.

(3) Individual or stand methods, when each stand is investigated for its maturity and designated for cutting, provided other age classes are in existence to assure continuity of crops. (This is usually supplemented by area and volume check.)

An attempt has been made to merge the allotment principle (namely of alloting stands for cutting in a definite period) with the various methods which make use of the alloting of stands directly or indirectly.

A glance at table 11 shows the classification of regulation methods adopted in this volume as contrasted with Recknagel, Roth, and Schlich. The writer has tried to select one typical form method for *each different class of regulation.* Volume methods have been given first because they have first been used in the United States with irregular virgin stands. In this volume the methods have been arranged as follows:

A. Volume basis. (1) Growing stock, (2) Increment, (3) Increment and growing stock, (4) Size classes, and (5) Tree as unit.

B. Area basis. (1) Pure area, (2) Area (and age) allotment by periods.

C. Area-volume (and age) basis. (1) Volume and area—volume allotment by periods, (2) Americanized stand selection, and (3) Cutting cycle and felling reserve.

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* Moore, B., Methods for Regulating the Cut on National Forests (P. S. A. F. Vol. VII, 1912, p. 11).

TABLE 11. Relative Classification of Methods for Regulating the Cut used by Different Writers.

Schlich (p. 3111, vol. III, 3d Ed.).	Roth (p. 139-159 also p. VII).	Recknagel (p. VIII, also p. 67-126).	Woolsey in this volume.
I. Stand Selection (Judeich). II. A. Fixed Annual Coupes. B. Allotment by Periods 1. Area. 2. Volume. 3. Area and Volume. C. Increment and Growing Stock. 1. Austrian. 2. Hundeshagen. 3. Von Mantel. 4. Brandis. D. Increment and Growing Stock Combined with Allotment of Areas to Periods (Heyer).	A. Area methods. 1. Fixed yearly cut. 2. Area allotment. 3. Limited area allotment (Judeich). B. Volume Methods. 1. Volume allotment. 2. Growing stock. a. Austrian (and Heyer). b. Hundeshagen (and Von Mantel modification). c. Combined methods (see p. 158). d. Diameter limit.	A. Area. B. Volume. I. Growing Stock Basis. 1. Von Mantel. 2. Masson. II. Increment. 1. Current Annual Increment. III. Growing Stock and Increment. 1. Austrian. 2. Karl. 3. Hundeshagen. 4. Breymann. 5. Heyer. IV. Diameter Classes. 1. French method of 1883. 2. Indian method. 3. Diameter class method (Hufnagle). C. By Area and Volume. I. For Entire Forest. 1. Gurnaud. II. Based on Age Classes. 1. Direct method. 2. Hufnagl. 3. Stand Method (Judeich). III. Periods. 1. Area. 2. Volume. 3. Area and volume. 4. American method (Chapman).	A. Volume Basis. 1. Growing Stock. 2. Increment. 3. Increment and Growing Stock. 4. Size Classes (and Periods). 5. Tree as Unit (and Increase in Size). B. Area Basis. 1. Pure Area. 2. Area Allotment by Periods. C. Area-volume Basis. 1. Volume and Area-volume Allotment by Periods. 2. Americanized Stand Selection. 3. Cutting Cycles and Felling Reserve.

(Vertical text in Recknagel/Woolsey columns: "Basic Scheme of Periods")

The following methods of regulating the cut cited by Recknagel (his symbols have been used) have not been described in this volume for the reasons given:

TABLE 12. List of Formulae Omitted from Text.

Name of method	Page*	Scheme or Basis.	Why discarded.
Masson's method	74	Same basis as Von Mantel.	Duplication.
Swiss method**	74	Divide volume of oldest size classes by c. a. i. of entire stand to get number of years volume of class must last.	Faulty regulation unless forest normal. Scientific interest only.
Austrian formula "Kameraltaxe"	78	$Cut = i + \dfrac{ga - gn}{r}$ where $i = $ *actual* m. a. i.	Because r is rigid; it is better to distribute surplus or deficit according to local conditions.
Hundeshagen's	85	$Cut = \dfrac{v}{v} = \dfrac{ny}{ny}$, or $y = v\dfrac{ny}{ny}$	Identical to Von Mantel or Karls "Austrian," if period of distribution $= \frac{1}{2}$ rotation.

Breymann's	86	$y = ny \dfrac{a}{na}$ (here a = age).	Because surplus or deficit distributed over whole rotation.
Heyer	88	$y = \dfrac{n + ix - nv}{x}$ where i = a. m. a. i. x = x years or period of distribution.	See paragraph 85.
Diameter class method (Hufnagl)	100	Cut = vol. of trees or of diameter classes $\dfrac{r}{2}$ years $+$ over-plus increment thereof in $\dfrac{r}{4}$ years; this sum divided by $\dfrac{r}{2}$ equals the cut.	A rigid scheme rather than a distinct method of regulation. If volume of upper classes very deficient, there might be no cutting.
Direct method (Hufnagl)	108	(Average volume per acre = volume of oldest stands divided by area occupied by stand) $\times$ allowed area to be cut = volume to be cut.	Too rigid and no basic method of regulation. If data it requires is available, modified allotment method feasible and preferable.
Hufnagl's method	110	Yield = $\dfrac{\text{volume} + \text{area} \times \text{increment***} \times \dfrac{\text{rotation}}{4}}{\dfrac{\text{rotation}}{2}}$	See above.

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* In Recknagel's "Theory and Practice of Working Plans."

** C. H. Guise, in J. of F., 1917, pp. 564-573 on "The Swiss Method of Regulating the Cut in Practice" advocates a further trial of the method and states it gives a higher cut than does the Von Mantel formula in the case cited.

*** Mean annual increment gives a cut 10-20% less than if current increment used.

(A) VOLUME METHODS OF REGULATION

81. General Principles and Classification of Volume Methods.[*] Formula methods should rarely be relied upon as the sole basis for establishing the cut; they should be used as a rough check against other methods that take into consideration volume and area as well as age. The use of a formula may be necessary in order to answer a problem in yield which does not yet justify the use of more intensive methods. Under American conditions the use of the board foot unit of measure is a dangerous complication in the use of volume because young stands may yield no board feet and yet the aggregate of trees have a considerable cubic content per acre. The trees from such stands yield cordwood but no lumber. Therefore the use of an area check when using formulae methods is all the more essential.

Care has been taken to recommend certain formulae methods for use under specified conditions as differentiated from methods of mere scientific interest which nevertheless are explained for the information of the student.

Regulation on the basis of *volume* has been classified as follows:

Main Basis	Secondary Basis	Formulae
(A) Volume.	(1) Growing stock.	(a) Von Mantel.
	(2) Increment.	(a) Gurnaud.
	(3) Increment and growing stock.	(a) Austrian. (Other forms of Austrian formulae discarded.)
	(4) Size classes (and periods).	(a) French method of 1883.
	(5) Tree as unit.	(a) Indian single tree method.
		(b) Diameter limit.

Intermediate yield. Whatever method of calculating the cut is employed, the regulation of the intermediate cut from thinnings, clearings, weedings, etc. should be based upon the principle of cutting approximately equal areas annually or periodically. It is most essential to keep the young stands from becoming too dense and to eliminate undesirable trees as well as the less promising species; then if intermediate cuttings be limited by volume, it might occur that areas in need of thinnings could not be reached. Such areas must be cut over systematically and this can be best insured by covering a certain area each year even if the volume cut is slightly exceeded. This

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[*] Methods noted as "of scientific interest" might have been termed "of academic interest."

yield from intermediate cuttings is usually estimated so as to secure a tentative volume figure for the annual or periodic budget.

In the treatment of the various formulae the method has been (1) defined, (2) discussed and the advantages and disadvantages summarized, and then (3) illustrated by practical examples. Methods noted as "of scientific interest" will not generally be used in the United States.

82. (1) Volume Regulation Based on Growing Stock. a. Von Mantel's* method (chiefly of historical interest but often recommended during the initial stage of organization) is as follows:

$$\text{Annual cut} = \frac{\text{actual growing stock}}{\frac{1}{2} \text{ rotation}}, \text{ i.e., annual cut} = \frac{Ga}{\frac{1}{2} r}$$

$$\text{where r' is used, this becomes: annual cut} = \frac{Ga}{\frac{1}{2} r'}$$

$$\text{Basis: on theory } Gn = \frac{r \times i}{2} \text{ or } Gn = \frac{r' \times i}{2}$$

surplus distributed over $\frac{r'}{2}$ years." It gives the same results as Hundeshagens when he finds Gn by the $\frac{r \times i}{2}$ method.

As Moore** points out, if r' is used "the yield will be the same as that given in the Austrian formula in which Gn is found by the use of r' and the surplus distributed over $\frac{r}{2}$ years." But the Wolff formula is preferable to Moore's although the basic ideas are similar (see § 66-67).

Discussion. Since this method does not require a study of increment, it has been widely used by the Forest Service in its rough preliminary regulation. The volume to be cut is the keynote instead of the area reproduced or the age of the stand.

This formula is faulty in that it assumes *normality* but is always applied to the actual forest which cannot fail to be *abnormal*. By this assumption it provides that an amount equal to the present growing stock, surplus or deficit included be cut in half the rotation. The condition of the forest after that time will depend on the amount of increment laid on,

a. On stands previous to cutting

b. On stands originating after cutting

c. On young stands becoming of estimable size after the calculations are made.

Howard*** suggests a modification of Von Mantel's formula to $\frac{Ga}{\frac{3}{8} r}$ for use

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* Masson's (France) formula is identical only it is written $\frac{2Ga}{r}$ instead of $\frac{Ga}{\frac{1}{2}r}$.

** Ibid. It should be remembered that about twice the normal growing stock is produced by a forest during the rotation; therefore the amount that can be cut is 2 Gn.

*** J. of F., Vol. 46, pp. 417-421, August 1, 1920. Von Mantel's formula, or modifications of it, should primarily be used as a check against other methods as has been explained in the text. The disadvantages in using this formula, or any other formula, may be diminished if there are very frequent recalculations of yield based on a re-estimate of the growing stock. The main difficulty is that frequent estimates, even under intensive conditions in Europe, are a burden of expense.

in Indian selection forests. This has the same disadvantages as Von Mantel's but might be a useful idea under certain conditions.

It follows that over-stocked forests of over-mature timber will be stripped

CUT ACCORDING TO VON MANTEL (UNCORRECTED)

- - - - - CUT WITH CORRECTION FACTOR APPLIED (APPROXIMATE)
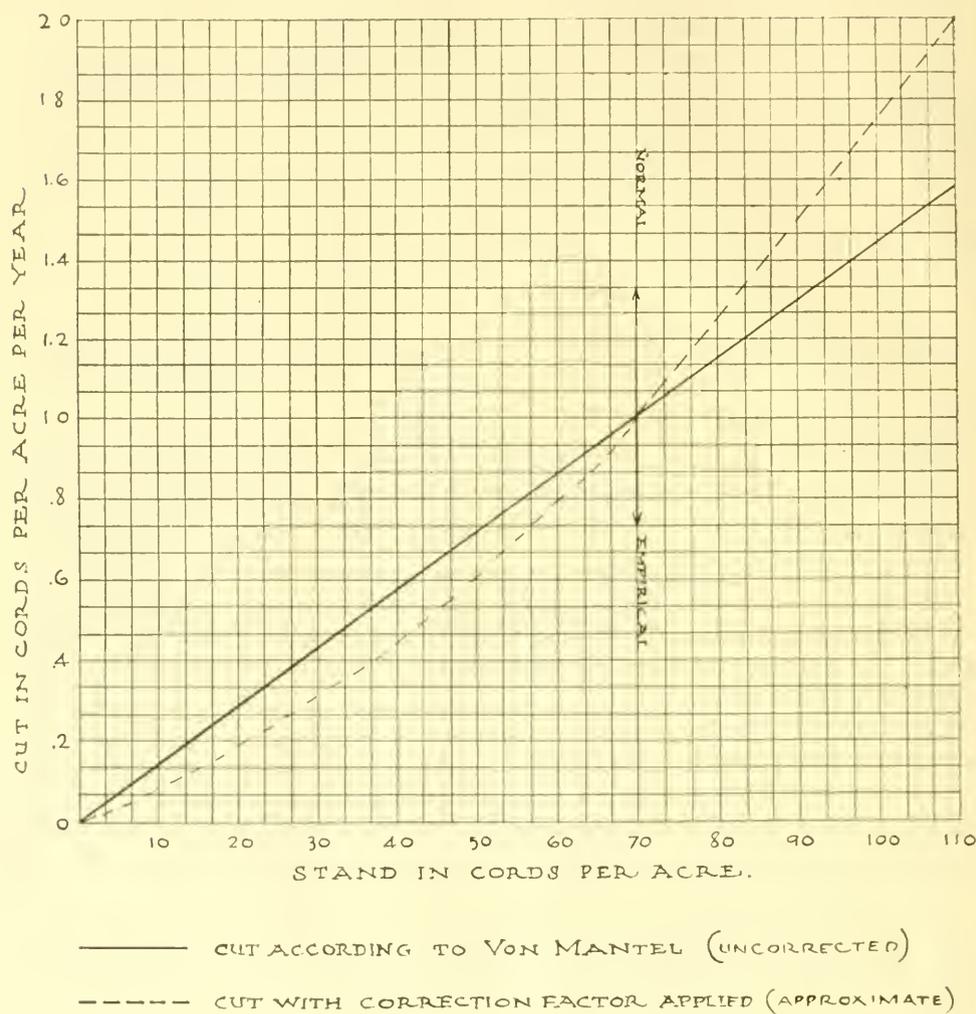
FIG. 5. Illustration of the Result of Using a Correction Factor for Von Mantel's Formula.

of all merchantable timber in half the rotation; this would probably save waste but might be a serious overcut where the cut was in board feet; the remaining stand might be too small for merchantable sawlogs. Frequent re-estimating and re-calculation of the cut would lessen these dangers.

The formula error of exaggerating the cut for an impoverished forest and cutting too little on one that is rich in material can be modified by correction

factors. The *per cent* of the growing stock to be cut, Schaeffer says,* should be higher with 60 cords per acre than with but 20.

"To enable an impoverished forest to restock less than the amount indicated by the formula should be cut; the per cent cut should be reduced."

This correction factor is systematized by considering that the per cent given by the formula (cut $= \dfrac{Ga}{\frac{r}{2}}$) is approximately correct for an empirically normal stand. Then a table is constructed diminishing the formula per cent 0.1 for stands that are 50 cubic metres less than normal and increasing the per cent 0.1 for each 50 cubic metres above normal. A correction factor was then worked out for 5 soil qualities corresponding to rotations of 120, 140, 160, 180, and 200 years for silver fir. The idea can be applied in the United States, where this formula is used. For a second quality silver fir stand (with a rotation of 140 years) the *actual volume* to cut by the formula (corrected and uncorrected) is illustrated by figure 5.

Where r' (after Wolff) is used instead of r, this means that the merchantable timber will be cut even more rapidly.

Disadvantages:

(1) It is inelastic because the surplus or deficit is always taken up in half the rotation; if the cut can be frequently re-calculated upon the basis of new estimates this objection is less serious.

(2) With board feet it gives too low** a cut unless r' is used.

(3) It rests on *faulty regulation* because it neglects the age and rate of growth of stands and area of cuttings (an area check corrects this to a certain extent).

(4) *Only* of use in preliminary and crude regulation (even then should be used only *with* area check).

(5) It has not been thoroughly tried out by experience*** (abandoned in Europe).

Advantages:

(1) "........Will gradually lead to the establishment* of the normal growing stock" and "........adapts the cut to the actual growing stock on the land........."

(2) It is easy to apply since it merely requires the actual growing stock and rotation; it is handy.

(3) Of value in preliminary and crude regulation where an approximate volume *check* is required by law (as on National forests).

Illustration. Given:- Case (1) Ga = 1,043,000 board feet.

Case (2) Ga = 1,304,000 board feet. (This coincides with Gn.)

Case (3) Ga = 1,565,000 board feet.

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* Schaeffer, A., Un Correctif a la Methode Masson, Bulletin de la Societe forestierre de Franche—Comte at Belfort, No. 3, 1905.

** Ibid., p. 18.

*** Roth, Filibert, Forest Regulation, p. 157.

* Schlich, Vol. III, p. 320.

Where r = 60, r' = 45 years and the area 60 acres.

Then by cut = $\frac{Ga}{\frac{1}{2}r}$ Case (1) $\frac{1,043,000}{30}$ = 34,766.

Case (2) $\frac{1,304,000}{30}$ = 43,466.

Case (3) $\frac{1,565,000}{30}$ = 52,166.

Reference is made to a comparison with the Austrian formula § 85; see also § 66-67.

83. (2) Volume Regulation Based on Increment Alone. Since all forests are abnormal (see Chapter VI), the use of increment alone for purposes of regulation is considered dangerous and inadvisable especially under American conditions.

The idea expressed in the Gurnaud* plan is little more than of scientific interest. Gurnaud simply treated the forest as a sample plot and increased or decreased his cut according to the results of past cutting modified by the dictates of current silviculture and market conditions. If the forest was about normal (on an empirical basis), the annual cut was supposed to equal,

(Present Ga — former Ga) + (cut between stock takings)
(Years between measurements)

In applying the allowed yield they endeavored to cut according to the empirical representation of age classes in the ideal selection stand for the species in question.

This is of course faulty in that it presumes (unless applied with great judgment) the growth should be the cut—a mistaken ideal. It also necessitates frequent remeasurement, a factor which is exceedingly costly in the United States.

Furthermore the Gurnaud* idea really goes further and seems to subordinate the modern conceptions of a fixed rotation, of a sustained or fixed yield, or of a normal forest to a flexible method of silviculture that will give the owner the *greatest possible growth*. The forest is to be intensively managed as a number of sample plots with frequent stock taking (every 5 or 10 years). The cut is to be based on the results obtained over short periods rather than on predictions for several decades. The sustained yield and the ideal normal forest will be secured, Biolley claims, by carrying out the aim of getting the largest possible growth with the minimum possible growing stock. The method aims at largely subordinating forest regulation to silviculture. As a method it would rarely be applicable in the United States even under intensive conditions; moreover, the method is really an *idea or policy rather than a recognized and distinct system of regulation*. It is an idea that could be applied with any regulation method and as a matter of fact, is made use of by the best management men in France, when applying the French method of 1883. In fixing the yield the regulator studies the area, volume, age classes, and growth on each lot.

Disadvantages: (1) If current increment is taken as the basis of the cut, it will be too small with decadent forests and too great with immature stands.

(2) If mean increment is taken (if *actual* mean is taken for each age class, then it is much too high for young stands and too low for overmature stands) overmature stands will not be reduced, nor immature built up by merely cutting the increment because the present amount and age of timber is not considered.

(3) It is expensive and difficult to measure the increment on the entire forest.

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* Those who wish to study Gurnaud's ideas on regulation should refer to La Methode du Controle, P. Jacquin, Besancon, 1886, pp. 1-124; also La Methode du Controle a'l exposition universelle de 1889 published in 1890. See Recknagel (ibid.) p. 106 and pp. 74-77; also Studies in French Forestry by T. S. Woolsey, Jr., John Wiley & Sons, 1920, pp. 206 to 243.

** Recknagel, A. B., Forest Working Plans, described (pp. 74-77) as the "Swiss" method regulation by increment alone, but the writer prefers not to introduce this to American forest students.

* Biolley already cited, p. 29 and 59.

(4) To be at all satisfactory there must be a normal age class distribution which is not found.

Advantages: None; but often of interest and value as a rule of thumb check on actual increment under the practical conditions that have prevailed in the forest. Losses through suppression, etc. are shown in the calculation.

84. (3) Volume Regulation Based on Growing Stock and Increment. The stumbling blocks to this class of formula are: (1) How to calculate the normal growing stock; (2) whether to use current or mean annual increment; should this be the normal or actual increment?; (3) the term of years during which the surplus or deficit should be distributed.*

The best results in regulation based on growing stock and increment are obtained by the following methods:

(1) Calculate the normal growing stock by the yield table method (see par. 68-69) where practicable; if not, use $\dfrac{r \times i}{2}$ or where board feet are used, substitute $\dfrac{i\,(r^2 - s^2)}{2\,r}$ (see § 66-67).

(2) Use actual mean annual increment instead of the current annual. Normal increment should not be used.

(3) The surplus or deficit should be distributed according to the condition of the stand and according to the economic possibilities for saving. Rarely, if ever, will the entire rotation* be used as the time within which to distribute a surplus or deficit.

The distinctions between the various formulae based on growing stock and increment are illustrated in the table which follows.

TABLE 13. Distinctions Between Formulae Based on Growing Stock and Increment.

Name of Method	Historical Reference	Formulae	Remarks
Austrian (as modified by Von Guttenburg or Heyer).	Roth, p. 150 Schlich, p. 314 Recknagel, p. 78	Cut = actual M. An. $i + \dfrac{Ga - Gn}{x}$ (Most practical adaptation).	Actual mean annual increment is used and it is assured x is flexible rather than the rotation time.
Karl's*	Roth Schlich (not given) Recknagel, p. 83	(Of scientific interest.) Cut = actual current An. i $+ \dfrac{Ga - Gn}{x}$	Actual current annual is used. Not described by Roth and Schlich.
Hundeshagens** (see Von Mantel, p. 75)	Roth, p. 56 Schlich, 317 Recknagel, p. 85	(Of scientific interest.) Cut = $Ga \times \dfrac{ni}{Gn}$	Avoids the calculation of actual increment. Is inelastic. Basis incorrect.

* Roth, Filibert, Forest Regulation, p. 151 holds, as does Von Guttenberg, that it is an error to consider the Austrian formula as spreading the surplus or deficit over *an entire rotation.* See also Indian Forester, March 1922, pp. 122, 126.

** Those who are interested in the variations between these formulae are referred to page 91 of Forest Working Plans by A. B. Recknagel, but it should be borne in mind that the variations will change according to the period of distributing the surplus or deficit and according to the data assumed as a basis for the example.

Breymann's**	Roth Schlich (not given) Recknagel, p. 86	(Of scientific interest.) $\text{Cut} = \text{M. An. } i \times \dfrac{\text{Normal Age}}{\text{Actual Age}}$	Normal age = half the rotation. Has the disadvantage of being inelastic.
Heyer's** (see par. 85).	Roth, p. 154 Schlich, 325 Recknagel, p. 89	$\text{Cut} = \dfrac{Ga + i - Gn}{x}$ Roth does not distinguish the Heyer formula from the Austrian.	i is the actual M. an. increment for rotation. See discussion of Austrian method where x is variable.

Of these formulae Heyer's is the most accurate in theory, but since formula methods are approximate, a simpler form is preferred.

To give satisfactory results the formula must be based on actual mean annual increment and the surplus never rigidly distributed over the *whole* rotation. An analysis of the formulae shows that Karl's can be discarded because it is based on actual current annual increment and possesses no advantages secured by the flexible type of the Austrian formula. Hundeshagen's is too inflexible because there is no choice as to decreasing or lengthening the time for the distribution of surplus or deficit. Breymann's presents too intricate a problem when it comes to determining the actual average age. Heyer's embodies the same principles as the modified Austrian but no improvement. Therefore but one type of formula is described and illustrated.

85. (a) **The Modified Austrian Formula.** (Von Guttenberg form; often termed Heyer modification). The formula reads:

Annual cut = actual mean annual growth +
actual growing stock — normal growing stock
÷ years over which cut is distributed

$$\text{i.e., annual cut} = \frac{\text{m. a. i.} + Ga - Gn}{X}$$

Discussion. The increment used is ordinarily the actual mean annual increment. The actual growing stock must be obtained by an inventory of the forest. The normal growing stock is computed preferably from yield tables, or from the formulae $\dfrac{r \times i}{2}$ or $\dfrac{r' \times i}{2}$ (see § 67 to 68). The surplus or deficit is distributed in a shorter or longer period according to the dictates of good silviculture and good business. If the timber were very over-mature, the tendency would be to reduce the surplus rapidly. If a deficit existed, it should not be made up so quickly that the resulting forest would contain diseased timber. Nor could economy be practiced to such a degree that the yield for local dependent industries would be dangerously reduced. Where the actual stock (as in the West) consists largely of mature and overmature timber, the apparent surplus over the theoretical normal stock is not potentially as great as it might appear to be. For when all the over-ripe timber is cut for silvical reasons there is likely to be a deficit in growing stock because there is no middle-aged timber.

The Austrian formula gives the same results as Von Mantel's (see § 82) if the period of distribution (or equalization) is taken at ½ r.[2] With longer

or shorter periods of distribution the cut by the Austrian formula will be *less* or greater than that by Von Mantel's.*

Before using the Austrian formula it is well to bear in mind its peculiarities,

(1) Application to a given volume in the forest. The smaller the mean annual increment on this volume, the more overmature the forest and the larger the annual cut because the normal stock depends on increment; the increased cut due to the surplus more than offsets the loss due to the small increment. The result of cutting is a large reduction in the surplus. Hence if actual *current* increment in old stands were used, heavy cutting is indicated which is obviously good forestry. Conversely, the larger the increment, the smaller the cut, until the forest becomes normal, because a large normal stock is indicated.

(2) With a long rotation the cut is diminished because of the increase in the normal stock. Therefore a conservative cutting of the present forest is best secured by adapting as long a rotation as possible.

With a longer period for the distribution of the surplus the cut is of course diminished; again, if there is a surplus in the growing stock, then the cut would be increased by a short period of distribution.

A conservative cut demands the use of the actual mean annual increment at its culmination as the basis for the normal stock. For a rapid cut use actual current increment (especially in old stands), with a short rotation and a short period for distributing the surplus.

Disadvantages:

(1) It is highly artificial and tricky, especially with a board foot measure, unless the normal stock is calculated by the formula $\dfrac{i\,(n^2 - s^2)}{2\,r}$ (see § 66-67) or from yield tables; even then it is subject to error.

(2) It assumes that i and Gn remain constant whereas they are continually changing because of natural and artificial causes. This is not as serious an objection as might appear because it is corrected at the time of revision.

(3) It ignores area and age. It is an "office" rather than a "field" method of regulation.

Advantages:

(1) It is elastic because there is wide choice as to the number of years in which to distribute the surplus or deficit.

(2) The objective of always trying to approach the normal stock is clearly before the regulator.

(3) Adapted to extensive forestry and clearly distinguishes between capital and income, but its value lies chiefly in its use as a check on other methods.

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* For example given $i = 100$, $r = 100$, $Ga = 7,000$, $Gn = \dfrac{100 \times 100}{2} = 5,000$ and if $x = 50$ years, the Austrian formula works out $50 \times 100 + \dfrac{7,000 - 5,000}{50} = 140$, while by Von Mantel we have $\dfrac{7,000}{50} = 140$, an identical figure. The Austrian and Von Mantel give the same results only in case the inaccurate $\dfrac{r \times i}{2}$ formula is used to calculate the normal growing stock.

Illustrations. Given for a forest of 60 acres:

	Case (1)	Case (2)	Case (3)
Ga	1,043,000	1,304,000	1,565,000
Gn	1,304,000	1,304,000	1,304,000
m. a. i	1,003	1,003	1,003
r	60	60	60
x	50	30	15

It follows that:

$$\text{Case (1). Cut} = 60,180 + \frac{1,043,000 - 1,304,000}{50} = 54,960$$

$$\text{Case (2), Cut} = 60,180 + \frac{1,304,000 - 1,304,000}{30} = 60,180$$

$$\text{Case (3), Cut} = 60,180 + \frac{1,565,000 - 1,304,000}{15} = 77,580$$

In case (1) there was a deficit of growing stock, so the cut was reduced; in case (2) there was no change because the growing stock was normal; in case (3) there was an excess growing stock, so the allowed cut was largely increased and especially because the excess was to be cut in 15 years.

86. (4) Volume Regulation Based (on Growing Stock and) Size Classes (and Periods). (a) This so-called method* of 1883 as applied to *selection forests* of *tolerant* species is as follows: After inventory (by diameter classes), determine the rotation and the corresponding size of tree, then classify the stock in three classes: (1) *Old wood,* trees more than two-thirds the exploitable (rotation) size; (2) *Average wood,* trees less than two-thirds and more than one-third; (3) *Young wood,* less than one-third (usually not calipered). *Where there is a normal (or nearly normal) proportion of old and average wood (see discussion), the cut** equals the volume of the old wood divided by a third of the rotation plus half the annual growth on the old wood class while it is being cut.*

87. Discussion of French Method of 1883. The method was designed for selection high forests of tolerant species, where the regeneration could be secured in at least one-third the rotation, and where a sustained yield was important. It is based on the conception that a selection forest, normally constituted, is just like an even-aged forest (where, on equal areas, stands of all ages up to the rotation age are found), except that the various aged trees are intermingled. In the latter case an equal cut is secured by cutting

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* Based on the original official instructions issued by the French Secretary of Agriculture and on the Chamonix Working Plan by A. S. Schaeffer.

** Compare this method with the Hufnagl *"diameter class method"* described by Recknagel (ibid.), pp. 100-105; The Hufnagl method (Variation I) is: Annual cut = volume of trees or of diameter classes $\frac{r}{2}$ years and over, plus increment thereof in $\frac{r}{4}$ years."

Recknagel gives an interesting example of (Variation 2) where the trees have been grouped by 3-inch classes with the basis data (for each class) of volume per tree, average number of trees per acre, and years required to grow from one class to the next (and "average age of the average tree in each diameter class). For each class the cut is equal to volume of class × number of trees per acre. The yield for all classes can then be increased or decreased according to the surplus or deficit in the growing stock. According to Recknagel's example the surplus is reduced in one cutting cycle, which is made equal to the number of years to grow to the highest diameter class from the preceding class. For more complete discussion see Recknagel.

each year areas of the same size and productivity. But in the selection forest the cutting must remove only ripe trees here and there over the entire area without any comparison of *surface*. Therefore, in this case *volume* must be substituted for surface.

The method is based on the assumption (see diagram) that the volume of the old wood is ⅝ and the volume of the average wood ⅜ the total *merchantable volume*, it being presumed that the young wood is unmerchantable.
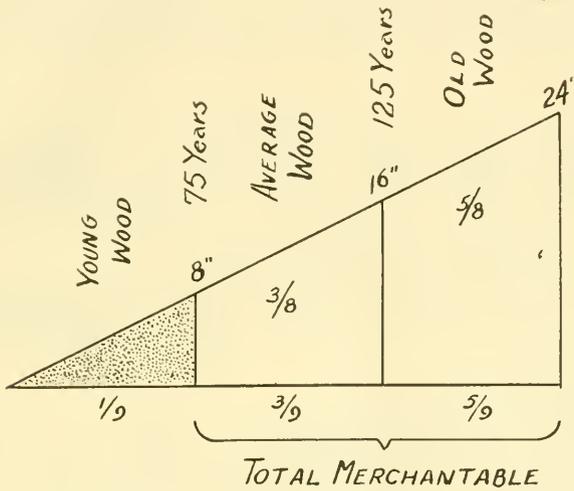
According to the French Secretary of Agriculture, the data furnished by research on the mean annual rate of growth of high forests shows that this relationship is approximately as 5 is to 3. Therefore whenever in a selection forest the volume of the old wood and the average wood is as 5 is to 3, it can be taken for granted that these two groups are similar to the first two periodic blocks of a high forest. To demonstrate that the volume covering the two first periodic blocks of a regular high forest (divided into three periodic blocks) are about as 5 is to 3, which represents their average age respectively. it suffices to note that the trees of the second periodic block are the average wood, which has arrived at a state where the annual growth is very uniform and just about equal to the average of the stand and at a period when it is safe to figure the future growth as equal to the past average. Suppose a high forest with a 150-year rotation were divided into three periods of 50 years each. The average age of the first (old wood) and second (average wood) periodic blocks will be 125 and 75 years and will be separated by a length of time equal to a period of 50 years. In admitting that the future growth will be equal to the average growth, the volume of the 125-year wood will be equal to that of the 75-year old wood *increased* by an amount

equal to 50 times the annual growth. Then if we designate the volume of the 75-year old wood as 3, the 125-year old volume will be $3 + \frac{3}{75} \times 50 =$ $3 + 2$, or 5. This assumption of an equal mean annual growth, of course, is not exact, but according to French reasoning it is sufficiently accurate for an *approximate formula*, which is being continually revised at working plan revisions, when the standing timber is re-calipered.

> "One can object to this method of classification because the diameters are not exactly proportional to the ages, that they are not equal for the same species, or same age, inasmuch as the trees of a selection forest are very far from growing under the same conditions. But it is to be supposed that with a large number of trees . . . . a sufficient compensation will take place in order to even off the inaccuracies and render them negligible. Moreover it is not essential to arrive at exact mathematical results (nor possible)."

The language and argument of the original French instructions is instructive in considering the method and in applying it. As originally promulgated, so as to be conservative, no increase was made in the cut for the growth which took place on the old wood while it was being harvested. But within recent years it is customary to figure growth.

The method is simple when the proportion of the old wood to the young wood is as 5 is to 3, *or nearly so,* but this normal ratio is not usually found. Instead there is,

    (1)   An excess of old wood, or

    (2)   An excess of average wood.

In either case (1) or (2) an approximately normal ratio is secured by transferring diameter classes from the old wood to the average wood or vice versa if it is safe silviculturally to hold over some of the older trees or if (where the average wood is too great) the large average wood sizes can be cut without too great a sacrifice.

An important feature of the *application* of this method by the best French working plan officers is that they compare the actual growing stock (on the basis of number of trees per acre of different sizes) with an empirical "normal" stand (an adjusted average for the region). This is an essential and important part of the method *as best applied* but is not mentioned in the official instructions.

If desired, a rough area check can be applied by considering that the area cut over should be proportional to the volume removed. The original instructions stipulated that (1) the length of the cutting period be a submultiple of a third of the rotation, (2) the number of compartments be about equal to the years in the period, (3) the local forester be free to allot the amount of the cut in each compartment according to local requirements at the time of cutting, and (4) the yield be revised at the end of each felling period.

Disadvantages:

    (1)   Unless there is some other check on the normality of the old wood and average wood besides the proportion of 5 to 3, it is insufficient because an acre might contain 5 board feet of old wood and 3 board feet of average

wood without being normally constituted. There must be some conception of total volume.

(2) Trees must be tallied down to ⅓ the rotation age.

Advantages:

(1) The yield is in accordance with the condition of the stand.

(2) The tendency is to work towards normal diameter classes.

(3) A sustained yield is secured and the growing stock is being continually built up.

(4) The method has worked fairly well in practice.

88. Illustration* of French Method of 1883. The exploitable size is 24 inches corresponding to 180 years.

The old wood is 17 inches and over, the average wood 9 to 16 inches inclusive and the young wood 1 to 8 inches.

A sample inventory follows:

	Young wood			Average wood			Old wood	
D. B. H. inches	Number trees	Total volume bd. ft.	D. B. H. inches	Number trees	Total volume bd. ft.	D. B. H. inches	Number trees	Total volume bd. ft.
1								
2								
3								
4	Not calipered							
5	nor computed.							
6								
7								
8								
			9					
			10					
			11	Completely				
			12	calipered				
			13	and computed				
			14					
			15					
			16					
						17		
						18		
						19	Completely	
						20	calipered	
						21	and	
						22	computed	
						23		
Totals	......				3,000 M			5,000 M

A. According to the inventory the normal proportion exists, the average wood totalling 3,000 M and the old wood 5,000 M; therefore, the cut is $\frac{5,000}{60} = 83$ M per year, or if the old wood were growing at the rate of 2% per year, $\frac{5,000 \times .02 \times 60}{2}$, or 3 M would be added, making the cut 86 M.

B. Suppose the volume of the old wood = 6,200 M, and
the volume of the average wood = 1,800 M.

Here the old wood exceeds the normal proportion so the old wood diameter classes should be examined to see if they can be transferred to the average wood group and held over a period equal to 60 years (⅓ the rotation). If there is no objection to this transfer, the trees in the 17- and 18-inch diameter classes (which we will presume totals

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* An exact adaption of an official French illustration of the Method, but also based on the Chamonix Working Plan by A. Schaeffer, with American units substituted.

800 M) will be deducted from the old wood. Thus 6,200 M — 800 M = $\frac{5,400}{60}$, equals 90 M (plus growth).

C. Suppose the volume of the old wood = 3,300 M and
the volume of the average wood = 4,700 M.

Here the average wood is in excess of the normal ratio so it is determined whether one or more of the largest average wood diameter classes can be transferred to the old wood for immediate cutting. If it is found that the 16-inch diameter class (which we will presume totals 600 M) can be added to the old wood, the volume will be 3,300 M plus 600 M, which equals 3,900 M, and the cut, $\frac{3,900}{60}$, equals 65 M (plus growth).

89.   (5)   Volume Regulation Based on the Tree as a Unit; (a) Indian Single Tree Method (Brandis*). (Of scientific interest, but might be used in the Philippines.)

The forest is first inventoried by broad diameter (in India = girth) classes, the current rate of diameter growth determined, a technical rotation established, the mortality loss estimated, and finally the average number of trees maturing annually computed (by multiplying the trees in each class by the percentage that will survive) and the cut fixed so as to remove the surplus stock (or supply a deficiency) within a reasonable period. (See illustration.)

Discussion. The method originated in Burmese teak forests where the merchantable timber comprised but one tenth the stand. According to Schlich,

". . . . Brandis's object was to ascertain as quickly as possible the number of first class teak trees which might be removed annually without exposing the forests to deterioration."   •

It must therefore be clear that the method is approximate and was designed simply to prevent overcutting in a tropical forest where but few species were merchantable. Since it deals with trees rather than a unit of measure, it is simple and easy of application in a country where low class labor must be used in valuation surveys. In recent** years,

"The area check is applied by prescribing the order of the fellings through the different subdivisions (compartments) of the working circle. A table is drawn up showing for each year the subdvision on which the cut is to be located and number of trees to be removed."

In the United States there appears to be no justification for the use of this method but it might be of value in the Philippines during the initial stages of forest management.

The *weaknesses* of the so-called Brandis method are as follows:

(1)   The growth calculations are based on current growth in diameter, and in India particularly, this data is often scanty and unfortunately must be applied for considerable periods.

(2)   The mortality per cent is evidently a most essential part of the calculation, and yet according to the authors themselves, the basis for this mortality per cent is a mere guess.

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* This is based on Vol. III, Schlich's Manual of Forestry, pp. 321-325. The illustration is adapted directly but with added explanation.

** Moore, Barrington, Methods for Regulating the Cut on National Forests (P. S. A. F. 1912, p. 25).

(3) The basis for determining the rotation is the length of time it takes a single tree to grow to a certain size. The factors of the mean annual volume production per acre cannot be weighed—a most unfortunate feature in any rotation method.

(4) Particularly where the forest is a mixed stand and where only one species in this stand is merchantable, there is grave question whether the younger age classes will survive a selection cutting which cuts one species which is merchantable and must leave less desirable species in possession of the ground. With this form of cutting the inference is that natural regeneration of the desirable species will be unsatisfactory and therefore any method which counts on the survival of the desirable species now being lumbered is dangerous unless very frequent stock taking can be afforded.

(5) The question of individual judgment is paramount, and different men might calculate a vastly different number of trees to cut. While this criticism is true in a certain measure of almost all yield calculations in their final analysis, and rightly so, yet in other methods the personal judgment is of less weight.

The following might be cited as advantages:

(1) It is suited for extensive tropical forests where only one or two species (such as teak) are merchantable and where crude selection felling is the rule.

(2) Stock taking by native labor is possible owing to the use of broad diameter or circumference classes.*

(3) Adapted for an initial check on cutting, where, because of economy, more modern methods cannot be applied.

Illustration. The productive forest area is taken as 84,022 acres of 51 compartments. The field work showed:

1 Class (D. B. H.) inches.	2 Initial No. of trees (trees available).	3 Total age (years) on entering class.	4 Years to pass through each class.	5 Percentage surviving and entering next class.
I over 28	31,523 (29,947)	156		95
II 24–28	18,114 (15,397)	130	26	85
III 18–24	42,768 (29,938)	93	37	70
IV 12–18	101,737 (50,869)	60	33	50
V 6–12	150,910 (37,728)	31	29	25
Below 6 not counted.				
Totals	345,052 (163,879)	156	156	
Class II–V	(133,932)			

* For a further discussion of this method see P. S. A. F., 1912, pp. 24-27 and Forestry Quarterly, p. 910, p. 52, and pp. 332-333. In the Quarterly, p. 52, Class I should be $\frac{83\frac{1}{2}}{100}$ instead of $\frac{3\frac{1}{2}}{100}$.

These figures are from a Burmese working plan by A. Roger. In the original plan column 1 was by girth classes. In column 2 the upper figure in each class is the result of the original stock taking and the bracketed figure the original stock multiplied by the percentage in column 5.

Column 3 is based on the data in column 4 which is the result of stump analysis of only 198 trees. Column 5—the crucial and important figures—is based on

"observations made in this and other forests in Burma from which it was ascertained that the following percentages of sound trees are likely to survive and be available for utilization."

The rotation was 160 years, 5 periods of 32 years each. It is clearly based on the number of years it takes a tree to grow *up to* the class V following 31 years to grow *up to* class I.

90. (b) Diameter Limit (Pinchot-Graves). (Of scientific interest.) This method (now abandoned by American foresters) is similar to the Indian single tree method in that it is based on current growth in diameter of single trees but with a volume unit for yield instead of the number of trees. *It is of historical interest, only,* and was first used in America in "The Adirondack Spruce" by Pinchot. Any method of regulation (unless the forest can be frequently re-estimated) based on current growth of individual trees is of little or doubtful value because of the uncertainty regarding the number of trees which pass from one diameter class to another (i.e., mortality per cent). It was described in France* as early as 1867 and is now only applied to beech selection coppice (taillis furété) chiefly in the Pyrenees. Huffel says that

"such a system can evidently be applied only to forests very nearly normal. (This 'normality' is rarely found.) In a fir stand *rich* in large trees, seedlings and saplings but *poor* in average sized trees, it would result in a short period of super-abundance, which would be followed by a period of largely reduced fellings or even by a complete suspension of income."

Such a method is clearly unwise especially for virgin forests in the United States; nor is the Gazin** idea of more than scientific interest.

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* Huffel, Économie Forestière, Vol. III, page 68. The term " of scientific interest" might be "of academic interest" throughout the text.

** *Stem Space Method (Gazin)* (Of scientific interest). The stem space method of regulation is based on silviculture rather than on any mathematical formula. It is a silvicultural idea rather than a method that can be defined in a few words. Its basic features are:

(1) Normal spacing of the boles without reference to form of stand.

(2) To yield the maximum volume with the smallest growing stock by keeping the boles normally spaced.

(3) *The idea of rotation is done away with.*

(4) The details are worked out on an average acre (normal in an empirical sense) and the treatment of the actual forest in hand patterned after it.

The method (too intensive for present conditions in the United States) is of scientific interest because of the ideas it introduces, but it is of doubtful practicability until it has been successfully tried out and applied. Its advantages or disadvantages cannot be appraised as yet. (From Gazin, A., Le Traitement des Sapinieres base sur la notion d'l'espacement des tiges, Paris, Imprimerie Lahure, 1902, pp. 1-17. The metric system is used. Translation of this article may be studied in the 1917 Journal of Forestry.) See also § 83.

91. **Quiz.** Define regulation of cut.

What are three aims of regulating the cut?

Explain why compromises are necessary.

Explain the classification of methods of regulating the cut.

What are the three main bases?

Explain the main differences in regulating the forest on the main basis of (a) volume (b) area, and (c) area-volume (see Chapter IX).

Give four bases of subdividing regulation on the basis of volume.

What is the Von Mantel formula? its faults? its advantages?

What is the Gurnaud idea?

Is it a method of regulation?

What is the basis of the Austrian formula? Explain it.

Cite some peculiarities of the Austrian formula. Its advantages and disadvantages.

Explain the French method of 1883.

How was the formula derived?

Illustrate its application to a selection forest.

Is it customary to figure growth on the "old wood" while it is being cut? Why?

What are the advantages and disadvantages of the method of 1883?

Why is the Brandis single tree method unsuitable for the United States?

What is the fundamental error in the Pinchot-Graves diameter limit scheme?

Why is the Gazin scheme of no practical value?

(B) AREA, AND (C) AREA-VOLUME METHODS OF REGULATION

92. (B) Value and Classification of Area Methods. Proper regulation must take into consideration the volume, age, and area of a stand. Volume alone, as exemplified by the various formulae methods already described, is insufficient. Regulation by *pure* area alone is lacking in flexibility and does not consider sufficiently the essential factors of volume and changes of treatment necessitated by acts of Providence (such as windfall or disease).

The inclusion of area allotment by periods under regulation by area tends to simplify the classification but is a departure from German procedure. Regulation on the basis of area (and age) has been classified as follows:

Main basis,	Secondary basis,
(B) Area (and age).	(1) Pure area.
	(2) Area allotment by periods.

93. (1) Fixed Area as a Basis for Regulation of Cut. The simplest conception of pure area regulation is, *the forest is divided into a number of cutting areas equal to the years in the rotation and one area is cut each year.* Two modifications of this basic plan may be necessary: (a) If the soil quality of the forest varies, then a proportionately larger area of the poorer sites must be laid out on the ground. (b) If the forest is so small that yearly logging is not justified, then the cutting areas are made proportionately larger to provide cutting every two, three, ... or more years as the circumstances require.

Discussion. Regulation by fixed area may be of practical value in coppice forests or coppice under standards where regeneration is certain. It might also be used in stands managed on a very short rotation and where the new crop is obtained by planting or sowing; a case in point would be the commercial production of Christmas trees. The fundamental idea of working over equal areas each year or periodically is the basis for regulating cork oak production or resin crops, with the necessary silvical and commercial limitation on what cork is marketed or what trees are tapped for resin.*

The European conception of fixed area regulation is to follow the order of cutting marked on the ground, but there is no practical reason why a stand, nearly ripe but damaged by fire, could not be cut ahead of its maturity. Shifts must then be made and a corresponding area held past maturity.

Disadvantages:

(1) The method is rigid and with a change in rotation or scheme of

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* See French Forests and Forestry and Studies in French Forestry, both John Wiley & Sons, for a discussion of cork, oak and resin regulation.

working, the whole forest must be redivided into entirely different cutting areas.

(2) Forces cutting without considering the condition of the stand.

Advantages:

(1) Easy to apply.

(2) Equal annual or periodic cut and absolute regularity of age classes.

94. Illustration of Fixed Area for Limiting the Cut. Given: Coppice forest of 100 acres half on ridge (site III) and half in a valley (site I); rotation and cutting cycle 20 years; annual cut required for constant fuel supply. Site I yields 20 cords at 20 years and site III only 10 cords.

If the soil value had been equal, the annual cutting areas would be $\frac{100}{20} = 5$ acres; but here half the stand is on a rocky ridge with one-half the soil value of the remainder; so the average reduced cutting area must take into consideration that the cut from two acres of the poor soil equals only one acre of the good soil. By a simple calculation (i.e., $\frac{50 \times 1 + 50 \times .5}{20} = 3.75$ acres, and $\frac{50}{3.75} = 13$ areas with 1.25 acres of site I left over; on site III the cutting area would be double that of site I, i.e., $3.75 \times 2 = 7.50$, and $\frac{50}{7.50} = 6$ areas with 5 acres left over), the cutting areas are found to be as follows: for site I, 13 areas of 3.75 acres each: for site III 6 areas of 7.50 acres each. This would leave one area composed of 1.25 acres site I, and 5 acres site III, which would be equal in producing capacity to 2.50 acres of site I or a total of 3.75 acres (site I). The annual yield in cords would be obtained by multiplying 3.75 acres (site I) by 20 cords $= 75$ cords or on site III 7.50 acres $\times 10 = 75$ cords, which is an identical figure.

95. (2) Area Allotment by Periods as a Basis for Regulation.* *An allot-ment method—when a rotation is fixed and for a given year or period of rotation a certain area is allotted to be cut.*

Discussion. This is somewhat similar to regulation by pure area (with fixed cutting areas) but decidedly less rigid and differs in that the cutting areas are not permanently fixed on the ground in the order of cutting but instead compartments or lots are allotted to the various periods of the rota-tion. These periods are 10 to 30 years in length and the total number depends on the length of the rotation. The stands allotted to the first period are,**

"measured, their volume calculated, and the increment for half the number of years in the period added. The total of the volume thus obtained is divided by the number of years in the period . . . . to obtain the average of the final annual yield during the first period . . . . thinnings must be added."

As a matter of fact, in the modern European working plan allotments are only recorded for one, or at most two, periods. Since the working plan will be revised at the end of the period, it is unnecessary to make permanent allotments far ahead because changed conditions may force a complete change; it is for this reason Judeich originated his stand selection method (see par. 100).

It must be clear that before individual stands (which may be allotted) are cut the growth continues on the uncut growing stock in these stands. After

* See Schlich, Vol. III. 3d Edition, p. 311.
** Ibid., p. 313.

the cutting, regeneration and development of the seedlings goes on, but there is no immediate tangible merchantable increment. If, for example, 20 stands are allotted to a 20-year period, then after the first year 19 stands will be growing while at the beginning of the 20th year only one stand will remain. This explains why in all methods of regulation dealing with individual stands or age classes (as in the French method of 1883) half the growth is added to the estimated yield of the stands to be cut.

To sum up, there is no reason for using *area allotment* when better results can be obtained by taking into consideration volume and "stand selection." Even in Prussia the area allotment was only used for very regular stands.

Disadvantages:

(1)   Age class distribution may be neglected in first rotation.

(2)   Surplus growing stock is not reduced, and immature stands may be sacrificed.

Advantages:

(1)   It is simple and easily applied in the office, and tends to quickly establish the normal distribution of age classes.

Illustration. Since the method is not recommended, no original illustration is given. Those interested in seeing how the method is applied in Europe are referred to pages 382-387 Schlich, Vol. III, 3d edition. Here it will be noted that after the various stands are allotted to each of the five periods, there is still a considerable variation in the areas to be cut over; namely, in round figures 30, 34, 33, 32, and 30½ acres, the mean area of the period being 32.03 acres. The smaller the lots, the more accurate the area equalization for each period. The period in the illustration is 20 years, so the age of the stands listed for cutting are taken not at the beginning of the period but to the middle of the period (i.e., age at beginning of period plus 10 years). The yield is then read from the yield table for the species and age and then multiplied by the number of acres; this procedure of taking the yield to the middle of the period obviates making a separate calculation for growth. The estimated yield from thinnings is then added.

96.   Use of Yield Tables in Computing Volumes.   When using yield tables with a period (or stand) method of regulation, it is often convenient to reduce a yield table which is fully stocked to terms of the stand which is not fully stocked. This is done by comparing the average stand volume per acre with the volume per acre given in the yield table. Before making the comparison, it is of course necessary to obtain the average age of the stand either by sample trees or on the basis of the age of the tree corresponding to the average diameter. For example, suppose the mature age class 200 years old averaged 8,375 feet per acre and the yield table 16,750, then in reading future empirical yields to apply on the forest all figures in the yield table are reduced one half, because,

$$\frac{\text{stand}}{\text{yield table}} = \frac{8,375}{16,750}, \text{ or } \frac{1}{2}.$$

When long periods are used in calculations, it may be advisable to compute the cut by the weighted yield table formula instead of computing the cut by (a) reading to the middle of the period in the yield table or by (b) reading

from the yield table to the first year of the period and then adding half the growth. The weighted yield table method merely recognized that the mean annual growth is a curve and not a straight line and is fully explained in the Journal of Forestry.*

97. (C) Area-Volume (and Age) Basis of Regulation—Value and Classification. Volume alone is not a satisfactory basis for regulation, nor is age and area alone, because in the latter case the factor of volume is omitted as a primary determining factor. It is clear then that the ideal of regulation is to consider *area, volume and age.* Taken together they constitute the essentials to be considered in regulating a forest, while singly they are simply important, but not determining, factors. As many writers point out, and as has been repeatedly emphasized in this book, the old fashioned idea of allotment to all periods of the rotation is generally abandoned. With this modification there is not such a vital difference between (1) and (2) given below. Regulation on the basis of area-volume (and age) has been classified as follows:

Main basis,	Secondary basis,
(C) Area-volume (and age).	(1) Volume and area-volume (age) allotment by periods.
	(2) Stand selection.
	(3) Cutting cycles and felling reserve (see part II).

98. (1) Volume and Area-volume (and Age) Allotment as a Basis for Regulation. The definition is similar to that for area allotments by periods: *When a rotation is fixed and for a given year or period of the rotation a certain area or a certain amount of stock is allotted to be cut.*

Discussion. The so-called volume allotment method has not been separately discussed because it possesses no advantage over the method of periods by area and volume combined. In volume allotment by periods the chief aim is to equalize the volume rather than the area (see § 95). Volume allotment as practiced in Europe is illustrated by Schlich, Vol. III, 3d Edition, page 388. Volume allotment was the dominant method in Prussia during the 19th century but is now replaced by volume-area allotment with a view to age class distribution and felling series. With area-volume allotments the areas and volumes allotted to the first period are divided by the years in the period to obtain the area to be cut over and the volume which will be secured from the main fellings. Then the aggregate of individual stands is either increased or diminished according to the areas and volumes (and ages) of the areas which should be felled. The goal is regulation on the basis of the individual compartments, and the smaller the stand (lot), the more equalized is the estimate of volume and the more intensive the regulation. Taking into consideration and weighing both area and volume gives somewhat similar results to area allotment but with a very careful check on the site quality of

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* Woolsey, T. S., Jr., Computing Volumes in Period Allotment. (J. of F., 1917, pp. 431-434.)

each lot gauged by volume. The choice of the stands to be allotted depends on maturity (and age), their relation to the felling series, a sustained yield and the regeneration of the most desirable and suitable species.

Disadvantages:

(1)   Equalization and allotment of both area and volume is a difficult task.

(2)   Suitable grouping of age classes is difficult.

(3)   Cuts of equal area and volume are not desirable if stands of over-mature timber must be held over or young timber sacrificed.

(4)   It possesses no clear cut advantage over the stand method described in § 100.

Advantages:

(1)   It trains the working plans officer to think in terms of age, area and volume.

(2)   If broadly applied it may result in a good distribution of age classes and cutting series,* as well as a sustained yield and is very similar to the stand selection.

Illustration. Since this method is better fitted for European forests which have already been regulated under working plans, the student is referred to Schlich's Vol. III (p. 382 and 388) for examples of area and volume allotment. See also § 101.

99.   **Modern Allotment Principles.**   From a review of the modern allotment methods used in the various German states the following principles appear to have been evolved after years of regulation practice:

(1)   Area allotment is used only for simple regular stands; combined allotment (volume and area) is preferred for irregular stands.

(2)   Yield calculations are usually *recorded* only for the first period, though sometimes calculated for more as a trial balance.

(3)   The age class table is the most important basis of the working plan for a timber forest; in mixed stands areas are classified proportionately, and in selection forests estimated carefully, considering age or size class relations.

(4)   The normal periodic area, i.e., $\dfrac{\text{total area divided by number of periods}}{\text{years in period}}$

is the basis for the cut determination. If excess of mature stands occur, more than the normal area (and vice versa) may be allotted.

(5)   Trees of main cut are calipered; intermediate cut estimated. Thinnings regulated by area and their yield estimated. The periods are usually 20 years.

(6)   Revisions of the cut calculations usually take place every 10 years.

(7)   The assignment of compartments or lots to the first period depends

* It is taken for granted that the silvical needs for a proper cutting series are thoroughly understood and that under intensive forestry the age of the bordering stands must be planned long in advance

on the condition of each stand, felling series, age class relation and natural phenomena, as well as area and volume.

100. Regulation by (Americanized) Stand Selection (after Judeich). The stand (or individualizing) methods may be defined as follows: *Each stand is investigated for its maturity and designated for cutting provided other age classes are in existence to assure continuity of crops.*

Schlich rightly considers "financial maturity" too narrow a conception of stand selection because the object of management may not be solely financial considerations. Actual practice in Europe seems to justify his position, because the selection of stands to be cut depends on a number of factors; namely, (1) Financial maturity, (2) Technical or administrative needs, (3) Maturity judged by local age, soil and stand conditions, (4) Poor growth, (5) Felling series, full increment and normal conditions generally.

Roth calls this method "limited area allotment" and classes it as *an area allotment for the first period only,* while Schlich emphasizes the selection of stands for cutting on silvicultural grounds or objects of management. The forest certainly progresses toward the normal if the method is intelligently applied. Roth says (p. 145) that,

"It is usually claimed that this method only binds the action for the coming ten or twenty years, while regular area allotment is claimed to be binding for *an entire rotation.* This is not true."

Roth is correct; paper work tabulation today would never be binding over revision periods.

The amount to cut depends (in Europe) partly on the results of former working plans and partly on an area-volume check. No considerable error in over-cutting or under-cutting is likely with careful revisions every 10 to 20 years. To sum up, the cutting of stands is according to local requirements checked at frequent intervals.

Disadvantages: (1) Stands may become mixed as to age class arrangement owing to the freedom allowed in selecting stands.

(2) The sustained yield may be departed from if too much freedom is given to selections for cutting solely on silvicultural grounds.

Advantages: (1) The method is supple and broad gauge.

(2) It can be readily applied under many existing American conditions.

101. Illustration of Stand Selection in Eastern and Western Forests. *A. Eastern Forest.* Given: Irregular lots or compartments of white pine, old field spruce, and mixed hardwoods in Northern New England, with an excellent market (except for pine-spruce cordwood) and sufficient transportation. The white pine is to be naturally regenerated after clear cutting and the old field spruce clear cut and replanted. The mixed hardwoods are to be retained as hardwood stands and are in need of heavy improvement fellings for the first 30 years of the rotation, which has been fixed tentatively at 80 years with the expectation of a reduction to 70 or 60 years after 20-40 years. After stock taking the lots were tabulated as given below. It must be realized, however, that within the lots there is considerable variation in age. Except for the small scenic lot, the object of management is to obtain the best financial returns compatible with a reasonably sustained yield. A small local sawmill is largely dependent on the forest for logs; the high grade logs are shipped by rail to a larger mill. The resident forester is also manager of some 25,000 acres additional so must systematize his business. The timber is designated or marked for cutting under his direction and the logging done by contract with penalties for damage to reproduction or standing timber and for waste in logging.

Lot No. (1)	Area Acres (2)	Age Class (3)	Forest* Type (4)	(5)	Estimated volume** M. Board Feet (6)	Cords (7)	Remarks. (8)
1	10	90	P I	1.	850	...	Thrifty, good increment.
2	42	30	H 2	.66	...	560	
3	11	100	P 2	.70	600	...	Fungus infected.
4	8	120	H I	.90	(100)	(580)	Scenic forest reserved for park.
5	16	60	P 2	.90	680	...	Rapid growth & still very thrifty.
6	15	40	S	1.	300	...	Needs thinning.
7	21	70	P 2	.50	590	...	Hardwoods in openings.
8	81	20	P 2	1.	...	...	Fully stocked, thrifty.
9	20	70	PH	.50	560	...	Open stand.
10	10	100	P 2	.80	620	...	Mature, needs cutting.
11	6	80	H 2	.60	30	130	One fourth stand dead chestnut.
12	33	50	P 2	.70	850	...	
13	24	60	S	.90	650	...	Fine thrifty stand.
14	25	50	P 2	.70	640	...	
15	17	60	P 2	.50	400	...	Poorly pruned.
16	12	30	P 3	.60	100	...	
17	18	40	P H	.80	470	...	
18	60	30	P 2	.50	154	...	
19	30	50	P 3	.80	580	...	Ridge, slow growth.
20	25	30	P 1	.70	243	...	Some windfall or snowbrake.
21	35	60	P 2	.50	820	...	
22	36	80	S	.80	1,150	...	Trees stunted due to lack of
23	28	60	H 2	.90	120	710	(thinnings.
24	45	40	P 2	.70	740	...	
25	60	20	P 1	1.	270	...	Planted in 1900, very regular.
26	45	50	S	.80	900	...	Some windfall.
27	32	40	P 3	.70	320	...	5 acres fire killed.
28	100	0	H 3	.20	...	...	Burned over 1919.
29	75	50	P 3	.50	900	...	Birch in openings.
30	60	20	P H	.80	220	...	Very wet soil, liable to windfall.
Totals	1,000				13,750	1,400	(Scenic forest not added in totals.)

Before making a decision what to cut during the next 20 years, a number of factors must be carefully weighed. *The figures are approximations only for purposes of illustration.*

(1) Age classes. Dividing the forest into four age classes of 20 years each, we have the following acres in each class:

"I Period" 61–80 years and over 122 acres	"II Period" 41–60 years 328 acres	"III Period" 21–30 years 249 acres	"IV Period" 1–20 years 301 acres

The "normal periodic area" is $\frac{1000}{80} \times 20 = 250$ acres, or 12½ acres per year. Thus the III period is nearly normal, while I is very deficient.

(2) Growth. For an approximation of hardwood volumes and growth the basis is as follows: Hardwood quality I, 1 cord per acre per year (if fully stocked); hardwood quality II, .7 per acre per year; hardwood quality III, .3 per acre per year. It is presumed from local data that ⅓ the hardwood yield in stands 50 years or over will be board feet and ⅔ cordwood. White pine growth is from Bulletin 13, Forest Service. The spruce if fully stocked is estimated at 500 board feet per acre per year. The actual mean annual growth on the whole forest is estimated at 250,000 ft. (from table 7 Forest Service Bulletin 13, already referred to; reduced to conform with per cent stocked). The normal growth should be about 360,000 ft. B. M. (cordwood excluded).

(3) Growing stock. The actual growing stock, reduced to a common factor of board feet (counting 3 cords as equal to 1,000 board feet, obviously a rule of thumb ratio based on local conditions) is 13,750 M ft. B. M. and 1,400 cords or total of 14,216 M ft. B. M. This is based on actual calipering on 20% of the area where over 30 years

* Key to abbreviations used: P H = Pine and Hemlock; H 1 = Hardwoods Site 1; H 2 = Hardwoods Site II; H 3 = Hardwoods Site III; S = Pure Spruce; P 1 = Pure Pine Site I; P 2 = Pure Pine Site II.

** From tables for white pine, page 23, Bull. 13, Forest Service, figures evened off.

old and on ocular guesses in stands 30 years and under. It is clear that the hardwood cordwood problem is not a serious one, since it can be sold locally on the cutting areas.

The normal growing stock (estimated by one of the methods already described) should be 14,400 M ft. for a rotation of 80 years; the apparent approach to normality of the actual growing stock is because there are stands past the rotation age with high yields per acre.

(4) *Cutting series* is not considered except that in the spruce stands a shelter belt of pine or hardwoods is left on the N. W. to protect the spruce from the heavy spring wind storms so frequent in the locality.

(5) *How much to cut? Where to cut?* Because it is likely that the growing stock will be decreased (since it is anticipated that the rotation will be decreased from 80 to 60 years within the next 40 years), it is proposed to cut the following lots (cutting order to be left to local forester) from 1920-1940 which it is estimated will yield the amounts shown:

Lot No.	Acres	Av. age when cut	Yield M. bd. ft.	cords	Reason for cutting.
1	10	100	850	..	Should be cut last since growth excellent.
3	11	110	600	..	Needs cutting, fungus infected.
4	8	130	20	10	Dying and down timber only to be cut.
7	21	80	590	..	Open stand with advance regeneration, part of area needs replanting.
9	20	80	560	..	Open stand.
10	10	110	620	..	Fully mature.
11	6	90	30	130	Dead chestnut will be lost unless cut at once.
22	36	90	1,150	..	Growth very slow.
Totals	122		4,420	140±	
Per year	6.1		221	7	

Apparently the area cut over is too small and the age class distribution will be disarranged. but it should be noted that lot No. 28 has just been burned over and comprises 100 acres, which plus 122 ÷ 20 = an annual cut of 11.1 acres while the normal area is 12.5. The volume to be cut compares favorably with the mean annual growth: i.e.. 221,000 of main cut plus half the growth of the stands cut for 20 years or about 26 M and an estimated 2 M ft. per year from thinnings or a total of 249,000 ft. B. M. In case there was considerable doubt about the advisability of increasing the cut, so as to allow cutting other stands which were overmature and declining in vigor, proper technique would probably justify largely exceeding the mean annual growth. It should nevertheless be recognized that in New England stumpage prices may double or treble thirty years from now when the bulk of the best timber used must be transported from the Pacific Coast. This is an argument for retaining a stand (such as is found in Lot 1) that is growing thriftily, notwithstanding the fact it is well over the rotation age. In this instance further checks are hardly necessary but might be applied before reaching a decision on the cut. It must be emphasized that the answer given to this particular problem is not necessarily the one and only correct solution. A good deal would depend on the minute local circumstances. But in any case, it is clear from the table of lots that there will be ample merchantable timber for future cutting after 20 years have elapsed.

As a further illustration of the broad application of the stand method to a forest actually under management for more than 10 years, reference is made to appendix B and especially to the tabular summary of forest types by area and age given in Bulletin No. 1, Harvard Forest. In 1909 Professor Fisher estimated the mean annual increment on the Harvard Forest at about 250,000 board feet and cut that amount for ten years, i.e., 2,500,000 feet. The estimated growing stock in 1919 was 12,435,000 and only 10,500,000 in 1909. an increase of 1,935,000 which plus 2,500,000, the amount cut, gives a total of 4,435,000 ÷ 10 years = 443,500 ft. B. M.; so the cutting of only 250,000 was clearly very conservative and the forest is being enriched and built up. But part of the increase is perhaps due to trees (which had no board foot value) reaching merchantable size through increase in diameter. The clever classification by forest types subdivided into "tracts" and age classes is worthy of adoption under similar conditions.

B. *Western Forest.* Let us suppose that in 1920 an Arizona western yellow pine forest of 10,000 acres (within a National Forest) is divided into four age classes which could be approximately separated and mapped (based on strip surveys for 10% of area) as follows:

Age Class (1)	Age Limits (2)	Area Acres (3)	Per Acre (4)	Total (5)
(A) Overmature (merchantable)	200–360 300	4,000	10,000	40,000
(B) Mature (merchantable)	140–199 180	2,000	12,000	24,000
(C) Immature (¾ merchantable)	20–139 100	2,000	7,000	14,000
(D) Reproduction (no merchantable trees)	1–19	2,000	0	0
Totals		10,000		78,000 M

This condition is typical of many forest areas in the United States but class (A) and (B) would be usually grouped as one overmature age class, and an accurate separation of age classes is often impossible (see Part II of this book).

The established rotation is 200 years. A local sawmill (cutting 8,000 M per year) must be supplied with timber under practical logging conditions, and it is desired to retain the sawmill as a permanent local industry. Dividing the total stand (column 5) 78,000 M by the area (column 3), we have an average stand of 7,800 ft. per acre or 4,992 M per section (640 acres) which must be completely logged over to make sure of cutting all the overmature timber. Since the logging (owing to silvicultural factors) must remove all the overmature timber, about 80% of the mature and 10% of the immature (thinnings and improvement cutting of diseased trees), the average cut per acre will be 4,000 + 1,920 + 140 board feet or a total of 6,060 and will leave uncut 1,740 feet B. M.

From extensive sample plots on land cut over under existing conditions we know that the growth is approximately from 41 to 141 board feet per acre depending on the percentage of immature stands of rapid growth. As a rule of thumb figure $\frac{41+141}{2} = 91$, or say 100 board feet may be assumed. On 10,000 acres of cut over land the current growth would be about 1,000,000 feet per year. Dividing 10,000 by the rotation age, $\frac{10,000}{200} = 50$ acres to be cut each year. Assuming 6,060 as the cut, we have 6,060 × 50 = 303,000 board feet, which is less than ⅓ the estimated current growth after logging (if the whole tract were rapidly cut over, say within 5 years). There is a further complication in that the rotation may later on be reduced to from 140 to 160 years owing to protection from fire, sheep grazing and the judicious thinning of immature stands. Moreover, under present conditions it is assumed practical logging requires a cut of at least 2½ million bd. ft. per section (640 acres) or about 4,000 ft. per acre.

What annual cut should be allowed? Classes (A) and (B) cover 6,000 acres and contain 64,000 M feet. The 10% cut from class (C) is omitted from consideration since the cut of 140 board feet additional is practically immaterial to the answer. The slower the rate of cutting, the greater the losses from death, windfall, mistletoe, etc. in classes (A) and (B), but the greater the hiatus in cut, when this overmature stock is removed.

Case (a), If (A) and (B) are cut in 10 years the annual cut is 5,920,000 + thinnings.
" (b), " " " " " " " 20 " " " " 2,960,000 + "
" (c), " " " " " " " 30 " " " " 1,973,000 + "
" (d), " " " " " " " 40 " " " " 1,480,000 + "

If class (A) only were cut the yield would be 4,000 M if cut in 10 years, 2,000 M if cut in 30 years, 1,000 M in 40 years; with thinnings added in each case. Cutting trees in class (A) in 20 years the cut per acre would be 4,000 ft. our minimum logging requirement. Ten years is certainly too short a period and 40 too long because class (A) will suffer through death and disease. The choice then lies between 20 or 30 years. The final choice we will assume should be 20 years because it prolongs the cut, gives an ample cut per acre, and by commencing sales in areas where most of the overmature timber is found, the loss through overmaturity is minimized. Moreover, it is possible to cover the whole transaction in a 20-year timber sale.

(*Solution No. 1*). The cut will then be, 2,960,000 (from A & B) + 70,000 (from C) = 3,030,000 per year (500 acres or ⅜ the necessary supply to run the mill). The governing factors have been overmaturity of timber which has necessitated cutting 10 times the normal area of 50 acres (or 7½ times even if the rotation were reduced to 150

years). The decision, obviously a compromise, is wise silviculturally and economically, *but from the regulation standpoint leaves much to be desired.* It omits any attempt to be exact as to loss from decadence, growth during 20 years cutting period, etc. since it does not appear necessary to have more exact figures. If yield tables are made, the figures of decadence and growth are easily approximated. One of two things must then be done. The mill must buy private timber or the government must increase the size of the working circle to about 26½ thousand acres with the understanding that at the end of 20 years (1940) *the capacity of the mill* must be reduced to the capacity of the forest—a- reasonable restriction. It is even possible that in 1940 the character of logging will have changed and the logging railroad in use will be scraped and the logging conducted by small gasoline mills with motor transport. In other words, the 8,000 M cut of the present mill should not influence the solution of the problem after 1940.

Solution No. 1 is based on a compromise clearly recognizing the necessity of a complete readjustment after the overmature timber is salvaged. If there were no additional private or public stumpage available and if the mill would be forced to shut down on a cut of 3 million per year (but could operate on 6 million) the cutting of class (A) and (B) might have to be sanctioned in 10 years. The problem as solved is really on the basis of the Americanized stand method and without holding overmature timber so as to equalize the cut 20 years from now—a transition period of cutting is frankly acknowledged as a necessity to prevent loss through decadence. The preliminary cutting cycle is 20 years. It should be clearly noted what the age class and stand condition will be at the end of 20 years if this solution of the cut is adopted. For the sake of simplicity, the arrangement of age classes already used is followed:

Age Class	Age Limits	Area	Volume Board Feet	
			Per acre	Total
A	0–19	4,000	0	0
B	160–219	2,000	2,880*	5,760,000
C	40–159	2,000	9,000**	18,000,000
D	20–39	2,000	1,000**	2,000,000
Totals		10,000		25,760,000

Had class B been uncut, the stand in 1940 would have been about 45 million, a far preferable figure from the standpoint of regulation and much better adapted to continue a reasonably sustained yield. But in the example given this was *sacrificed* to give a larger cut per acre and to avoid loss in mature timber.

The fundamental error made by some foresters in their calculations is that they assume that the answer today must be completely and logically worked out for conditions 20 to 50 years from now, which it is reasonable to suppose will be totally different and unquestionably much more intensive *than we can bring ourselves to realize.* Compare forest conditions in 1870 with those of 1920 and see what a great change is in effect.

(*Solution No. 2.*) Now suppose that the working plans officer wanted to make some sacrifice in order to ensure a better sustained yield in the future and so as to avoid the hiatus or lack of merchantable stands, which would occur with solution No. 1. Let us further suppose that the normal growing stock on 10,000 acres averages 7,000 feet per acre or a total of 70,000 M ft. By comparing this 70,000 M ft. with the total of column (5) in the first table, it is seen there is an apparent surplus of 8,000 M ft. But considering there is 40,000 M of overmature timber (age class A), it is evident that even today a deficit in real producing capacity actually exists, and a very serious one. In solution No. 1 we cut 6,060 feet per acre or 77% and left 1,740 feet or 23%. Granted we could change our silvicultural methods, let us see what we could do to secure a better sustained yield in the future by the following plan: cut all of (A), 20% of (B) and 10% of (C) as before. Make the cutting cycle 30 years. Our cut would then be (figures evened off) as follows:

$$40,000 \text{ M} - \frac{1}{2}(2,810^{**} \text{ feet} \times 4,000 \text{ acres}) + \frac{2}{10} \ (24,000 \text{ M})^*$$

$$+ \frac{1}{2}(\frac{2}{10} \times 2,000 \times 2,000 \text{ acres}) + \frac{1}{10}(14,000 \text{ M}) = 40,980 \text{ M} \div 30 \text{ years}$$

$$= 1,366 \text{ M per year (this solution thus gives less than half the yield given in plan}$$

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* 2% per year growth added to 20% of 12,000 ft. per acre. This figure however had best be obtained from yield table.

** Read from yield table. 5% cut in thinnings, etc. is not deducted because this is pure gain (being saved from loss).

*** A loss here from 10 M per acre to 7,190 board feet over a period of 30 years.

* Growth from 12 M per acre to 14 M.

No. 1). To get our cut of 8,000 per year, we adopt the equation $\frac{1,366}{10,000} = \frac{8,000}{x}$, which when solved for x gives an answer of 60,000 acres in round figures, for the working circle. Now if we cut as indicated commencing in 1920, the condition of the forest in 1950 will be as follows:

Age class (1)	Age (2)	Area acres (3)	Per acre year 1950 (4)	Total (5)
A	1–20 / 15	4,400	....	....
B	170–229 / 210	1,600	14,000	22,400
C	50–169 / 130	2,000	2,000	4,000
D	30–49 / 40		10.000	20,000
		10,000		46,000 M ft.

In this case we have cut 4½ M per acre removing but 57% of the stand but the stand is left in a much better shape for regulation and probably for regeneration, and we have only lost 4.8 million feet from decay, etc. in Class (A). This loss will perhaps be more than made up by an increase in stumpage price. Yet our growing stock is still much less than normal. With 4/10 the forest stocked with an overmature stand, it would be unwise to try to bridge the gap made by our getting rid of the overmature Class (A). This solution No. 2 is better than solution No. 1 judged from the standpoint of future regulation. Yet even in this case we are left after the first cutting cycle with insufficient growing stock and too many young age classes. We will have 0-50 years, 64%; 51-100 years, 0; 101-50, 20%; and 151-200, 0, but 16% at the age of 210. This is typical of the age class confusion that results after cutting in virgin stands even when "conservative logging" is followed. Were it possible to reduce the rotation to 150 years, then the situation would be less serious, and even as it stands, it will be possible to whip the forest into more normal condition as the rotation proceeds.

102. Differences between Area-volume Allotment and Stand Method.* As originally used the area-volume allotment recorded the areas and amounts for all the periods. Today allotments are usually made only for the first, or at most the second period. In other words, it approaches the stand method, where the cutting is arranged for 10 to 20 years only. In making allotments, the main stress is on equal areas and equal volumes to be cut in each period. With the stand method the main objective is to select stands in financial or technical need of cutting. Another difference is that the yield in the allotment method is largely based on a comparison of areas and volumes, while in stand selection the cut may be based on equal cutting areas, on mean

* In Oregon it is likely (according to Weidman) that clear cutting of western yellow pine to free the advance regeneration would be a sound silvicultural system. A few seed trees may be retained on the chance that fire might destroy the existing young growth. It is therefore anticipated that the present system of periodic cuts every 50 or 60 years in the many-aged yellow pine climax type will be abandoned, because the next crop will be *even-aged*. Under these conditions how will a sustained yield be secured? The problem is readily solved. (a) Divide the working circle into convenient compartments. (b) Decide on the rotation. (c) Adopt a cutting cycle. (d) Cut the most mature timber first. (e) Regulate the cut by allotment to periods (or by the stand method) frankly admitting that the present yield is preliminary and must be radically readjusted when the (excess) mature growing stock is removed.

annual growth if the age class distribution is fairly normal, or on any established method of gauging the cut.

Formerly there was thus the rigid allotment "framework" but today the allotment and stand methods tend to become more and more similar.

103. **Use of Age Classes in Regulation.** The various Hufnagl methods (described in detail by Recknagel in his "Forest Working Plans" (pp. 100, 108, 110)) are of interest, since they introduce new ideas of regulation, but usually the problem will be reduced in the final analysis to using the stand method with allotments of age classes to the current cutting cycle or (if the age class distribution happened to be fairly normal) to the proportionate share of the rotation, as with the French method of 1883. Even in American selection forests, empirical age classes may be distinguished and separated by correlating age with diameter as given in § 160, and then the age class can be allotted for cutting as if a distinct stand. This plan was the basis for Professor Chapman's so-called "American Method" as it was first devised (see part II for present revised "American Method of Horizontal Cut").

It is of value to remember that in uneven age stands; (1) the volume of one or more mature age classes chosen for cutting divided by the (a) years of the cutting cycle or (b) their proportionate share of the years in the rotation or (c) years in the period to which these mature age classes are allotted for cutting, gives an indication of what can be cut.

(2) The volume of one or more mature age classes chosen for cutting, divided by the area they occupy, gives the average cut per acre; and if multiplied by the mean area to be cut over gives an indicated check on the volume that can be cut under given conditions.

(3) The normality or abnormality of age classes, after their average age and volume is obtained, can be checked by comparing the areas they occupy. The relative area occupied by the merchantable age classes is obtained by dividing their actual total volume by the empirical yield table figure for the same age (see chapter XII).

(4) When age classes are allotted for cutting, a figure equal to half the growth (or loss through decadence) while they are being cut should be added to (or subtracted from) their volume. Owing to the generally unknown and uncertain factor of natural loss of numbers in forest stands, it is dangerous to apply current growth to diameter classes in order to compute future growth except for very short periods, followed by stock taking and a readjustment of figures.

104. **Regulation on Basis of Cutting Cycles and Felling Reserve.** The so-called "American method" is defined by Professor Chapman as follows: *Determination and equalization of the annual cut on basis of volume, by means of varying the length of the first and second cutting cycles, and determination of the actual annual cut by using the principle of a felling reserve and cutting series, instead of an allotment of areas or stands for cutting within the period.*

Discussion. The whole of Part II of this volume is devoted to a very detailed treatise on the foundations of the "American method," the conditions that force its application, with very complete illustrations of the plan as variously applied. There is also considerable detail regarding the correlation

of age with diameter, and yield table volumes with stand estimates, in order to predict growth and correlate growth with our irregular and perplexing extensive stands. This mass of data teaches the student to think regulation in terms of cutting cycles, age classes, per acre growth in board feet and a future sustained yield; it is a correlation of growth and regulation in extensive stands. But where age classes can be differentiated in the forest at a reasonable cost and cutting cycles largely reduced from the extremes of ½ r or ⅓ r, then the "American method" does not appear necessary. Furthermore, during the first cutting cycle it may be necessary to sacrifice something in future regularity of cut in order to save overmature timber that will otherwise be lost through decay, windfall, and other natural accidents to the veteran stand? Judging from § 154, Part II, this loss would amount to at least one-fourth the stand if ripe western yellow pine trees are held 100 years beyond the rotation age. As a matter of fact, the actual loss, though often exaggerated, is sometimes also far greater, because the soil covered by the veteran stands is not only actually losing timber, but is occupying space that ought to be producing a rapidly growing young stand. Moreover the longer overmature stands are held, the more difficult will be regeneration, which with high labor costs and extensive areas in the West, must be secured largely by natural regeneration. Therefore deliberately planned cutting cycles of fifty to a hundred years are economically unsound, when not absolutely forced by local conditions.

For example in § 176 the cut for a second cutting cycle is worked out for lodgepole pine. There is no objection to this merely as a trial balance but of course it must be recognized that in the second cycle (1940-1980) there will be clear cutting, intensive thinnings and probably the use of the allotment or stand method of regulating the cut.

Professor Chapman has given an illustration from the Coconino Forest (Arizona) considered *as a whole*. Ultimately there will probably be evolved two classes of local conditions, namely, (a) intensive and (b) extensive. If this prediction is accepted as likely, then the two classes of conditions might have been recognized today by varying the length of the cutting cycle in different portions of the forest. At least this can be done within the next 20 years. To presume that a cutting cycle of a hundred years will continue, even in the West, seems absolutely improbable. There is another important point in policy to be considered in weighing a method. How much accuracy is justified in extensive conditions? To my mind a rather crude method that will give rule of thumb results is sufficiently accurate if the more accurate calculation means an appreciably greater initial expense. Take a case in point—*the amount to cut on the Coconino Forest (par. 166)*. According to Chapman, the French method of 1883 indicated 28 million feet as the annual cut. Von Mantel's crude formula 31½ million, the Austrian 38½ million and the American method 27, the last figure being assumed by Chapman as the correct cut. The mean annual growth was computed to be 42½ million. Who would say that the French method is not sufficiently accurate in this particular case? And cannot the forest be split up into a number of working circles? And should not the cutting cycle of 100 years be reduced to

50 ± ? Furthermore, if we allow the regulator to guess at the future, it is certain that with fire protection, protection from destructive sheep grazing, thinnings, some planting or sowing, and with better methods of silviculture, we shall probably reduce our 200-year rotation to from 140 to 160 years. Moreover, today we know for a fact that much of the growing stock is in overmature stands. Why not cut 35 to 40 million and get rid of the mature timber faster? Can the Forest Service justify the smaller cut of 27 million? This is extremely doubtful. This discussion, which admittedly is open to argument, merely tends to show the student the danger of placing too much emphasis on regulating the cut by mathematics, as opposed to the demands of silviculture and policy. The administrator must base the final decision on a compromise between regulation mathematics, silviculture, and basic policy. Whatever the answer, it is at least difficult to justify holding saleable overmature timber longer than necessary. Just now should not sound silviculture come first? Even in Europe the tendency is towards silviculture rather than towards rigid regulation.

The great similarity between Chapman's former "American method," as described by Recknagel, and the French method of 1883 is evident. In 1917 it was really an allotment of diameter classes to irregular periods (gauged by the years allotted to each age class) instead of a straight volume-area allotment. But the method has been considerably modified from time to time. In 1917 Recknagel said regarding it that it was "........an adaptation of Hartig's volume-period method ....but greatly simplified." Today it emphasizes cutting cycles and felling reserves. By demonstrating the ease of correlating diameter, age, and growth in irregular stands Professor Chapman has rendered a great service. For the details of the American method the student is referred to Part II, which follows, and which contains an immense amount of valuable and sound *mensuration,* besides a philosophical discussion of the application of regulation to extensive American stands.

In studying the methods described in Part II it is important to visualize the probable future development of permanent *transportation* in the South and West. It is confidently predicted that permanent transportation must be secured within the next half century, for without it forest management will prove a partial failure. The building of *temporary* logging railroads and the deliberate plan of cutting cycles 50 to 100 years in length will surely result in the failure of forest regulation, because *permanent transportation* is the foundation on which our future continuous forest production and stable local forest industries must rest. Moreover it must be admitted that the basic regulation plans of Part II may be gradually replaced by the allotment or stand method when a clear cutting system becomes more general with intolerant species, as it must eventually. But it must be recognized that regulated clear cutting means a delay in harvesting the stands in the last period.*

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* For all clear cutting silvicultural systems an allotment, simple area, or stand method should usually be employed. For selection fellings the French method of 1883, or a modification of it, or the new "American Method," may be used if formulae methods are

105. **Quiz.** Why is volume alone an unsatisfactory basis for regulation?
Is area alone satisfactory?
Explain regulation by fixed areas?
When should it be used?
How does area allotment differ from regulation of cut by fixed areas?
Explain area allotment.
Why is an area-volume basis of regulation more satisfactory than volume allotment?
Explain deficiencies of volume allotment.
Cite the more important principles of allotment methods as applied in Germany.
Give disadvantages and advantages or area-volume allotment.
Define stand selection; what is its basis?
Why is the stand method a good scheme of regulating the cut?
Illustrate conditions which would fully justify its application.
What is the essential difference between area-volume allotment and the stand method?
What is the basis for the "American method" of regulating the cut?
What are its weaknesses? Its strong points?
Is it a permanent or temporary method of regulating the cut? Why?

(See Part II for further and detailed quiz questions.)

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considered undesirable, but see also Part II for methods which are recommended by Chapman. The frank discussion of the "American method" will not be misunderstood by those who have read H. G. Wells' recent "Outlines of History." (See § 101.)

When checking over my references to his own writings Professor Roth made many valuable suggestions. Every student of regulation should read Roth's article in the October, 1921, Forest Leaves.

PART II

CORRELATION OF REGULATION AND GROWTH
IN EXTENSIVE AMERICAN FORESTS

BY

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CHAPTER X

THE CUTTING CYCLE AS A DETERMINING INFLUENCE
IN AMERICAN FOREST REGULATION

106. Attitude of Private Owners. Forest Regulation in America with the object of securing a sustained yield is as yet but little understood by private owners. The idea itself marks such a departure from accepted standards of forest practice, and entails so many apparent risks and sacrifices of immediate profit, that it is usually rejected in favor of a more rapid realization of value from cutting mature timber. The private investor understands stumpage values. He does not yet grasp forest values, and seeks to convert stumpage into forms of property and investments with which he is familiar.

107. Preliminary Requirements. Before regulation of cut to secure sustained yield is possible on forest properties in this country, several preliminary developments are necessary. First comes the acquisition, establishment and improvement of a forest estate of sufficient size to justify management as a separate financial venture rather than as a side issue to some other source of income such as farming.

The permanence of ownership, which in this country is sadly lacking, and also of policy, which here means a more complete acceptance of the economic and technical basis of forest production, is next in importance. As yet, areas of sufficient size when managed for timber are usually not intended as permanent holdings. This is the case with the vast bulk of lumbermen's lands, and often those which might constitute true forest estates are chiefly of interest to the owners as parks or for game and fish preserves.

The improvement of markets and of accessibility by better transportation comes next. On tracts where in the past but a small percentage of the standing timber by species or sizes could be marketed, no permanent plan for

sustained yield was possible. The final development of stumpage values for the main body of the timber will alone permit of the intelligent consideration of regulation of the forest.

108. Obstacles to Regulation of Yield. One of the greatest obstacles to regulation of yield is the character of the forests themselves; the fact that so far the cut has been largely from virgin forests often of mixed species, instead of from second growth produced artificially or grown as even-aged stands free from suppression. The difficulties are:

First, a surplus of overmature, usually decadent timber which not only requires rapid removal leading to and establishing the custom of overcutting, but is accompanied frequently by a deficiency in younger age classes, hence tends under any method of regulation to perpetuate an abnormal condition leading to a reduction of the cut below the normal sustained output at the expiration of the first cutting cycle.

Second, the extensive character of investment and of operation indicated in order to remove this surplus of large stock economically and profitably, render the largest possible area accessible by reducing logging costs, and realize the greatest stumpage value. The rate of annual cut so established, and the rate of depreciation on the investments required usually tend to exhaust the growing stock completely in a period far too short to secure a continuous sustained yield. This does not preclude forest management, for it is possible to secure on such cutover areas a renewal of forest growth by natural or artificial reproduction. It *does* substitute periodic or intermittent yields for regular annual or sustained yields. Where transportation will continue to be expensive, a permanent policy of periodic rather than annual yields may be necessary, with intervening periods during which practically no revenue is realized from timber cutting.

Third, the absence of data on the rate of growth of the forest prevents the determination of the proper annual cut by which sustained yield might be secured. The problem is to prolong the first cut on virgin forests until a second cut can be made on areas previously cut over. To determine the length of this period, the rate of growth of timber left on cutover lands and of reproduction, is required—while to determine the amount which should be cut annually *during* this period, the rate of growth of the timber now standing is needed. There are considerable difficulties in the way of determining both problems, and until this data becomes more reliable, the regulation of the cut on virgin forests will be equally unreliable.

Effect of over-cutting. On forest areas which have already passed through this first cutting cycle, especially where the processes of cutting have been those of forest denudation, the problem of regulation of the cut is indefinitely postponed until the establishment or re-creation of a growing stock which may be regulated. Silviculture, not regulation, is the important consideration on such depleted forests.

Regulation of yield in this country can be applied at this time only on forests which have not already been cut over, or on which a second growth is approaching maturity, hence the problem first in importance is one of providing a gradual transition of a virgin forest to one capable of permanent sus-

tained yield, in place of the process of overcutting which involves a subsequent slow and discouraging period of restoration of forest capital.

109. Policy as Influenced by Character of Ownership. *Owners who can Afford Sustained Yield.* Under present conditions in America the classes of owners who can best afford to prolong the cut of virgin timber so as to completely bridge the gap between first and second cuttings are public owners and private owners whose principal investments are in some form of manufacturing dependent on wood, and who desire to own and control a sufficient supply to insure the perpetuation of their business. Public forests stocked with mature timber and managed for commercial production lie chiefly in national ownership, and should always be managed for sustained yield unless it can be positively shown that such management would prevent the proper exploitation of the timber and permit it to go to waste unused.

Policy for Other Private Owners. But with private owners, other than the class mentioned, the course apparently indicated is, first, a considerable reduction of the investment in overmature, merchantable forest capital, second, the reservation of young thrifty timber and the reproduction of the forest by sound silviculture and protection, third, the final restoration of the forest capital by growth.

It is impractical for such typical forest owners as the majority of lumbermen to curtail the rate of cutting to a point which will permit of sustained yield during such period of transition. The one item of taxes on mature timber tends to prevent this, even without the additional costs due to losses in timber and interest charges. But this economic justification of overcutting makes it doubly difficult to check the process of denudation in time to secure *reproduction,* and ultimate restoration of the forest capital. With the exhaustion of the growing stock, the owner's interest is gone. He has never grasped the idea of forestry as a sustained business of timber growing. For practically all private forest owners whose interest in forests as productive property is not based on larger outside investments, sound management demands not the complete removal of the merchantable capital, but rather the determination of the *largest per cent of young timber which it is possible for them to leave for a second cut.* By this means the *value* tied up in the investment can be reduced, yet its *future productiveness* preserved, and not only will the reproduction of the forest be made more certain but the period which must elapse before a second cut can be made will be greatly lessened.

In this form which tends to future, though intermittent yield, the regulation of yield is already being practiced by many private forest owners, and should be universally and immediately adopted by the remainder. On denuded forest lands, regulation will be postponed until the growing stock is built up to a point where there is something to regulate.

Goal of Private Owners. It is evident that in this transition of a virgin forest to a regulated forest, the process, both as to speed and thoroughness of execution *is not an end in itself,* but a means of making the property more useful and profitable, and of accomplishing to a greater degree the purposes for which the business involved in its management is conducted. It is a basic premise that true forest land cannot be as profitably used for any other purpose as for tim-

ber production and often has no other use whatever. On this basis its permanent denudation is not profitable to the future owners, whoever they may be, whether public or private. Hence, clear cutting can profit the present owner only in the sense that he is a wrecker of a going concern and intends to sacrifice the permanent assets, that is, to abandon the land, or sell it, and junk the enterprise.

If the present owner once recognizes this responsibility or trusteeship for land capable of growing crops of timber, his entire attitude towards the management of forest land must necessarily change. This does *not* involve an immediate attempt to secure *present sustained yield* or complete transition to a regulated forest, but it will mean the careful appraisal of the possibilities of forest management for production of timber by growth, its costs, the relative profitableness of logging small versus large timber, and the measures required to secure, at some future time, a second cut of timber, and finally the extent to which the period which must elapse between cuts can be shortened by curtailing the present operation. In all of this, the ruling consideration must be financial, a question of returns on the investment. But there must be no deliberate intention to destroy the possibility of forest renewal.

110. **Goal of Public Management.** But with public and especially with national forests, no such limitations exist to prevent the immediate adoption of the principle of complete transition to a regulated forest by proper cutting of the original growth. The public purposes of management are primarily public benefits through the yield of forest products, not through profits from sale of timber. With lower interest rates and the emphasis shifted from the side of income to that of production and supply, national and other public forests *must* be managed to obtain sustained yield, and the annual cut must be regulated before it threatens to exceed the capacity of the forest or the requirements of the transition period.

111. **Influences Determining Initial Cut per Acre.** In the practical application of regulation either to virgin forests or to restocked areas, the owner is at once called on to determine the character and severity of the first cutting to be permitted. Even on public forests, logging cannot be conducted at a loss. In such case it should not be conducted at all, either by purchasers of stumpage or at public expense. Timber which must be logged at a loss is in effect inaccessible until economic conditions change.

In direct proportion as the cut per acre and consequent total cut on a logging unit is increased, the logging costs per unit of product are reduced, the accessible area thereby extended, and the marginal value of stumpage enlarged. But at the same time the stock remaining after cutting is reduced, the period required to produce a second cut is lengthened, the risks from slash and insects increased and the difficulties of obtaining sustained yield multiplied.

Whatever tends to increase logging costs and thus reduce the margin between such costs and sale value of the logs or lumber tends to require a heavier first cut per acre. Transportation has the greatest effect on logging costs. Permanent road systems have seldom been provided as yet. Tem-

porary means of transportation is the rule, and the entire cost of such expenditures is borne by the stumpage logged in the first cutting.

Where these conditions demand so severe a cutting that the possibility of natural reproduction would be destroyed, private owners are accustomed to proceed with this forest destruction. Where such conditions are true on a public forest, the timber should be reserved for an increase in marginal profits and not cut until it can be logged in a manner which will safeguard the future stand.

From the standpoint of the best silvicultural treatment of the forest, it frequently happens that natural reproduction is most easily obtained and thrives best when a fairly heavy cut is made, and that too conservative a cutting per acre leaves the forest still in a stagnant condition, retards renewal, or unfavorably affects its composition. In other cases a more conservative cut is indicated. If forest management is to be practiced at all, the cut per acre cannot exceed the minimum which will leave the forest in condition to perpetuate itself by reseeding unless it is definitely determined that artificial planting following clean cutting is the most desirable practice.

These two practical considerations, lumbering, and silviculture, *come first* in determining the exact nature of the problem of regulation confronting any class of owner. Together, they determine *the per cent of the stand to be taken in the first cutting.* Neglect of the need for regulation would induce the operator to take too heavy a toll of the forest, while, on the other hand, over-emphasis of sustained yield, to the neglect of the actual practical conditions affecting both the utilization and reproduction of the forest, might erroneously indicate a cut far too light for sound management.

112. The Cutting Cycle. Definition. Length. By definition, the cutting cycle is, first, the period elapsing between two successive cuts on the same cutting area or logging unit, and second, the period which is required for logging operations to go once over the entire working group.

In order to obtain a sustained yield, these two definitions must both hold good, for if the period required for cutting operations to go once over the entire area is shorter than the number of years which must elapse between successive cuts on the same area, intermittent yields with intervening periods of suspended cutting will result.

In order to return for a second cut on an area, there must be some timber to return for. While the first cut, which may remove a large surplus of over-mature timber, will normally exceed the second, yet the second cut must yield a sufficient quantity per acre to pay the cost of going after it, just as in the first operation.

The length of a cutting cycle based on a plan for continuous cutting or sustained yield will therefore depend first on the per cent of the original stand which is removed; second, on the character and age of the stand left on the area; third, on the rate of growth, after cutting, on this residual stand and on the immature timber and reproduction. Upon these factors depends the volume of the future crop and the period required to produce it.

113. Growth on Cutover Lands. To determine this period thus requires a knowledge of the growth which will be secured on *cutover lands on the basis*

of area. Otherwise, the determination of the period before a return is possible is but a guess. The first effort in American regulation for sustained yield must therefore be directed to obtaining the basis for growth predictions on the trees left on cutover lands and on stands of immature timber. Merely to decide upon a given period for cutting the present volume in the forest gets us nowhere, unless we know just why the said period is chosen and what will happen when it is ended. The logger usually knows about how long a cut he has. But the span of life of the logger's operations *has no relation to the next cut.* Regulation is an attempt to prolong logging until the second cut is ready and knowledge of growth is the key to this problem whose solution must precede intelligent regulation.

114. **Growth on Virgin Forests. Intermittent Yields.** The second need is to determine directly how much can be cut annually from the unit, in order to round out or prolong the cutting to the year of beginning the second cut. If it is found that the indicated cut per year is too small to permit of economical and efficient logging, then sustained yield will probably give place to intermittent yields. But to determine the true permissible annual cut, the change in volume of the stand by growth or decadence during this period must be approximately known, else the cut is more or less approximate. This requires a separate study of growth in the virgin forest. This data is less important than the study of growth on cutover lands which determines the length of the cycle,—it merely aids in carrying out the intention to complete the cut in this given period, without having it either fall short or overlap.

The solution of this double problem of growth may be sought either on the basis of accurate and painstaking investigations, or in their absence, upon such approximate evidence as can be obtained pending more definite determination. The point to be emphasized here is that without the *double decision,* first on the length of the initial cutting cycle, second on the limitation of the annual cut during this cycle, there can be no effectual progress in regulation of yield, but only general assumptions based on crude suppositions such as that expressed by Von Mantel's formula. (See paragraph 82.)

115. **Relation between the Cut per Acre and the Cutting Cycle.** The determination of the rotation is itself the result of growth study. Without the rotation, not even these rough and ready methods of approximation such as Von Mantel's, are possible. But the cutting cycle takes into immediate account the *actual condition* of the entire area, with especial reference to the distribution of existing age classes and the proportionate area stocked with young timber. This the rotation alone does not do.

A short cutting cycle means a relatively small cut on each acre which is cut over in a given logging operation, and the corresponding spreading of the logging over a proportionately larger area in each year to cut the same quantity annually. Permanent road systems coupled with intensive demand permit of cutting cycles even as short as six to eight years. Conversely, a heavy cut per acre and concentration of the annual cut on a small area demands a lengthening of the cutting cycle in the same ratio. American forest regulation since it is primarily concerned for the immediate present with the

remaining stands of virgin timber, which are comparatively inaccessible, will be based largely on a heavy cut per acre and a correspondingly long rather than a short cutting cycle. Conditions similar to most well managed, artificially grown and accessible European forests, with short cutting cycles, will govern the regulation of the more accessible second growth forest areas in the East and elsewhere, and should similar conditions become established in regions now relatively inaccessible, the cutting cycle can and will be shortened to coincide with these altered conditions.

The creation or adoption of a relatively long cutting cycle as a basis of regulation of these virgin forests is the only measure which permits of the orderly working out of practical regulation under the conditions of transition cuttings where it is now most urgently needed. But a cutting cycle equalling from $\frac{1}{4}$ to $\frac{1}{2}$ of the rotation will affect all the other elements entering into the problem of regulating the cut. These elements are,

> The area to be cut during the cycle,
> The felling reserve,
> The minimum exploitable age,
> The growth available for cutting during the cycle,
> The volume of the total cut and of the annual cut,
> The "normal" growing stock.

These relations have apparently been overlooked in previous discussions of regulation of American transition forests but their comprehension must precede the formulation of any practical plan of regulation involving a long initial or transition-cutting cycle.

116. **Similarity of Even-aged and Many-aged Forests.** In order to make clear the influence of the cutting cycle upon these several factors, we must first harmonize the conception of a forest composed of even-aged, and one of many-aged stands, termed frequently a selection forest. In theory, a forest of even-aged stands may contain but a single series of age classes each composed of a single even-aged stand. But in practice, especially in forests where the best silvicultural management has been applied, such a forest would be composed of many different series of age classes and of a much larger number of relatively smaller areas occupied by stands of even age. These separate stands are intermingled but still exist as distinct areas. But in *cutting,* the operations will be spread in any year over a much wider general area to reach these patches than would be the case with a single series of age classes; and within a single cutting cycle, logging operations would reach into and cut only the mature stands in each block or logging unit in the forest in succession.

It is but one step further to carry the process of intermingling to areas of less than an acre, or to the single tree or small group. The number of age classes, their volume, and the total area occupied by each age class can be the same,—the form and management only is different.

The two forms of forest are not identical from a silvicultural standpoint, since the laws of tree growth differ specifically, but from the standpoint of regulation and of the cutting cycle they may be considered as essentially the same.

117. **Residual Growing Stock and Felling Reserve.** Under the definition of a cutting cycle, no cutting (except thinnings) is done on an area between two successive major logging jobs or fellings which are separated by the period representing this cycle.

After each cutting, a residual stand is left on the logging unit, composed in forests of even-aged stands of all the stands below the felling age, and in forests of many-aged stands, of all stands below the felling size, i.e., too small to cut under the limitations agreed upon as to size or age. This may be termed the *residual growing stock* (not to be confused with the term "normal growing stock" as commonly used to indicate a theoretical total growing stock required in a normal forest. Chapter VI.)

During the cutting cycle, the stands and trees constituting this young stock are growing, and a certain proportion of the older stands in the even-aged form, and of the older trees in the many-aged form, grow into the age and size classes suitable for cutting, after the area has been cut over, and replace the timber cut. This portion of the growing stock is termed the *felling reserve.*

118. **Illustration of a Transition Cutting Cycle in a Normal Forest.** The influence of the cutting cycle upon the forest can best be brought out by an illustration. Let us assume that we have a forest of all ages ranging from one to fifty years, and that each of these age classes is scattered over the entire area of the forest and not grouped, so that in order to harvest each crop when it reaches fifty years of age, the entire area would have to be gone over every year. But it is desired to concentrate operations on one-tenth of the area annually, with a cutting cycle of ten years, or $1/5$ r.

Let cc = cutting cycle of 10 years and r = rotation of 50 years.

The area of the forest can be assumed as 500 acres, divided into 10 blocks or logging units of 50 acres each. The amount of ripe timber to be harvested annually will occupy 10 acres all told.

To fulfil these conditions, this forest may have 500 separate even-aged stands of one acre each, ten of which fall in each age class, or, if it is of a typical many-aged form, every acre will have trees of all of the 50 age classes present, but the aggregate area of each age class on the forest will be just 10 acres.

If regularly distributed, the even-aged form will have on each of the 10 fifty acre blocks or annual cutting areas forming the 10 year cutting cycle, but 1 acre fully ripe,— while on the many-aged forest trees fully ripe are found on each of the 50 acres in the block, but their total volume is equivalent to but one acre of ripe timber in each block. To cut each stand or tree when ripe, in such a forest, would require cutting within every block, in every year, or a cutting cycle of 1 year.

Effect of Transition Cuttings on Forest. By contrast, in the first year of a ten-year cutting cycle the annual cut must be concentrated on one block of one-tenth of the total area or 50 acres and it must cover 10 acres instead of but 1 acre, in this block, and neglect the ripe timber in the other nine blocks for the present. To secure this amount of timber, the first year's cut must include besides the one acre of ripe timber on this area, 9 acres more—and to do this we must cut timber down to 41 years in age. The age of the youngest timber cut would thus include stands down to the limit of r — cc or 40 years.

But at the end of the second year, when cutting in the second block of 50 acres, it is not necessary to cut 41 year old timber. Each of the 10 acres to be cut is one year older, ranging from 42 to 51 years. Should the cut be made to include all timber on the block down to the same age or the same minimum size limit as in the first year, i.e., r — cc years, 11 acres would be ready for cutting aged 41 to 52 years. This comparison can be traced through the 10 year cutting cycle. In the first case, where but

10 acres are cut annually, the average age of the stands cut increases until at the end of the 10th year the cut is from 51 to 60 year old timber; 100 acres have been cut over. The average age of the timber cut during the 10 years was, for the first year, 45 years, for the last year 55 years, and for the cycle 50, or r, years. This process can be repeated in five successive cycles until the entire forest of 500 acres is cut.

The effect of this cutting cycle on the form of the forest now becomes evident. If reproduction is by planting or occurs immediately, the forest in the fifty-first year will be composed of fifty instead of five hundred crops, each ten acres instead of one acre in size. On each block there are but five age classes, one for each 10-year cutting cycle. In this rotation the *average* period .of growth, ½ cc or 5 years marks the extreme variation in average age of annual cuttings from r or fifty years, but the average of all cuttings is fifty years in the second rotation, each stand matures at exactly fifty years, each is 10 acres in size and each can therefore be cut when ripe, although the cutting is now made on a ten-year cutting cycle.

Establishment of Minimum Exploitable Age. Thus the felling reserve originally contained all stands from 41 to 50 years old inclusive, but in the tenth year contains stands up to 60 years old, or stands from r — cc to r + cc years respectively. The cutting limit must evidently permit the removal of timber below r years in age in order to effect the transformation from a many-aged to a regulated forest. The age r — cc or 40 years is the *minimum exploitable age,* in this illustration, and is evidently affected by the length of the cutting cycle—the longer the cycle, the greater the inroads upon the stock not yet fully matured to the age of r years.

Relation between Rotation and Cutting Cycle. It is evident that as soon as the transition of form and arrangement of age classes is completed, the timber can all be cut at the age r years which is the maximum age of the residual growing stock, plus the period of the cutting cycle, and equals the rotation.

In this case, a transition of one perfectly normal forest to another is chosen as an illustration, in which there was originally no overmature stock, and the only change made was a regrouping of age classes made necessary by the adoption of a 10 year instead of a 1 year cutting cycle.

The same principles apply to the transition of a virgin forest composed of timber of all ages, whether scattered as single trees, grouped in small patches, or assembled in larger areas. The rotation r will mark the average age at which the stands should be cut—but unless the minimum exploitable age is set lower than this the timber even in the second cutting cycle will reach *an average age greater than r years before it can be cut.* The cutting creates, from this original forest, a forest moulded after the plan on which this cutting is regulated.

This felling reserve is simply the upper portion of the growing stock. In a regulated forest none of it *finally* need be allowed to exceed the age of the rotation, although it *did* and must *exceed it in part* during the period of transition cuttings. The final result is, that *the cutting cycle is merely the last period of the rotation* r, while timber both below and above r in age and size has been cut.

119. Ultimate Form of the Forest. The first ultimate effect of the cutting cycle, granting that reproduction is secured promptly, is then to modify the arrangement of age classes as to area and number to conform to the routine system of cutting of which the cycle is an application. There will be, ultimately, as many age classes on each area or logging unit as there are cutting cycles in a rotation. If the cycle is ½ r, the many-aged character of a stand

will tend to give place to two main age classes,—if $\frac{1}{3}$ r, to three classes. The second ultimate effect, contingent on the first, is to produce crops which will reach just the merchantable age desired, or r years, on successive areas of proper size, annually. A short cycle, adapted to the perpetuation of a many-aged form of stand, permits numerous separate crops to originate on the same area unit during the rotation. Under the moulding force of a consistent policy of regulation the plastic forest tends to assume the form which most nearly fulfills the desired objectives.

120. Principle of Allotment of Definite Stands for Cutting During Period. But the *immediate* effect of the cutting cycle, for the first rotation, will depend upon the *method of its application.*

In the illustration given, the principle of regulation employed is that of allotment of definite stands occupying a definite total area, for cutting during a given period. The cut for the period is the initial volume of these stands plus the growth for $\frac{1}{2}$ cc years. The fact that during the period younger stands will mature to a minimum exploitable age over the whole area is ignored, although approximately half of this maturing volume will be upon areas not yet reached in cutting, and this accretion of exploitable volume on such areas is wholly apart and in addition to the growth on the areas and stands allotted for cutting during the period.

If, in theory, *none* of these maturing stands are to be cut till the second period, then the cut is *in effect* as described by the first illustration, and the forest at the end of the first cutting cycle *in theory* has no regular established felling series for the next cutting cycle, but is again covered by an equal number of stands of all ages in each cutting area. Only the reproduction for this period has been "regulated" to conform to the new cutting cycle, and this will not be cut until the next rotation.

But *in practice* this is not the way it is done. The calculation of volume to be cut is a quantity check, leaving the areas or specific stands to be selected by the forester. He will take the oldest or those most in need of cuttting. Allotment of specific stands long in advance of operations has lost favor in European practice where the effects of a cutting cycle are reduced to a minimum by shortening the cycle and going twice or three times over the area in an allotted period, e.g., for a period of 20 years, the cycle may be but 5 years in length and each area is cut 4 times within the period. Or the periodic allotment of areas is made moveable or progressive by the continuous addition of areas as others are cut over. (French quartier bleu method.)*

With short five to eight year cycles the difference in age between stands cut at r years, or at r — cc or r + cc years does not exceed the limits expected in the ordinary management of a regulated forest.

121. Principle of a Horizontal Cut to Fixed Limits of Age or Size. A *felling reserve*, or serial arrangement of the merchantable age classes, is actually created by cutting a forest once over during a cutting cycle, whether or not it is recognized in the plan of management.

But when as in the transition rotation for virgin forests, the rotation may be fairly long to begin with, and the cutting cycle, being $\frac{1}{3}$ or $\frac{1}{2}$ r, may

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* See page 239, Studies in French Forestry, John Wiley & Sons, New York.

be between 40 and 100 years in length, the method of theoretical allotment of given stands or age classes for removal during such a long cycle will differ so widely from the practical demands of regulation and of logging, that these discrepancies can no longer be concealed or ignored. The progress of the stands by growth and decadence goes on. In the logging of successive stands, by the *theory of allotments* only the timber which had reached the age or size agreed upon at the *beginning* of the period would be logged within the period and this would mean, as in the illustration given, a constantly increasing age or diameter, but this time *over a long period*.

Instead, the *cut* will be forced to proceed along a horizontal line of cleavage, removing from each successive area *not* merely the stands which *originally* were ready for cutting, but also those which have matured since and are ready for cutting when the area is to be cut over. By this method, a felling reserve grows up on the areas behind the saws, i.e., is created in the first cutting cycle instead of at the end of the first rotation, for the reason that on areas ahead of the saws all the newly maturing crops are cut along with the original stands. It is self-evident that if logging and silvicultural conditions originally demand the removal of a given per cent of the stand, they will continue to do so as long as the basic economic factors remain unchanged, and after that the working plan itself must be revised.

Application of this Principle to Transition Cuttings. This working principle may be termed the *principle of a horizontal cut and felling reserve* as contrasted with that of specific allotment of stands. Taking the forest described in the former illustration, but applying this principle of cutting instead, the forest will be cut over by removing each year all the stands on each cutting area which are ready to cut, i.e., are forty $(r - cc)$ years old, in order to create at once a cutting series equivalent to a ten (cc) year cutting cycle.

Effect on Area and Volume to be Cut Annually. As one additional crop reaches the minimum exploitable age each year in each block, the cut at the end of the first year under this plan in the previously regulated or normal many-aged forest would cover eleven acres and for the twentieth year, twenty acres, while during the ten-year cycle, instead of 100 acres being cut, the area logged will be 150 acres. This method not only increases the area cut in the first period by fifty per cent but increases the volume by a somewhat smaller per cent. (The young maturing stands have ten years less growth than those originally in this period, hence a smaller volume.) The process would remove all of any surplus stock during the first cutting cycle. This surplus consists of the stands which must grow to a maximum age of $r + cc$ years (60 years), before being reached in logging, the actual ages of these overmature stands falling between r and $r + cc$ years (51 to 60 years). The effect of the horizontal cut would be to reduce the growing stock below normal, and prevent any stand in the future from growing to an age exceeding r years, as long as the plan is adhered to.

During this first cutting cycle, the advancing age of the surplus would raise the average age of the stands cut, from $45(r - \frac{1}{2}cc)$ to a final 50 (r) years in the last or tenth year of the cycle.

For each cutting cycle *after* the surplus is removed, during the first rotation, the average age of the stands cut will be $r - \frac{1}{2}cc$ or 45 years, after which the normal arrangement being secured, the stands during the second rotation may be cut at r or 50 years.

122. **Application of These Two Principles in Contracts for Purchase of Timber Cutting Rights.** The distinction between these two methods of regulation may be

further illustrated by citing certain timber sale contracts for the purchase of standing timber for cutting. In these contracts a diameter limit is usually specified, and a period fixed within which all timber so purchased must be removed. Numerous lawsuits have resulted from failure to recognize the fact that trees grow in size. The owner who sells would favor the allotment method of cutting described above, by which none but the trees which were of the stipulated size of age classes at the time of sale could be cut within the period. This would coincide with the first illustration— the purchaser would get the growth on the allotted stands but no new or maturing stands.

The purchaser, however, insists that he is entitled to a horizontal cut of all timber which is of the specified diameter at the time he reaches the area in question, claiming that it is utterly impractical to distinguish from year to year, in cutting, the trees which were below the given sizes in the first year of the cycle and that nothing was said about this anyway in the contract. If permitted, he therefore cuts on the plan described in the second illustration leaving only the timber which matures behind the saws or the so-called felling reserve. If the contract is so loosely drawn as to permit him to cut the same area over more than once, i.e., cut in two cutting cycles, he can of course begin where he left off and cut the felling reserve, continuing this process indefinitely as long as his contract permits him to cut. The Carr contract for the sale of timber on the former Vanderbilt holdings, now the Pisgah National Forest was let on this basis, and has resulted in great embarrassment to the government. It would be just as well for owners of timber to recognize sooner or later that trees grow in spite of their indifference to forestry. The basis of a straight or horizontal cut is the only practical basis of a contract for cutting, but the payment should not be in a lump sum at time of sale,—rather, on the basis of scaled cut and with provisions for advance in rates on a long period, with confinement of the cut to one cutting cycle, or once over the area.

123. Effect of a Surplus of Overmature Timber upon the Minimum Exploitable Age. While in large areas the original growth may resemble the normal forest of our illustration in having no regularly arranged felling reserve but rather, a distribution of all age classes over the entire area, yet their chief characteristic is an excessive surplus of growing stock when measured by empirical normality (§ 65). When, even on this empirical basis, the forest, because of past fires and abuse has less than the normal quantity of overmature and ripe timber, yet it is sure to have stands whose age greatly exceeds that of any reasonable rotation for future management.

This surplus, or in its absence, the excess in age of the mature stands, makes it unnecessary in regulation to draw on stands as young as $r - cc$ years to make up the cut for the first cycle. If on account of good transportation the cycle can be shortened and the annual cut distributed correspondingly on a larger gross area, the cut for the first or even the first two cycles, depending on length of cycle and condition and quantity of overmature stands, may be confined entirely to trees which are older than r years. This postpones the reduction of the surplus over a corresponding period.

But with a long cutting cycle, the lack of properly arranged cutting series in the forest and the necessity of a heavy cut per acre will compel the cutting of trees less than r years old in the first cycle, until this series is established. It will *not* be necessary to cut trees $r - cc$ years of age, however, because of the existence of this surplus whose tendency is to supply sufficient timber of a larger age, i.e., to *raise the minimum exploitable age*. This might be set, for instance, at $r - \frac{1}{2}cc$ years instead of $r - cc$ years.

This process contains the key to the regulation of the cut in transition forests in order to equalize the yield during the cutting cycles in which the surplus is being disposed of. The greater the surplus, and the shorter the cycle, the nearer can the minimum exploitable age coincide with the rotation age r. Conversely, with a fixed cycle, the higher this minimum age or size is placed, and the nearer it coincides with r years, the more timber will be left per acre, the more surplus will be carried over to the second cutting cycle and the more the cut will be evened off as between successive cycles while the surplus is being removed.

124. Desirability of Short Cutting Cycles when Possible. It is evident that from the standpoint of the forest, in order to reduce waste from over-maturity, carry over and distribute the surplus, break up the cutting areas into smaller units and reduce the volume required in the felling series to a negligible factor, a short cutting cycle is indicated for transition cutting, and only the necessity of harmonizing the methods of regulation with unavoidable economic factors (§111) will force us to adopt long cutting cycles for the present on some of our forests.*

With the short cutting cycle the allotment principle can be adopted (first illustration §115-116) as the basis of calculating the cut, especially in forests which have already been partly or entirely cut over and now consist of culled stands and second growth, with small residual tracts of original growth— as in many of our national forests in the Appalachians and White Mountains.

125. Necessity for Horizontal Cut and Long Cutting Cycles on Virgin Forests. But where economic conditions require a long cutting cycle for the transition of a large area of original and overmature forest, the actual practical difference between the required standard of cutting in logging operations and a theoretical allotment of definite stands or size classes becomes too great to be ignored, and the allotment of cutting areas and calculation of the annual cut must be made to conform with these conditions. The cut must be determined or limited on the basis either of area, or volume, or both. Apparently in the transition of a forest already normal, as in the illustration (§ 116), this method of horizontal cut would increase both the area cut over and the volume removed in the first cutting cycle to an excessive amount and be no better than the allotment plan in its ultimate effect.

But we are not dealing with a normal forest. The two practical considerations which we face are the surplus in overmature age classes, and the decadence and loss occurring in these classes.

As seen, the surplus tends to raise the minimum exploitable age, hence removes one objection to the horizontal cut, that of lowering the average age of cutting.

Determining Influence of Factor of Decadence. But the real factor is the loss from decadence. A certain portion of the volume of overmature timber inevitably dies or is killed or destroyed annually in such forests. This reduces both the area occupied by the merchantable stands, and the available volume which can be cut during the cycle. If we falsely assume that this loss does not occur, and proceed on the allotment principle in fact, by progressively raising the age or diameter limits during the cycle (§ 115-116), both the

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* The cutting cycle on the western yellow pine type in Arizona and New Mexico was unconsciously lengthened from about 60 or 70 to 100 years by a change in the practice of marking, which removed a greater per cent of the mature yellow pine timber, and increased the cut per acre and, as applied in practice, lowered the average minimum exploitable age to between $r - \frac{3}{4}cc$, and $r - cc$ years by heavy marking in Blackjack age classes. The reasons for this change were the absence of silvicultural necessity for leaving $\frac{1}{3}$ of the stand, the favorable effect on stumpage prices of increasing the cut per acre, and the avoidance of loss in leaving large valuable timber at time of first cut. There was also in many stands the necessity of cutting heavily to wipe out loss from mistletoe and disease.

volume available for cutting and the area occupied by the assigned stands will diminish to the extent of this decadence, which in a cycle of ⅓ or ½ r will constitute a large per cent of the total available cut (25 per cent is not unreasonable).

This unavoidable loss is accompanied by a natural reproduction which will be available in the next rotation, but not in the present one. For this reason, not only because of practical economic conditions of logging, but in order to apply common sense in regulating the cut and renewing the forest, the *age and size classes which mature ahead of the saws during the first cutting cycle must be included in the cut for that cycle,* by adopting the principle of a horizontal cut and felling reserve in regulation.

126. Illustration of Application of Principles to Western Yellow Pine. To illustrate the effect of this principle upon transition forests we will assume a rotation of two hundred years for western yellow pine, and a cut of eighty per cent of the merchantable volume. This cut is heavier than will be necessary in the second cutting cycle, i.e., constitutes a larger per cent of the stand, because of the surplus of overmature timber present and resultant deficit of younger age classes. The growth predicted on the remaining stand indicates a period of one hundred years as required to produce, from the twenty per cent of merchantable timber plus the maturing of young stock, a cut of sufficient volume per acre to justify logging operations similar in character to the original operations and the logging of timber which would otherwise be rendered inaccessible. The cutting cycle is then fixed at one hundred years or ½ r. On an area of 1,000,000 acres, the annual cutting area will be 10,000 acres. But on this area the cut actually covers but one half for the other half is occupied by young timber and reproduction. Actually then, 5,000 acres of mature timber is cut annually, and in two hundred years the tract is gone over twice but each acre of ground is logged clean only once.

The average age desired is 200 or r years. If this forest were a typical many-aged form, and no overmature timber existed, the maximum age of the standing timber would at the start be 200 years, ranging down to 1 year, with an average age for all stands, of 100 years or ½ r.

But the actual age of the overmature timber is 300 years, and the average age of all stands is nearer 200 than 100 years.

If the cut is determined on the allotment principle, the volume of the annual cut will be the present volume of the stands which constitute eighty per cent of the volume of merchantable timber, plus the net growth for one hundred years, on the age classes which make up this eighty per cent.

The timber lost by decadence in overmature stands must be deducted from the total available cut. The area reproduced, as the *combined result of cutting and of replacement following natural losses* in the stands, will or should be about one half the total area, or 5,000 acres per year.

Effect of Substitution of Horizontal Principle. But if, in logging, the same diameter or age limitations are applied to the cut each year, and the principle of a horizontal cut is adopted, the following conditions are faced:

1. If the total loss by decadence has been calculated and deducted from the total available cut, the limitation of the annual cut will be correspondingly reduced by 1/cc of this amount. Now, unless the cut is actually confined to the allotted age classes, (if instead) the younger timber maturing ahead of the saws is cut as logging operations reach the areas, the additional volume thus available per acre slows up the progress of cutting if limited as above, and the failure to coördinate the calculated cut with operating conditions will result in a failure to complete the removal of the old timber in the desired cutting cycle.

2. If on the other hand the amount of timber maturing ahead of the saws has also

been calculated, and included in the possible total cut, the annual cut as calculated should agree with the volume which will be available, and the cycle will see the removal of the overmature timber as planned.

By either plan, because the actual cut is on the horizontal principle, a felling reserve consisting of a cutting series of graduated age classes will be built up behind the saws, from the timber left standing, but in the latter case it will be of the required arrangement, with a maximum age equal to the minimum exploitable age plus cc years and containing cc age classes.

It is not necessary, in the first cut, to remove from this forest in the first cycle all timber down to ½ r years in age, i.e., to 100 years. The preponderance of overmature timber may be such that the minimum exploitable age may be set instead, at ¾ r. The second cutting cycle will take care of this surplus which is carried over.

For illustration, assume that the average age of the timber to be cut is 250 years and the minimum exploitable age of 150 years or fifty (½ r = cc) years less than r years. If the principle of allotment is applied, the average age of the stands cut during the first cutting cycle would finally, in the last year, reach to 350 years, and the average age for the whole period or cycle would be 300 or r + cc years, *with a constant serious loss from decadence for 100 years.*

If we now include the additional areas which will mature ahead of the saws, during the cutting cycle of 100 years, this should amount to one half of the timber now between 150 (minimum exploitable age) and 50 years of age.

Knowing the area of this young timber, this quantity can be obtained. If for instance, two thirds of the area of young timber below 150 years is from 50 to 150 years of age, and the sum of these young age classes covers half the total area, then 333,333 acres will mature in 100 years, one half of which will be on areas ahead of the saws and one half on areas behind the saws or on areas already cut over. Then 166,666 acres of young timber should be cut and reproduced in the cutting cycle of ½ r years. This increases the area of the annual cut by 33⅓ per cent. The increase in volume depends upon the rate of growth of the stands, and should be calculated from yield tables, as was done for the old timber. The total cut would be materially increased, the annual limitation of cut correspondingly increased, the decadent timber all removed in ½ r years, the surplus largely reduced and a felling reserve created containing timber from 150 to 250 years old. On the other hand, if the allotment idea is theoretically held to, the 150 year old timber standing on the *last cutting area* would not be cut in 100 years when it was 250 years old but would go over into the second cycle and reach a considerably greater age before cutting.

To sum up:

The presence of a surplus of overmature stock enables a transition cutting to be carried out with a minimum exploitable age higher than r — cc years. But if the allotment principle of calculating the annual cut is applied, this in itself results in slowing down the cut and holding over the standing timber to a greater average age. The proper minimum exploitable age is best calculated when the annual cut is made to include the timber reaching this minimum age during the period.

127. Basis of Computing the Annual Cut by the Principle of a Horizontal Cut. *Summary of Previous Conclusions.* It has been shown that the cutting cycle is merely the last period in the rotation coinciding with the period between the minimum exploitable age and the normal age of cutting; that in a transition cutting, either from one normal forest to another, or from an unregulated forest to a regulated form, a rearrangement of age classes takes place, creating a felling reserve for the succeeding cutting cycle; that this felling reserve is the apex of the triangle or final group (see fig. 6) in a complete series of age classes required by a normal forest; that in the first period, the presence of a surplus enables the transition cutting to take

place by placing the minimum exploitable age at r — ½ cc years, and tends to secure an average of r years or over; and that after regulation, the cutting age of all stands cut can be r years.

Relations of Growth to Cut in Normal Forest. The calculation of the possible cut for the cutting cycle is based on very simple principles which relate directly to the desired normal series of age classes created by progressive cutting. These are,

1.   *a.*   The cut from a normal forest for the rotation is just equal to the total growth during the rotation.

b.   If the growth is (incorrectly) assumed to be laid on in equal annual quantities, then the growing stock required to maintain an annual cut is just ½ of the total growth or of the total cut for the rotation.
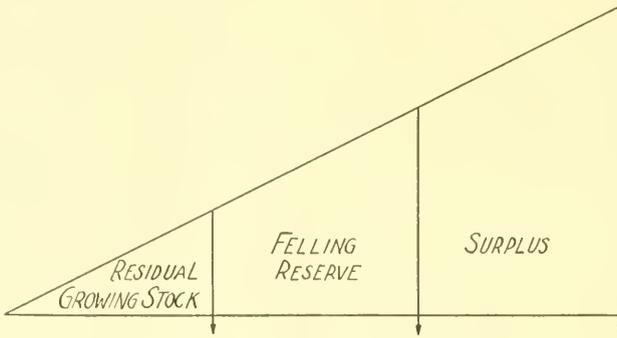

Fig. 6.—Illustration of Residual Growing Stock, Felling Reserve and Surplus.

c.   The average age of this growing stock at any time is ½ r years.

d.   The period which the average stand will remain before being cut is ½ r years. The growth put on is the growth for ½ r years. The cutting period is r years.

Analogy with any Lesser Period as a Cutting Cycle. Allotment of Timber Now Mature.

2.   These same relations hold good for any lesser cutting period, such as a cutting cycle, as follows:

a.   The timber which may be cut during a cutting cycle under the allotment plan, consists of all the timber now above the minimum exploitable age or size. This constitutes in an unregulated forest, the felling reserve plus the surplus.

b.   The timber below this age, or residual growing stock, coincides with the age classes of a normal forest below the minimum exploitable age. This division may be indicated as follows:

c.   During the cutting cycle, the stands allotted for cutting, i.e., those that are ripe at the beginning of the cycle, will be cut progressively, so that the average period elapsing before cutting is ½ cc years.

d.   The average growth put on by these stands is therefore either

the growth for ½ cc years, or ½ the growth for cc years, which is not the same thing. These two ways of expressing the growth are more nearly the same for any period or cutting cycle of less than r years than for the rotation as there is not so much diversion between current and mean annual growth for the shorter period. The latter method of calculation can therefore be adopted, and is universally used in European regulation to determine the total growth available for cutting.

c. The total volume available for cutting from stands allotted to the cutting cycle at the beginning of the period is then

Volume + Growth for ½ cc years.

3. In practical operations, on a large area and with a fairly long cutting cycle, all trees which reach the minimum size or age during the cycle, and on areas which have not yet been reached by the progressive cutting operations, will be cut with the remaining mature stand which constituted the original volume above this size or age.

If it were possible to cut all the mature stock above the exploitable age in *one-half the cycle,* the growth realized on this stock before cutting would be ½ of ½ of the total growth, or ¼; ½ because of the reduction in length of the cutting period, and only ½ of this because of the serial progression of cutting which reduces the period elapsing before cutting to half of the cutting period. Again, if the maturing stands could all be cut in the last half of the cycle, the growth on these stands would be ½ plus ¼, the first half because no cutting occurs for half the period and the remaining ¼th because of the serial progression of cutting. Thus the sum of the growth realized on both classes is roughly ½ of that on all stands cut.

Because of the fact that both the mature and the maturing stands are cut simultaneously throughout the *period,* the growth realized on the mature stands instead of being ¼th will be ½ of the total, while that on the maturing stands will be *less than* ¾ths and will more nearly approximate ½. Actually, it will slightly exceed ½ in a forest of all ages, since even with progressive serial cutting, the larger portion of the maturing stands will mature in the latter half of the period. Therefore the assumption that ½ of the growth will be cut is conservative and practical.

By fixing the minimum exploitable age at r — ½ cc years, the stands which will reach this exploitable age in cc years will be all those ranging from r — ½ cc to r — 1½ cc years at present. Of those stands, a volume equal to ½ the total, or approximating those now r — ½ cc to r — cc years will be cut, plus ½ the growth on these stands. The remainder will constitute part of the felling reserve for the next cycle.

The cut for the first cycle can then be recast as follows:

1. Volume of all stands above r years plus ½ growth for cycle.
2. Volume of all stands from r to r — cc years plus ½ growth for cycle.
   or,
   Volume of all age classes down to r — cc years, plus ½ growth for cycle.

It is thus seen that the one essential step in securing a horizontal cut, and in calculating the volume and increment of the stands to be cut, is to get the minimum exploitable age at r — ½ cc years, which step will permit

of the formation of a felling series and felling reserve during the first cycle whose average age is r — ½ cc years, and whose age, when cut, will average r years.

The cut for each progressive cycle will then equal the volume of all trees above r — cc years at the beginning of the cycle plus ½ the growth for the cycle, the minimum exploitable age being retained at r — ½ cc years, until the forest has been completely cut over, which will require a full rotation.

128. **Quiz.** What three preliminary conditions are required to permit of undertaking sustained yield management?

How does the character of our forests make regulation difficult?

What is the cause of overcutting?

What classes of growth data are required?

What classes of owners should practice sustained yield?

What cutting policy is indicated for other classes of owners?

What is the danger in such a policy?

How is this danger to be avoided?

Contrast sustained yield, destructive lumbering, and preservation of forest from destruction as goals for private management; and for public management.

What is the effect of costs of logging on the required initial cut per acre?

How do the demands of silviculture influence the initial cuts?

Define the term cutting cycle.

What three factors determine the length of a cutting cycle?

What bearing has growth on cutover land and growth on virgin forests, respectively, on the length of cutting cycles, and amount of the annual cut?

How does the cutting cycle differ from the rotation?

What is the relation between the cutting cycle and the cut per acre?

What element of forest regulation is affected by the length of a cutting cycle?

Describe the differences and similarities of forests composed of even-aged and many-aged stands.

Define the terms residual growing stock, and felling reserve.

Compare a normal forest of even-aged stands with one composed of many-aged stands.

Describe the effect of cutting these forests on a 10-year cutting cycle.

Define the term, minimum exploitable age.

What is the relation between the cutting cycle, the rotation, and the minimum exploitable age?

How will the ultimate form of a forest be determined by the cutting cycle?

How is the theory of the allotment method departed from in practice?

Describe the principle of cutting termed the horizontal cut, and its effect in creating a felling reserve.

What effect does it have on the surplus, normal growing stock, and average age of cutting?

How are the allotment principles and those of the horizontal cut illustrated in contracts for the purchase of timber stumpage for future cutting?

Describe the effects of surplus of over-matured timber on the determination of minimum exploitable age.

How can this surplus be thus distributed in point of time?

What factors indicate a choice of short cutting cycles in virgin forests?

Why do long cutting cycles require a horizontal cut?

What effect has the factor of decadence in virgin forests favoring the adoption of horizontal cuts?

THE APPLICATION OF REGULATION TO AMERICAN FORESTS

129. Resumé of Principles. 1. The management of American forests must be based primarily on protecting and continuing the productiveness of forest land, and in this form it is applicable to all classes of owners.

2. The regulation of the annual cut to attain a sustained yield is not always possible and can be attained only when both the economic and physical conditions are favorable.

3. Market conditions and the cost of transportation and logging as reflected in stumpage prices, combined with the silvicultural demands of type and species as influencing reproduction and health of the stand, will determine the character and per cent of the initial cutting per acre, and cannot be materially modified.

4. The per cent of the stand which is cut and the resultant rate of growth upon the cutover lands, taken in connection with the future conditions of logging and transportation, will determine the period which must elapse before the second cut. This period is the cutting cycle.

5. The total available cut of mature timber as determined by the area, stand per acre to be cut, and growth available before cutting on these stands, will indicate the limitation of the annual cut required in order to secure sustained yield.

6. The same basic principles of regulation apply to forests of all forms, whether even-aged or many-aged.

7. Wherever transportation conditions make forests readily accessible to intensive markets, short cutting cycles are adopted, and the principle of regulation most frequently employed is that of allotting a definite per cent of the mature timber by volume and by area, to be cut during the cycle.

8. When, because of difficult transportation problems, forests are relatively inaccessible and a long cutting cycle must be adopted, the principle of a horizontal or progressive cut which coincides with the method of cutting actually applied on such forests must become the basis of calculating the amount of the annual cut and regulation of yield.

9. This principle recognizes the fact that the cutting on successive areas will continue to require the same age and diameter limits as originally agreed upon, regardless of the growth and change taking place in the forest.

10. This means the inclusion in the cut of all stands which reach the minimum exploitable age ahead of cutting on the specific areas.

11. The apparent excess of cut which would result, both by area and volume, in this enlargement of the cutting areas allotted for the period is offset, for unregulated original growth, by the unavoidable decadence and death of a per cent of the stands, and by the resultant natural reproduction, which factors reduce the area actually cut over.

12. The regulation of unregulated forests is a transition resembling in

character the transformation of a regulated or normal forest from one form or grouping of age classes to a different form, such as would be made necessary by a change in the length of the cutting cycle.

13. *The ultimate form and arrangement of the age classes in any forest is the direct result of the cutting cycle adopted.*

14. *The period represented by the cutting cycle is not an addition to the rotation, but is the last period in the rotation.*

15. The transition cuttings under a given cutting cycle require the cutting of stands of less than rotation age, to a minimum age of r — ½ cc years, and require the holding of other stands to an age exceeding the rotation by a maximum of ½ cc years, even in a normal or regulated many-aged forest.

16. The same range of ages for cutting is required in transition cuttings in an unregulated forest,—but in forests possessing a surplus of overmature timber, the minimum exploitable age in the first cutting cycle can be set higher, if desired, in order to conserve the surplus and prolong sustained yield.

17. In either case the minimum exploitable age during this cycle *should be just ½ cc years less than the average age of the timber to be cut.*

18. The adoption of the principle of a horizontal cut in the first cutting cycle establishes in that cycle a cutting series constituting a felling reserve for the succeeding cycle, consisting of a series of age classes whose number equals cc years and whose individual areas equal the annual cutting areas.

19. This felling reserve is created by the growth of the timber below the minimum exploitable age (size) constituting the residual growing stock, which growth causes this timber to mature or enter the exploitable age or size classes.

20. The cut for the first cycle comprises the timber above the exploitable age plus half the growth on the entire forest during the period.

21. The portion of the cut representing growth is made up from ½ the growth on the above merchantable timber plus ½ of the total remaining growth on the entire forest.

22. This latter quantity is equivalent to ½ of the volume of stands entering the exploitable class and ½ of the growth for the period on these stands, or, the volume of all stands between r and r — ½ cc years plus ½ their growth.

23. Although the volume of stands entering the exploitable class during the period is equivalent to the growth for the period on all the remaining young stands in a normal forest, this is not true of an abnormal forest, with irregular distribution of age classes, and statement 20 must be modified by substituting statement 21 and 22, for the expression, ½ the growth on the entire forest for the period.

24. For all forms of forest, regular or irregular, the cut for any cycle is equal to,

        a. The timber above the exploitable age,

        b. Plus all the volume occurring either as growth on this timber, or in the form of maturing timber entering the merchantable age class on areas before they are cut over.

25. The volume and growth on timber entering the merchantable age class (above the minimum exploitable age) after the areas are cut over plus the

volume and growth which will mature before cutting, in the next cycle, will in a normal forest about equal the volume and growth cut during the cycle, and will constitute the next felling reserve for the succeeding cycle.

26. The adjustment of annual cut over 2 or more cutting cycles to distribute a surplus, in transition cuttings, depends on the possibility of shortening the cutting cycle, raising the minimum exploitable age and diminishing the per cent of the cut per acre in the first cutting.

27. Actual logging operations in all classes, types and forms of forests in America will be governed by these principles no matter what theoretical basis is used to determine the annual limitation of cutting. The *cut per acre* will be the starting point, the recovery by growth will fix the *desired* period for the first cycle. Whether or not the forest is actually regulated for sustained yield will then depend upon the ability of the forester to limit the annual cut so as to bridge the gap. Only when the *total annual cut,* as determined by the *area cut annually from the working unit, as well as the cut per acre,* can be reduced to the indicated quantity, can a sustained annual yield be attained. But if the silvicultural limit has not been exceeded in the cut per acre, protection given, and reproduction secured, then continued production is assured on the basis not of sustained annual, but intermittent periodic yield, which in the long run will produce fully as large a total yield of wood. Only when the productiveness or reproductive capacity of the forest is destroyed or impaired is its ultimate total yield reduced or destroyed.

28. The question as to whether a given forest unit shall be cut so as to prolong the existing stock in such a way as to produce from now on a sustained annual cut and revenue, instead of a much larger cut during a shorter period followed by a cessation of cutting until the forest recuperates, contains the gist of forest regulation and must be determined for private forests by self interest, while for public forests, public benefits will clearly point to a sustained yield where the economic factors permit it.

130. Application of these Principles to American Forests. The conception that forests of even-aged and of many-aged stands are affected in the same manner by the above laws of cutting and growth, in the establishment of cutting series and felling reserves, simplifies the consideration of the application of these principles to American forests.

131. Preliminary Cutting Cycles for Valuable Species in Mixed Forests. In cases where originally a single species is merchantable in a mixed stand, it is almost inevitable that later on the remaining species will become merchantable. In this case, the *growth* required will be the economic growth of markets and stumpage values. The first cutting cycle can not be based solely on the period required to produce an equal yield of the given species, for the chances are that this single species, as the result of cutting in a mixed stand, *will decrease in numbers and growth by suppression.* The cutting cycle may be based on the combined factors of growth of the species in question and future merchantability of the remaining species. The total growth of the stand, not that of a fraction of it, is the only safe basis of regulation. Cutting cycles based on selection of species in mixed forests are *strictly preliminary in character, rather than transitional, since an abundant volume of*

virgin timber is left whose later transitional regulation constitutes the real problem. This problem is quite common in tropical forests.

Since the development of the market cannot be predicted, and the heavy cutting of valuable species might lead to their serious reduction or extermination,* the possible future growth of the residual stock of the exploited species after cutting, and the period which would be required to obtain an equal cut of the species in the future might be used as a guide for determining the total cut, which could then be regulated to extend over this period, if sustained yield of the species is to be attempted. This principle of regulation was admirably brought out by Pinchot and Graves in the "Adirondack Spruce" (Gifford Pinchot 1898), for the Nehasane Forest, N. Y., although later research shows that the rate of growth after cutting fell short of their predictions on account of the severe competition of the hardwoods in mixture. The original cut of spruce which was completed in a very short period and was intermittent rather than sustained since the desired concentration of the annual cut required this and the overhead cost for a smaller annual output would have made the extension of the cut over the period 1896-1916 unprofitable.

132. **Transition Cutting Cycle. Example of Intermittent Yields under Private Management.** The real transitional cutting on this tract is now taking place. Now the problem is, to determine how long it will take the residual forest, cut for hardwoods and spruce, to recover so as to produce a yield which would justify a third cut whose volume will approximate the average productiveness of the forest. This tract is in the hands of an owner who is independent of the necessity of sustained yield, and no effort is being made to find out what this cutting cycle should be, but the tract is being logged over on a cycle evidently much shorter than would be required to sustain the cut, much as a lumberman would operate. To reduce this operation to a regulated annual cut and income, the rates of growth must be determined for hardwood stands left in the condition of these cutover areas. Such data are not at present available. But if the proper per cent per acre of the stand is being cut to secure the best growth and reproduction, criticism can be made of the operation only on the basis of the scheme of regulation adopted, and *regulation for sustained annual yield in this second cutting cycle is optional with the owner just as it was in the initial cutting cycle for spruce.*

Under government ownership, the first step now, after fixing the limits of cut per acre and the species to cut and products to sell, would be to find out at once what is going to happen on that land, *before contracting for the sale of so much timber that the length of the period to complete the first cutting is already determined by the amount of the annual cut* and sustained yield rendered impossible. The amount to cut must be fixed by the period, volume available and growth, or the cut will be intermittent.

Regulation, therefore, presupposes some definite knowledge of *growth of stands and areas, not merely of single trees,*** growth of *average* stands, not

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* As a result of cutting and of fire protection, teak is not maintaining itself in many Indian forests.

** See *Forest Mensuration,* pages 315 to 455, H. H. Chapman, John Wiley & Sons, 1921.

merely of normal or selected fully stocked stands, and growth of cutover stands, not merely of stands in the original forest. This knowledge can be obtained, and to try to regulate the forest without it is a poor makeshift, but not so bad as failure to regulate it at all.

133. **Assumption that Growth Balances Decadence.** The previous discussion has shown that the straight allotment plan of regulation of the cut will give too small a cut if the loss from decadence of the timber is known and properly deducted, and that to offset this factor the volume entering the exploitable class by growth is included in the cut, by including the volume of trees falling in an additional class equal to ½ cc years.

The determination of loss from decadence is admittedly difficult. Few successful attempts have been made to measure it though it is possible to do so. Owing directly to this fact, such efforts as have been made so far to determine the total available cut for the first cycle in a transition forest have usually been based on the balancing of one error against another. This is, the assumption that growth in such virgin stands exactly balances loss from decadence and that therefore there will be no net change in volume of this timber above the exploitable age on the average acre during the cutting cycle.

This conclusion is probably a conservative one, since to offset the loss on decadent timber we have not only the net growth on the age classes already mature or ready for cutting, but will add to this the volume and growth of one half of the maturing age class as well. The trouble is, that it *may be too conservative, and fail to indicate the true amount of the available cut.* For a preliminary period of cutting, and for forests where the market or possible cut is probably below the permissible cut, this assumption might be as acceptable as any other since there is no danger of overcutting. If the rate of growth ascertained on cutover areas has indicated a cutting cycle of ½ r years, the *cut* per year would then be x per cent (the cutting per cent) of the total merchantable stand above the exploitable age or size, divided by ½ r years. Since the Von Mantel formula calls for a cut equal to

$$\frac{\text{total merchantable volume}}{\text{½ r}}$$ the above result would be more conservative

than that obtained by this formula for an equal cutting cycle. If the cutting cycle were found to be ⅓ r or ¼ r years the cut per year would be decreased proportionately. But the crude Von Mantel's or the Austrian formulae both differ from this assumption in that both take for granted that the forest is under management, has no decadent stock and is therefore *replacing the growing stock rapidly by growth,* and for *this reason,* that the *entire* present stock can be removed in ½ r years or less, without depleting the forest capital. With an absolutely stagnant stock, only the fact of overmature and excessive volume, and the desire to rapidly replace this stock with a young growing stock, would justify such an assumption.

134. **Formula for Regulation of Cut Based on this Assumption.** This formula for the annual cut may be expressed as

$$\text{Annual cut} = \frac{\text{x\% of merchantable volume}}{\text{cc}} = \frac{\text{exploitable volume}}{\text{cutting cycle}}$$

The basis thus indicated becomes safer, the shorter the cutting cycle is made and the smaller the per cent that is taken, since the x per cent then applies more nearly to age classes on which decadence and growth for the period cc is apt to balance. This idea is practically the same as that of the French method of 1883, in which the cutting cycle, *based on growth,* was first fixed at $\frac{1}{3}$ r, the exploitable age at $\frac{2}{3}$ r and the per cent to cut at $\frac{5}{8}$ or $62\frac{1}{2}\%$ of the merchantable stand. (§ 87)

Then if Ga = Merchantable growing stock

$$\text{Annual cut} = \frac{.625\ Ga}{\frac{1}{3}\ r}$$

The later addition by the French of growth of the veteran stands before cutting, to obtain the total permissible cut, is an attempt to get closer to the actual cut by studying the growth of mature age classes.

135. Illustration—Coconino National Forest. The application of this method, and comparison with other formula methods, to the actual conditions on the Coconino National Forest, Arizona will bring out its characteristics.

Merchantable growing stock 3,151,147 M ft.

Area, 554,560 acres. Species, Western Yellow Pine.

Area cut over, 116,137 acres.

Net area of original forest 438,423 acres.

Average stand, on uncut area, 7,194 bd. ft.

Based on conditions of accessibility, and the silvicultural demands of the species, and upon the measured results of past cuttings, the per cent of the stand to cut is fixed at 80%.

Based on the average yields per acre, and the products desired, the rotation is fixed at 200 years.

Based on the rate of growth of the stands left on cutover lands,[*] and the stand required per acre to justify a second cut, the cutting cycle is fixed at $\frac{1}{2}$r or 100 years.

Assuming no further knowledge of the composition of the stand, or the growth of the original forest, the cut will be,

$$\text{By the formula, Annual Cut} = \frac{X\%\ Ga}{cc}$$

$$\text{Annual Cut} = \frac{.80\ (3151147\ M)}{100}$$

$$= 25,249\ M$$

136. Comparison with Von Mantel's Formula. Von Mantel's formula is based on the theory, not that there is no growth on the mature stand, but that this stand is growing and will be cut and replaced by growth, and that it now constitutes a serially arranged felling reserve. Since the relations of growth and growing stock on such a forest are,

Growth in r years = Cut in r years

Merchantable stock = $\frac{1}{2}$ Growth or $\frac{1}{2}$ Cut in r years

the cut per year on this forest would be

$$\text{Annual Cut} = \frac{Ga}{\frac{1}{2}\ r}$$

$$= \frac{3151147\ M}{100}$$

$$= 31,511\ M\ ft.$$

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[*] This rate was conservatively set at the rate realized on the original stand. Further study may indicate a dependable increase in growth after cutting.

This comparison indicates that it is unsafe to neglect the factor of growth on the mature timber, or of the volume added by maturing stands, in a long cutting cycle.

Effect of Shortening the Cutting Cycle. The effect of shortening the cycle, based on increased rate of growth after logging, or upon decision to require a smaller stand per acre in the future as the basis of continuous cutting, is shown in the above case as follows:

$$cc = \tfrac{1}{3} r = 67 \text{ years}$$

$$\text{Annual cut} = \frac{.80 \times 3151147 \text{ M}}{67}$$

$$= 37,685 \text{ M}$$

which exceeds the cut by Von Mantel's formula, while if $\tfrac{1}{4} r$ or fifty years could be used, the cut would be

$$\text{Annual cut} = \frac{.80 \times 3151147 \text{ M}}{50}$$

$$= 50,498 \text{ M.}$$

Hence, by shifting the *length of period* over which the present merchantable volume is to be spread, the annual cut obtained in the first cutting cycle can be greatly modified. The determination of the amount of cut which the forest will yield annually without overcutting, and which will bridge the gap between first and second cutting cycles so as to actually produce a sustained yield, is not a question of formulae or mathematics at all but an attempt to predict the results of living forces over a long future period. On the soundness of the observations and measurements of growth on which we make this prediction will rest the success of our efforts.

In both France and Germany the policy is to be sufficiently conservative so that whatever mistakes they make in their predictions, the cut will not exceed the rate of growth actually realized, and the growing stock will increase. With our decadent and overmature forests, such conservatism during the transition cycle is wasteful, for natural agencies are sure to reap what man spares.

The conclusion is that we should not be satisfied with crude guesses as to this cutting cycle, and should seek means of actually predicting the growth or decadence of the timber, not only that which is left after cutting, but in the original forest as well.

137. Illustration—Munger—Western Yellow Pine in Oregon. First Cutting Cycle. The best example of an attempt to formulate a plan of regulation of the cut suited to American transition cuttings is that discussed by Munger.[*] The conditions assumed are,

Species, Western Yellow Pine—Oregon.
Stand, 16,000 bd. ft. per acre.
Per cent to cut, 75%.
Stand remaining, 4,000 bd. ft. per acre.
Cutting cycle, 50 years
Rotation, 200 years.
Growth on cutover lands, 100 bd. ft. per year or 5,000 bd. ft. per acre in cc years.

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[*] Proceedings of Society of American Foresters, Vol. X, No. 1, page 18; see also §§ 70-71.

The area included within the working circle will of course determine the annual cut. To discuss the problem this must be assumed. If 200,000 acres is taken, the annual cutting area annually is 4,000 acres, over which 75 per cent of the stand is removed leaving 4,000 bd. ft. per acre as a residual growing stock.

The cut for the first cycle of 50 years is based on the assumption of stagnation, expressed by the formula, Annual cut $= \dfrac{X\% \ Ga}{cc}$ and on the area, will be,

$$\text{Annual cut} = \frac{.75 \times 16 \text{ M bd. ft.} \times 200,000 \text{ acres}}{50}$$

$$= 48,000 \text{ M bd. ft.}$$

This is a cut of 240 bd. ft. per acre annually.

The growth per acre annually, after cutting, is only 100 bd. ft. for 50 years. Including the residual growing stock of 4,000 bd. ft., the resultant stock per acre is thus reduced from 16,000 to 9,000 bd. ft. in this cycle by the removal of the overmature surplus.

The method of cutting proposed is horizontal, i.e., to given diameter or age limits, thus creating a felling reserve by the growth and maturing after the saws of the stands now containing 4,000 bd. ft. per acre on areas cut over. The fact that an equal growth may be taking place on these same stands before the saws, is offset against the decadence of the virgin stands—it is also true that the rate of increase on this nucleus of 4,000 bd. ft. after cutting is probably greater than in the virgin forest before cutting. The growth on this 4,000 bd. ft. *in the virgin forest* was not studied.

Second Cutting Cycle. Assumption of Normal Forest. This brings us to the end of the first cutting cycle. The one element which is based on research is the length of the cycle. The cut can be continued in the next cycle though at a reduced rate. Can it be continued indefinitely, and on what basis? To answer this question Munger assumes the existence of a normal (empirical) growing stock, based on the assumption that the residual growing stock of 4,000 bd. ft. per acre can be perpetually maintained, and that the growth expressed by the increase on these stands, of 100 bd. ft. per acre, represents the total annual cut possible. In each subsequent cutting cycle, under this assumption the cut is,

$$\text{Annual cut} = 100 \text{ bd. ft.} \times 200,000 \text{ acres}$$

$$= 20,000,000 \text{ bd. ft.}$$

or 5/12ths of the cut permitted during the first cutting cycle.

Analysis of Data. Felling Reserve. This conception must be analyzed for if sound it could be used widely in American regulation. In the present instance, with $r = 200$ years, it is evident that the lower limitation of exploitable size or age was set at 150 or $r - cc$ years. In the first cycle, the average age and size of the merchantable timber was much above 150 and might even exceed 200 years. The felling reserve created in the first cutting cycle, however, will grow from 150 up to 200 years in maximum age, and will average 175 or $r - \frac{1}{2} cc$ years at end of the period, with an *average stand* of 6,500, or $4,000 + 2,500$ bd. ft. per acre. The cut, each year, is 5,000 bd. ft. per acre on 4,000 acres (20,000 M bd. ft.), the ages ranging from 150 to 200 years on each cut.

Growth: The growth on these stands during the cutting cycle is,

Present volume $+$ (growth per year x $\frac{1}{2} cc$ years)

or $6,500 + 2,500$ bd. ft.

This 2,500 bd. ft. or 100 bd. ft. per acre for $\frac{1}{2} cc$ (25 years) is the growth taking place ahead of the saws. The total growth is 5,000 bd. ft. and this amount is to be cut. So the other half; or 2,500 bd. ft. was what took place behind the saws in the last cutting cycle and is added to the residual growing stock of 4,000 bd. ft. In this second cycle 2,500 bd. ft. or $\frac{1}{2}$ the total growth will again be put on behind the saws, and will in turn form the felling reserve for the future.

But this "growth" must be further analyzed to understand the state of the forest, and to comprehend how sustained yield is assumed.

Correlating age and diameter we can assume that the stand of 4,000 bd. ft. of residual

growing stock per acre is less than 150 years old, or below the diameter limit of cutting, and that it represents the growth of this 150 year period. No trees of this class can be cut, but all the trees of the class above, 150 to 200 years, are to be cut when reached in logging. But these latter trees are the same trees which in the previous cycle had laid on 4,000 bd. ft. of volume. Since the cut takes the whole tree, the 5,000 bd. ft. of growth (100 bd. ft. per year) to be cut must include such part of this 4,000 bd. ft. as is in the trees which mature plus the increase in size and volume of these same trees.

The growth of 100 bd. ft. is evidently not the mere current increase alone on the trees to be cut minus the volume possessed by these trees at the beginning of the period. The *average stand* of 4,000 bd. ft. per acre is said to increase to 9,000 bd. ft. in 50 years. Measured to the minimum exploitable diameter limit this 5,000 bd. ft. of "growth" to be cut does not comprise the current growth of the trees *originally containing* 4,000 bd. ft., but instead the total volume in 50 years of all the trees which grow out of this residual growing stock, which was too small to cut, and into the exploitable class, plus the current growth of these trees after they enter the class.

Growth of Separate Age Classes. Supposing that of this residual 4,000 bd. ft., 1,000 bd. ft. is from 50 to 100 years old, and 3,000 bd. ft. from 100 to 150 years. During the next 50 years, this 3,000 bd. ft. grows into the 150 to 200 year class, and becomes 5,000 bd. ft. which is to be cut. It is evident that $\frac{3}{5}$ of the cut was laid on before the period began, and $\frac{2}{5}$ only constitutes growth for the 50-year period on the trees cut. It is equally evident that the $\frac{3}{5}$ growth is the total growth put on by the younger sizes during this 50 years, or by the rest of the forest or rest of the area, or remainder of the average acre, and that 5,000 bd. ft. is the growth per acre for 50 years *not merely of the trees now mature, but represents the growth of the forest as a whole.*

In practice, then, the difference or increase in merchantable volume of the entire stand per acre correctly represents the growth on all classes of trees and all ages in a forest composed of a normal distribution of ages. (See § 62.)

But in predicting this growth, the analysis of the forest into its respective age classes will not only show clearly on what classes the increase occurs, but will show up the difference, if one exists, between a normal and an irregular distribution, instead of blindly assuming that the forest is already normal.

Growth Per Cent. Lacking this data on age classes, it is customary to predict growth in terms of a per cent of existing merchantable board foot volumes. This disregards the effect of maturing age classes now unmerchantable. The per cent obtained is a function not merely of current growth but of volume on which it is laid, e.g., if the 6,500 bd. ft. in the above instance grew even at 2 per cent for 50 years, a cut of 130 bd. ft. per acre is indicated.

The trouble with our efforts to devise means of regulating our forests is that there does not exist in the minds of American foresters or owners a sufficient background of knowledge of the composition of a forest, the influence of the distribution of its age classes, the difference in growth of these different age classes, or the relation of the successive maturing of age classes in determining the annual sustained yield. In this example (§ 137), the elements not determined were, first, the distribution of age classes; second, the per cent of total area occupied by the 12,000 bd. ft. of stand removed, and by the 4,000 bd. ft. left plus the unmerchantable age classes and reproduction; third, the true growth per acre of these younger age classes, or the effect of maturing timber on the possible cut.

As a result, while the outward form of the conclusions reached is sound, and a sustained yield of 100 bd. ft. per acre annually is indicated after 50 years, yet the actual indications as soon as we begin to analyze these assumptions may not bear out these conclusions.

Actual Versus Assumed Age Classes. If the stand is actually from 0 to 200 years old, and in the form of a normal forest, four age classes of 50 years each must stand on each acre. Each year 4,000 out of 200,000 acres is cut, removing 20,000,000 bd. ft. But on this same 4,000 acres, three other age classes are present, occupying $\frac{3}{4}$ of the area. The real cut is taken from $\frac{1}{4}$ of each acre, or from 1,000 acres, and the stand on one

full acre of this age class if segregated is 20,000 bd. ft., while on the second acre the stand would be 12,000 bd. ft. (4 × 3,000) — on the third acre 4,000 bd. ft. (4 × 1,000) while the fourth acre is covered by young growth. Consequently, the per cent to be cut, if a constant reserve of 4,000 bd. ft. per acre is maintained, will be but 5/9 or 55 per cent as against 75 per cent, in the first cut. Unless these premises hold good, the assumption of 4,000 bd. ft. per acre as a residual growing stock is incorrect.

But the most sweeping assumption is that after the removal of the excessive surplus in the first cutting cycle, the arrangement of age classes remaining is normal, as above indicated. The chances are that the overmature timber removed in the first cut really occupies more than 25 per cent of the area—probably also, the average age of the remaining timber may be greater than r or 200 years when cut,—and 2 cycles be required to reduce the surplus, or else the cycle chosen is too short. The plan, *since it assumes normality following the first cut, makes no provision for securing normality* in case, as indicated, the actual distribution of ages is decidedly abnormal.

Difference in Basis of Cut Between First and Second Cycles. In the French method of 1883 (§87-88) after the cutting cycle and per cent of total volume to be cut has been theoretically computed, as ⅓ r and ⅝ Ga respectively, no such assumption of normality is made. Were the original formula and method to be applied to the cut in the second cycle, as it was to the transition cutting, we would have the following comparisons— per acre.

By method of 1883

$$\text{Annual cut} = \frac{.62\tfrac{1}{2} \times 6500 \text{ bd. ft. per acre}}{66 \text{ years}} = 61 \text{ bd. ft. per acre per year}$$

$$\text{By Von Mantel's} = \frac{6500 \text{ bd. ft.}}{100 \text{ years}} = 65 \text{ bd. ft. per acre per year}$$

By Munger's, basis of ¼ r and 5/9 Ga.

$$\text{Annual cut} = \frac{.55\tfrac{1}{2} \times 6500}{50} = 73 \text{ bd. ft. per acre per year}$$

But in the second cycle, with surplus removed, *this method is already obsolete.* The French assume an allotment of the upper ⅓ of the stand for the period, and since their cutting cycle is not ⅓ r but a period of but 5 to 8 years only, *the felling series is not coincident with the cutting cycle at all,* but is insignificant, and the actual average stock per acre of timber in the upper third of the stand should be ⅝ of the total and not ½ of this, or 5,000 and not 2,500 bd. ft. above the 4,000 bd. ft. reserve, thus providing for an average cutting age of r or 200 years, with timber probably varying from r — ½cc or 196 to r + ½ cc or 204 years in age. Substituting 9,000 for 6,500 bd. ft. the results are,

$$\text{By method of 1883, annual cut} = \frac{.62\tfrac{1}{2} \times 9000}{66} = 85 \text{ feet per year per acre.}$$

Recognition of Growth in Second Cycle. Because of our long cutting cycle, this simple French allotment method will not work.* What Munger actually assumes is, that, although but 6,500 bd. ft. is on hand per acre, there will be 9,000 bd. ft. on the cutting area when it is to be cut, hence the annual cut $= \dfrac{.55\tfrac{1}{2} \times 9000}{50} = 100$ bd. ft. per year.

The specific difference in management caused by the shorter cutting cycle can be further illustrated.

With a cycle of 10 years instead of 50 years, the area cut over annually would be

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* We must bear in mind that the French method of 1883 is applied to selection forests of silver fir and spruce. They would never use the method for pine stands with groups of even-aged trees, nor would they calculate ahead for more than 20 to 30 years. They are apt to discard refinements as immaterial to the result.

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We must also bear in mind that the reason that they would not do so is the possibility of a short cutting cycle, rather than the difference in the silvicultural system.

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20,000 acres instead of 4,000 acres, or 1/10 of the total area of 200,000 acres. The total cut by Munger's figures is 100 bd. ft. × 200,000 acres or 20,000,000 bd. ft. Concentrated on 20,000 acres, the annual cut per acre on the cutting area only is but 1,000 instead of 5,000 bd. ft. which means that only the trees which have fully matured need to be cut, and there is no felling reserve worth mentioning. The acre is cut 5 times in 50 years, yielding 1,000 bd. ft. at each cutting. But with a cutting cycle of 50 years, this felling reserve and the growth which takes place during the cycle are the factors which permit of a cut of 5,000 instead of 1,000 bd. ft. per acre and since it is evident that but 6,500 bd. ft. per acre is present on the area as a whole (2,500 bd. ft. of which is mature), the assumption of a cut equal to 55 per cent of this stand for the cycle would not do. To get 100 bd. ft. per acre, 77 per cent must be cut, or $\frac{5000}{6500}$ of the stand,—and 77 per cent *can* be cut, since it is cut annually on an area which has put on 50 years' growth and contains actually 9,000 bd. ft. per acre, not 6,500 bd. ft.

For these reasons, the formula, annual cut $= \frac{x\% \, Ga}{cc}$ cannot be used in the second cutting cycle, for *growth must here be recognized as a material factor in* the cut.

Need for Determining Condition of Normality. The relation of volumes, as ⅜ to ⅝ assumed by the French method of 1883, is not the relation actually existing in the forest, nor even that assumed to exist after one cutting cycle, but it is the theoretically calculated normal relation which should exist in a forest which has a normal form, regardless of the density or degree of stocking of each age class,—a normal arrangement on a basis of empirical stocking. The real work of regulation is to secure this relation in the actual stand, and this will be our problem in the second cycle and thereafter. But we must first ascertain as did the French, what is the normal proportion of volumes to be striven for, and what actual proportions exist in the forest. This calls for the separation of age classes in the forest, on the basis of age, area occupied, and volume produced or yield per acre, regardless of whether this forest is all-aged or even-aged in form. This same information is needed, not merely for a continuance of regulation after the surplus is cut, *but for the initial determination of the cutting cycle, and of the annual cut.*

138. Summary of Principles. To sum up: *a.* Unless the species constituting the main volume of the stand are merchantable, regulation of the cut in the first cycle is preliminary in form and confined to the valuable merchantable percentage, which should be treated if possible for a sustained yield, based on growth,—but this cannot always be done.

b. When the main yield becomes merchantable and accessible, the first cutting cycle is transitional, involving the creation of a felling reserve, and is usually long, even up to ½ r years.

c. Although the length of the period must be based on studies of growth on cutover lands, the amount of the cut in the first cutting cycle may for the present and in absence of proper growth data be fixed on the basis that the loss will balance growth in the virgin stands previous to cutting.

The annual cut of timber now mature then becomes

$$\frac{X\% \, Ga}{cc}$$

d. Current growth per year on the stand left per acre after cutting, if calculated to include the total volume of trees maturing or becoming merchantable, is sometimes assumed to indicate the sustained annual cut.

But this assumes a normal forest, which does not exist in fact.

We need to know the composition and yield per acre of the forest by

separate age classes, in order, first, to determine what is a normal forest, second, what is a sustained yield, third, what steps should be taken to attain these objects.

After determining the length of the initial cutting cycle, and the per cent of the stand to cut, the general method of regulation, applicable to American forests is,

1. The annual cut, during the first or transitional felling cycles should be

   a. X per cent of the present merchantable volume, which will constitute the exploitable age or size classes, which should be set at r — ½ cc years.

   b. Plus the net growth in volume on these stands before cutting (total growth minus decadence), which is ½ the growth in cc years

   c. Plus ½ the total growth for cc years of the remaining stands in the forest including all age classes, which is equivalent to the volume and ½ the growth for cc years on ½ of the stands which would mature during this period cc, and is equal to all stands now between r — ½ cc and r — cc years.

2. The cut during the second cutting cycle should be,

   a. The felling reserve, which is the other half of the volume and growth of the stands maturing during cutting cycle,

   b. Plus an additional quantity made up from the growth of the forest during this period cc and represented by growth during this cycle on the felling reserve plus the maturing of stands into the exploitable class and growth thereon before cutting. In a normal forest this would give a total approximately equal to the volume of the felling reserve. Together, these elements equal the volume at beginning of cycle, of stands between r and r — cc years, plus ½ the growth during the cycle.

3. The maintenance of the cut in subsequent cycles therefore depends on whether the forest, after the first cutting cycle, is normal in distribution of age classes.

4. Regulation of the annual cut as between cutting cycles is impossible without a knowledge of the composition of the forest with respect to the area, age and volume of each age class, and a yield table based on empirical average yields for the forest unit. It is best accomplished by

   a. Ability to modify or reduce the per cent of the cut in the first cutting cycle and thus shorten the cycle and hold over the surplus to the second cycle.

   b. Ability to reduce the total annual cut from the forest in case of a long first cutting cycle so as to permit the accumulation of a larger cut per acre in the succeeding cycle.

   c. Ability to predict the cut of immature timber and the proportional area and per cent of the rotation which it will occupy.

139. Separation of the Forest into Age Classes. The basis of separation of the stands comprising a working group is fundamentally age;—since the time required by growth will eventually govern the rate of cutting. In forests naturally composed of even-aged stands, which can be mapped and whose average age is easily determined, age will be directly ascertained by cutting

into sample trees, and the age classes can be separated by area and by volume for the forest during the forest survey.

The separation of age classes in the many-aged form of forest cannot be made by area mapping, but must be correlated with average diameter—a principle sanctioned by the French in 1883 as the basis of their method of regulating many-aged forests.*

Need for Empirical Yield Table. Where age and yield per acre can be used, the basis of regulation becomes *the yield table giving volume per acre at different ages.* But in the construction of this table, which is by selection of plots, it is *neither possible nor necessary to attempt to secure average stands or yields,* which will represent the empirical or actual condition of the forest. Yet this latter data is what is required rather than selected yields which represent a higher average of stocking, approaching "normality."

Determination of a Reduction Per Cent. The principle which must be applied to solve this problem is to determine the relation of the volumes of the different age classes in the forest to the corresponding volumes for the same ages in the yield table, on the basis of equal areas. On this basis a *reduction per cent* is obtained and the yield of the age classes in the forest can then be gauged by the yield table after reducing this table to the empirical standard by applying this reduction per cent. If for instance an age class is now but 50 per cent of normal density its future yield will be computed at 50 per cent of the yield shown in the normal table. This basis is extremely conservative, since it is well known that sparsely stocked stands tend to close up with increasing age.

There are several variations in the methods of applying this principle, but in some form it must be worked out for every forest on which regulation of yield is contemplated. The volume per acre of a given age class is a function primarily of age, and secondly of density of stocking. The three factors which must be determined, then, are age, area and volume. In the yield table, the normal relation of these three factors is shown, areas being standardized as one acre.

140. Summary of Possible Conditions. (1) *For Even-aged Mapped Areas.* The different conditions encountered may be summed up as follows:

Problem 1. Even-aged mapped areas. Age, volume and area of each age class in the forest is directly ascertained. Usually true of regulated forests managed by clear cutting or shelterwood system, and can be found for sprout cuttings, or forest originating on burns.

Solution. Divide the yield per acre of the age class by the yield from table. This gives the reduction per cent, separately for each age class, by which its future yield can be predicted by applying this per cent to the yields in the table for future years.

For stands of less than merchantable age, this per cent of normality must be directly estimated by inspection, based on silvicultural knowledge of the stand.** For lodgepole pine, this normality per cent is reduced by overstocking a greater degree than by understocking.

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* Refer to § 87-88.
** Utilization and Management of Lodgepole Pine in the Rocky Mountains by D. T. Mason, Bul. 234 U. S. Dept. Agr., Page 36, Table 18.

(2) *For Even-aged Stands whose Volumes but not Areas are Known.*

Problem 2. Age and volume of each age class can be found. The area occupied is not separately mapped, but the total area occupied is obtained for all age classes.

Solution. This problem is easily soluble if it can be assumed that an average reduction per cent, applying equally to all age classes, will serve the purposes of regulation, as follows:

1. Divide the volume of each age class by the yield of one acre of the given age, from the yield table. This gives the *area* which would be required by the age class if the stand were fully or 100 per cent stocked.

2. Obtain the total of fully or 100 per cent stocked areas by adding together the areas of all merchantable age classes.

3. By comparing this area with the total area actually occupied by the sum of the age classes the density or reduction per cent would be obtained. But this process disregards actual silvicultural conditions and young growth. It is far preferable to

4. Subtract from the total area the area stocked with young growth saplings, poles and seedlings established,—the residue is the area stocked with merchantable timber. Divide the "fully stocked" net area obtained as above, by this net area stocked with merchantable timber. This gives the density of stocking of the age classes whose volume can be measured. This per cent is assumed to apply equally to all these merchantable age classes.

5. If the area "fully or 100 per cent stocked" thus obtained for each age class is taken as the basis, and is divided by the density per cent, then the area in acres theoretically occupied by each age class of merchantable timber may be found. This method of solution fulfills all practical conditions of regulation.

141. Illustration from Tusayan National Forest. The volume of this stand has been previously separated into veterans, mature, and blackjack, but the areas cannot be separated directly in the field.

Net area in timber, original growth,	52,004 acres.	
Deducted for saplings and seedlings,	13,002 acres—25 per cent.	
Deducted for poles,	6,500 acres—12½ per cent.	
Net area occupied by merchantable timber,	32,502 acres.	

Determination of the reduction per cent, or factor of density.

Age class	Age years	Yield per acre from yield table ft. B.M.	Area fully or 100 per cent stocked* acres	Per cent of total area in each age class
Veteran	300	18,200	8,345	58.3
Mature	200	25,300	1,745	12.2
Blackjack	100	11,300	4,211	29.5
Total fully stocked			14,301	

Reduction or density per cent

$$\frac{14301}{32502} = 44 \text{ per cent}$$

Area in each age class.

$$\text{Ratio} \frac{100}{44} = 2.2727$$

* obtained by dividing the volume in each age class in the forest by the yield shown in column 2.

Veterans   8,345 × 2.2727 = 18,966 acres
Mature   1,745 × 2.2727 = 3,966 acres
Blackjack   4,211 × 2.2727 = 9,570 acres
Poles   6,500 acres
Saplings and seedlings   13,002 acres
                                _____
          Total area   52,004 acres

To predict the yield of these age classes, whose *area* and *age* we now have, the yield table must be reduced in this instance to 44 per cent of its original value. This assumes that stands now showing a density of 44 per cent of normal will continue to maintain this relation or better, and that if better the surplus is not considered.

The yield table so obtained is a true empirical or actual average yield, adapted to the conditions of the forest or unit as a whole or to the type or working unit or group for which it was constructed.

142. (3) For Many-aged Stands. *Problem 3.* Volume and diameter are known but age classes cannot be directly determined. This is the typical form of problem for many-aged forests or forests in which the age classes are impossible of separation by area. The average age of different age classes is impossible of determination directly. Yet since age and the separation of age classes are fundamental to regulation, some means of separation and determination must be found to permit of any systematic regulation whatever.

Correlation of Diameter and Age. Solution. Diameters of the trees in the stands are readily determined. Diameter is a rough indication of the age of average trees. By determining the average relation between diameter and age, whether this be for total age or merely for current growth for a lesser period, the time factor (age) is supplied and the growth rate of the stand may be measured.

The simplest principle of separation is that by diameter classes or groups. The rate of diameter growth is measured on a large number of trees to eliminate individual variations. The curve of growth, to be accurate, *should be actually based on diameter and not on age.* The resultant table should show the average age of trees of each diameter class.

Owing to the period of suppression common to trees of tolerant species growing in many-aged forests, the absolute age of such trees is valueless for purposes of regulation, since the individual trees, if they had the benefit of sunlight or freedom from suppression, would mature without this period of delayed development. For this reason, one of two modifications are usually made in this curve—either the juvenile period of growth is omitted, and the table indicates the number of years it requires for trees of given sizes to grow to the next larger size,—or else if the total age is shown, this juvenile period is taken from trees which have not been suppressed.

Function of the Yield Table. The yields per acre at different ages are now based primarily upon the sizes of the trees, their average volumes, and the number of trees of the given size which would stand on one acre of ground. The same relation as before exists between the normal or well stocked forest and the average or empirical forest. The yields for a normal or full stocking at different ages must be found, in the form of a yield table, in order to determine the normal relation or proportion existing between volumes on one acre at different ages, so that this relation or percentage of increase

from decade to decade, which is the law of growth of the stand, may then be applied to determine the actual density of the forest in question, and to predict the yields of existing stands.

For instance, in the French method of 1883 the relation of ⅝ to ⅜ which it was stated should exist between stands respectively over ⅔ r in age, and between ⅔ and ⅓ r, was first found for an assumed "normal" series of age classes, in which the volume of the stand was calculated for the normal acre, and the average growth relation between the two groups roughly determined (§ 87). The establishment of this same relation is sought in the actual forest—its existence is the proof of empirical normality, independent of actual density.

Derivation of the Normal Yield Table. From Crown Spread. This "normal" yield table, from which the percentage or proportional relation of stands of different ages or average sizes can be found may be worked out for our conditions on a sound basis in one of two ways. First, the average growing space demanded by trees of different diameters may be found. Crown spread is almost always directly related to diameter, and is a direct indication in turn of the space required by a tree. If the proportional space per tree, for trees of different diameters, can be found, thus giving a curve of normal relations between *number of trees per acre* for different diameters, it makes no difference whether on the whole this curve gives too many trees provided the proportion is correct as between classes, for it is as easy to reduce a table giving 110 per cent of the "normal" number, to 60 per cent as it is to reduce one giving 90 per cent, to 60 per cent. The volume of trees of these dimensions gives the normal yields per acre, while the age is taken from the average diameter.

143. Illustration—from "Yellow Poplar in Tennessee" by W. W. Ashe, Bulletin 10 C State Geological Survey:

TABLE 14. Number of trees in different diameter classes per acre, required to obtain a continuous yield from a fully stocked group selection stand of pure poplar.

Diameter classes. Inches	Number of trees per acre on average quality site	Approximate per cent of each diameter class which should exist in a normal stand
2–4	280	54
5–8	151	30
9–12	57	11
13–16	19	4
17–20	5	1
above 20	1	.30
	513	

Ashe then states, "Since this table is based on fully stocked pure stands, it is necessary in the consideration of a mixed stand to ascertain the average number of trees of the different diameter classes per acre. The relation of this number in each diameter class to the corresponding table number gives the proportional annual yield which is to be expected from this diameter class when mature, that is when larger than 20 inches." If in place of 19 trees to the acre in the 13 to 16 inch diameter class there were 6 trees, the proportion of stocking would be 6/19 as far as this diameter class is concerned. The annual yield per acre from a fully stocked stand is 430 board feet,

consequently the annual yield with the proportion of stocking given would be $6/19 \times 430 = 135$ ft.

In this illustration, application of the principle of proportion or reduction per cent between a so-called normal stand and yield table and the actual forest is based on number determined directly by crown spread.

The real difficulty in this method lies in forests containing decadent stands of over-mature timber, for here, not only does the space required by an old tree exceed the proportion indicated by its crown as compared to a young tree, but the stand is losing its grip and is becoming open by the death of individuals.

From Plots. For these reasons, the second method proposed below is preferable for such forests. This consists of actually laying out plots, in stands composed of trees of as nearly as possible the same size class, and determining on an area basis, which takes into account all the silvicultural factors affecting the stand, the number of trees on the acre and their average size and volume, and from this size, the age of the stand as in the first method.

Once the table giving number of trees per acre for a normal stand is found for different ages, the results can be used to predict the yields even of mixed stands of hardwoods.

In some form or other, this principle must always be used, and will serve as a means of applying to the exact conditions of stocking in the forest the laws of growth as ascertained by a special study of selected stands and trees. In the illustration given, the proportion between the number of trees of different diameters is the basis of comparison. In even-aged stands, the direct proportion between volumes is used. But the final result in each case is an empirical yield table adapted to the degree of stocking of the forest unit to be regulated.

144. A System of Regulation of Yield, for Many-aged or Selection Forests. *Based on Diameters and Diameter Growth. Preliminary in character, and dispensing with the yield table. Data Needed.* The following data is needed:

Stand table showing the number of trees and volume of each diameter class on the average acre in the forest.

Table of growth of trees of different diameters, preferably showing number of years required to grow one inch.

Volume table, based on diameter, applicable to the site class or average heights for the unit.

The principle to be applied is explained in paragraph 127. A cutting cycle is determined on, which bears a reasonable relation to the rotation, and conforms with the required conditions of logging and silviculture. The minimum exploitable *size* or diameter is fixed, which conforms to those conditions.

The *cut* for the first cycle will include all trees above this size with ½ their growth during the cycle plus a volume equal to all trees in a diameter group below this size, whose scope coincides with a period equal to ½ the cutting cycle, to which ½ the growth on these trees for the cycle is added.

145. Illustration—with scattered shortleaf and loblolly pine growing with mixed hardwoods. (Southern States.)

Cutting Cycle. On basis of logging conditions, condition of forest with respect to distribution of age classes, and silvicultural needs, the per cent of the stand to remove in first cutting cycle was set at 83 per cent and the minimum exploitable diameter limit which this called for in the cut, was 15 inches.

On basis of rate of growth of the trees in diameter, stand per acre desired on return cut, and number of years required to produce this yield from the existing forest, the length of the cutting cycle was fixed at 20 years.

Calculation of the Possible Cut.—Calculation of Cut in First 20-Year Cycle. Average growth in diameter for ½ the period, or 10 years, 2.5 inches. Hence, trees maturing and cut within period of 20 years, are those from 12.5 to 15 inches in diameter.

Volume of trees above 15 inches	1,408 M. bd. ft.
Growth in 20 years (total growth less 15 per cent for losses) .... 403 M. bd. ft.	
½ total growth is cut	201 M. bd. ft.
Volume of trees from 12.5 to 15 inches	147 M. bd. ft.
Growth in 20 years on these trees .... 248 M. bd. ft.	
½ growth is cut	124 M. bd. ft.
Total to cut within 20 years	1,880 M. bd. ft.
Or, total volume of all trees above 12.5 inches	1,555 M. bd. ft.
½ growth in 20 years	325 M. bd. ft.
Total cut	1,880 M. bd. ft.

Calculation of Cut in Second Period of 20 Years. During this period, the age class from 12.5 inches downward is to be cut. The diameter group includes 20 years growth. If the rate of 5 inches in 20 years holds good, this group embraces trees now 7.5 to 12.5 inches in diameter.

Twenty years growth during the first period brings this group above 12.5 inches. The volume thus maturing is that of the original group, plus 20 years growth, minus the losses occurring during the period.

With the same minimum exploitable diameter as before, namely, 15 inches, this entire group will be cut during the next 20-year cycle, plus ½ the growth for this period.

Volume, at end of period, of trees then above 12.5 inches, being the present volume of trees 7.5 to 12.5 inches, plus net growth for 20 years	790 M. bd. ft.
Growth for next 20 years .... 400 M. bd. ft.	
½ growth, cut in next period	200 M. bd. ft.
Total cut for second period	990 M. bd. ft.

This general method is not based on cutting a definite number of trees (as in India for teak), but upon the volume produced by the existing forest, computed as usual by knowing the number and size of the trees in the forest.

146. Factor of Loss of Numbers. The weak point in the method is the prediction of growth, based on number of trees which will survive. The actual net growth in any forest is the difference in volume of the separate age classes, found by comparing the merchantable volume of the *live* trees at one period with those of a succeeding period. A "normal" acre or stand table would help to indicate the progressive reduction in numbers with age. The improvement which this method evidently needs is the application of a yield table or guide in determining, at least, the loss in numbers, instead of having to guess at this vital factor. (See Ashe's illustration, § 143.) Another great difference between forests under intensive management and primeval forests being brought under regulation is that in the former, the trees which normally die will be cut instead as thinnings or salvaged and are included in the yield, while in the latter, their volume at the beginning of the period is a net reduction from the total increase and is lost.

When it is necessary to predict this growth by measurement of growth per tree, applied to the total number of trees, as in the above example, the loss of trees must be offset against this growth in volume. In the example given, for lack of data, this loss was arrived at rather arbitrarily by deducting 15 per cent of the final volume as lost during the 20 year period, this amount being 44 per cent of the assumed or indicated total growth had all the trees survived. The diminution in number of trees, by diameter classes, as indicated in a stand table or a normal acre, would show the average loss in a normal many-aged forest in which no cutting whatever was done, and all trees eventually disappeared. In forests cut over at intervals, this rate of loss of trees is reduced materially. Graves, in the "Adirondack Spruce" claimed that on cutover land it could be ignored altogether. As it stands, the true growth realized depends,

(a) upon the effect of cutting on the rate of survival of trees left after cutting, as well as upon their increased growth.

(b) upon the ability of the forester to secure or salvage the trees which would otherwise be lost. This is largely a function of the conditions which permit of a short cutting cycle, the probability of salvage increasing as the cycle shortens.

The true rate and amount of growth, when predicted from growth of trees, will fall somewhere between that indicated by survival of all trees, and that indicated by the diminishing curve of numbers of trees per acre based on diameter. Only a careful study of the composition of the forest with respect to growth will give accurate knowledge of this factor. In India it is approximated by guess based on the judgment and silvicultural knowledge of the forester.

This data, taken from an actual stand on Henry Hardtner's forest at Urania, Louisiana, brings out some of the difficulties in actually bridging the gap between theory and practice in securing sustained yield on a forest not now under regulation. This stand had been logged once, removing large mature pines. The cutting cycle suggested is therefore in effect a second cycle—the first cut was to about 17 or 18 inches. In spite of the conservative (high) 15 inch limit, leaving 17 per cent of timber now merchantable, the second 20 year cycle gives a prospective sustained yield of approximately 50 per cent of that in the first cycle.

147. **Determining of Normality.** To regulate or equalize the cut for these two cycles, which is evidently abnormal, a comparison could be made between the stands required for a normal forest and those in the actual forest. Data for this is lacking in the illustration. Granting that the 20 year cycle is the proper subdivision or period of the rotation, which for this forest is 80 years, we have four age groups of 20 years each. The average age of the merchantable timber in the second cutting cycle might be set at r — ½ cc or 70 years, and the cutting age r or 80 years (§ 127).

The approximate diameters are respectively:

for 0–20 years	0–4″
for 21–40 years	5–9″
for 41–60 years	10–15″
over 60 years	16″ and over.

The normality of the stand, if based on the 20 year cutting cycle to permit the maximum cut per cent per acre, would be determined by the volume *available for cutting* in the successive periods, and not as in the French system of 1883 upon the present volume.

Now, in order to confine the cutting during the first cycle to trees now over 60 years of age, or falling in the last period, the minimum exploitable age must be set at 70 years, and the diameter corresponding to this mark the minimum limit of cutting. This, by the relations explained in § 127 will result in cutting a volume equivalent to that of the 60 to 80 year 2nd class only, and will conform to a rotation of 80 years, reduce the cut in the first cycle by raising the diameter, and tend to equalize the cut from the first and second cycles. This method consists merely in adopting a short cutting cycle and a long rotation simultaneously.

But the same general result can be obtained with a *long* cutting cycle, provided the cut is actually prolonged to last throughout the cycle, and does not proceed to remove all the available timber within a shorter period. This means reducing the amount of the annual cut, and acreage cut over annually, to the proper proportion of the total available for the cycle. The same principles will apply in determining the annual cut as were illustrated in the above example.

148. Overcutting. *The securing of a sustained yield and the mere prolonging* of the cut are two different things.* The latter is accomplished (as in the above illustration) if the second cut can begin in the year when the first cut terminates. But the cut in the second period is but 50 per cent of that in the first period (and in Munger's illustration, 42 per cent). The drop in production is partly due to the removal of an actual surplus stock accumulated by overmaturity. But it may also indicate actual overcutting.** For instance, in each of two or three successive cycles, the diameter limit may be lowered, thus holding up the apparent yield but at the expense of the forest capital which is being depleted. The level of sustained production must obviously be determined—a short cutting cycle based on supplementary cutting from forest capital is obviously an absurdity—for the "surplus" created by successively heavier per cents of cutting per acre in effect indicates successively longer periods before the recovery of the forest or a second cut on the same area, and demands successively larger present quantities of growing stock or surplus if the cut is to continue throughout this cutting cycle. In mixed forests the successive cutting of different species as they become merchantable has frequently prolonged the ordinary logging operations over two or three cutting cycles, without in any way providing for a sustained yield in the end. The usual result of such overcutting is a final clean cut and abandonment of the enterprise.

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* Judging from data submitted to a bond house by a well known paper company such concerns, through vitally concerned with a sustained yield, are merely prolonging the cut. T. S. W., Jr.

** It is virtually paying unearned dividends (a) *out of surplus* so long as there is excess growing stock but (b) *out of capital* when this surplus stock is disposed of; (a) is good business while (b) is usually contrary to sound business principles. T. S. W., Jr.

In the above illustration, a reduction to 50 per cent of the first cut, on a 15 inch cutting limit, may permit of continuing the cut every 20 years, on this reduced basis. Or the forest may be capable of a sustained output exceeding this figure. This would be the case if the 40 to 60 year age class, 10 to 15 inches in diameter on which the cut and prediction of yield is based, were deficient in numbers. Here again is where the normal acre, showing distribution of numbers, would serve as an indication.

149. **Method of Regulating Yield.** To regulate or better distribute such a yield, the volume of the cut per year in the first period must be reduced, thus carrying over some of the surplus to the second period. This can be done by raising the diameter limit of cutting during this period, by one or more inches, thus shifting a portion of the cut to the second period.

Beyond the first two periods, the distribution of age classes and regulation of the cut by this method is not feasible; nor would it be advisable. The numerical representation of trees required is subject to great reduction by suppression and other natural losses. Inspection is about as reliable as counting to determine the success of reproduction and degree of stocking by poles and saplings, and since the trees have no merchantable volume they are seldom tallied.

Summary. For the regulation of many-aged selection forests, where it is impossible to determine age of stands from age of individual trees, age of stands must be determined from diameter of trees, by depending on the general laws of relation between diameter and age for trees.

The cutting limit can correspond to a given diameter, and the volume available for cutting in the first cycle to the volume above this diameter, plus the volume of all trees which would reach this diameter in $\frac{1}{2}$ the cutting cycle, plus $\frac{1}{2}$ the growth on this total volume (§ 127).

The cut in the second cycle will be equal to the volume of timber which at that time has reached the same diameter limit as indicated above, namely, a diameter representing an age $\frac{1}{2}$ cc years less than that of the cutting limit.

150. **Comparison with French System of 1883.** The annual cut can be sustained if necessary at a regular volume by raising or lowering the diameter limit* of cutting, based on comparison of yields thus secured in the two cutting cycles.

A comparison of this general method with that of the French system of 1883 shows that this latter method pays no attention to the quantity or enumeration of growing stock of the first third of the rotation leaving this to silvicultural practice, being assured it is probably sufficient (with the silver fir and spruce forests to which it is usually applied. T. S. W., Jr.). The actual stand table is completed for the entire merchantable stand. This is comparatively simple for us to secure, by assembling a stand table for the portion tallied, and expressing it as applying to the average acre. It is not necessary to tally every tree, either for estimating volume, or securing distribution of

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* The student of course must recognize the silvical disadvantage of strictly adhering to a rigid diameter limit; in practice mature trees below the limit are cut and young trees above the limit retained.

diameters. The percentage relation taken from a stand table prepared on a portion of the area will give this for the whole.

The French, by a crude and inaccurate assumption (see discussion in § 87) arrive at the conclusion that if the second third of the area or age classes has three units of volume, the same stand in the third period should have five. This is based on the Von Mantel's principle that mean and current growth coincide throughout the rotation, hence the growing stock has the form shown below
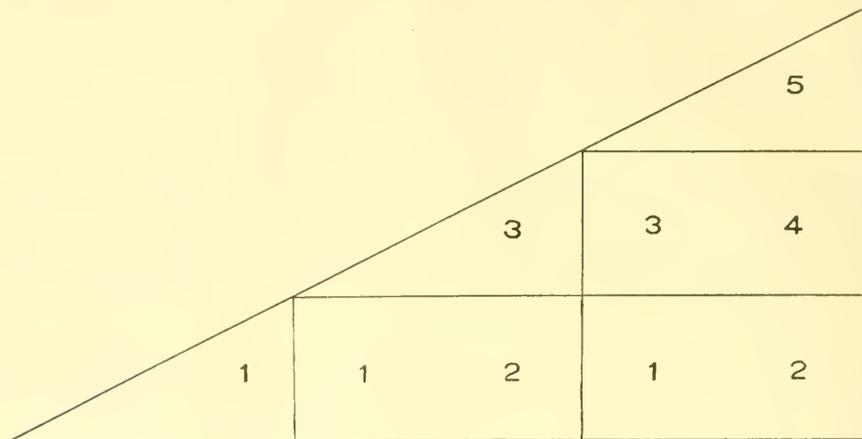
and the removal of the entire volume on the last third of the area and rotation is possible in ⅓ r years. In practice, the volume of the upper third of the stock grows to the age of the rotation before it is cut, due to the short cutting cycle.

Protests have been voiced against some of the methods here discussed for American regulation because said methods are not based on accurate mathematical data and principles but "pass from one assumption to another until the basis of accuracy is completely destroyed." If anything is more apparently inaccurate, and based on ranker assumption than this French method of 1883 it has not yet been found, yet it has worked successfully for thirty-eight years, and furnished a workable solution for the problem of regulation of many-aged forests.*

Improvements Possible for American Application. Instead of basing the size or age classes upon the assumption that diameter growth is practically uniform, and that trees of ⅓ the final average size required in the rotation are also ⅓ the age,—the same proportion holding for ⅔—the actual relations may be worked out from local growth studies. When the fundamental relations between size and age are established, the relations which should

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* It has been successful because there is frequent stock taking, because it has been applied by experienced foresters, and because there is good silvicultural practice in the forest with due regard to a proper distribution of size classes (without unnecessary refinements). T. S. W., Jr.

exist between the volumes of the different age groups or classes can be obtained by these studies and the construction of normal acres. This period ⅓ r in the French system is independent of the cutting cycle and felling reserve. Here as repeatedly pointed out, the latter factors are too great to be ignored and the form and volume of the growing stock required must be computed with respect to the felling series. We cannot import a method even as simple and crude as this, without adapting it to our forest and economic conditions. The desire of American foresters for mathematical accuracy born in a large part from the lack of opportunity for the practical application of growth problems, can still be gratified to a considerable extent without splitting too many hairs.

The progress of the forest towards normality of stocking, obtained by the French through conservative cutting, and by their curves showing the relation of the number of trees per acre in actual versus normal forest, will be seriously delayed here by the removal of excess overmature stock, but can be secured by raising the diameter limit of cutting, where shorter cycles are possible, or by extending the length of the cutting cycle when the cut per acre cannot be reduced because of danger of blowdown or other silvicultural factors.

Determining the Allowed Cut. Sustained yield in many-aged forests means, finally, the determination of the "allowed cut" or actual production per year, and the adjustment of the cut to leave the forest in shape to produce this. The reason for success with the method of 1883 is that the indicated annual cut, by the basis proposed, is practically certain to be somewhat, but not too much, less than the growth; second, it effects a removal of surplus large stock, or its conservation as needed, and third, it increases only as the forest becomes more densely stocked through better silviculture. Until our overmature and decadent stock is removed, conservative cutting should be based on cutting the smallest possible per cent of the standing timber per acre, and the largest possible cut per year which will enable us to cover the forest in one cutting cycle, which by the above considerations would be as short as possible. At best we will be forced to adopt long cycles on National Forests, where regulation is feasible. The stock needs reduction, and the worst problem is to secure better distribution of age classes or prevent the still further disturbance, by overcutting, of such distribution as may already exist.

151. Summary of Distinctive Characteristics of American Regulation. The distinctive features of the method proposed, as applicable to all forms of forests in America, are:

1. A period for regulation of yield, which is based upon and coincides with a cutting cycle. This may give place later to periods *exceeding* a cutting cycle in length (provided the cutting cycles can be shortened so as to become a negligible factor), but never to be shorter than the required cutting cycle.

2. The length of the cutting cycle to be the governing factor in determining the regulation of the cut and to be based upon the existing conditions, forest, and economic.

3. Regulation of the annual cut to be effected by lengthening or shortening

the initial or transition cutting cycle, corresponding to increase or decrease in the per cent of the stand per acre taken in the first cut.

4.   The amount of the annual cut to depend upon the cutting cycle, present volume, per cent to cut, growth of old stands and inclusion of the maturing crops of young timber entering the exploitable class within the cycle.

5.   The result of the first cutting cycle to be the establishment of a felling reserve and cutting series of normal arrangement for continuance of the cut in the second cycle.

6.   Regulation of yield to be based on the use of a yield table and reduction per cent, the separation of age classes in the forest, and the prediction of empirical or actual growth, including decadence, on the age classes as they exist in the forest.

The last requirement is so obviously in keeping with universal practice in forestry that only the assumed difficulties and expense of obtaining the required data has held back the science of regulation on our National Forests, and at present, the tendency is to go ahead at once with whatever data is available, to formulate some basis of regulation wherever it is needed.

152.   **Quiz.**   Why are cutting cycles for mixed stands preliminary?
Why is a study of growth essential?
When does growth balance decadence?
Explain formula cited in § 134.
Can the growth of mature timber be neglected in a long cutting cycle?
Can the length of cutting cycle be guessed at?
Discuss Munger formula; felling reserve.
Why must age classes be analyzed?
What is the danger of using growth per cent?
Why must condition of normality be determined?
Explain how empirical yield tables are necessary in regulation.
How is a "reduction per cent" obtained for even-aged areas where mapped, and where areas are not separated?
In all-aged stands how is diameter and age correlated?
How is normal yield table derived from crown spread?   from plots?
How can the yield table be dispensed with?
Explain a preliminary system of yield regulation for selection forests.
What data is needed?
Discuss complication of loss of numbers, normality, overcutting.
Compare this method with French system of 1883.
Enumerate essential distinctive characteristics of "American Regulation."

CHAPTER XII

THE PROBLEM OF SUSTAINED YIELD

153. The Ultimate Problem—Sustained Yield. Owing to the importance of the preliminary and transition periods and the unavoidable disturbance of the forest capital and postponement of the creation of a complete series of age classes, the ultimate problem of regulation to secure that balance and arrangement in the forest which will permit of a permanent sustained cut, is necessarily obscured.

In the many-aged forest, as well as in that composed of even-aged stands, a rotation is fixed upon, which is supposed to coincide with the average age of the timber to be cut. Although the volume of the immature stands falling in the last third of this rotation is immaterial, the period required for them to grow to given sizes, and the area stocked by these young stands, is important.

To finally determine whether or not a forest is being over-cut; i.e., working capital instead of mere surplus is being withdrawn, we must determine three factors, all dependent on the rotation,—first, what the annual growth will be upon a normally arranged forest stocked at no greater degree of density than the existing forest, for this is the gauge of whether capital is being reduced; second, the amount of actual measureable (merchantable) capital required to produce this quantity annually, and its arrangement by age classes as to volume and area, in each age class; third, the comparison with the actual forest as to volume and area, in existing age classes.

The crude assumptions in the illustration in § 137 as to growing stock and age classes are plainly insufficient to show these facts. An annual growth of 100 feet per year on cutover lands may or may not be obtained continuously. A growing stock of 4,000 bd. ft. per acre may or may not constitute the normal reserve. The elasticity of the French conception of normal relations of growing stock between medium forest as $\frac{3}{8}$, and old forest as $\frac{5}{8}$ of the total merchantable volume, lies in the fact that it applies only to the form and relation of the two broad age groups, and equally to all degrees of stocking. This may be the only practical conception to apply to such forests, yet if possible, owing to the importance of the cutting cycle and the greater difficulty of our problem, a more concrete idea of possible sustained empirical yield is desirable.

154. Allowed Cut, Empirical Yield Table and Normal Stock. This can be secured when it is possible to obtain an empirical yield table (by methods described in § 141) applicable directly to the degree of stocking in the forest. This the French did not attempt.

With such a table, the allowed cut of the forest is at once indicated. It consists of the yield, at rotation age, of 1 acre $\times$ the $\dfrac{\text{area in the working circle}}{\text{rotation}}$

This yield equals the total growth of a forest of this density for one year, if normally arranged as to age classes, or, its equivalent, the mean annual growth on one acre $\times$ total area.

On this basis, the normal growing stock can be computed, not by the method of approximating the residual growing stock below the size exploited, as being normal at 4,000 bd. ft. per acre, for instance, but from the yield table. An example of an empirical yield table is given below for Western Yellow Pine, Coconino National Forest:

TABLE 15. Empirical yield table of Western Yellow Pine reduced from normal by factor 66.2%.

Scribner Dec C. Log Rule.

Age	Yield Feet. B.M.	Mean annual growth Feet. B.M.
80	4,700	59
90	6,220	69
100	7,480	75
110	8,610	78
120	9,670	81
130	10,660	82
140	11,580	83
150	12,510	83
160	13,370	83
170	14,300	84
180	15,090	84
190	15,950	84
200	16,750	84
210	17,540	84
220	18,070	82
230	18,270	79
240	17,940	75
250	17,280	69
260	16,350	63
270	15,360	57
280	14,300	51
290	13,170	45
300	12,050	40
310	10,920	35
320	9,800	31
330	8,670	26
340	7,610	22
350	6,420	18
360	5,300	15
370	4,100	11

In § 135 the annual cut for the Coconino based on Von Mantel's assumption, was found as 31,511 M ft.

Based on the assumption that the annual cut should equal the annual growth, the cut, for a rotation of 200 years and area of 509,087 acres at 84 bd. ft. per year mean annual growth, would be 42,763,308 bd. ft. annually. The growing stock required to perpetuate this cut would be, not $\frac{i \times r}{2}$, which would call for 4,276,330 M feet, but $\frac{(a + b + c + \quad\quad + \frac{n}{2})10}{200} \times 509,087$

acres $= \frac{138,515 \times 10}{200} \times 509,087$ (6,925 bd. ft. per acre)

$= 3,525,427$ M, or approximately 80 per cent of that required by the formula $\frac{i \times r}{2} = Gn$.

This determination of the real basis for a growing stock which would perpetuate the rate of growth now possible and realized in the past from the virgin forests enables us, first, to measure the actual growing stock to discover whether there is a surplus or deficit, and second, prevents us from attempting to reserve, as working capital, wood which is actually surplus.

155. Comparison of Mean Annual Increment and Austrian Formula. Its Limitations. The mean annual growth of a stand to maturity rather than current growth per cent correctly gauges the increment for a stand which is cut since this cut takes, not the current increase from standing trees, but their total past growth, which is the mean annual growth times age of the stand.

If the present stock exceeds or falls short of this normal growing stock, it is an indication that there is either a surplus caused by an excess of overmature timber, or a deficit caused by past cutting, fires or other destructive agencies. It cannot mean that the indicated yield, or normal stock, is wrong since the actual past production of the forest itself has been taken as the basis for calculating this growing stock.

It follows then that the Austrian formula, when based upon the empirical yield table to obtain the normal growing stock, and when the mean annual increment for the rotation age is used as the basis of increment, is an instructive check on the proper annual cut. The surplus, by our methods, should in order to save further loss be removed in one cutting cycle if the latter is fairly long. Cc, or at most 2 cc, becomes the period of regulation. Then

$$\text{Annual cut} = \text{mean annual increment} + \frac{Ga - \text{Empirical } Gn}{cc \text{ or } 2 cc}$$

Applying this formula to the Coconino:

$$\text{Annual cut} = 42,763 \text{ M} + \frac{3151147 \text{ M} - 3525427 \text{ M}}{100}$$

$$= 42,763 \text{ M} - \frac{374280 \text{ M}}{100}$$

$$= 39,020 \text{ M}$$

But applying the Austrian formula to current growth as in Munger's illustration, his empirical normal growing stock is first calculated as

$$Gn = \left(\frac{I \times cc}{2} + \text{Reserve} \right) \times \text{area}.$$

With total current annual increment in the forest, per acre, as 100 feet, and cc as 50 years, reserve per acre 4,000 feet,

$$Gn = \frac{100 \times 50}{2} + 400$$

$$= 6,500 \text{ feet per acre}.$$

The actual growing stock is now 16,000 feet. Munger wants to cut 12,000 feet per acre on 4,000 acres or 48,000 M bd. ft. annually, on 200,000 acres, leaving the reserve of 4,000 feet to grow to 9,000 feet in 50 years.

By the Austrian formula:

$$\text{Annual cut} = 100 + \frac{16000 - 6500}{50} \text{ (area)}$$

$$= 290 \text{ bd. ft. per acre or } 58,000 \text{ M bd. ft. in the first cutting cycle which}$$

is evidently excessive, due to the inclusion of growth in the formula which was *not* included by Munger in the first cutting cycle. The Austrian formula is thus quite evidently inapplicable to this transition problem on the basis of current growth on the cutover areas.

The undertaking of regulation requires a sufficient knowledge of growth to indicate a rotation. Upon this basis, and the conception of a uniform felling series for even-aged stands, the empirical normal growing stock can be compared with the actual forest in order to separate the forest capital from surplus or deficit and obtain an indication of the amount of the required annual cut.

The annual cut by any system of regulation will seek to remove an amount equal to the "interest" or growth, plus or minus an amount which will bring the capital either down or up to normal form within a reasonable period.

When the true form of a series of age classes is not obtainable, a relation based on the growth of trees and broad age groups can be constructed, as done by the French in 1883, by which the surplus or deficit can be indicated as well as the growth. For our conditions, this relation should be based on the felling reserve and the influence of maturing crops of timber in determining the cut.

Whenever it is possible to determine this true form and volume of the empirical normal forest by means of an empirical yield table, and to base increment upon the mean annual growth from this table, the true relations between the empirical increment and surplus or deficit in the actual forest caused by abnormal age class distribution can be found, and the annual cut approximated by the Austrian formula check. Without this data the Austrian formula is no more accurate than Von Mantel's and if $cc = \frac{1}{2}$ r and "normal" stock is taken as $\frac{r \times i}{2}$ the two formulae will give identical results.

This pure volume check on regulation accomplishes in a rough approximate manner, what should be determined on a basis of definite knowledge of the forest, as soon as that knowledge is available.

The utility and value of the Austrian formula is dependent, then, not on the formula itself, which is merely the expression of a sound principle of regulation universally sought, but upon the determination of the three factors, actual increment, empirical "normal" stock required by this increment, and the actual stock on hand. The cutting cycle then enables the determination of the cut per year. No knowledge of the age classes in the forest is required, and this is just where the formula fails.

Every method of regulation seeks to establish this same result, but the differences between a practical plan and a formula check lie chiefly in recognition of the fact that abnormality in volume is caused by abnormality in distribution of the respective age classes. Only by securing this proper distribution of age classes can the true normal volume and sustained cut ever be secured. The growth actually laid on in the forest during a given cutting cycle is not the mean annual but the current growth, and this is dependent upon the age and condition of these abnormally arranged age classes.

Being sound in theory, the Austrian formula *when based on facts* as deter-

mined by growth studies, does surprisingly well, but it is better to deal with the facts at first hand. In other words, since the regulation of the forest must be determined by the area, volume and current growth of the existing age classes, the determination of these areas, volumes, and the actual current growth expected, will in turn indicate the area and actual volume of the annual cut best adapted to securing progress towards a normal forest.

156. Necessity for Data on Age Classes. In the system proposed for many-aged forests, the present volume and actual current growth of the exploitable and of the maturing age classes were found as a prerequisite of fixing the cut. But for lack of data on areas, the yield for the entire rotation and the true condition of abnormality of the forest could not be accurately obtained which delays the progress toward normal forest and sustained yield.

In choosing a method of working out this problem of sustained yield the silvicultural behavior of the species must decide. If the trees customarily undergo a period of suppression in growth, the age of individual trees gives a very unreliable index of the number of years required for an acre to produce a given yield in wood.* But if the species is intolerant, we have two distinct advantages; first, the individual trees which survive and form the final cut are usually dominant throughout their life cycle and are seldom suppressed. Second, in spite of fires and other agencies, the forest tends towards even-aged groups, of varying size to be sure, but distinctly different from typical many-aged stands which result from suppression and natural selection over a long period of struggle.

157. A Method of Separation of Age Classes. The method to be described is applicable to intolerant species growing in stands of all ages in original forests. Since species susceptible to fire occur in even-aged stands and can be measured by direct yield tables, while tolerant species such as hemlock or spruce are subject to suppression, this method is especially applicable to Western Yellow Pine, Southern Longleaf or Loblolly Pine and similar species, and may have a wider application. For even in forests composed of tolerant species, many-aged, and mixed, the interference of fire, insects and wind constantly tends to produce groups of even age, and this fact can be taken advantage of to secure data for a yield table based on age, which will serve as a model or standard from which these essential relations of age and volume per.acre can be obtained even for all-aged stands. Owing to its great importance in future regulation, the method of securing and applying such a yield table is given in detail. The species to which it was applied was Western Yellow Pine, but the method should be applicable, with suitable modifications of field technique, to nearly all our American forests of mixed age.

Essential Steps. The three steps in this regulation are:

    (a.)   Securing the normal or standard yield table,
    (b.)   Application to the forest to secure the empirical yield table and to separate the forest into age classes by area and volume
    (c.)   Regulation of the cut based on area, volume and prediction of growth of these age classes, by use of this yield table.

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* Chapman's Forest mensuration §§ 263, 298, 299.

Standard Yield Table. Selection of Plots. (a) Yield table. The standard methods are followed in securing plots. These plots are laid off in groups or stands whose *appearance* indicated that practically the entire stand is of a given *age class,* though not necessarily of *even age.* A curve of average height based on diameter should be drawn for each plot or group of plots, preliminary to computing volume.*

Where trees evidently of an older or younger age class are included in the plot, the crown space, or the proportional area occupied by such trees may if desired be deducted along with their volume to confine the results to a single broad age class.

Determining Age of Plots. Age of the plots is best determined by felling at least three trees, selected to represent average volumes. But when the timber is very large and old, and is inaccessible to logging for the present, the felling is not only time consuming (increasing the cost of plot measurement by 300 per cent or more) but wasteful of timber, especially in the older stands. A substitute method of obtaining the age of the plot is as follows:

a'. A curve of growth in diameter must be obtained from numerous stump measurements on logged areas. This should show the *age* at B.H. outside bark for average trees *of given diameters.* It is necessary that these growth figures be obtained for trees and stands of the same type and quality as the plots measured, else the conclusions regarding age of the plot will be in error.

b'. The diameter of the average tree in the plot must be determined. In reducing stands of uneven age to their equivalent for an even-aged stand, the standard practice is to determine the age of an even-aged stand which will yield a *volume equal* to that of the uneven-aged stand in question.** The basis of volume must be the volume table and volume unit used in calculating growth. The first step in finding the tree of average diameter is to determine the tree of average volume from the total number of trees on the plot, and total volume.

But as height is a variable, and the tree of this volume may be a tall tree with smaller diameter, or a short tree with larger diameter, we must first obtain the average height of a tree of this average volume, for the plot in question. The curve of average height on diameter for the plot has already been made for computing the volume on the plot, hence is available.

With average height on diameter for the plot determined, there can be but one average diameter for a tree of a given volume on the plot. This is read from the curve of volume on diameter usually interpolated to 1/10 inch.

The age of a tree of this diameter from the growth curve is taken as the age of the stand on the plot.

Wherever site qualities can be separated, based on total heights of merchantable timber, and the curves of diameter growth obtained are coördinated with trees on these separate site qualities, this method has the double advantage of enabling the field crew to secure three times as many plots in a given time, and of basing the age of each plot upon a curve based on a large number of representative trees instead of but one or two trees which, on single plots in these uneven-aged stands may happen to be much older or younger than the real average desired. The stand not being truly even-aged, the advantage of felling single trees to determine age for the plot is much lessened, provided always that the growth data for the use of the alternative method is properly coördinated with the site.

158. Application of Yield Table to the Forest. (b.) Separation of age classes in the forest. The problem is twofold, first, to find a method by which the age classes in the forest may be separated, second, to determine actual average density or degree of stocking for the entire area.

Experience in former experimental attempts to solve this problem has shown the futility of trying to determine the area and volumes in different age classes on a large

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* See § 129 and 130, Forest Mensuration, John Wiley & Sons, 1921.

** Ibid., § 260.

area of this character by mapping the crowns, or by any direct method. Instead, dependence must be placed directly upon the volume of the stand, and its direct division into age classes by aid of our knowledge of the number of trees in the stand and the volume, diameter and age of average trees.

The Stand Table. To obtain the number of trees in the age classes, the volume of the average tree and the total volume of the class, a stand table is required.

This stand table is best obtained during timber estimating by any method which provides for a table of diameters. In estimating, it is accepted that strips covering 5 to 10 per cent of a large area give a sufficiently accurate per cent of the total volume. This percentage principle applies as well to a stand table. If made to include the trees tallied in estimating, the resultant table should show the distribution of diameters in the stand, on a percentage basis, regardless of whether all or only a portion of the trees in the stand are tallied.

The total volume of the trees actually tallied in a stand table may be correlated with the volume of the forest or unit in one of two ways.

By area. 1. The area covered by the trees tallied is known. This enables one to reduce the table to a stand *per acre,* which is assumed to be average for the forest.

By volume. 2. The *volume* tallied is taken as the basis. In this case, the average stand per acre tallied need *not* coincide with that of the forest.

The relation in volume is found by comparing the total volume in the stand table with that of the forest. If 20 per cent has been tallied, the proportion is as 1 to 5. This is a more useful relation than area and more easily obtained.

Purpose and Application. (c.) The real purpose of the stand table is to serve as a basis for determining the *percentage* of volume in the different diameters or age classes for the large area or working group which it represents. If a stand table can be divided into groups representing age classes, and the volumes in these age classes separated, these volumes can be expressed in terms of per cent of total volume for the stand table and if this table is properly constructed and representative of the forest, then these per cents will apply to the entire unit and will separate the total estimate into volume in the respective age classes. The steps then are:

1. Separate the volume in the stand table into volumes of given age classes.
2. Find the per cent of total volume which these age classes represent.
3. Apply these per cents to the total estimate to divide the forest into age classes.

159. Separation of Stand Table into Age Classes. The factors of the problem are: age of average tree of each age class, and its diameter, volume of said tree, number of trees in age class, in the stand table. When these factors are determined, the volume in the age class, its age and the area occupied can be determined and the results applied to the forest unit.

In any method, *only a few broad age classes should be separated* for the working group.

By Diameter Groups. The simplest basis of division of the stand table is by diameter groups, assuming that the average age of a diameter class holds true for the trees in the class or will serve as a basis of volume separation (French method of 1883).

But the division of mature or merchantable timber into age classes based on diameter alone, actually runs counter to a law of growth of trees growing in stands. Diameter growth of individual trees is far more variable than height growth, being affected by the density of the stand and the origin and dominance of the individual tree. For trees of a given age class, whether growing in even-aged stands or scattered through older stands, the dominant trees grow more rapidly and reach larger ultimate sizes before death than do the intermediate, while the suppressed trees are much smaller in diameter for their age than the more vigorous trees.

Trees of a given diameter over a large area include always a range of ages, and this range becomes greater as the diameter of the class increases.*

By Age Groups. If as few as three broad groups are made (corresponding with the

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* In the larger diameter classes the range of age may again diminish due to the fact that only dominant trees reach these sizes.

French system of two groups, plus a third overmature or decadent group), it may be possible to separate the stand on a basis of average age rather than diameter limits.

For Western Yellow Pine, the young, merchantable age class, below the exploitable age, or up to 150 years in a 200 year rotation, may be tallied separately by the black color of bark and thus actually separated, as an age group, from the mature and veteran yellow pine timber. If this has not been done in general estimating, the stand table at least will have to show separate tallies for blackjack, and the per cent relation thus obtained is applied to the total estimate.

Lacking this differentiation in appearance based on color of bark, the younger age class will probably have to be separated by diameter. It is in the determination of average age for the groups that a flaw appears (ignored by the French as immaterial).

160. Average Age of Groups. *To Determine Average Age of the Group.* The process is identical with that described for determining the age of plots in constructing the yield table,

1.   Determine total volume in the diameter group.
2.   Get volume of average tree,
3.   From table of volumes on diameter for type, get diameter of this average tree.
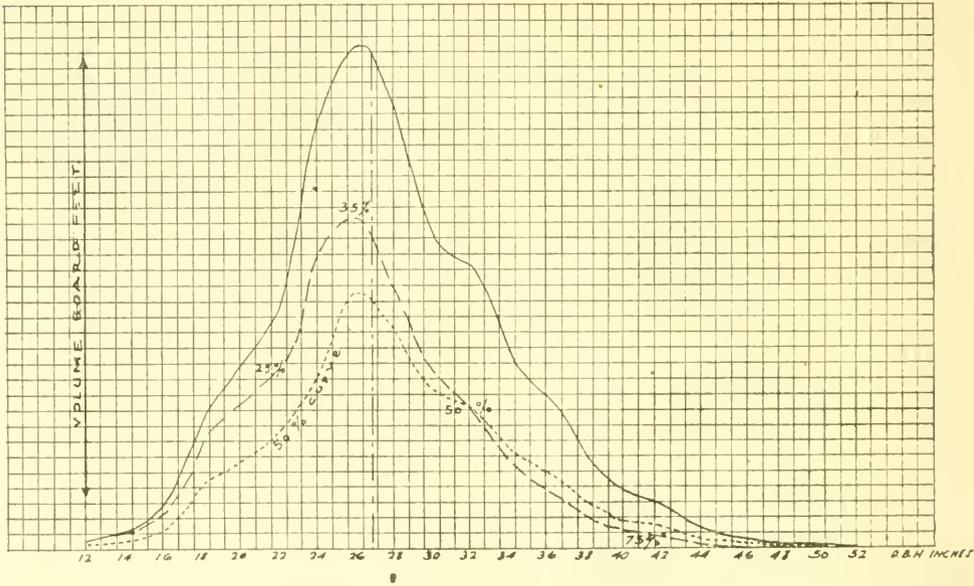4.   Look up age of said tree from growth curve based on diameter.

Fig. 7. Volume of Western Yellow Pine, Distributed by Diameter Classes, Coconino National Forest.

————————   Total Volume.

— — — —   Volume of Mature Class, Decreasing by 5% for each 2-inch Diameter Class.

- - - - - -   Volume of Mature Class, Taking 50% of each Diameter Class.

———— — ——   Division of Volumes into Mature and Veteran Classes, by Diameter Groups, each Containing an Equal Volume.

Figure 7 illustrates three different methods of dividing the stand or group into two age classes. The upper curve represents the volume actually occurring in each diameter class.

By the first method, it is considered that the trees which belong to the veteran age class form an increasing per cent of each diameter class. This increase is taken for illustration as 5 per cent beginning with 14 inches. The resultant volume of the veterans

is separated from that of the remaining mature age class by the line ———. This method was tried out on the Plumas National Forest in 1912, and described by Barrington Moore in Proceedings of Society of American Foresters, Vol. IX, No. 2, Page 216.

This method uses diameter as a basis, but endeavors to follow the known laws of diameter growth by this cumbersome and impractical subdivision of each class.

The second method makes an arbitrary division, based on diameter classes, between veterans and mature trees, and is illustrated by the vertical line — - — -. This is simple of application, but departs widely from the laws of growth, throwing many veterans in with the mature group, and vice versa.

The third method is never used and is included only for purposes of comparison of results. It is to divide each diameter group into equal volumes for veterans and for mature, by the line ———.

The resulting average tree, taken from the stand table on which these curves are based, for each of the three methods resulted as follows:

Method used	Age class	Volume of average tree board feet	Diameter of average tree inches	Age of average tree years
Diameter Classes Subdivided				
	Veteran	837	27	302
	Mature	515	23.5	245
Two Diameter Groups				
	Veteran	1,267	29.5	345
	Mature	393	21.5	214
Equal Volumes				
	Veteran	609	24.5	261
	Mature	609	24.5	261

These results indicate, first, that by the method of dividing by diameter groups, the average volume and diameter of the older group is raised arbitrarily by the exclusion of the slower growing smaller trees. When the average age is sought from a curve of diameter based on age, the indicated age is incorrect and exceeds the normal age of the group, so that it is necessary under these circumstances *to derive age from a curve of age based* directly on diameter.

The reverse of this condition is shown by the purely theoretical division into groups of equal volume, by which the resulting average tree and age of each group is equal. The *true* average age and volume evidently lies between these extremes. While the crude basis of division adopted in the illustration is evidently incorrect in that it includes too great a portion of the total volume in the mature class and raises its age to 245 years, yet evidently this method comes close to a division in which volume and age of the average tree for each group correspond reasonably with the probable conditions whose determination is sought.

This method is impractical in application, since the determination of the correct per cents of each diameter class to take for each age group is difficult, and the computation bunglesome.

Based Directly on Age. But there is another and simpler way of solving this problem. The yield table is the best indication of the ages at which *stands* of the species approach maturity and begin to retrograde. The forest is composed of a series of age classes each including several diameters. When this continuous series is to be combined into but two groups, each group in turn embraces trees whose diameters overlap those in the other group. By shifting the average age of either group, the number of separate age classes included in both groups is changed, but there is no inherent difficulty in grouping the total number of age classes in any desired combination provided the two averages are far enough apart to fall within separate groups.

It is possible, for instance, in a forest containing a definite number of trees, and a given total volume, to select two trees of given volume, one for each of two broad groups. With these two volumes fixed, a definite number of trees will be required in each group to make up both the total volume and total number of trees in the forest.

If falsely based on equal division of each diameter class, each group would take half the total, and the average volume of each group would be equal to that for the total stand. If based on division into 2 diameter groups the excess in normal size of the veterans would require too few trees in the class, the remainder required to make up the total being trees with the smaller average volume.

To approximate the actual conditions in the forest, which is the result desired, let age be the starting point, since it is the basis sought. From the yield table select the age indicated as most characteristic of each class required. The steps then are:

1. Age required for class.
2. Diameter of a tree of this age.
3. Average volume of a tree of this diameter.

If the number of trees required for each age class, in order to make up both the total number and the total volume in the stand table, can now be found, the problem is solved.

The solution given below can be applied only to two groups. In the example given Western Yellow Pine, the younger group has already been separated by the appearance of the bark. The method then will accomplish the separation of the mature or exploitable portion of the timber in a forest, above a given diameter, into the two groups representing decadent and vigorous trees. This is well worth doing. In forests already under management, in the second cutting cycle, the method will separate the mature from the young merchantable group.

Formula. For this solution the full data for each separate diameter class in the stand table *is not needed*. A count of all trees tallied, and their total volume, will suffice. (It is assumed that Blackjack are tallied separately.)

Then

$$x = \text{number of mature trees.}$$
$$y = \text{number of veteran trees.}$$
$$a = \text{volume of an average mature tree.}$$
$$b = \text{volume of an average veteran tree.}$$

Evidently $ax + by = $ total volume of stand.
But $x + y = $ total number of trees in stand.

If this total is multiplied by the volume of the average mature or smaller tree, a, the resultant volume $a(x + y)$ can be subtracted from the total volume of the stand, to indicate the surplus over $a(x + y)$ in the forest, due to the fact that a certain number of the trees actually have the average volume b instead of a. The surplus contained in one such tree is $b - a$ or the difference in volume between a veteran and a mature tree. By dividing the total surplus by the surplus of one tree $(b - a)$ the number of trees is found which must contain an average volume of b instead of a, and the remainder is the number of mature or a trees.

$$\text{Let} \quad c = \text{total number of trees}$$
$$d = \text{total volume}$$

Then

$$ax + by = d$$
$$a(x + y) = ac$$
$$(b - a)y = d - ac$$
$$y = \frac{d - ac}{b - a}$$
$$x = c - y$$

161.   Illustration from Coconino National Forest.

<div align="center">STAND TABLE</div>

Age class	Trees	Volume	Per cent
Blackjack	43,084	5,931 M	18
Yellow Pine	44,423	27,042 M	82
		32,973 M	100

<div align="center">DIVISION OF YELLOW PINE INTO VETERANS AND MATURE</div>

	Age*	Diameter B.H. inches**	Volume per tree Ft. B.M.***
Veterans	300	27	805
Mature	200	20.7	340
Blackjack	90	17	137

$$x = \text{number of mature trees.}$$
$$y = \text{number of veterans.}$$
$$340 x + 805 y = 27,042,800 \text{ ft. B. M.}$$
$$340 x + 340 y = 340 \times 44.423 \text{ or } 15,103,820 \text{ ft. B. M.}$$
$$465 y = 11,938,780 \text{ ft. B. M.}$$
$$y = 25,677 \text{ trees.}$$
$$x = 18,746 \text{ trees.}$$

Mature pine = 6,373,640 ft. B. M.
Veterans   = 20,669,985 ft. B. M.
Total   = 27,043,625 ft. B. M.*

<div align="center">PERCENT OF MATURE AGE CLASSES IN VIRGIN STANDS ONLY</div>
<div align="center">Timber above 12 inches D.B.H.</div>

	In yellow pine. Volume	In total stand. Volume
Mature	23.6%	19.4%
Veteran	76.4%	62.6%
Blackjack	....	18.0%

<div align="center">TOTAL STAND OF SAWTIMBER IN VIRGIN STANDS, DIVIDED INTO AGE CLASSES</div>

Veterans	1,972,618 M
Mature	611,323 M
Blackjack	567,206 M
Total	3,151,147 M

This gives us the volume in each of three age classes, corresponding to a definite average age. It is evident, by the method used, that should we decide to divide the stand into age classes based on an increased average age for veterans, the number of veteran trees in the forest would be reduced and of mature trees increased, which coincides with the laws of growth operating in the forest. The age groups are composite averages, and these averages may be altered by altering the basis, age, without introducing an error in fact or misinterpreting the true conditions of the stand.

162.   Immature Age Classes. In discussing the factor of the empirical yield table

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* Data from yield table.
** Data from table, Diameter Growth, Bulletin 101 (Page 20), T. S. Woolsey, Jr.
*** Data from table, Volume on Diameter.
* Error of 825 feet by neglecting decimals in obtaining volume per tree.

(§ 139), or actual density of the forest, it was shown that age and volume of the separate age classes in a forest must first be found, for owing to the difference which the age of a stand makes in its normal volume, no possible comparison with actual volume or estimated stand in a forest can be attempted without age as a basis. By the above method, the age of three classes, all that are needed, has been found.

But before determining the density factor and empirical yield table (by the method described in § 141), a further analysis of the forest is necessary, to bring out the importance of the role which reproduction and timber below merchantable sizes plays in any scheme of permanent regulation of yield.

Effect on Density of Stand. The density of a given forest is determined by *three* factors; first, the age classes, themselves, as shown; second, the actual degree of stocking or occupation of the site by the merchantable stand compared to full stocking (to be determined); third, the proportion of the total area occupied by age classes below merchantable sizes.

A forest composed of trees and groups of all ages intermingled may have 50 per cent of its area occupied by merchantable timber. If the remaining 50 per cent is stocked with young or unmerchantable sizes the forest may have an actual density of 100 per cent. But unless it is possible to ascertain the area so stocked with young timber and deduct it, the 100 per cent stocking is not apparent in the mature stand. Thus the *average stand per acre* of merchantable timber of most forests is far below the stands on average acres of mature timber and should normally be less than half of this figure. (See yield table for ½ r years.)

For computing the future yield of these mature classes, there are two alternatives, either to assume, e.g., that 100 per cent of the area is occupied by mature age classes, with a density of 50 per cent, a yield of ½ the full yield per acre from the yield table, or else, to determine that but 50 per cent of the area is stocked with merchantable age classes but that the yield on this area will be 100 per cent of or equal to that of the yield table. In the even-aged form of forest the latter condition is evident. It is equally true of the many-aged form and should be so treated. The total future yield of these merchantable age classes will be the same in either case, but the average density of stocking is absolutely different.

So much for the forest which is fully stocked. In the actual or partially stocked forest, the same relations exist. Assuming that one half of the area is reproduced to unmerchantable, young ages, and that the merchantable timber, in quantity, by age classes, is but 60 per cent of a full yield; this merchantable timber may be considered as occupying 30 per cent of the area with a yield 100 per cent of that of the yield table. And if the immature timber is disregarded, the mature stand if figured either way will give the same volume in future yield. Its actual volume and yield is not changed. Area and density are reciprocal factors.

$$.50 \times 60\% = .30 \times 100\% \text{ of the standard yields.}$$

For regulation extending beyond the first cutting cycle, it is important to know what the immature age classes will yield. This yield will be largely determined, not by the number of seedlings established, but by the area restocked in acres. Yields are based on area, not on single trees.

Effect on First Cutting Cycle. If in the forest survey, this principle is recognized it will be possible to note the percentage of total area which is covered by young timber not under suppression, and having good chances for survival, just as separate areas are mapped in even-aged young stands. The more accurately this final result, i.e., the area ultimately stocked with timber by this reproduction, is predicted, the more accurate will be the prediction of the growth for the period when this young timber matures. On the other hand, quite a large error in this determination will not affect in any way the possible yields obtainable or predicted *for the timber now of merchantable sizes.* What it will do is to give a false or erroneous idea of the possible total *yield* and consequent length of cutting cycle to be assigned during the rotation *to this young timber,* and hence to *influence erroneously the length of the first cutting cycle required to remove the timber now mature.*

Another reason in favor of determining the area restocked with young timber is this—if this area is subtracted before computing the density of stocking of the mature stands, this latter density tends to approach normal and be indicative of the *actual yields per acre* obtainable, while if *not* subtracted these yields are evidently much too low per acre. If the work is carefully done and the maximum area of young growth is secured and the stocking or reproduction is plentiful, the density factor obtained for the mature timber may be applied not merely to these mature stands, but to *the young growth as well*, to assure a conservative prediction of future yields.

These relations are illustrated below:

Density of Stand, or Reduction Per Cent. To determine this average density or reduction per cent, in the illustration, § 161, the area occupied by seedlings and saplings, i.e., reproduction, and by poles, is to be first deducted from the net area, 438,423 acres not yet cut over.

Based on data obtained in the forest survey, the figure 25 per cent was adopted as representing the area within the working circle which is reproduced to seedlings and saplings; 25 per cent of 438,423 acres is 109,806 acres. The net area occupied by poles plus timber over 12 inches was then 328,617 acres.

Poles, 6 to 12 inches in diameter, by data obtained from plots in normal or fully stocked stands averaged 88 poles per acre. On 7,034 acres tallied in preparing the stand table for the forest, the average number of poles 6 to 12 inches was 4.9. This gives $\frac{4.9}{88}$ or 5.5 per cent of the total area stocked with poles at rate of 88 per acre, or 24,842 acres, leaving 303,775 acres net for timber over 12 inches.

163. **The Prediction of Actual or Empirical Yields for the Forest.** *Density of Stand, Timber 12" and Over.* Applying the principle described in § 161 we get, for the merchantable timber,

Class	Age Years	Yield per acre "Normal" ft. B.M.	Acreage required if normally stocked (x)	Per cent total net area, 12" only
Blackjack	90	9,400	60,341	31.3
Mature	200	25,300	24,163	12.5
Veterans	300	18,200	108,385	56.2
Total "normally stocked" area			192,889	100.0

Then the density of mature age classes 12" and over is $\frac{192,889}{303,775}$ or 63.5 per cent.

Since the density of the timber above 12" is computed on the basis of 63.5 per cent of normal, it will be convenient to compute the density of the pole class 6" to 12" on the same basis instead of as normal density, since in the former case, the corrected empirical yield table can then be applied to all the age classes including poles and seedlings. Since the *area* of seedlings has been established on the basis of a stand which will produce a mature crop of average density, the assumption of the same density for seedlings is conservative, rather than "normal" density.

By adding the normally stocked pole area, 24,842 acres, to the total *actual* area for timber 12" and over, the total *actual* area inclusive of poles is found, as 328,617 acres. But if poles are computed at 63.5 density, poles would occupy 39,121 acres instead of 24,842 acres, giving an overlapping or surplus area to adjust of 14,279 acres.

Then ratio of density $= 63.5 \frac{328,617 + 14,279}{328,617}$

$= 63.5 \times 1.0422$ or 66.2 (actually 66.18)

Then .662 is the true density factor for the entire accessible area of yellow pine, the reduction per cent to apply to the yields given in the "normal" or standard yield table.

(x) Found by dividing stand (§ 161) by yield of one acre "normal" from yield table for given age of stand.

If the area occupied by poles had been estimated on the basis of fully stocked stands correction would have been necessary as before to reduce poles to empirical density. Otherwise a "normal" yield per acre would be assumed for these classes at maturity. The above plan seems preferable.

Area Occupied by Age Classes. From ratio $\dfrac{100}{66.2}$ (True ratio is 66.18, error 260 acres adjusted.)

AREA OF AGE CLASSES

Class	"Normal" area acres	Actual area acres	Per cent of 438,423 acres	Age Years
Poles	24,842	37,486	8.5	50
Blackjack	60,341	91,072	20.8	100
Mature	24,163	36,469	8.3	200
Veterans	108,385	163,590	37.4	300
Total	217,731	328,617	75.0	
Reproduction		109,806	25.0	20
Total in forest working group		438,423	100.0	

164. Application to Group Selection Forests. *Relation of Cutting Cycle to Area Cut Over Already.* Nothing illustrates so well the interdependence of area and volume in regulation as the relation of the area already cut over, in a virgin forest, to the cutting cycle.

Clear cut and ruined areas requiring restocking cannot be included in regulation for the first rotation at all. But areas cut by conservative methods, or areas in which restocking has taken place after former cuttings, are so included.

To determine the length of the first cutting cycle, which is to complete the first cut of virgin timber, the total area may be reduced by the area clear cut or destroyed, but on the area cut under conservative methods, it is better, if the process has not gone too far, to compute the proportion or per cent of the area which has been already cut as part of this first or transition cutting cycle, which has already elapsed. Where the cycle is ½ r and the per cent of the original stand cut is proportional to this cutting cycle, then each acre cut over in logging is equivalent to but ½ an acre actually cut clear, but to one full superficial acre for the cutting cycle itself. An acre cut clear is equivalent not merely to one acre cut over in the first cycle, but, if reproduction and young timber are destroyed, to one acre in the second and subsequent cycles as well, which would thus have their yields reduced. Hence the elimination of such areas in regulation during the first rotation.

Illustration. Coconino. Areas:

Virgin Timber	438,423 acres
Cut over	116,137 acres
Total	554,560 acres

Of the area cut over, there is

Cut clear		45,473 acres
Cut, leaving seed trees	8,208	
Cut by Forest Service marking rules	62,456	
Area conservatively cut		70,664
Total		116,137 acres

On the area of 70,664 acres, a second cut can be obtained in ½ r years. This is borne out, also, by the per cent of area theoretically cut over as shown by the area of each age class in the remaining stand.

An 80% cut will take, approximately

Veterans	100% = 37.4%	of acre
Mature	90% = 7.5%	
Total	45%	of area

or nearly ½. Then this area if included as part of the unit, gives a total of 509,087 acres, and an area cut over, in the first cycle, of 13.9 per cent equivalent to 14 years, on this reduced working circle.

By including the clear cut area in a total of 554,560 acres, the per cent of area cut over for first cycle is 21 per cent or 21 years, and for the second cycle, 8 per cent or 8 years, a total of 29 years cut, equivalent to 15 per cent of the total area.

The total amount cut from the forest has been 593,621 M bd. ft. On the basis of 84 bd. ft. mean annual growth on 554,560 acres, this is equivalent to 13 years' growth. The conclusion is, that a conservative reduction of 10 years can be made in the length of the first cutting cycle as having been already cut, and by reducing the area to 509,087 acres, a period of 90 years should be allowed to complete the cut, with the assumption that 10 years' growth has taken place on the areas first cut over.

For this cycle of 90 years, the cut can be calculated based upon the actual age classes present, by volume, growth and area.

165. Coordination of Cutting Cycle with Area and Volume of Existing Age Classes. There remains one problem in calculating growth. The progression or change represented, on the one hand by growth, and on the other by cutting, when it extends over a period of 50 to 100 years affects the percentage of present or existing age classes cut, progressively. When the volume per cent cut, as 80 per cent, coincides with the volume of age classes, as veterans plus mature, it is best to assume, as do the French, that the cutting actually removes these classes completely. The volume left as seed trees in marking is balanced against an equal volume cut from a younger class.

Then the cut for cc years will be the present volume plus ½ the growth of these classes, plus the volume of the timber falling, by age or size, in the period ½ cc below, with half its growth for cc years. To get the ½ growth over so long a period, it is better to take the yield of one acre at ½ the cutting period than ½ the difference in yield at beginning and end of period. The difference in results is shown below.

Veterans,	at 300 years =	12,050	ft.
	at 390 years =	1,600	ft.
	average =	6,825	ft.
Yield at	345 years =	7,015	ft.

Difference in yield, by second method, + 190 ft. per acre or 2.7%.

The maturing class, since its age limits coincide with ½ the cutting cycle, may be computed on the basis that the entire area of the next class covering cc years matures,

½ is cut, and the average age of the stands cut is the present age plus ½ of the cutting cycle, thus giving ¼ the "growth" on the total maturing stand.

But when the first cut takes only a part of an age class, say 90 per cent of the mature timber class, it is a question as to whether we shall assume that the 10 per cent remaining shall be carried through to the end of the cutting cycle—which it would not be in practice—or our basis of calculation revised during the period to conform with the actual practice of marking.

The best plan is probably to add the 10 per cent of mature timber to the area of the residual growing stock where it belongs, and then in turn to deduct an equal area from the maturing Blackjack class which usually constitutes the residual growing stock, to be held over for the following cutting cycle, instead of figuring the entire class as entering the exploitable age class in this cycle. This is the same principle as raising the diameter limit (§ 144).

On this basis the cut for the first 90 years will be,

Exploitable class:

Age class	Age	Average age when cut	Yield per acre. ft.	Per cent of total area to be cut	Area, acres	Total cut
Veterans	300	345	7,015	100	163,590	1,147,583 M
Mature	200	245	17,610	90	32,823	578,013 M
						1,725,596 M

Maturing crop:

	Age	Average age when cut	Yield per acre, bd. ft. when cut	Per cent of total area to be cut	Area, acres	Total cut
Mature	200	245	17,600	10	3,646	64,206 M
Blackjack	100	145	12,045	96*	87,423	1,053,010 M
						1,127,216 M

½ cut = 563,608 M

Total cut for cutting cycle   2,289,204 M bd. ft.

Annual cut for 90 years   25,435 M bd. ft.

166. Comparison of Annual Cut by Methods of Regulation Proposed.

A comparison of results may now be made, for the different methods of regulation proposed.

Accepting a 100 year cutting cycle reduced to 90 years by previous cutting, for the removal of the first or original growth, and a cut of 80 per cent of the merchantable stand above 12 inches, as scaled in board feet, Scribner's Dec. C. Rule, we get, for a growing stock of 3,151,147 M ft.:

By French method of 1883,

$$\text{Annual cut} = \frac{.80 \times Ga}{90} = 28,054 \ M.$$ This assumes a balance of growth and decadence.

By Von Mantel's formula,

$$\text{Annual cut} = \frac{Ga}{.5r} = 31,511 \ M.$$ This result must be rejected as based on false assumptions of normality.

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*91,072 — 3,646 acres = 4 per cent of the Blackjack area, equivalent to 10 per cent of the smaller area of mature timber.

By cutting the mean empirical annual growth,

Annual cut = 84 bd. ft. × 509,087 acres = 42,763 M.   This fails to recognize the presence of overmature, stagnant surplus.

By Austrian formula,

building up the stock to 3,525,427 M in 90 years,
Annual cut = 38,605 M.

By cutting the actual volume, plus growth, to 80 per cent and creating a felling reserve,

Annual cut = 25,435 M.

The agreement between the latter figure and the first, based on the original French method of 1883 which ignores growth and a felling reserve, and the difference of 13,170 M ft. in the annual cut as indicated by the Austrian formula are very significant, for upon these data rest the proof of the fact that the Austrian formula is not applicable to virgin forests in America if sustained yield is sought.   Theoretically, the cut by this formula is nearly 50 per cent higher than it should be by the best analysis of facts that we can get.   This won't do.   Evidently Munger's assumption of a balance between growth and decadence, and the original French plan of ignoring growth gives results much closer to the facts.   The explanation lies in the fact that the Austrian formula *assumes* that the forest is already under regulation and is producing an annual increment on all stands.   It does not take into account the natural loss from decadence, which *must* be incurred previous to cutting, on all stands, and in a long cutting cycle is a serious factor.

In the present instance, the loss on 163,590 acres of veteran timber is the difference between the yield of one acre at 300 and 345 years, or half the period, multiplied by the area.   This is,

$$12,050 - 7,015 = 5,035 \text{ bd. ft. per acre}$$
$$5035 \times 163,590 = 823,675 \text{ M bd. ft. in 90 years}$$

This represents a loss of 9,152 M ft. per year.   Added to the indicated cut, by the last method, it would total 34,587 M bd. ft. or but 4,018 M bd. ft. per year less than the cut indicated by the Austrian formula.   The formula fails because it is not based on actual conditions.   The simple formula used by Munger is approximately correct because it does coincide with actual conditions.   What is needed is a method by which the *actual conditions and not formula determine the cut*.   The method proposed, whether it is applied by means of diameter classes and growth as in many-aged forests, or age classes, as in the above illustration, is based on the conditions in the forest, and makes no erroneous assumptions as to either form or arrangement of age classes, or growth.   In this illustration, the growth reaching maturity in the 90 year period fails to balance the decadence or loss by 78,030 M bd. ft. or 867 M bd. ft. per year.   In a forest composed largely of younger timber the reverse would be true.

167. **Summary of Basic Principles.**   To sum up:

The basis of applied regulation in America as elsewhere must be the determination of growth in the forest, for the average empirical stocking, and the

division of the forest into age classes by volume and area either by diameter classes or directly on age.

With a long cutting cycle and correspondingly large felling reserve required by our economic conditions of transition from virgin to regulated areas, the annual cut during the cutting cycle will be found by dividing by cc years the sum of:

1. The volume *now exploitable* plus ½ the growth during the cycle—best computed as, the volume which the exploitable timber will have in ½ cc years,

2. Plus ½ the present volume of the timber which will mature within the cycle, increased by ½ of the growth on the volume cut, which is ¼ of the growth on this total volume.

The felling reserve will be the volume, at end of cutting cycle, of all stands which have matured within the cycle, on areas after cutting is past on the area. This will be equivalent to the volume, at end of cycle, of stands now ranging in age from r — cc to r — 2 cc years. This basis is applicable to all forms of forest whether even- or many-aged.

The analysis of the forest into age classes, the determination of the immature age classes by area and the obtaining of an empirical yield table will make possible the further regulation of the cut covering the second cutting cycle and remainder of the rotation.

The balancing of the cut between the first and second cutting cycle, as far as permitted by silvicultural conditions, means carrying over the surplus, and can be accomplished by reducing the per cent of cut in first cutting, equivalent to raising the diameter limit and age, or vice versa.

168. Factors Indicating a Shortening of the Cutting Cycle. *Illustrations.* The loss by decadence of 25 per cent of the total available timber, or 36 per cent of the cut actually realized, as shown above, is sufficiently serious to raise a question as to whether the cutting cycle in virgin forest should be prolonged to ½ r even if the per cent of the stand which must be cut indicates this procedure. The possibility of shortening the cycle, say to ⅓ r, depends upon the data on growth obtained for cutover lands, and the reliability of conclusions drawn as to the behavior of the forest under management. Assuming, in the above case, that growth on cutover lands, *per acre of timber,* increases, from 84 bd. ft. to 105 bd. ft. per year, or 131 per cent, this would permit of shortening the cutting cycle to 80 years which at 105 bd. ft. per year would yield 8,400 bd. ft. as before. Then, if 10 years cut has already been made, a cutting cycle of 70 years would be indicated instead of 90 years. On this basis, the annual cut by the three methods discussed would be:

1. By French Method,

$$\text{Annual cut} = \frac{.80 \text{ Ga}}{70} = 36013 \text{ M.}$$

2. By Austrian formula,

$$\text{Annual cut} = 42{,}763 \text{ M} + \frac{3151147 \text{ M} - 3525427 \text{ M}}{70} = 37416 \text{ M}$$

3. By American Method,
   Annual cut = 34927 M.

The latter figures are obtained as follows:

1. Exploitable class.

Age class	Age	Average age when cut	Yield per acre	Area	Total cut
Veterans	300	335	8,140	163,590	1,331,622 M
Mature	200	335	18,105	32,823	594,224 M
					1,925,846 M

2. Maturing group.

	Age	Average age when cut	Yield per acre when cut	Area	Total cut
Mature	200	235	18,105	3,646	66,010 M
Blackjack	100	135	11,120	87,423	972,143 M
					1,038,153 M

½ to be cut	519,076
Total for cutting cycle	2,444,922 M
Annual cut	34,927 M

For this reduced cycle, the loss from decadence is 639,636 M bd. ft. or 3,910 bd. ft. per acre on 163,590 acres, giving a total, with the cut, of 3,084,458 M bd. ft. This loss is 9,137 M bd. ft. per year—nearly the same annual loss as before, but *less* by 20 years, or by 174,039 M bd. ft. on account of the shortened cycle. The total cut is nearly the same being greater by 155,718 M for the shorter cycle. The real difference lies in the more rapid cutting, giving an annual increase in the cut, of 9,492 M ft. or over 37 per cent.

As this increased annual cut is justified only by a showing that growth on *cutover lands* will permit the shortening of the cycle without interrupting the continuity of the yield, the importance of the point originally made, that growth studies on cutover land are the beginning of regulation, is again emphasized. Knowing the proper length of cycle, the disposal of the virgin timber even in the absence of data on decadence may usually be regulated *on a conservative basis* by ignoring both growth and decadence.

169. Quiz. Why is sustained yield the ultimate problem?
What are the limitations of the Austrian formula? Its good points?
In many-aged stands how can yield tables be constructed?
How can the yield table be applied to the forest?
How can the stand table be separated into age classes and average age determined?
How should immature age classes be treated?
What must be done to secure "reduction per cent"?
How is the area occupied by age classes secured?
How is the cutting cycle coördinated with area and volume of existing age classes?
Explain how the prediction of actual or empirical yields is done.
In the case cited in § 166 which method indicates the largest yield? Why?
Which two methods give similar results? Why?
What are the basic principles of the American Method?
With a long felling cycle how can the annual cut be calculated?
What will the felling reserve be?
Discuss the relative evils of loss through decadence as balanced by interruption of yield.

CHAPTER XIII

REGULATION OF FORESTS
COMPOSED OF EVEN-AGED STANDS

170. Relation of Cutting Cycle to Distribution of Age Classes in the Working Group. The same principles apply to the regulation of forests composed of even-aged stands, as to many-aged, or group selection forms. The method of cutting adopted will determine the future form of these forests. Clear cutting with artificial reproduction simply means a 100 per cent cut, and a cutting cycle equal to r years, unless modified by the inter-mixture of young stands on the general cutting area, forming several series of age classes as explained in § 116, when cutting cycles of less than r years are actually practiced. In this case, while each acre is cut but once in a rotation, the logging operations return to the logging unit to cut the succes-sively maturing stands at shorter intervals. If this were not so, at least during the first or transition rotation, these stands would reach ages ranging from r to 2 r years before they were all cut on the final logging unit.

Just because a stand is even-aged now, it need not be clear cut. For instance in the Lodgepole pine forests on the Deerlodge National Forest, Montana and elsewhere, a long period of experimental cutting evolved a standard of marking which removed not 100 per cent but only 64 per cent of the stands which had reached exploitable size, leaving the other 36 per cent to put on growth. This process, continued, will break up the even age of these stands and bring on a group form. It will also increase* the yield per acre of large sized material and the total yield of wood. It introduces the factor of thinnings into the question of yields.

171. Similarity of Problem with that of Many-aged Forms. The problem of regulating the even-aged form of forests should be approached in the same way as shown for many-aged forms. The first decision should be to deter-mine the length of the cutting cycle which is required to grow the second cut, basing this on the maturing of younger age classes. In even-aged stands the second cut will include the remainder of the mature timber in the stands which have been cut over in the first cutting cycle (the 34 per cent in the illustration) ; plus the stands, now immature, which will reach maturity within the second cycle, and which, in this form of forest are on separate areas, where in the many-aged forest they are mixed with the mature timber.

It will probably be impossible to return to cut again even for thinnings or improvement cuttings, in stands once cut over until all the remaining access-ible exploitable stands of overmature growth have been cut over once. The limitations of logging, as expressed by the cutting cycle, will prevent it.

172. Application to Eastern Mixed Hardwoods. For lack of analysis and separation of the forest into its respective age classes, the application of

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* Subject to losses from windfall, etc., which will probably be excessive. T. S. W., Jr.

this system in Eastern hardwoods at present is being based on the assumption that the forest can be divided into even-aged stands, which will be clear cut. Areas are classed or allotted according as their average age is veteran, mature, or young merchantable. The periods favored in the Appalachian forests are 20 years in length. The stands in the oldest class are roughly assumed to be cut clean, and to furnish the annual cut for the next period. (See data on Harvard Forest in appendix B.) The amount of the annual cut is based on the first plan proposed, corresponding with the French System of 1883 by neglecting both growth and decadence.

Regulation on this basis is by the allotment principle. The areas regulated are small and the period of 20 years may not coincide with the cutting cycle, which may be much less, in case transportation is well organized. Or the forest may be composed of such large and irregular blocks of different age on account of past cuttings that no regular cutting cycle or felling series can possibly be hoped for in this rotation. If, for instance, all the over-mature timber in a working group were located on one logging unit, and it was decided to remove it in 20 years, the cutting within this period would not touch the remainder of the logging units. If each of the remaining logging units were also comparatively even-aged so that the major logging operations were concentrated in them successively, during the entire rotation, then the cutting cycle as far as there can be said to be one, is coincident with the rotation. The creation of such large areas of forest composed of a single age group is one of the evil results of our unavoidable former system of extensive logging operations conducted without thought for the future of the forest as a productive property. One of the main objects of regulation on such culled and mangled forests should be to plan as soon as possible for the adoption of a cutting cycle of reasonable shortness, which will permit of logging in every unit once during the cycle, and will thus create a number of series of age classes in each unit instead of one or two only.

Just as, in the West, a cycle of $\frac{1}{3}$ to $\frac{1}{2}$ r may be forced on us by inaccessibility (and the necessity for extensive railroad logging operations), thus reducing the component age groups on any one area to 2 or 3, so the unregulated exploitation of private areas has done the same thing in part on the Eastern forests which the government is now about to attempt to put under regulation for sustained yield. If we stop with the assumption that even when stands are in reality composed of several ages, we must, for the sake of simplicity, assume them to be of even age and, because it is apparently difficult to know how to calculate the possible cut under a system of partial cutting, we assume that the cut will be clear, then the outward form or model of our regulation will tend, not towards the actual creation of these several age series in each unit, but towards their further elimination; either that or else there will be no real coördination between the calculated cut and cutting cycle, and the distribution of this cut by area and by per cent of the stands taken.

The argument here is not against the adoption of some plan of regulating the annual cut, which should be done on whatever basis is possible, pending the determination of the true condition of the age classes in the forest. It

is merely intended to point out the tendency to adopt the simplest conception of regulation, that of a single series of even-aged stands with cc = r, when possibly a little more study of the data at hand would permit of a basis more in harmony with the true state of the forest, and with the ultimate form required for best silvicultural results. If Appalachian hardwood forests are to be transposed by clear cutting into even-aged stands, the assumption of even-aged groups now tends in the right direction—but *even then,* the failure to recognize more than *one* of these groups to a logging unit tends to uselessly perpetuate the *large cutting area* which characterizes the *long cutting cycle.* An analysis of the forest into 2, 3 or 4 age classes on *each logging unit* is a great improvement over the neglect of these subdivisions by the process of lumping off the age of the whole unit.

Any plan of regulation is better than none—but the initial plan, adopted admittedly in the absence of sufficient data, should as soon as possible give way to a plan based on accurate knowledge. Sometimes this additional data may be expensive to secure—but in the experience of the writer this is seldom the case provided the object or character of the data needed is understood, and the methods of securing it are well thought out. The expense of pre- paring the yield table, stand table and growth data for the Coconino Yellow Pine working plan was trivial compared with the value of the information secured.

173. Prediction of Yields of Mixed Hardwoods. As long as investigators are tied to the fetish of mathematical accuracy in the interpretation of the play of living forces, whose results can only be mathematically ascertained *after they have occurred,* just so long will we be forced to the other extreme of adopting grossly inaccurate makeshifts in regulation of yield for lack of data of *approximate* accuracy which *can* be obtained and will vastly increase the certainty of our predictions, and management. The prediction of yield in mixed hardwood forests has for many years been considered an insoluble problem. No problem is insoluble provided the methods used are in harmony with the known laws governing the growth of the forests under investigation, and provided the allowable margin of error is not set so small as to be entirely out of harmony with the purposes of the prediction. All predictions of growth for long periods are subject to correction based on *actual growth* (see Gurnaud method § 83) after shorter periods have elapsed, hence why insist that they must be correct in the first place or else unserviceable? A little common sense is needed in tackling the problems of predicting growth in mixed forests.

This is a discussion of regulation, not of growth studies—yet there can be no permanent regulation without growth studies. Where several species exist together, they may grow at different rates. What is needed for regu- lation is the total net growth on an acre in board feet or other units (cubic feet would be more desirable as a permanent basis)—not the growth of each separate species. It is necessary to know something of the relation of these species to each other, their survival and dominance and the per cent of each in the average stand to get closer to the total production per acre, but the stand table shows this composition of the stand, and the growth study should

be based on silvicultural knowledge of relations of species. Composite yield tables while lacking the apparent reliability and superficial accuracy of those made for pure stands are perfectly practical for the present when based on site qualities, and described as to average contents. Undoubtedly the best plan is to obtain *yields per acre* rather than to depend upon growth of individual trees in diameter as described for many-aged forests, since the former method is based on *results* of growth on an area basis, while the latter takes no account of forces outside the individual tree measured, hence fails to record the loss or suppression in the stand (and losses through competition between species).

174. Correlation of Regulation with Methods Proposed. Assuming that a standard "cove type" yield table has been constructed which gives the *relative yields* per acre of this type at different ages, the problem of regulation consists,

(a.) In separating the forest into component age classes,

(b.) In determining the reduction per cent to apply to these age classes in order to predict the yield with the aid of the yield table.

For the present the whole question of growth and future regulation is postponed by assuming the allotment plan with no growth, for cutting the mature timber.

The measures which are possible are:

1. An estimate, by area, of the young timber, either by maps, or by per cents, in as many age groups as is feasible or necessary, discounting for suppression to get net area of survival as nearly as possible.

2. Separation of net remaining area of mature timber into 2 or 3 age classes based on:

(a.) Mapped areas, where the form of forest permits it and average age can be obtained for each area.

(b.) Diameter groups, when the first method is impossible; and correlation of age of these groups with age in the yield table by use of the tree of average diameter in each case, or,

(c.) Further improvement on b by substituting the age of the average tree and its volume as a means of dividing the stand into 2 age groups as described in § 160. In applying this principle to mixed forests, the same method by which the average ages of plots for the yield table was determined may be used to get the age of the tree of average volume in the forest.

The one requisite needed for the application of any of the methods dependent on the average tree for age, is a curve of growth based on diameter, which can be accepted as an average or representative curve for the type, and mixture. It will be said that with several species this is impossible. The answer is again that absolute mathematical accuracy is impossible for any method of determining an average unless all the elements are measured. An average, in forest mensuration, is used to *avoid the need* of complete measurements, and is not the result of total measurements. An average growth rate for several species does not presuppose that every tree in the forest must be measured for growth to insure correctness. If curves or growth showing age based on diameter for several species are weighted by

the average per cent of species in the type as shown by the stand table, the resultant curve will suffice for the purposes intended. Always bear in mind that forest mensuration is not exact mathematics; judgment in the use of the figures must decide the final answer.

Growth studies, either in the original stand or on cutover land, must depend as much upon the stand table or growing stock, as upon the growth of the individual trees in the stand, hence the stand table is the first essential step in making any kind of a growth study of the forest as a whole, as distinguished from standard plots or sample trees. It is the growth of the *forest* that we must have in order to regulate it, and it is the failure of our investigators to devise simple means of coördinating growth studies with the average stand in the forest which has discredited the utility of these growth studies and prevented their proper application.

175. Coördination of Regulation with the Silvicultural Practice. Once the forest is separated into age classes by volume and area, it is no longer necessary to make false generalizations as to the per cent of each stand to cut. In the group selection type described under Western Yellow Pine, the per cent of the stand cut on the average acre can be coördinated easily with the age classes present and as these classes are mixed together, the assumption of a clear cut of each age class, or the removal of part of any age class and the reservation of the remainder as part of the residual growing stock, incurs no appreciable error in calculation.

Where stands actually of even age are not cut clear but are culled, the initial problem of separating the areas of these stands and the calculation of growth is so simple that there is no reason why this growth data should not be coördinated with the actual silvicultural practice.

176. Illustration for Lodgepole Pine. For example, if lodgepole pine should be cut on a rotation of 140 years, we need a yield table with reduction factor for the average stocking of the forest, and a table of areas, volumes, and ages of the age classes. The cutting cycle may then be fixed at say 40 years. This may be based on the fact that at least 70 per cent of the area is covered by timber below 100 years old, a satisfactory percentage of which will mature in this period. If timber approaching maturity is scarce, the cycle may be prolonged and vice versa. Due regard can be shown also to the necessity of carrying over a surplus of overmature timber, but this also is best attained by prolonging the cutting cycle rather than by raising the diameter limits or increasing the per cent of each stand to be left in the first cut—factors which are more or less fixed by silvicultural and logging conditions.

Following the principles laid down for the transition cutting cycle (par. 138), the stands which will represent the cut in the first cycle will embrace all whose age is above r — cc years, or from 100 years up, including the surplus of over-mature timber. The growth on these stands is found by determining the yield which they will have in ½ cc years, or 20 years, by taking the yield for each age class, at the increased age thus fixed, from the yield table. But to successfully transform the forest, the minimum age of stands to be cut as the operations progress over the area must be set at r — ½ cc, or 120 years.

To take a concrete case for Lodgepole pine on the Bernice working circle, Deerlodge National Forest,* where the rotation is 140 years:

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* Bulletin 234, U. S. Dept. of Agriculture, page 35; yield table, Bul. 154, U. S. Dept. of Agriculture, page 32. At 140 years, normal yield is 15,840 bd. ft. or 113 bd. ft., mean annual growth per acre.

Since the reduction factor on this forest was applied, in estimating, to each age class separately, *the growth per acre can be predicted separately as well, for these age classes* by using the correct reduction per cent for each age class. But to simplify the illustration an average factor will be adopted.

On the basis of area stocked: i.e., stocking reduced to normal acres, which weighs equally *all age classes,* the density factor averages 49 per cent. But on the basis of comparative present volume which gives greatest weight to the older age classes, the density factor is but 33⅓ per cent. The latter ratio will be adopted for the first two cutting cycles for this reason. The empirical yield table then becomes,

TABLE 16. Yield Table for Bernice Division, Deerlodge National Forest.

Lodgepole Pine. Reduction to 33⅓ per cent.

Age Years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.	Age Years	Bd. ft.
30	180	60	1,620	90	3,160	120	4,540	150	5,640
40	640	70	2,140	100	3,640	130	4,920	160	5,960
50	1,120	80	2,680	110	4,100	140	5,280	170	6,240

The areas in the working circle are:

Age years	Area acres	Present yield M. bd. ft.	Age years	Area acres	Present yield M. bd. ft.
10	1,570	.....	70	1,928	4,125
20	9,742	.....	80	2,448	6,560
30	5,511	991	90	2,092	6,620
40	7,559	4,837	100	3,040	4,985
50	1,412	1,581	110	396	1,623
60	4,887	7,916			
70	1,928	4,125	Total		39,238 M
80	2,448	6,560			
120 to 160		14,443			
160 to 200		2,844	Total		53,603 M
over 200		474			
Total Acres		58,346			92,841 M

The present volume in stands containing merchantable timber is 92,831 M bd. ft. of which 80 per cent is Lodgepole; therefore, growth can be based solely on Lodgepole without incurring too great an error. Of this, 53,603 M bd. ft. is in stands 120 years and over in age.

Trial Calculation to Determine the Cutting Cycle. First Trial. The area now occupied by mature timber is 33 per cent of the total area stocked. On this basis, and to aid in establishing a cutting cycle approximately ⅓ r, the cycle will be first tested at 40 years. The per cent of cut will be 66 or two-thirds of the present stand.

The minimum of exploitable age will be set at r — ½ cc or 120 years.

The cut for the first 40-year cycle will be but 66 per cent of each stand leaving 34 per cent for the next cycle. This is approximated as the average per cent to leave. The older stands will be cut more heavily, and the younger, more lightly.

Growth in all stands is computed for ½ cc or 20 years. On the older stands, above 120 years, an average of 37 board feet per year is calculated from the yield table and applied to all stands. This gives, on 17,761 acres, for 20 years, a total of 13,143 M board feet.

A more accurate method can be applied, which will be illustrated in the case of the stands below 120 years. Since the volume and age of each stand is known and therefore its relative density, the growth should be predicted directly on the existing stands.

This can be done by determining the per cent of increase shown by the yield table for a 20-year period for each age class, and applying this per cent to the present volume.

For 110-year class this is $\frac{4920}{4100}$ or 120 per cent.

For 100-year class it is $\frac{4540}{3640}$ or 124.7 per cent.

The yield of these stands in 20 years is then,

For 110-year class, 1,623 M plus 20 per cent or	1,947 M.
For 100-year class, 4,985 M plus 24.7 per cent or	6,216 M.
Total	8,163 M.

The total volume to be cut within the 40-year cycle is,

Volume of stands 120 years and older	53,603 M.
Growth at 37 bd. ft. per acre annually	13,143 M.
Volume and growth in 110 and 100-year stands	8,163 M.
Total	74,909 M.
66 per cent to be cut	49,439 M.
Annual cut, 1/40th	1,235 M.

At the beginning of the second cycle, the 34 per cent left from these stands has already laid on an average of 20-years growth, and will lay on 20 years additional growth before cutting during this 40-year cycle. The growth of these thinned stands cannot be predicted with certainty, but such data as is available tend to show that the species has marked recuperation powers even to the age of 400 years. Hence it is fair to assume that on the remaining stand the growth will equal that laid on in the first cycle, or 37 bd. ft. per acre.

For 40 years and on 21,197 acres, this equals	31,371 M bd. ft.
Upon the residual stand of	25,470 M bd. ft.
or a total of	66,841 M bd. ft.

To this must be added the yield of stands now between 100 and 60 years of age, which will grow for 40 years in the first cycle and an average of 20 years during the second cycle before cutting.

Using the same method of percentages as for the first cycle, these are, for 60 years' growth,

For 90-year stands $\frac{5640}{3160}$ or 178 per cent.

80-year stands $\frac{5280}{2680}$ or 197 per cent.

70-year stands $\frac{4920}{2140}$ or 230 per cent.

60-year stands $\frac{4540}{1620}$ or 280 per cent.

The yields of these classes will then be,

For 90-year stands at 150 years, 6,620 M, plus 78 per cent or	11,883 M.
For 80-year stands at 140 years, 6,560 M, plus 97 per cent or	12,923 M.
For 70-year stands at 130 years, 4,125 M, plus 130 per cent or	9,487 M.
For 60-year stands at 120 years, 7,916 M, plus 180 per cent or	22,164 M.
Total	56,457 M.

If 66 per cent of these stands is cut as before, this gives a cut of   37,261 M.
This, with the older thinned stands gives a total cut of   104,102 M.
and an annual cut of 1/40, or   2,605 M.

Thus by the plan of cutting but ⅔ of each stand now, at a sacrifice of 637 M bd. ft. per year of the possible cut, it appears that the probable cut in the next cycle will be more than doubled. If the stands are cut clean the respective cuts will be,

For the first cycle	74,909 M.
annual cut	1,872 M.
For the second cycle	56,457 M.
annual cut	1,411 M.
Total for both cycles	131,366 M.
Total, if ⅔ is cut	153,541 M,

plus a reserve, in this case of 19,196 M or a total gain in production by the second method of 41,371 M in 80 years or 517 M per year, which is about 32 per cent of the average 80-year cuts of 1,642 M by the first or clear cutting method. In effect, such a system is equivalent to lengthening the rotation by at least 20 years.

These figures are given to illustrate the method by which different cutting cycles and rotations may be tested, to determine the actual yields and to decide upon the proper factors to use in regulation. They serve also to bring out the enormous influence of growth upon the volume of the possible cut.

If the discrepancy between the predicted cut for the first two cycles appears too great, the cut for the first cycle can be increased, and made more nearly equal with the second, by shortening this cycle and removing the surplus of timber above the age of 140 years in a shorter period. It is suggested that the student perform one or more of these calculations by the methods indicated.

177. **Summary of Principles for American Regulation.** The European allotment principle attains progress towards regulation by transferring stands whose age classifies them with a given fixed period, into an earlier or later period for cutting, thus equalizing the areas reproduced within the period by advancing or retarding the normal age of exploitation for specific stands.

The periods are of fixed length, equal to a definite proportion of the rotation, and as the cutting cycle is usually ½ to ¼ of this short period, there is no difficulty in reaching and cutting any stand when needed.

In America the cutting cycle or length of time elapsing between successive cuts is determined by transportation costs and frequently becomes the governing principle of cutting and hence of regulation.

The first principle of securing sustained yield in America is therefore to determine the length of the first cutting cycle so as to fix the amount of the annual cut, on the basis of a *determined cut per acre.* As an aid in this determination, the growth on cutover lands, in selection or group cuttings, and the growth on cutover lands plus the young stands which mature, in even-aged forests, will be measured to indicate the annual cut possible in the second cycle.

The annual cut in the two cycles can best be equalized *by lengthening or shortening the first cutting cycle,* the former reducing the cut in the first cycle and increasing it in the second, and vice versa.

Where more than two cycles are apportioned to a rotation, the per cent of the rotation assigned to the remaining cycles may be made proportional to the per cent of the area of the working circle, occupied by timber whose

age classes it with these cycles. The first two cycles can usually include all the timber *now merchantable*.

The working out of this principle is well illustrated by the above case, and as set forth it constitutes what has been termed the "American" method of regulation whose characteristics are, determination and equalization of the annual cut on basis of volume, *by means of varying the length of the first and second cutting cycles,* and determination of the actual annual cut by using the principle of a felling reserve and cutting series with a minimum exploitable age of $r - \frac{1}{2}$ cc years and an allotment of areas or stands for cutting within the period, down to and including $r - cc$ years. Just to the extent that the per cent of the stand per acre, in many-aged forests, or the per cent of the total area of a logging unit, in even-aged stands, which must be cut, can be reduced because of increased accessibility and better transportation conditions, does the cutting cycle lose its controlling force in regulation, and the need for basing regulation on length of this cycle, and upon the cutting series and felling reserve which is created by it, diminishes, until with short cycles of 5 to 8 years and perfect transportation, the allotment principle of regulation may be applied without regard to the cutting cycle. But these conditions are for the future in many sections of the West, and the principles above described will be applied in cutting whether or not they are recognized as they should be in regulation.

178. Quiz. Can these principles be applied to even-aged stands? or to Eastern mixed hardwoods?

How could the mixed hardwoods of the Southern Appalachians be regulated under present conditions?

Why must regulation be coördinated with silvicultural practice?

How can the annual cut in two cutting cycles be best equalized?

Why is this better than an allotment of areas for cutting within a definite period?

When should an allotment method be used?

APPENDIX

CONTENTS

APPENDIX A. (a) FOREST MANAGEMENT IN NINE EUROPEAN STATES.

The data on European management is a free and condensed and not a literal translation of the third edition of H. Martin's Forsteinrichtung. The wording has frequently been simplified but without changing the real meaning nor diminishing the value of the original text. The synonyms management plan, and working plan have been freely varied. In some instances considerable liberty has been taken in completely rearranging the text. But in adhering to a translation at all, the "English" has had to be sacrificed to a considerable extent. The use of brackets to simplify some of the involved and complex German sentences perhaps has been carried to extremes but seems necessary to make the text understandable.

The following countries are included: (1) Prussia, (2) Bavaria, (3) Kingdom of Saxony, (4) Würtemberg, (5) Baden, (6) Grand Duchy of Hesse, (7) Grand Duchy of Saxony, (8) Alsace-Lorraine, (9) Austria. Martin's comment on French regulation has been omitted since this is discussed in great detail in the text and in the Appendix of "Studies in French Forestry." Accepted principles proven by these discussions have been embodied in the main text of this book.

I. PRUSSIA. (Page 223)*

During the nineteenth century the allotment method was the dominant method of regulating the yield in Prussia. It came into use through G. L. Hartig, in the form of the strict volume allotment (Massenfachwerk). According to the Instructions of 1819 the yield was to be shown for all periods of the 120 year rotation (or period of organization), separated into main and preliminary yield, divided into classes (timber, split fuelwood, round billets, brushwood). This method of Hartig's on account of the "circumstantiality" of the calculations (for which a satisfactory basis was lacking), could not long be maintained. The elaboration of working plans progressed too slowly. Therefore new instructions were issued in the year 1836 by Oberlandforstmeister von

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* Figures in brackets denote the page in Martin's Forsteinrichtung, third edition, and thus facilitate reference to the original text.

Mrs. Fernow, who kindly read the translation to Dr. Fernow, writes that Dr. Fernow . . . . "thinks you have generally improved on Martin, whose style is certainly most cumbrous" . . . . It should be noted that "abtheilung" means lot when "jagen" signifies compartment, but lot is usually the translation of "unterabtheilung" when the compartment is denoted by the German word "abtheilung."

An excellent way of mastering the variations and similarities of regulation in the foregoing states is to read through the translation subject by subject as well as country by country. For example take the subject of allotment by periods and it is instructive to find that all states have usually abandoned the cumbrous and methodical scheme of actually alloting stands to periods 40, and 60 years hence.

Reuss, after summary yield determinations for the State forests had been carried on in the years 1826 to 1835; these instructions continued to be used almost to the end of the nineteenth century; to be sure, they are also based on volume-allotment but they simplified the yield calculations and took area into consideration. At the same time attention was paid to a proper distribution of age classes and regulation of a felling series. In harmony with these instructions for the elaboration of working plans, two different kinds of allotment came into use according to the stand conditions in each case:

(a) The combined allotment (Fachwerk) which was preferably to be applied to irregular stands.

(b) The area allotment (Flaechenfachwerk) which under regular conditions was considered sufficient. Usually only simple areas formed the basis.

In recent times the yield calculations were limited more and more to the first period *and the allotment for later periods was often entirely omitted.* In other directions simplifications were also introduced. The most important essential prescriptions of the method in present use are as follows:

1. **Prescriptions for the Elaboration of New Working Plans. (1) Preliminary Discussion.** Before beginning the work of regulation preliminary discussion takes place between the district forester, inspector and supervisor, in which (on the basis of the detailed results of the former management), propositions for the future management are laid down. This discussion is centered on: the system of roads and division lines, the boundaries, maps and survey, the condition of the forest, the previous and future management, and the method to be followed in the organization of working plans.

2. **Administrative Subdivision; (a) Working Groups and Management Classes.** The formation of working groups is a special peculiarity of the Prussian State Forest management. Already in the instructions of Frederick the Great this is prescribed. To justify the formation of groups it is stated: "Partly the size of the forests united into one supervisorship and partly differences in portions of these forests as regards methods of management, condition of stands, market, or servitudes, make it desirable or necessary not only to regulate the cut for sustained yield for the Forest as a whole, but to divide it into more or less independent organic parts of the whole forest forming main management units or groups, within which the sustained yield management can be either introduced immediately or at least prepared for by the establishment of ordered age classes." (P. 225) According to present practice each protection district forms a group. Such coppice forests that are to form a felling series by themselves, as well as coppice under standards and selection forests, for which a special working plan is to be made, are segregated as special working groups.

Besides the division into groups, the formation of management classes is also instituted in Prussia. The reasons for these are first of all to be found in the occurrence of the four groups of timber species on large areas (oak, beech and other hardwoods, softwoods, and conifers), and further in differences of management (especially as regards rotation).

(b) *Permanent Subdivisions (Wirthschaftsfiguren).* The prescriptions given for the subdivision essentially agree with the rules given in the first section of the first part (of this volume), which are derived from Prussian practice. This subdivision into permanent subdivisions (Wirtschaftsfiguren), which are here called compartments (Jagen), is made by a network of straight lines, which cut each other as nearly as possible at right angles. The rides (Gestelle) are to be laid out from east to west and from south to north or parallel and perpendicular to an intersecting main road or railway. Where danger from wind is to be feared, the dividing lines are to be so laid that they form an angle of 45 degrees towards the most dangerous wind direction.

In mountain forests the division is to be made on the basis of the network of roads. "The roads are to form the shortest possible connection to market or to means of communication with the market; they are to be planned in relation to each other, to cross mountains over passes and to be located so as to be easily built. The grade

is not to exceed 6% except when thereby a specially favorable location of the roads can be secured."

The shape of the management units is to be as regular as possible without acute angles, so far as possible facing in one direction and bounded or intersected by roads in such a manner that all the wood cut in them can be readily moved to the highways. If the boundaries are not formed by roads, either natural boundaries should be relied upon or cultural limits, railroads or rides (Schneisen, which as far as possible are located in the direction of the steepest grade).

The size of the permanent management units is to average 50 to 75 acres—in spruce 25 to 62. The main rides of a compartment division, which run approximately from east to west, are marked with Roman (p. 226) capitals; the "fire-rides" which are perpendicular to these, are marked with small letters. The compartments in the plains are numbered from east to west, proceeding from south to north. In mountainous territory, sections of country of uniform character are combined into groups and numbered accordingly.

(*c*) *Stand Divisions.* The differences in the stands to be found within the permanent compartments are segregated as lots (Abtheilungen and Unterabtheilungen). Compartments are segregated, if the limits of the stand are likely to remain permanent and either coincide with rides, roads, watercourses, etc. or can be laid out on lines suitable for roads, which are then marked with posts and direction ditches. In all other cases, especially when the difference is to be obliterated in the course of the first period, a segregation as lots suffices, the boundaries of which are not indicated and marked locally. Severance fellings and safety lines are to be segregated as lots. Compartments are denoted by small Latin letters, the lots by the compartment letters with a small number (a^1, a^2).

3. **Site and Stand Survey.** (a) **Description and Valuation of Sites.** For the geological description of the soil and for its composition the geologic-agronomic maps of the Geological Survey on the scale of 1 to 25,000 are to be used. As regards terminology, that of the German Forest Experiment Stations is to be followed. The site class is to be estimated on the basis of the Experiment Station yield tables. The average height of the main stand, ascertained by a few measurements, serves as measure of the site value.

(*b*) *Description of Stand.* This is to be brief. Uniform stands of regular character are sufficiently described by stating the species, age, and the full yield. Striking defects of the stand are to be specially noted. In uneven-aged stands in which the age classes gradually merge into each other, the age limits and the average age are to be stated. If several age classes are strictly differentiated, the age of the classes is to be noted (p. 227). The degree of density is to be estimated specially for the different species. Their sum must coincide with the total density of the entire stand.

4. **Age Class Table.** This table forms the most important numerical basis of the working plan in the timber forest; in it the stands are arranged according to sequence of the groups, compartments and lots. In mixed stands, and in those containing different age classes, the areas are divided according to the proportion of these differences. The area (to be determined by survey or estimate), which each species and each separately stated age class occupies (within a compartment or lot) is entered on a separate line. Thus it is possible where mixed stands predominate to record the species more correctly than can be done, if, in the table the whole area is assigned to the dominant species. The areas are compiled, separately according to the four species groups and, if several management classes are involved, also separately for these, by groups and in totals.

If it appears desirable to record and compile the stands according to site class parcels, this may be done. On the basis of such data it is possible to calculate or estimate the actual and normal growing stock of the age classes and of the total forest.

5. **Regulating the Cut.** (a) **Standard of Measure.** The measure for the amount of cut and the proof of sustained yield is the normal periodic area. This is determined for each management class according to the relation of the length of the period ($= 20$

years) to the rotation. For the working groups it is not necessary to adhere to the normal felling area. With irregular age classes corresponding changes are made. The area of the first period is to be made smaller when there is a deficiency,—larger when a surplus of mature timber exists. Under difficult (cultural) conditions and especially when species with long regeneration periods are involved, the first and second periods are to have felling areas allotted. In cases where the sequence of cuts has special significance the progress of fellings is to be shown for a longer period. The felling areas of the first period are listed separately according to species, groups and management classes, group by group and for the whole forest. For the areas of latter periods and the segregation of stands according to species, groups and management classes are not required.

(b) *Choice of the Stands to be Regenerated (p. 228)*. The correct choice of the stands of the present period of management is considered one of the most important tasks of organization. It is essential that the stands are utilized at time of maturity, that the most suitable felling series is established, the sustained yield assured, and the most suitable species regenerated.

(c) *Rotation*. The (official) determination of the rotation for the main species is reserved for the Minister. The proposals for the length of the rotation are to be stated and argued in the preliminary proceedings. For a decision on the length of rotation, data are to be secured in suitable "reviers" (before the organization takes place) for the most important species and the most commonly occurring sites; the stumpage prices (free of logging cost) per cubic meter of timber for the most important age classes can thus be studied.

6. **Determination of Timber Volumes and Cut. (a) Main cut.** The allotment of the cut (main and intermediate) is done according to the instructions for keeping the control book. The yield (main cut) is composed of the present volume plus the increment for the next ten years. All volume data refer to timber and are separately listed according to the four species groups already mentioned.

The determination of the volume of the first period is made by calipering all stems, unless a simpler method appears satisfactory. For the calculation of the volumes the volume tables of the German Forest Experiment Stations are as a rule to be used. The volume of the young regular stands is estimated by yield tables or ascertained by sample plots. The increment percents are cited according to the yield tables; for open stands simple increment investigations are to be undertaken. The annual felling budget is then obtained by dividing the sum of the volumes assigned to the first period by 20 (i.e. years in period).

(b) *Intermediate Cuts (p. 229)*. To furnish a definite basis for the execution of thinnings, a plan is elaborated in which the areas of the stands to be thinned or cleaned in the next decade—separated into those under and over 40 years—are enumerated. The division of these areas by ten gives the yearly thinning area. If the stands are to be thinned twice (or thrice) in one decade their area is added again (or three times). The exact year of the thinning is not dictated for each stand.

The felling budget for the intermediate cut is estimated on the basis of the yields which the intermediate cuts . . . . . have furnished on the average in recent years, excluding unusually high or low yields. The average is increased or decreased if the annual area to be thinned deviates considerably from the area annually thinned (in the years used for comparison) or if other reasons give occasion for it (especially changes in the thinning technique).

7. **Coppice and Selection Forest Organization. (a) Coppice.** Extensive coppice forests are segregated as special working groups. Every group is to contain a number of annual felling areas corresponding to the rotation and with approximately equal areas. The felling areas are chosen according to their maturity and with regard to a satisfactory felling series. It is generally considered sufficient to determine in each group the number of felling areas and the year of their cutting, without locating the individual areas in the field or on the map. Lots are not segregated.

The yields of timber and brush are to be estimated on the basis of former results.

The annual cut is found by dividing the number of years of the rotation into the sum of the yield of all felling areas segregated by the species groups.

(*b*) *Selection Forest.* The regulation of the cut is simple. A segregation of lots within the compartments is as a rule to be avoided. In the age class table the areas by species and age classes are to be estimated and stated separately. The ascertainment of the growing stock stem by stem is not necessary. All wood yield is to be booked as main cut.

(P. 230) The cuts for each management unit of the first period are estimated from yield tables according to the maturity (of the parts) of the stand *for the middle of the period,* segregating (as usual) the four species groups; or are estimated by calipering. If the selection forest forms a special group the average increment for every management unit is estimated and the total increment revealed thereby is to be considered as prescribed cut (felling budget), in so far as the age group proportion does not reveal a lack or excess of growing stock, or the character of the stands does not necessitate a greater or reduced cut.

Wherever the selection forest has been in existence for a considerable time the future prescribed cut may be deduced from a consideration of the changes in the age group relations consequent upon the application of the previous felling budget. For a check on the progress of fellings a return period of ten years is as a rule established.

II. **Control and Development of Working Plans. A. Control.** For control of the management and for the development of the working plan there is: (1) the Control book, (2) the Ledger, and (3) the Area Register.

(1) **The Control Book** serves as a check on the estimates and fellings, and consists of three parts.

The *first part* (A) contains for every permanent stand a special record in which are entered annually, all fellings divided into main and intermediate, with the amount of the material realized. The main cut includes those cuts of the main stand which either produce an entire renewal of the stand or such a culling as to necessitate its entire renewal or filling in, or if there is a considerable diminution of the main yield as determined by the stock taking. The intermediate cut includes: (a) thinnings in the lower story; (b) fellings of single stems and groups carried out for the benefit of the main stand, which do not necessitate a renewal of the stand and (p. 231) which do not exceed 5% of the prescribed main yield (cleanings, improvement cuttings); (c) fellings which take place in consequence of injuries to the forest without, however, necessitating restocking, and without diminishing the prescribed main felling by more than 5%. Fellings from (a) to (c) which take place in stands of the current working period, are to be considered as main fellings.

All yields of the coppice under standards and selection forest are also reckoned as main fellings. When the cut prescribed by the working plan (in the main felling of the timber forest) is completed, the realized yields of timber are summed up and transferred to the *second part* (A₁) (see page 180) and here compared with the estimated yields. The intermediate yields are excluded from this transfer as is also the root and brush-wood. Every three years the part A₁ is balanced; it is then calculated whether the stand divisions (re final cut) during these three years have yielded more or less than the estimated yield and what amount of wood above the estimate may be utilized or how much the felling budget must be reduced (to make up for a deficit).

The *third part* (C₁) contains the annual comparison of the cut in timber with the estimated amount, taking into consideration the changes demanded by the results of part A₁. Excess or deficit in one year's fellings (as compared with the felling budget) is used for the determination of the usable volume of fellings added or subtracted from the felling budget. The result (the remainder or the sum) constitutes the standard for the following economic year; the permissible cut (in the main felling) may only be exceeded by 10% at the highest, without Ministerial permission. No limitation exists in this direction for intermediate returns; they are controlled only by area (and silvicultural practice).

2. **The Ledger (Hauptmerkbuch).** This aims (in conjunction with the Control

Book and the Area Register) at furnishing the bases for the control, proving and (p. 232) correction of the forest management. "It is to form a history of the Revier, which enables one to see the development and changes of conditions in the whole Revier as well as in its integral parts, and furnishes to the succeeding administrator a knowledge of events influencing the management, the measures adopted, the work performed, the observations and experiences had, at the same time permitting at any time the oversight of the status of the management, and hence also furnishing the needful basis for new organization work." In conformity with these purposes the Ledger is divided into a general and a special part.

The *general part,* arranged according to subjects, contains in historical sequence those noteworthy changes, phenomena and occurrences which concern the whole Revier or large parts of it and are of a general nature; it takes up the noteworthy data recorded in the course of management as well as any suggestions regarding improvements.

The *special part* of the Ledger is intended to record the events and changes occurring in the individual compartments; especially the changes in the stand produced by fellings and forestation; the logging costs are specified and explained. Certain sheets of a special map on a scale of 1:5,000, made for the use of the supervisor, form an addition to the Ledger and to the Area Register; on these are entered the changes in boundaries, the methods of using the soil and the stand changes made by fellings and forestation. If a road system has been planned, a road system map is put into the Ledger on the scale of 1:25,000, and also a blank map (on the same scale) on which the finished roads are entered. Detailed instructions for the correction of the maps are given in the manual.

3. **The Area Register.** The status of the area of the reviers is controlled in its entirety by the Area Register, which consists of four parts: Section A, the map register, records all existing maps, surveys and working plan data; Section B records all area changes which have been begun; in Section C the entire area of the Revier is controlled and Section D records the transfer of soil intended for wood production to areas not intended for wood production and vice versa.

B. **Intermediate Revision (p. 233).** The working plan is revised at the close of the first period (usually 20 years), but, in view of disturbances and changes in management occurring during the course of the period, an intermediate examination is undertaken in the eleventh year. To prepare for this the supervisor has to balance up the most important control books having reference to fellings and forestation. In a plenary conference, then taking place, a discussion ensues whether and in what respect there has been deviation from the regulations of the working plan or whether there is to be such deviation in the future. The working plan is then checked and revised as follows: (1) All changes in the felling time of stands of the first period; (2) the budget for the main yield according to the urgency of the necessary changes; (3) the felling budget of the intermediate yield; (4) the thinning plan for the next decade; and (5) if necessary, the road building plan.

II. BAVARIA.

The most important basis for forest organization has been up to this time the Instructions of 1830 together with some supplementary directions. Essential prescriptions are also contained in the basic protocols and the revisional notes of the ministry on the individual working plans. New directions for working plans are soon to be expected. The most important points which characterize the past procedure are the following:

(1) **Preliminary Work and Bases (p. 234)** (a) **Subdivision.** Large forests are segregated into districts, i.e. separate forest regions formed by natural conditions, units of contiguous location; they generally are named.

The permanent units of management (formed by systematic division), and which are marked by Arabic numbers, are called compartments. They are formed in the plain by straight rides (Schneisen). In the mountains the division lines are adapted to the contours and connected up with the road system. Moreover the compartments depend on forest conditions and management. Their size and shape are often very dissimilar.

Changes in the existing division are avoided as much as possible. No positive directions are given for the size of compartments. Varying parts of the compartments are separated as lots (marked with a, b, etc.). As regards their size no general prescriptions are given, but as a rule they are not to be less than 2½ acres. Differences in stand within the lots (wind fall openings, regeneration groups, etc.) are recognized by numerical exponents (a^1, a^2 . . . .). Regarding the character and the direction of the fellings, general prescriptions are given in the management plan (which are elaborated for working units) and special prescriptions for periodic fellings.

(*b*) *Basic Protocol* (*p. 235*). Before beginning the survey the main features of the plan of management are to be determined. This is done in a council of commissioners. This has reference to all conditions which are of essential influence on the wood production (soil, situation, increment, yield, market, legal conditions, etc.). Moreover the former management (in its most important technical and economic aspects) is discussed. The future management plan in its main features is determined from the previous plan. At the same time there is given here the basis for the segregation of working groups occasioned by difference of species and of rotation. The results of this council meeting are recorded in a "basic protocol."

(*c*) *Description and Determination of Cut.* The permanent bases for determining the cut (especially the site conditions) are stated for entire compartments, so far as no essential differences occur in their component parts. The conditions which are of a temporary nature, especially the stand conditions and measures of management, are stated for the lots. The description of the stand is to emphasize in the briefest possible manner the conditions which are of moment to the management, especially the dominant species, the mixtures, growth, density, and age. The age classes were hitherto so formed that each class comprised a period of a quarter of the rotation. In the future, the age classes will be established with 20-year periods (I. Class, 1-20 years, etc.).

The determination of the growing stock is by complete calipering for the stands that are to be exploited during the next period, unless simpler methods are indicated by former surveys or by experience of past management. The growing stock of later periods, as far as it is to be determined at all, is to be estimated from yield tables on the basis of average increment.

2. **Working Plan.** (a) **Method of Regulating the Yield.** The former method of yield regulation was a combined (area and volume) allotment (p. 236) method (Fachwerk) with 24-year periods. In recent times the yield regulation is confined to the next period, which in future will comprise only 20 years. The allotment of the areas is done by working groups, beginning with those under the longest rotation. Within the group the stands are enumerated according to the order of numbers of the districts, compartments, and lots. The working plan is to furnish a control over the management planned. The prescriptions are, however, so formulated that the management is not rigidly fixed for long periods. The allotment of the stands to the periods of the working plan is based largely on average age. Deviations from this rule are indicated by the condition of the stands and considerations of the establishment of a good felling series (which is helped by suitable severance fellings).

(*b*) *Determination of the Felling Budget.* The yield of the stands (lots) is calculated by adding to the present volume the increment for half the period. The felling budget for the main cut is determined by multiplying the felling area corresponding to the rotation ($\frac{a}{r}$, if rotations vary for separated working groups) with the average wood volume of the area unit of the stands to be felled. To this are added the volumes of deferred fellings and accidental yields. In case of irregular age class conditions suitable increases or decreases of the felling areas are made. The budget is stated in toto, not separated by species.

The yields (special estimates by yield tables) of intermediate fellings are given only for the first half of the first period. The total volume of thinnings is also stated in

per cent of the total yield and per acre of forest area. The annual budget of the intermediate yield is from estimated total volume divided by the number of years.

(*c*) *Special Management Plan.* To give the management needful suppleness it is a rule to allot in the working plan more areas than correspond to the debit of utilization. Stands are allotted to the working plan (which in future is to be made for 10 or 20 years), which contain 15 to 30 times the yearly budget (p. 237). This affords the possibility of multiplying felling areas and making gradual progress with regeneration fellings. The "basic protocols" give directions to the supervisors for the location of fellings.

Besides the felling plan there is a special forestation plan, which contains a list of forestation cost estimates arranged by lots. Plans are also prepared for the construction and maintenance of roads (and eventually for the most important secondary uses).

3. **Control and Revision.** The control of the fellings and stock estimates are carried on as in Prussia:

(a) By annual comparison of the total cut with the budget. The tabulation gives the main cut, intermediate cut, and total cut.

(b) By periodic comparison of the felling results with the estimates for each lot, which is carried in a special record. At the end of the 10-year working period this Control Book is balanced.

The periodic examination and revision of working plans, which may be either simple or comprehensive, is done by the Forest Revisions Bureau (Waldstandsrevisionen). The plans are "comprehensive," if important changes become necessary through extraordinary natural phenomena or for other reasons. Essentially, the revisions are carried on as in Prussia.

III. KINGDOM OF SAXONY.

The forest organization for a long time has been carried on by a separate bureau (Forsteinrichtungsanstalt), which has had special advantages for its development. Through this special bureau, the personnel is well trained and a uniform execution of (p. 238) all survey work is secured. The results of the working plans can be more effectively worked over and their relation to other technical branches (experiments, administration, economics, statistics) more appropriately kept in view. In Saxony too the yield regulation is based on the allotment method (Fachwerkmethode). H. Cotta, who systematically carried on the survey and organization of the Saxon State Forests in the years 1811-1831, advocated the area allotment as well as the combined allotment. Due to the regularly recurring revisions, it was early recognized that the yield calculations for later periods were superfluous. The allotment for these was therefore abandoned and the yield regulated only for the next decade. The most important points characteristic of the Saxon procedure have reference to (1) the preliminary work of estimating, (2) the determination of the felling budget and felling areas, (3) the control and revision.

1. **The Preliminary Work.** The subdivision into permanent management units (compartments) is (in the plains and in gently sloping country) done by a system of straight lines intersecting as far as possible at right angles. The main lines, so-called Wirthschaftsstreifen (management lines or strips) run in most reviers of Saxony from northeast to southwest. They serve as boundaries of the felling series and are 9 yards wide, in order that along their limits breaks (i.e., severance fellings) may be formed as a protection against wind damage. The rides, which are located at right angles to the management strips are to indicate the direction of the annual felling areas and as a rule are 4.5 yards wide.

In mountain reviers too, in the middle of the last century, the subdivision was carried out on similar principles, except that the division lines conform to the more important contour lines (ridges and saddles). With the progress in making roads (which came about independently of the subdivisions), many lines were replaced by roads. A sudden and systematic change of the existing subdivisions (as was carried on in the Prussian mountain districts) could not be carried out because of the prevalence of spruce, so

liable to windfall, and because of the straight division lines along which severance fellings are made. In working out road systems (in each case), it is investigated whether and how far the roads are to be used as division lines and what changes (of the latter) are to be made in consequence of the new road system.

The (p. 239) lots (stands) mainly due to differences of age, are segregated down to a minimum area of ½ acre. Binding rules are not given, however, in this regard. Local marking of the limits of lots is not attempted unless existing lines can serve. On account of the uniformity of stand conditions the descriptions of lots are made brief—in tabulated form. The soil classification is made by site and stand qualities. The former gives expression to the normal, the latter to the actual conditions of production. The segregation of sites is made according to the Instructions for Forest Experiment Stations. The stand quality is expressed in simple numbers, which show the combined effect of site and condition of stand. The age classes are stated in 20-year gradations (I. class 1-20 years, II. class 21-40 years, etc.). Each age class is again subdivided into decades. The resulting classification in decades is also shown on the stand maps.

To ascertain the growing stock, *the volumes of the stands below 40 years* are calculated on the basis of yield tables (based on stand quality and age classes). *The stock of stands over 40 years* is ascertained by ocular estimate, which is done at each ten-year main revision. Calipering is the exception. With regular stand conditions, the predominance of clear cutting, uniform stand management, the exact statistics of the results of former management plans, and the ability of the permanent personnel, the ocular estimate has hitherto given good results.

2. **The Determination of the Annual Felling Budget. Rotation. (a) Measure of Utilization.** If a clear cutting system is employed, the normal annual felling area furnishes an easily applicable measure of the annual cut. The determination of the rotation depends chiefly on expert judgment (based on existing rotations, on the requirements of the market, and on the price (p. 240) relations of the timber size classes). To determine the normal rotations investigations were formerly made for the spruce (which occurs throughout the whole country) and index per cents were calculated for characteristic stands. For the calculation of the volume increments per cents ample material is on hand. The calculation of the value increment per cent is based on the auction prices of the various timber size classes, which compose the average cubic meter of the stands of the various age classes. The value relations of the log sizes (which are classified according to a middle diameter of 6, 6-8, 8-11, 11-14, over 14 inches) indicate the value increment per cent.

With regular stand conditions the normal felling area is observed as accurately as possible, which offers no difficulties in the prevailing clear cutting system. Under irregular conditions deviations become necessary. The age class condition serves as an indication of the degree to which these appear desirable or allowable. If the older age classes are in excess, more area is included in the felling budget, and vice versa. Great stress is therefore laid on an accurate estimate of the age classes.

(b) *Determination of Felling Areas.* For felling during the next period of management, stands are chosen, which, according to age, soil, and stand conditions are mature in order of the need for felling. Next in importance in the choice of the felling areas is the regulation of the felling series. Since the spruce predominates, this consideration is of great importance for the whole country. Regard for the danger of windfall demands that the fellings proceed in a direction opposite to the dominant wind. Since the annual clear cuttings remain narrow and only gradually merge, the general rule is that the felling series remain *short*.

In order to satisfy the demands of these felling rules and to counteract the dangers which the segregation (or grouping) of large, even-aged stands may provoke, it is necessary that one have command of a sufficient number of points of attack. To secure these, the boundaries of the stands must early be accustomed to an open position through the formation of low crowns, especially where those stands are located so as to be exposed to storm by the removal of old stands in front of them. This is accom-

plished by making the *management strips* sufficiently wide, by *severance fellings,* and by cutting around those stands that can still develop a wind firm belt.

(P. 241) The most important task of forest organization lies in properly locating the order of the felling areas. The contiguous felling areas assigned to the next management period should not be larger than the rules of the progress of fellings justify. The future formation of the felling series (their continuation, interruption, etc.) is dependent on conditions which (at the time of the making of the working plans) can not yet be foreseen.

(*c*) *The Justification of the Felling Budget.* The felling budget is listed separately as main cut, clearings, and intermediate cuttings (thinnings, cleanings and accidental cuttings). After the felling area has been decided upon, the main felling budget is based on an ocular estimate of the growing stock (on the felling area). Estimating has proven sufficiently accurate for purposes of fixing the budget. To control the total estimated volume, the amounts per acre (of felling area) are compared with the results of the last decade's fellings; important deviations from the average hitherto obtained must be justified. The actual annual increment (which is calculated according to sites and age classes with the aid of the yield tables) also indicates the felling budget. To compare the increment thus obtained with the yield possibility of the revier, the normal increment is also calculated by site classes.

The probable yields from thinnings are estimated on the basis of the results of the last decade (with the aid of yield tables) taking into special consideration the condition of the stands. The separation of broadleaves and conifers is made only if broadleaves form a substantial amount (of the stand).

3. **Statistics.** The data collected by the working plans bureau (for every revier and for the whole country) date back to 1817, or in part to 1844. The importance of permanent records for working plans (p. 242) can best be shown by the Saxon yield statistics; therefore their results may find place here. The most important data are:

1. **The Age Classes.** In the State Forest the present condition of the age classes is:

Class	I	II	III	IV	V	VI		
						Open and bare ::		Totals
Per cent	23	21	25	18	11	2	::	100

2. **The Sites.** According to the last accounts the qualities are:

	I	II	III	IV	V		Average quality
Site qualities %:	3	36	49	11	1	::	2.7
Stand qualities %:	1	16	53	25	2	::	3.13

3. **Growing Stock.** This has in the second half of the 19th century increased from 152 cubic meters to 187 c. m. per hectare of forest area (from 2173 to 2674 cu. ft.). In the last 30 years it has remained pretty much unchanged.

4. **Main Stand Increment.** The normal increment corresponding to the site quality is estimated for 1 ha. at 6.18 c. m.; the actual increment (corresponding to the stand qualities) at 4.84 c. m. (88 and 69 cu. ft. per acre). The annual felling budget of the last revision period amounted on an average to 4.21 c. m. (60 cu. ft.).

5. **The Fellings on 1 Hectare of Forest Soil** amount on the average to:

	1854-63	1864-73	1874-83	1884-93	1894-03	1894-08	
Timber	3.44	4.28	4.72	4.88	5.03	5.34	c. m. per hectare.
Total volume	5.01	5.85	6.48	6.43	6.39	6.23	" " "

6. **The Proportion of the Timber Size Classes.** The timber per cent has in the course of the past century risen from 17% (in the decade 1817 to 1826) to 82% (1904-1908).

7. **The Income and Expenditure and the Net Yield** in marks per ha. of the entire area amounts on the average to:

1817-26	1827-36	1837-46	1847-53	1854-63	1864-73	1874-83	1884-93	1894-03	1904-08
				Income:					
17.5	18.6	20.2	25.6	35.4	49.1	62.4	66.7	76	90.4 M
				Expenditure:					
8.0	8.6	9.1	10.2	11.5	13.9	20.8	23.0	28.9	33.2 M
				Net yield:					
9.5	10.0	11.1	15.4	23.9	35.2	41.6	43.7	47.1	57.2 M

8. **The Forest Capital** was estimated (in marks per ha. of forest soil) to be:

1854-63	1864-73	1874-83	1884-93	1894-03	1894-08
1156	1417	1682	1859	2206	2311 M

(P. 243) To calculate the forest capital, soil and stand values must be ascertained. The soil value is estimated for the average area of the different reviers on the basis of expectation values. The value of the growing stock (for stands up to 40 years) is calculated by cost value formulae. The interest rate is based on the relation of the net yield to the forest capital.

4. **Control and Revision.** The felling budget (classed as final and preliminary cuts) is summed up as a total budget (the amount of timber to be cut and controlled is fixed). At the end of the 10-year management period, a *main revision* takes place; and in the middle of the period an *interim revision*. In the *main revision* an entire redrafting of the working plan takes place (on the basis of a new valuation of the revier). In the *interim revision*, necessary additions and corrections are considered; especially; (a) forestation, (b) comparison of the felling results with the estimate, (c) deviations of the fellings from the plan and (d) miscellaneous. Moreover the nature of the revision is dependent on the changes in the forest management which have taken place (as compared with the working plan), while the details of the revisions are determined by the instructions on the formulation of new plans.

5. **Maps.** For the management plan the Saxon stand maps are of the greatest importance; these show (on the scale of 1:20,000 or 1:15,000) the species, the age and the felling series. The felling areas of the next decade, the sequence of fellings, the severance fellings and the liberation cuttings are specially marked on the maps.

IV. WÜRTEMBERG.

The Instructions (printed in 1878) for the elaboration and renewal of working plans had the combined allotment method as a basis. In the year 1898 these Instructions were changed and supplemented by new regulations which abrogated the area allotment plan and limited *the regulation of the yield to the allotment (p. 244) of the felling area for the first period.* These regulations are in force for State and institution forests. The most important regulations concern the preparatory work, the formulation of the working plans and their execution and revision.

I. **Preparatory Work.** The regulations regarding the formation of working groups and the subdivision for management are of the next greatest importance (i.e., after the prescriptions for the determination of the felling areas, the surveying and mapping).

1. **The Forming of Working Groups.** Different methods of management and diverg-

ence from the normal rotation are emphasized as reasons for their segregation. For each working group an independent age class relation (with special order of fellings) is to be attempted and a special felling series established.

2. **Subdivision. (a) Districts.** As a rule the different large forest areas of an administrative unit are segregated as districts. Their main purpose is to afford a simpler orientation.

(*b*) *Compartments* are considered as the *permanent* local cornerstone of management. It is intended in the course of time to eradicate the differences occurring within the compartments (and lots) which on account of their form and size do not seem convenient. The average size of the compartments in moderately large working groups, for broad leafed trees and conifers, must not exceed 35 to 50 acres. Their boundaries should be located as far as possible on natural contour lines and on roads to facilitate easier identification, to economize area, to protect the edges of stands and to enable the careful skidding of logs. "The main road system generally forms the basis of the subdivision."

(*c*) *Lots* are the unit for the felling and silvical measures of the working plans. The reasons for the segregation of lots (not to be too rigidly carried out) are:

(P. 245) I. When the stand and soil on a part of the compartment is so different from the rest that a similar management (especially simultaneous regeneration) cannot take place;

2. When some species occurs other than that dominating the compartment;

3. When the dominant species shows a variation in age of over 20 years.

The boundaries of the lots are generally not marked in the forest. The lots are shown on the map by small Latin letters, which also indicate the age classes (a = 1-20, b = 21-40, c = 41-60 years, etc.).

(*d*) *Felling Area Division.* In coppice and coppice under standards only the division into yearly or periodic fellings is necessary.

II. The Working Plan. The general order reads: "The entire management is to be so regulated by the working plan that its purpose may be attained as quickly and as completely as possible—the most advantageous use of the forest,—at the same time securing a sustained yield, and with due consideration of the objects and needs of the owner."

1. **Form of Presentation.** The most usual form of the working plan (from several in existence) is:

District and Compartment	comp.				Stand Description.				Age-Classes							Cultures				Main Yields of 1 Period.				
	Yield Area.	Letter.	Area.	Site-Class.	Age.	Degree of Cover.	Species and Stand Form, Relation of Mixture.	101 and more	81—100	61—80	41—60	21—40	1—20	clear.	Method of Management.	Thinings	Cleanings	Seeding	Planting	Area-Basis Yield (timber wood)				
																						1. Decade		Decade
																				f e d c b	Character of Felling.	Cu.	Character of Felling.	Cu.
								f e d c b a A								Area-plan ffı								
	ha.		ha	Years				Hectare									Hectare			Hectare		m.		m.

2. **Economic Data.** The stand descriptions are brief and are limited to the essential points necessary for clearness. The recent yield tables of Lorey, Weise, Wimmenauer, and Eberhard form the basis for site classification (which relates to the dominant species—if in the first decade a change takes place by planting other species). It is given by lots, if differences within the compartments are to be emphasized, otherwise by compartments. The average age of the dominant stand (determined for the management) is used. Stands with sharply defined age classes (especially those in process of regeneration) are assigned to different age classes according to the proportional area occupied.

3. **The Area Regulation Plan (p. 247).** In contrast to the former rules for the allot-

ment method, at present only the area for the first 20-year period is actually allotted. The standard for the utilization area to be segregated, is the normal area of the 20-year period; but where there is a deficiency of mature stands, this is reduced, and if an excess above the normal amount, it is increased. The recording of the areas is by lots. If a lot is only partly assigned to regeneration in the first (I) period, only a corresponding part of its area is to be allotted to the (I) period (except for special cases); the remainder is left out of consideration (i.e. in group regeneration cuttings, seed fellings, etc.). In choosing the stands to be regenerated, the following must be weighed: a consideration of these stands themselves, a good felling series, and an arrangement of stands with a corresponding local distribution of age classes. A development of the stands (injurious to the technically correct cutting) must be prevented by sufficiently early liberation and improvement fellings. In large conifer areas, a gradual formation of short and, so far as possible, independent felling series must be particularly striven for. Accurate stand maps (colored if possible) are to be used for planning the work (on which measures are also to be noted).

If, for the purpose of enlarging the basis of the area plan, it appears desirable to consider the second (II) period as well as the first (I), its area must be also segregated.

4. **Plan for the Main Cut.** Up to the year 1898 the regulation of the main cut was in accordance with the simplified combined allotment method (described in the literature of Grebe, Graner, and Stoetzer). At present the regulation of the yield is limited to the first (I) period. The total of the lot yields assigned to the (I) period forms the basis for the periodic budget. These yields are determined according to the condition of the stand, and after a consideration of the felling series and the age class relations. Accidental fellings are to be added to the cut (from the stands not included in the felling plan of the (I) period); . . . . these are estimated according to average conditions without trying to consider (p. 248) the amount produced by unusual natural phenomena. The main felling budget of the next decade is, as a rule, to be put at half the yield of the first period. All yield data refer to timber. The volumes for the (I) period are usually secured by calipering 100% of the stand.

5. **Area Plan of Thinnings.** For carrying out the secondary fellings of the first decade either a mere area plan is provided, or else in addition an estimate of the timber yield (in cubic meters). All secondary fellings are to be treated as thinnings without reference to the age of the stand.

6. **Other Matters in Working Plans.** Besides the plans named there must be added to the working plan: an area plan for cleanings; an area plan for the forestation to be carried out in the first decade; and a plan for the use of litter.

7. **Statistics.** Since the year 1882 annual reports are made, which give the results of the management of the past year. These also include periodically the results of the working plans.

III. Execution and Revision of Working Plans. I. Control. "In carrying out the main fellings in the timber forest," says the forest service manual, "as well as in standards (coppice under standards forest) a volume control is applied so far as a budget of volume has been set. For the secondary fellings (in the timber forest and in the coppice under standards) an area control is to be used so far as the working plan provided for thinnings." The unit controlled includes the cubic of timberwood (Derbholz, 3 inch diameter and over).

II. Renewal of Working Plans. (a) Main Revision, (p. 249). This takes place at the termination of a decade. Either an exhaustive revision of the working plan in its essential parts is made, or merely a correction of the existing plan (especially as regards the fellings and forestation) depending on the changes which have or are to take place during the decade, through natural occurrences or economic conditions.

(b) *Interim Revisions.* In timber forests of more than 750 acres an interim revision is made at the end of five years; this considers mainly the felling budget and the influence of any natural injuries on the utilization.

V. BADEN.

In Baden also the yield regulation has been first of all by the allotment method (volume allotment). This method, however, did not appear suitable under the prevalent forest conditions which are characterized by natural regeneration (especially silver fir). Since the regeneration of the fir (including the preparatory cuttings) required much longer than the 20-year periods, the management could not be adapted (as is the basic condition of a good method) to the framework of the yield regulation.

For about 60 years decennial revisions have been made in Baden working plans. The results (the budgets actually realized and their effect on the condition of the forest) form an important basis for practical management. The present method was introduced in the year 1869. Essential changes in the present rules are expected in the near future as evidenced by the literature. The most important points of the Baden method are:

1. **Preparatory Work (p. 250).** Before drawing up a working plan there is an inspection of the forest by the officials charged with the work and the last plan is carefully investigated in all its details. This investigation includes the subdivisions of the forest, the former site and stand descriptions, the estimate of the growing stock and increment, the results of the previous working plan and the principles underlying the future management.

The general descriptions refer to the data on the site conditions, the existing species, method of management, rotation, management rules, etc. For each compartment or lot there is a brief description of the area, the stand, the growing stock and the increment. The growing stock in the compartments under regeneration is calipered; elsewhere as a rule it is estimated by yield tables, past experience and by sample plots. For a long time special weight has been laid on the estimate of the current increment for regulation purposes because of the present stand conditions (there was otherwise no sufficient basis). The importance of increment for the regulation of yield is emphasized in the most recent instructions. In the report, yield tables and sample plot data are used; but in the elaboration of the working plan special local investigations are also made (in suitable stands). Besides the current increment (which is the objective of such investigations) the mean increment at the felling age (accepted rotation) is also established.

2. **Determination of the Felling Budget.** The determination of the felling budget is derived by Karl Heyer's method (i.e. felling budget = total increment in period of regulation plus difference of actual and normal stock divided by period of regulation). The actual increment is thus the main basis and measure of the felling budget. This increment was conceived and determined according to the Instructions of 1869 as current increment, "as it will probably take place in the next decade." In consideration of the difficulty of an accurate calculation and the limitation of the use of the results of the calculation on the main felling budget, it appeared advisable to let the mean increment at felling age take the place of the current increment (p. 251).

The growing stock is estimated for all age classes according to the actual volume of the stand. In each age class the normal stock corresponding to it (to be ascertained by the use of yield tables) is employed for comparison with the actual growing stock. The total normal growing stock is besides to be determined according to the formula, increment on total area for half the rotation. "More than the increment is to be used if an excess above the normal stock exists, the utilization of which appears silvically and economically advisable. Less than the increment is to be used when the full normal stock is not yet in existence. In the latter case the quicker the normal stock can be attained (by saving of increment) the better, provided that in doing so no essential economic loss or mistake in management is caused; in no case, however, shall the equalization period be longer than the rotation. With these principles in mind, the felling budget is determined for each given case according to forest conditions and the special needs of the owner; but it must not be forgotten how undesirable it would

be, for communities and corporations, to have any considerable variation in the felling budget in the various decades, and how greatly this variation would detract from the standing of forestry. A steady gradual rise in the felling budget will be considered much more desirable by every forest owner, rather than a rapid rise, which must be followed by a considerable fall later on; the reverse is also true. Moreover, it is to be expected that in almost every decade, extraordinary happenings and needs make extraordinary utilization necessary, and that therefore very often the established budget must be exceeded. In case of doubt therefore, it is good policy to be conservative. To the main budget (figured as above) the secondary fellings are to be added according to estimate. Overcuts and undercuts, which (according to the rules of management are to be compensated for in the new decade) must, in so far as they affect the main cut, be considered when the new budget is decided upon. The budget for the coppice and coppice under standards forests, which are regulated by area, is the actual yield of the annual felling area (and is thus determined by area and not by volume).

3. **Statistics** (p. 252) are closely connected with forest organization. A uniform method of statement was established in Baden in 1869 to simplify the general descriptions in working plans, and to obtain good data on forest history and yields. The administration officials begin the statistics, which are continued and completed by the estimators when the working plans are revised. The importance of good connected statistics for forest organization is clearly recognized in Baden. The most important statistical data are:

1. **The Rotation.** In the State forests 59.4% of the area is under 120 years rotations, 26% 100 years, 9.4% 90 years, and 3.4% 80 years.

2. **The Increment.** The actual volume increment at felling (rotation) age is placed at 4.9 cubic meters; the normal is 5.4 in the State forests.

3. **The Growing Stock.** This is shown since 1862, when it amounted to 220 cu. m. for the timber forests, a steady increase up to the present figure of 290 cu. m.; the normal growing stock is estimated at 299 cu. m.

4. **The Felling Budget.** This amounts (according to present conditions) in main fellings to 4.5 cu. m., in secondary fellings to 1.6 cu. m. The cut has increased from 4.67 cu. m. in the year 1867 to 6.31 cu. m. in the year 1907.

5. **Average Prices (for log classes according to the Heilbronner standard).** The average price per cu. m. has risen from 8.63 marks in the year 1867 to 13.71 M in the year 1907.

6. **Income, Expenditures and Net Yield.** The income per hectare has risen (1867 to 1907) from 44.03 M to 89.86 M; the expenditures from 36.9 M to 41.8 M, the net yield from 26.77 M to 52.31 M (with normal exchange, about $3.70 to $4.20 per acre).

VI. GRAND DUCHY OF HESSE.

The directions and aims which are followed in formulating working plans are characterized by the words: "The management (p. 253) of the State and communal forests is to be directed, with adequate consideration of the needs of the present, so as to increase the yield (qualitatively and quantitatively) as quickly as possible to the highest possible amount. In order to attain this object, the aim must be to bring the actual increment as nearly as possible to the normal."

The most important measures for the attainment of the normal yield condition are:

early utilization of poor stands, choice of species adapted to the site, technically correct forestation, thorough care of the stand, and rational thinning practice. The most important prescriptions in the Instructions refer to:

1. **The Construction of the Stand Table.** The document most characteristic of the working plan bears the title "Stand Table and Management Book (Wirthschaftbuch)" and is drawn up according to the following scheme:

District and Compartment.   Wooded Area—ha.

Group.		Site and Stand Desc., Soil, Situation, Exposure, Species in Decimals of Stand. Justification of Management Hitherto.	Aim of Management, and Measures for next Decade.	Principal Species and Age.	Average Height of Stand and Site-Class.	Growing Stock in Timber-and Brushwood According to Yield Table.	
lit.	Area. ha. $\frac{1}{100}$					For 1 ha.	For the Group or Compartment. cu. m.
1.	2.	3.	4.	5.	6.	7.	8.

Reduction Factor.	Actual Growing Stock in Timber-and Brushwood for Group or Compartment. cu. m.	Growing Stock in Over-wood Volume. cu. m.	Current.		Estimate of Yield in Timber-and Brushwood Expected in next Decade.			
			Normal Increment	Actual Incr.	Main Yield.		Intermediary Fellings.	
			For next 10 Years in Timber-and Brushwood on the Average Per Year and ha. cu. m.		a) Over-wood Volume	b) Other Mature Timber Cut.		
					In the Group or Compartment. cu. m.		Per ha. cu. m.	In the Group or Compartment. cu. m.
9.	10.	11.	12.	13.	14.	15.	16.	17.

The following explanations are also given (p. 255): Parts, within the permanent compartments (Abteilungen) are segregated as lots or groups (Gruppe), which differ from each other so essentially in site, species, age, growth, etc. that they must be under special treatment. The groups are designated on the maps by small Latin letters and are locally bounded by shallow ditches . . . . The organizer decides whether the parts (as small as .7 acre) of the compartment are adapted by situation, size and shape to special management . . . . If groups are based on site, they assume a permanent character; but if based on the condition of the stand they are temporary. These differences are in the course of time to be diminished or eradicated. The site and stand descriptions follow the rules of the Forest Experiment Stations. Measures for the essential establishment and development of the stands are given in the stand descriptions.

The objects of management (as the stand appears at the time of survey) are entered in the plans; as a rule the local officer in charge coöperates directly in drawing up the working plan. The "objects of management" are not, however, binding for all time; it is only to assist newly appointed officials and changes may. be ordered at the time the annual working plan is drawn up, or be agreed upon at inspections. The urgently necessary measures of the next 10 years are to be briefly stated by the administrative officer.

In mixed stands the main species determines the management. Height forms the most important basis and measure of site classification. In every lot or group the average height of the stand is determined by measuring several stems of about medium height; on the basis of this height *and age,* the site classes **are** established according to the standard of current yield tables. The normal growing stock is also taken from the yield tables; the actual growing stock is found by multiplying the normal stock by a reduction factor, which like the full yield factor in Prussia is expressed by a decimal (p. 256). The current (normal and actual) increment, which appears in the stand table, refers to that part of the total increment, which goes into the permanent stand. The normal increment is found by subtracting the growing stock volume of the main stand (as found in the yield tables) at age (a) from that at (a — 10) and then dividing the difference by 10. The actual increment is found by multiplying the normal increment by the full yield factor.

2. **The Calculation of Growing Stock and Increment.** In order to give the total normal increment and normal growing stock, a statement of the site classification for the future main species is required. The normal increment, arranged according to species and site, is calculated as mean increment at felling age. On the basis of the conclusions of such a statement the normal increment and the normal growing stock may be figured from current yield tables. The calculation of the normal growing stock is made under the assumption of regularly graded age classes (I. 1-20, II. 21-40, etc.) the normal area of which is determined by their relation to the total rotation. The estimates of yield are made to the middle of the age classes. By adding the estimates of the different site classes, normal increment and normal growing stock for the different species is obtained. The total normal increment and normal growing stock is then found by adding the figures for the different site classes. The age class table serves as a basis for the statement of the actual growing stock; the area and the actual growing stock in timberwood and brushwood is given for every age class. At the end of this tabulation, the areas and growing stock of each age class are compared with the normal age classes and the normal growing stock. The budget is based on the result . . . . . .

3. **The Protocol of the Council.** After the preparation of the data cited above, a protocol of the council is taken down which is to be submitted to the ministerial division for approval. This must cover: the species to be planted or to be favored in the future, the rotation, the possibility of a uniform period of organization, the sequence of thinnings, the present silvicultural method of management, any contemplated changes, the normal felling area and the formulation of management rules.

4. **The Formulation of the Budget and the Method of Utilization. (Logging Practice).** 1. **Felling Budget (p. 257). A. Utilization in Mature Timber.** The normal felling area forms the basis for utilization, covered by the working plan. If the stand conditions are regular, it is sufficient to draw up the felling plan for a decade. Irregular conditions may indicate the desirability of planning the expected fellings for two or more decades. Deviations from the normal fellings are to be mainly justified as follows:

(*a*) *The Relation Between the Actual and Normal Growing Stock.* Present differences are to be diminished unless a change of rotation is contemplated. To determine the propriety of felling a growing stock surplus or of making up an existing deficit all silvicultural and financial conditions must be exhaustively considered.

(*b*) *The Age Class Relation:* The growing stock of the 2 or 3 oldest classes is to be especially considered; if the actual growing stock does not differ essentially from the

normal and if an appropriate part of the stock is found in the 3 oldest classes, the sustained yield may be considered as assured.

(*c*) *The Relation of Fellings to Increment.* A comparison of the felling budget with the actual increment gives an indication whether, in the next decade, a diminution or increase of the growing stock may be expected.

2. **Determination of the Felling Areas and Progress of Regeneration.** Areas of slow growth, where the increment differs most widely from the normal, should be felled first. Stands are chosen for the felling budget upon the following basis: I. Stands in need of felling: (a) Stands and parts of stands with poor increment, (b) remnants of high forest, improvement fellings, and clearing for roads, (c) parts of stands which must be sacrificed to establish a felling series; II. Mature Stands (p. 258); III. Questionable Stands. Great stress is laid on a regular felling series and a good distribution of fellings. Large areas of even-aged stands are to be limited as much as possible because of the dangers from storms, insects, etc. and to facilitate the local distribution of wood supplies. The Instructions prescribed, therefore, the formation of short felling series with cross-roads, railroads, rides, roads, watercourses, valleys, mountain crests, etc. as boundaries.

3. **Determination of the Wood Volume.** The following rule is of interest: "The stands selected for the main felling budget for the next 10 years generally need not be calipered; the volumes of the felling budget can be based on yield tables or on estimates. Errors in estimating (due to this mere approximation of the main felling budget) if they are established at the time of felling, may be corrected by changing the felling budget within the 10-year management period or at the close of the period.

II. **Secondary Fellings.** The thinnings (whose yields are entered in the table above mentioned) are listed in an area and volume budget corresponding to the main yield. The area budget is so made that about 1/10 of the total area to be thinned is felled annually, so that the felling is extended equally over younger and older stands, and if need be over stands of different species. The yield estimate is based on the yield tables, after carefully considering the actual conditions of the stand in question. Considering the difficulty of establishing and executing adequate thinning budgets, a rule has been made, that, at the close of the annual working plan, a compilation of the periodically thinned areas must be prepared. If it is found that according to this area statement, the secondary fellings are not progressing fast enough, the secondary felling budget must be increased accordingly.

5. **Mapwork (p. 259).** The stand maps made to accompany the working plan on the scale of 1 : 10,000 show the age classes by color, the species by tree figures, the sites by broken lines.

6. **Control.** An efficient control covers the total felling, main and intermediary, timberwood and non-timberwood.

VII. GRAND DUCHY OF SAXONY.

The Preparation of Working Plans (including surveys and check of management rules) is assigned to a special bureau ("Taxation Commission") whose president directs all work. Assurance of a present and future sustained yield is considered of first importance in forest organization, provided forest production maintains and increases the fertility of the soil, and the highest yields are produced in the shortest possible time.

The subdivision into permanent management units (compartments) has been carried out in a systematic way; in the plains by a net work of regular lines and in the mountains via contours connected with the road system. The average size of compartments is about 62 acres, and lots, if adequate stand differences exist (which form the basis of the management), are segregated to a minimum size.

Stand volumes for the first decade are secured by special stock taking, which gives for each stand: number of stems, diameter, height, form factor, increment in diameter, basal area, volume and increment per cents. The results of the volume calculations are filed with the Commission. The forest experiments on yield are connected up with forest regulation; in fact the president of the "Taxation Commission" directs the estab-

lishment of sample plots where the influence of the various methods of stand regeneration and treatment are studied . . . . . .

In each lot, description, area, site, age, height, and character of the stands are to be noted and (p. 260) entered in a survey register, which contains also the preliminary rules for management. At the same time the age class table is drawn up and placed opposite the periodic felling area plan.

The method of yield regulation is the combined allotment, which was upheld in literature by Grebe, for many years the director of the Grand Ducal forest organization. At present it is only used in its simplest form, in such a way that the yields are only shown for the first two periods. The main working plan is therefore to be formulated according to the following form:

	Results of Management.						
	There Was Felled:				Forestation:		
Year of Management.	Area.	Volume.	Designation of Felling Method and Number of Record.	Plant and Seed Supply. Character of Forestation.	Area.	Costs.	Secondary Uses.
	ha.	cu.m. $\frac{1}{100}$			ha.	m. | pf.	
18.	19.	20.	21.	22.	23.	24.	25.

The areas and volumes of the first (20-year) period are shown separately for the first and second decades. The timber yields in cubic meters are derived by adding the increment (up to the middle of the utilization period) to the present volume. The annual main felling budget is found by dividing the budget of the first decade by 10. Thinnings are regulated by area, but volumes are checked by local yield table estimates and special investigations. The control of fellings and forestation is according to the following scheme:

Property.			Actual Growing Stock.		Regulated Management.					
				Volume and Increment.	I 20 Year Period. from to					
					1. Decade. from to			2. Decade from to		
Designation and Character.	Area.	Site-Class.				Wood Yield.			Wood Yield.	
				per ha.	Total.	Felling Area.	per ha.	Total.	Felling Area.	per ha.	Total.
	ha.			cu. m.		ha.	cu. m.		ha.	cu. m.	

Felling Area.	II 20 Year Period. from to		III 20 Year Period.	IV 20 Year Period.	V 20 Year Period.	VI 20 Year Period.	Reforestation Area in First Decade.	Rules of Management.
	Wood Yield.							
	per ha.	Total.						
ha.	cu. m.		ha.	ha.	ha.	ha.	ha.	

The volumes of actual thinnings are compared with the budget. Revisions occur as a rule every 10 years (p. 261). The policy concerning silvicultural methods, rotations, as well as all conditions influencing the treatment of the forest must be clearly stated. The revised tables must show first of all the results of management during the past decade; next the plans for the coming decade. Otherwise the (working plan) revisions (which are similar in detail to those adopted by other states) depend on the changes which have taken place in the condition of the forest during the last decade.

Year.	Lot.	Areas.		Wood Yield.						Cultures.		Special Data as to Method of Felling and Cultures.
		Clearings.	Intermediary Fellings.	Timber.	Fuel wood.		Main Fellings.	Intermediary Fellings.	Root-wood.	Area.	Costs.	
					Wood.	Brush-wood.						
		ha.			cu. m.		cu. m.		rm.	ha.	M.	

VIII. ALSACE-LORRAINE.*

When formulating new working plans (for forests for which there are no plans, or if there are plans, after the expiration (p. 262) of the 20-year period, after essential changes in area, after considerable overcuts due to windfall, insect injuries, etc., or when changes to other silvicultural methods are contemplated) a preliminary project (which must include the map for subdivisions and road system as well as regulations regarding the methods of management and rotations) is drawn up by the revier supervisor; this is examined by the Forest Inspector and finally accepted by the Minister.

The most important regulations for the formulation of working-plans are:

1. **Subdivision.** The formation of permanent management units (compartments) is

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* See also the discussion in "Studies in French Forestry" already cited. German Forest Management in Alsace-Lorraine, now restored to France, is of special value to the student of regulation, especially when compared with French technique.

connected up with the road system. The area of the compartments must not as a rule exceed 25 to 37 acres in conifer stands, or 37-50 acres in broadleafed stands. Coppice and coppice under standards are subdivided into yearly felling areas as the local basis of management. In communal forests (as was prescribed in the ordinances of Colbert) one fourth the area is first to be set aside as a reserve. No binding rules are given for the formation of lots. In large forests (if several species are concerned) the smallest lot is 2.5 acres, provided a good boundary is possible, ... otherwise 5 acres . . . . . . where stands are being regenerated . . . . 2½ acres . . . . or if old timber is clear cut . . . . . The lot corners must be marked locally by stakes and non-continuous ditches and entered on the maps. The compartments are labeled as in Prussia with Arabic numbers, fellings in coppice under standards and selection forests with Roman numbers, lots with small Latin Letters, while non-forest soil is indicated with German letters. With new subdivisions (p. 263) the numbering of the compartments and lettering of the lots is from the northeast towards the southwest, so that compartments and lots always bear higher numbers or later letters towards the wind direction.

2. **Surveying and Mapping.** Survey work is as a rule limited to changes in interior subdivisions, since usable maps exist for the whole country. After the survey of the compartment and lot lines, highways, roads, and water courses, etc., the special map (or office map) is to be brought up to date by the working plans officer. With the corrected special map as a base, a control (Uebersicht) map, which differentiates the species by color, is to be made on the scale of 1:25,000. The dates of utilization are only given for the areas assigned to the (I) and (II) period. The symbols used are: (1) first period areas, (II) second period, (I. II.) areas to be regenerated within 40 years, (Pl.) selection stands, (S.) scenic forests; areas designated for oak reproduction (at least ⅓ acre in area) are outlined in red on the management map and must be marked in the forest.

3. **The General Description of the Revier** digests the characteristic features of management regarding the general condition of the revier (as regards ownership), boundaries, survey, etc., site conditions (climate, configuration, soil); the occurrence and preservation of the main species; the previous management and its results; future management, especially the species, methods of silviculture, rotation; formulation of management regulations for fellings, for regeneration and development of the stands, the location of the road system and subdivisions; the wood market, secondary uses, hunting, etc.

4. **Special Description of Site and Stand.** Site classes are given as a rule (if the lots do not show decided differences), for the whole compartment. They are based on the yield capacity (as compared with existing yield tables). Descriptions of situation, soil, and stands are as agreed upon by the Union (p. 264) of Forest Experiment Stations. The mineral content of the soil, its freshness, depth and humus content is gauged by sample borings; stand descriptions are brief to the exclusion of all unessential or self-evident statements.

5. **Segregation of Age Classes.** Age classes are formed for each species; when different ages occur the areas are separated, especially stands under regeneration where the wood volume is divided into old timber and young growth.

6. **Measure of Utilization and Periodic Area Division.** The normal periodic area serves as a measure for the periodic cut in the present management period. If all the stands are to be managed under the same rotation, the normal felling area for a period is obtained by multiplying the area by 20 r. (where r = rotation). If several rotations are used, the normal periodic felling area is similarly determined for each species separately; the total felling area is then found by adding up the areas for each species. The stand volumes for the first period (in which regeneration cuttings have begun) are reduced in accordance with the age classes. A further allotment of stands for the III, IV, V, and VI periods is not made; these are simply listed in the column "Later Periods." In selecting the stands for the periods, their age and vigor must be taken

into consideration. In conifer stands the formation of short felling series is recommended. The rigid allotment method is no longer in use in Alsace-Lorraine.

7. **Scaling and Listing of Wood Volumes.** Because of large contiguous stands of old timber and the long regeneration period (p. 265) the periodic area . . . . . . usually includes two periods. The volumes of all uncut regeneration fellings (Nachhiebsreste) of the (I) period as well as the mature and nearly mature stands of the (II) period are usually calipered. In regular stands of the (II) period the growing stock is approximated by sample plots . . . . . . The volume of the second period is subtracted from the totals of the two periods . . . . increment (calculated to the middle of period) added to determine felling budget . . . . . .

8. **Felling Budget.** This is obtained by dividing the totals of the volume measurements by 20. The felling budget, calculated in cubic meters of timberwood, is listed separately for the main and secondary fellings, by the four species groups: oak, beech, other broadleaved trees, conifers. In the communal forests a quarter of the area is held in reserve from the calculated main felling.

9. **Regulation of the Yield in Coppice and Coppice Under Standards.** The yearly cut in these forests is arranged in regular sequence in flooded districts in the direction of the water flow. In coppice under standards the standards are calipered (and calculated) by age classes . . . . . .

10. **Regulation of Yield in Selection Forests.** The felling budget is calculated from the actual increment and according to the relation of the actual to the normal growing stock (by the K. Heyer formula, felling budget = actual increment + or — difference of actual and normal stock divided by "equalization" period). To get the actual growing stock all stems 3 inches and over are calipered. The actual increment is (p. 266) determined (p. 266) by special investigation on stems of different diameter classes; the normal growing stock is figured by the formula rotation × mean increment (at felling age) divided by 2 (or mean increment at felling age multiplied by half the rotation). The length of the "equalization" period is determined in each case. The cutting cycle is usually short, i.e. 7-9 years.

11. **Forestation and Road Building Plans** are always included in the working plan. The Forestation plan includes; formation of stands, nursery work, seed collection, care of felling areas and trees, ... emphasis is laid on the care of the soil . . . . irrigation and drainage . . . . protection ditches and leaf catches. For the planning, building and maintenance of logging roads detailed and careful directions are given.

12. **Working Plan Revisions** take place in the middle of the 20-year period. The kind and extent of the work to be undertaken is dependent on the demands which are made on the working plans, and the changes which have occurred through management or through outside influences, in the first half of the management period. The data include; changes in area, annual felling volume and its comparison with the working plan, compilation of the final cuttings and comparison with the estimated yield, extraordinary fellings, secondary yields, execution and cost of forestation, changes in servitudes, influence of secondary logging, the road building, etc.

IX. AUSTRIA.

The most important technical instructions for the organization of the Austrian State forests concern:

1. **Subdivision of the Reviers (p. 267)** begins, where necessary, with the segregation of the protection and "ban" forests. Special protection belts are set aside where the forest reaches timber line . . . . The commercial forests have: management classes, felling series, compartments, and lots.

(a) *Management Classes.* Different working groups . . . . are formed for large contiguous forests because of differences in: transportation or market, method of treatment (high forest, coppice, etc.), method of cutting (clear cutting, natural regeneration, selection forest, etc.), rotation, or existing limitations of management.

(b) *Felling Series.* The working groups are divided (where sequence of fellings is

of consequence), into felling series, which are defined as "a contiguous series of felling areas." Their formation is dependent on the contours, the species and the kind of regeneration. The size of the felling series is determined by the size of the management unit, species, method of management, logging and transport conditions, but should not as a rule comprise more than three compartments. The boundaries of the felling series are formed along contours, or by roads, fire lines, or management strips opened up along the division lines to a breadth of 15-25 feet to develop windfirm border trees . . . . Younger stands . . . . . . exposed to the wind are protected by severance fellings . . . . . .

(c) *Compartments.* The boundaries of the management classes and felling series form the framework of the compartments . . . . adapted . . . . partly to the mountain ridges and valley depressions, and to the existing roads, railroads, etc. Where these (p. 268) do not suffice for subdivision boundaries, artificial rides are made . . . . The length of compartments (which corresponds with the breadth of the felling series) is 2400 to 3000 feet—the breadth about 1800 feet . . . .

(d) *Lots.* The reasons for forming lots are differences in: management and treatment, species in pure stands, mixture . . . . ; mean stand age (10 years in young pole high forests, 20 years in old timber), in site class or yield capacity when these clearly show themselves in the uneven development of the same species, especially height growth, on contiguous parts of an area, in stocking, need of reforestation . . . .

In the forest, the lot boundary lines are shown by small signs, shallow blazes, painted rings, timber scribe marks on trees and poles in old stands, and by narrow lanes in young growth.

2. **Survey and Description of Forest Conditions.** (a) **Preparation of Yield Tables.** It is generally prescribed in the organization of State forest reviers that yield tables shall be made for the different methods of treatment, species and site classes. These are based on carefully selected and combined sample plots (p. 269) . . . . . The data secured are as follows:

Age.	Number of Stems.	Sum of Basal Areas.	Diameter of Average Stem.	Average Stand Height.	Av. Annual Height Increment.	Wood Volume.		Increment.			Secondary Stand.
		At Breast Height.				Timber-wood.	Wood and Brush.	Average Annual.	Age Average.	%	Wood and Brush-wood.
		m²	cm.	m.		cu. m.					cu. m.

(b) *Stand Descriptions* contain: (1) Statements on the condition of the soil (subsoil, root space, humus contents, cover) and situation (slope, exposure, etc.). (2) Species, mixture, ... The space each species occupies is expressed in decimals. (3) Age. Mean, minimum, and maximum age is given.

The compilation of age classes is given in the age class tables separately for each

working group . . . . The areas under regeneration are entered in the column "Regeneration Class." The areas are also distributed as accurately as possible in the columns: "(old timber," young growth," and "openings or clearings)" (p. 270) . . . .

4. **Index of Yield.** The productivity is shown by: (a) The stand mean; (b) The total basal area; (c) The site class. To this must always be added the species to which it relates. In mixed stands only the main species is considered; (d) Per cent stocked . . . . .

5. **The Growing Stock; (a) Main Stand** . . . .
Secondary Stand (Zwischenbestand, Nebenbestand). This includes . . . . all suppressed trees and those that suppress the main stand (therefore to be removed if not resulting in undue openings). Secondary stand volumes that probably can not be utilized in the coming decade, are not given in the estimates.

6. **Mean Increment at Probable Felling Age** . . . . uncertain plantations are omitted . . . . .

7. **The Volume Increment Per Cent,** calculated according to the formula $i = \left(\dfrac{200}{n}\right) \left(\dfrac{M-m}{M+m}\right)$. M and m $=$ volumes n years apart. The volume and increment calculations in young and medium aged forests are as a rule from yield tables; in nearly mature and mature stands, on the contrary, an accurate calculation of the growing stock is always made. Unevenly stocked areas . . . . . . less than 5 acres in area, are completely calipered. In regular stands sample plots (5-10% of the stand area) are selected in suitable locations (p. 271). The volume calculation is based on mean trees . . . . All volume and increment figures are compiled and appended to the working plan.

8. **Quality Increment Per Cent,** calculated according to the formula $b = \left(\dfrac{200}{n}\right) \left(\dfrac{20-q}{20+q}\right)$ in which $Q - q =$ average net difference of value, $Q + q =$ the sum of values of the average cubic meter . . . . ., n $=$ the number of years which the stem requires to grow from one class to another.

9. **The Index Per Cent** (after Pressler) calculated according to the formula: $W = \dfrac{H}{H+G} (a - b)$, where a $=$ volume per cent, b $=$ value per cent, H $=$ the average value of the stand, G $=$ base capital (soil, administration and forestation capital . . .).

10. **Notes on the Management of the Stand** (time and method of utilization, cleaning, thinning, pruning, reforestation, drainage, etc.).
General Description. This records the current natural, legal, political, technical, commercial, financial and organization conditions, and includes especially: the area of the administrative unit (separated into forest and non-forest soil), how the non-forest soil will be used, ... property and legal conditions, boundaries, agricultural uses, water conditions, topography and soil, situation, climate, atmospheric influences, stand conditions, their history and management up to date, timber volume and money yield, secondary uses, hunting and fishing, timber prices in the forest and at the market, statements regarding personnel, etc.

3. **Determination of the Felling Budget.** This is given for a decade. The product is classified as main fellings, intermediary fellings and accident fellings.

All yields (p. 272) from the felling areas (selected for the next management period) belong to the main cut, as well as those accidental fellings that necessitate reforestation on at least .8 acre. Timber from windfall, snowbreak, frost or insect damage, and stolen timber recovered are entered separately as accidental fellings. The yield from weedings, thinnings and other improvement fellings . . . . are classed as secondary fellings.

(a) *Main Felling.* The normal felling area forms the basis for the allotment to the next management period . . . . The determination of the rotation . . . . is based on the following policy: If there are no forceful reasons (due to transportation conditions or market) for the retention of the present rotation (especially if very high), the new

rotation should aim at securing an adequate interest rate on the capital investment. Those stands are considered mature where the index per cent has sunk below the current rate of interest (provided fellings are possible, with due regard to the rigid demands of the felling series).

Unquestionably the following stands must be alloted (for utilization) to the next period: necessary severance fellings, safety strips, irregular stands with low increment (whose speedy regeneration is desirable because of low increment and poor soil conditions), and finally those stands which must be sacrificed to obtain a proper felling series. In irregular stands the felling areas are to be corrected . . . . The Instructions prescribe: "In determining the main yield in the annual management plan for each working group, on the basis of the age class table, it must be stated whether mature stands or stands capable of being cut and younger age classes (to be cut later) are sufficient, whether the cutting of mature growing stock is to be curtailed (and if so for how long), or whether, on the basis of general management rules a more rapid utilization of any existing volume surplus is desirable or justified (p. 273). "The time in which the creation of the normal age classes is to be attempted, is to be based on expert advice. The budget justifies the determination of the normal felling area by a summary of past fellings and the influence which these fellings have had on the development of the age classes. The age class conditions are therefore shown for a considerable period." "These comparisons and considerations," say the Instructions at the close of this section, "will lead to a final determination of the felling area; and the calculated volume (increased by the current mean increment up to the middle of the period of management), forms the volume budget for the decade. The strictly sustained yield is not necessary for each working group, except in those forests which are heavily burdened with servitudes.

(*b*) *Secondary and Accidental Fellings.* Secondary fellings are classified as cleanings, weedings, thinnings, and fellings of seed trees* in young stands. The secondary fellings budget is found by summing up the proper merchantable volumes (estimated for each lot in the stand descriptions . . . .). The estimate for accidental fellings for each working group is summarized according to the records of past years, or according to experience.

(*c*) *Estimate of Yield in Selection Forests.* Since the selection forest aims primarily at the protection of the soil, and since a regular sale of the cut is frequently unfeasible, the determination of a sustained yield budget (according to the definite established method) is usually given up and the felling budget is estimated by judgment.

4. **Control and Revision.** To show the changes which have taken place in the course of the management period, a number of records are kept by the administration; these control the estimates of the working plan and its execution, and serve as a basis for future revisions. Of special importance is:

(*a*) *The Journal* (p. 274) which is similar to the general part of the Prussian ledger (Hauptmerkbuch). In it, are recorded: all changes . . . . occasioned by fellings . . . . contrary . . . . to plans, changes in area or boundaries, in transportation and communication, important injuries by man, natural phenomena, fires, etc.; also statements about hunting and fishing, labor conditions, statistics regarding volume and financial results, works for the control of torrents, forest experiments, personnel, etc.

(*b*) *The Management Book* (like the Prussian Control Book and the special part of the ledger) is divided into two parts. The first gives for every single lot (Kontrollfigur) the cut of material in round numbers (divided into timber and fuel wood, hard and soft wood, main, secondary and accidental fellings) together with the respective felling areas; also the reforestation carried out (divided into sowing and planting) as well as drainage data and the care of the felling areas and stands. The second part

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* So called "overholders" are not misshapen trees stealing light and food from the main crop but instead are trees held over from the former crop to furnish seed.

contains the annual compilation of fellings from the whole administrative district and the check of fellings (actually cut) together with their estimates.

(*c*) *Statistics* concerning: changes in ownership, cut of stands (compared with the estimate), fellings (compared with the volume and area given in the felling budget) not prescribed in the plan, forestation and cost, income and expenditures, material and money results, etc.

There are 2 kinds of revisions: (1) intermediate revisions, which become necessary in the course of the management period, due to unforeseen conditions (windfall, injuries by insects, etc., and (2) regular periodic revisions, which are undertaken the last year of the decade (for which the working plan was drawn up). The most important problems of the periodic revision are: In the first place an investigation as to whether the working plans have been closely adhered to in all parts, whether and to what extent the deviations have been justified, and how far the regulations of the old working plan have been proven correct in detail and as a whole. Secondly, the correction of the existing geodetic and mensuration data (or such new data as may be required for the next decade's working plan). Thirdly, the preparation of the working plan for the next decade (p. 275). The intensiveness of the revisions depends on local conditions, but as a general rule the work must be done according to the "Instructions for New Forest Organization."

X. FRANCE.

See "Studies in French Forestry," by Theodore S. Woolsey, Jr., John Wiley & Sons, 1921, pages 206-261, 469-495, and 500-534, for a discussion of regulation in France.

APPENDIX A. (b) FINANCIAL ROTATIONS (FROM ENDRES).

A. Concept and Reckoning. By financial rotation we understand that period which, *according to the soil rent theory*, will produce the *greatest land rental*. It therefore falls at the time when the proceeds from the land are greatest.

a. *The financial rotation of single stands.* If the stands are normal one reckons the soil rent for the several age classes (considering together those having similar earnings and cost) and the financial rotation is fixed at that age which indicates the greatest land returns. If it is a case of fixing the rotation for a stand not yet planted then one has to have interest tables to guide him in the work of fixing the rotation period.

It is obvious that the rotation period found in this manner is valid only so long as those data, which has been used to figure out the rotation, remains unchanged. Each permanent change of these conditions also causes a change of financial rotation.

Since there is no cost of administration and management the cost is very small and owing to the fact that it would have a long drawn out effect upon the final interest, it suffices to state, for the final rotation, the following formula:

$$B_u = \frac{A_u \text{ plus } D_a \text{ I, o } p^{u-a} \text{ plus } \ldots \ldots}{\text{I, O} p^u - \text{I}}$$

Where B = Capital land value.

A = Yield.

D = Value from thinnings.

u = Years in rotation.

a = Time of thinnings.

Or, when the thinnings that have been computed ahead are expressed as a per cent of the yield, we have

$$B_u = \frac{A_u \cdot \text{I.o}d}{\text{I, O} p^u - \text{I}}$$

The financial rotation or better still the rotation in *abnormal stands* is arrived at.

(a)   Through figuring the largest future return.

(b)   Through figuring the growth per cent.

In both cases we consider the maximum normal use of the forest soil for continual use. If we contemplate putting the soil to other uses such as farms or sale then we must figure in the higher value.

This formula could also be used to figure future value of *normal* stands. The largest future stand value of normal stands is figured on that rotation in which the soil rent culmination and the per cent earned will at the same time be equal to the rate of interest.

Owing to its simplicity the growth per cent is used in preference to the method of largest future returns.

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b. *The financial rotation of the working circle.* In order to approximate the area on which money returns will be forthcoming yearly, and to make sure of the area to be thinned the forest working plan must set forth some definite time limit as a working basis, that will suffice for the timely or orderly use. This time limit will serve a general rotation period of the working circle.

Because the largest forest is never made up of equal working stands it is impossible to figure rotation by a mathematical formula. It is more likely to be the average financial rotation of all single stands, from which again the older marketable wood must be given primary consideration.

We cannot measure the influence which the general rotation will have on the single stands. We cannot characterize it as Kraft has done.

The length of the general rotation is influenced by the financial working of the single stands. The financial producing power of the stand depends on the manner of handling. . . . . . . It does not all depend on whether the stand has a general rotation that is too long or too short; whether the stand is too old or too young; whether or not the age of the stand surpasses the general rotation; or whether the stand is growing on good agricultural soil. These are all considerations but they do not determine the rotation period. *It is, moreover, through the use of growth per cent that we get at the producing power and usefulness of the stand.* This is arrived at through the measurement of the product. All stands that cannot come up to the desired quantity of products should not be considered for felling; they deserve consideration on account of their growing condition for the building up of a good later cut.

In normal forests the financial rotation falls at the time when the formula gives a maximum result.

$$\frac{A_u \text{ plus } D_a \text{ plus } \ldots D_q - (c \text{ plus } uv \text{ plus } uNO. \ Op)}{u}$$

This period of time culminates with the soil rent period, because:

$$\frac{A_u - D_a - \ldots D_q - (c - uv) - N. \ O. \ Op = (B_u \text{ plus } N) \ O. \ Op - N. \ OOp = B_u}{u}$$

By N is to be understood the soil rent value of the figured rotation "u" or, the value of the soil under normal conditions. Therefore it is shown that the use of the first formula is a roundabout manner of determining the financial rotation; having to figure first the soil value for different rotations it is useless to figure financial rotation by the first formula.

In recent times, Martin has used the first formula however with certain changes. He used instead of expected value or cost value the value it would have if of actual use. This is theoretically unreliable. Nothing is gained thereby from a practical standpoint as the determination of the actual value of usefulness of young stands is very difficult and, more often, impossible.

B. The Length of the Financial Rotation. *The length of the financial rotation is influenced by all of the following factors which affect* the climax of the soil rent. Of the aforementioned facts it is important to note (p. 72). Of *great influence is the rate of interest used.* For high interest rates you figure short rotations, for low rates long rotations . . . . . .

That you exercise care in the general handling and forest management of the two

categories of soil;—namely, *profitable* and *unprofitable* soil. For the question of putting through and continuing the financial rotation only the *productive soils can be given consideration as forest soil.*

In soils belonging to the unprofitable category you figure for pure, even-aged, closed stands with a working interest of 3% a financial rotation of from *60 to 90* years. The absolute length of the rotation depends principally upon the value of older stands to the younger stand. *The longer the value continues to increase the longer will be the rotation.* Of primary importance is the *quality* increase. Should the quality increase soon cease and should it not be possible to continue the quality by clearings and liberation cuttings then the rotation will be much *lower.*

In dense even-aged stands the financial cutting period comes later with poorer soil and slower growth. In both cases the quality increase of the wood is concentrated on the *higher stand ages.*

From the measurements by Oberforster Schulze (Allg. Forst und Jagd. Zeit. 1889, p. 329) the financial felling age in the Royal State forests using $p = 3\%$ is shown in the following table:

<div align="center">

SPRUCE.

</div>

On	2%	of the area	=	1,200	ha.	in the	55– 60	years
"	9%	" " "	=	5,700	"	" "	60– 65	"
"	25%	" " "	=	16,500	"	" "	65– 70	"
"	21%	" " "	=	14,300	"	" "	70– 75	"
"	21%	" " "	=	13,800	"	" "	75– 80	"
"	7%	" " "	=	4,800	"	" "	80– 85	"
"	11%	" " "	=	7,300	"	" "	85– 90	"
"	2%	" " "	=	1,500	"	" "	90– 95	"
"	2%	" " "	=	1,200	"	" "	100–10–	"

(The highest rotations fall on the ore mountains of Saxony.)

<div align="center">

PINE.

</div>

On	7%	of the area	=	1,500	ha.	in the	50– 55	years
"	20%	" " "	=	4,400	"	" "	55– 60	"
"	26%	" " "	=	5,600	"	" "	60– 65	"
"	19%	" " "	=	4,000	"	" "	65– 70	"
"	6%	" " "	=	1,300	"	" "	70– 75	"
"	12%	" " "	=	2,600	"	" "	75– 80	"
"	10%	" " "	=	2,200	"	" "	80– 85	"

For the spruce stands of the Thuringerwalder, Forstmeister Schmidt shows the lengthened time of the financial rotation for the different soils, gotten at by figuring the growth per cent. Figuring $p = 3\%$, the table shows the following average yield per cents:

for 87–92 year old stands of	II soil 2.74%
	III soil 2.89%
	IV soil 3.28%
for 95 year old stands on	II soil 2.86%
	IV soil 2.97%
for 97–105 year old stands	II soil 2.66%
	III soil 2.57%
	IV soil 3.14%
for older stands	II soil 2.60%
	IV soil 2.79%

Wimmennaurer figured in three different forests of the Grand Duchy Kissen for the pine II and III stand classes; rotations from 60-70 years when $p = 2.5\%$. He remarks that by *introducing liberation cuttings* many rotations are reduced from 120 to 100 years.

Oberforster Walter figured, in his forest Grebanare, the following growth per cent values for the pine:

(Allg. Forst und Jagd., 1888, p. 202.)

Age	60 years	80 years	100 years	120 years
for p = 2%	$149	$163	$153	$131
p = 2.5%	. 100	104	93	76
p = 3%	70	68	58	46

C. Estimating the Financial Rotation. For the unprejudiced forester it is needless to say that it is practically impossible to set a definite year for the determination of the financial rotation; . . . . . . We can be satisfied if we are able to figure the time of cutting within a ten-year period . . . . . . we should not speak of *one year* but of the *period of financial cutting* . . . . . .

The computed financial rotation is then an indication which serves to tell the time of greatest soil rent according to the given conditions. It indicates a possible point but it should not be taken as the only and inflexible program for regulating the *growth per cent.* It endeavors to realize from the soil the measurement of its productiveness and to determine the largest obtainable soil rent. The means by which this is secured is not only in obtaining and carrying out the financial rotation but in harnessing and assessing the productive strength of the forest soil. The proper distribution of species, rational systems of management carried to old age, making use of increased growth due to light, reproduction, understory, growing valuable species,—these are the means which the forester can apply and they must be made use of by him in obtaining the highest possible soil rent. (See the work by G. Kraft, dealing with the "Management of the Soil's Productive Power,"—1890, also,—"Consideration of Forest Valuation,"— 1887. The fundamentals given there are gold nuggets of the German literature and every thinking forester should take them to heart.)

When the existing stands are not capable of producing a large enough soil rent (or when in order to obtain a reasonable soil rent a very short rotation is needed) then the means of remedy lie in building up and improving the stand and in part through applying modern technique as a guide in selecting certain kinds of species. These considerations are more fully brought out in the following viewpoints.

(a) First consideration for quality are: Clearness of bole, little taper, soundness of the wood . . . . . . If stocking was incomplete when the stand was started, if the young stand was grazed, if neglected in the thicket or polewood stage, or if damaged by atrocious cutting, or abused through unregulated cuttings or thinnings,—these stands will show no improvement in stocking and will produce chiefly scrubby, poorly formed, branchy and unhealthy trees with excessive taper . . . . . .

Such stands are not capable of a high soil rent; on the contrary a low rate of increase in valuable timber is the result. The sooner we clear off such undesirable stands and replace them with more worthy species,—and thereby utilize the full productive power of the soil—the less will be the loss to the forest owner . . . . (Endres now emphasizes the need for raising *timber* rather than fuel and poorly shaped poles).

(b) It must be concluded that spruce and fir are best grown for timber purposes. Spruce and fir have their principal use as lumber and dimension stuff. It is now a universal fact in the European market that there is no demand for boards wider than 11.4 inches. Squared timbers 13.8 inches in diameter command comparatively low prices; sizes larger than this have practically no sale. The average price paid for spruce timbers in the Royal-State forests during the ten years 1880-1889 per cubic meter:—

Average diameter	Per cu. m.	Per 1000 board feet	Increase in price per cu m.
5.9 inches	$2.50	$10.00	. . . .
6.3 to 8.7 "	3.07	12.28	$0.57
9 " 11.4 "	4.02	16.08	.95
11.8 " 14.2 "	4.65	18.60	.63
over 14.2 "	4.75	19.00	.10

Timbers over 14.2 inches in diameter as compared to those from 11.8 to 14.2 in diameter have a quality increase of only $.10 per cubic meter. The largest increase in price lies in the timbers between 9. to 11.4 inches.

Regarding the sale of construction timber the conditions are not much different. The industries of modern times demand *iron for the heavier uses.* The buildings that formerly used heavy fir timbers for girders now use *metal;* for other uses, where formerly very strong beams were required, they *obtain the same strength by joining several pieces together.* It becomes necessary for the mills to cut out of large logs smaller sized dimension timber and boards according to the sizes called for.

Oberforster Karl observed the same conditions for the Alsace-Lorraine and Klein markets. It is interesting to note that the fir (the so called "Holland wood"), which was raised purposely in the Black Forest for heavy timbers no longer is demanded; already there is an over-supply . . . . . .

"These latter, or so called standard sizes are the most saleable and can be disposed of in large quantities. In view of the fact that the *increase in growth of the older trees at 120 years will be at the highest only 1.5%* and the increase in price from standard grade to "Holland wood" (largest size) will be at the most $.25 per cubic meter, it can be easily figured what will become of the profits if we raise large sized fir timbers . . . .

The practice of growing large timber can only be continued for *pine* and *oak. For these timbers you can command a high price and they are sought after . . . . . . But it can not be believed that the increase in quality by raising large timber of these species will compensate for the higher soil charge.* In connection with the increase in price that is achieved you have a longer producing period to consider. Only in case you can so handle the forest through thinnings that the larger timbers are produced in reasonably short rotations is the growing of such material possible. It is probably only possible on good soils and in connection with a two storied forest.

(c) Pure beech stands are not suitable for earning reasonable financial returns.

Up to 1840, pure *beech forests* were found in great abundance due, primarily, to its prolific natural reproduction. The beech was highly prized for its *fuel value* and no one would have thought that during the development of the railroads *and within a ten year period coal would replace the wood as fuel.* The later attempts to encourage the use of beech for lumber have been unsuccessful.

The per cent of lumber produced (by pure beech) is very small, *only 20% at the most,* and then the lumber prices are not much above those received for cord wood. Even an exceptionally clear piece of beech lumber will not be worth more than a similar sized piece of soft wood. Where the beech thrives best are good sites for softwoods and they will give a proportionally larger yield. If softwood is the primary species, beech can be grown as an understory and, owing to the beneficial effect on the soil and tendencies to cause a better development of the bole in the softwoods and remaining hardwoods, it would raise the income of the stand indirectly.

"In such a practice one should not forget that the *beech is used only as an improver of the dominant species which earns the highest soil rent. In other words it is a means to an end.* Through proper forest management it is possible to restrict its development on its natural site . . . . . .

APPENDIX B.   GROWING STOCK AND YIELD, HARVARD FOREST.

The ascertainment of the annual yield, or total amount of saw timber to be cut annually from the Forest was based upon a rough consideration of area, age and volume. In the beginning only those stands were reckoned with which contained 50% or more of white pine, since hardwood timber was comparatively unprofitable, and yield tables applying to it were not available. The rotation and the mean annual increment for the whole area were determined from a yield table for white pine made by L. Margolin and published by the New Hampshire Forest Commission in 1906. Since quality increment in most of the pure pine type is unimportant, the rotation for the bulk of the Forest was fixed at 60 years which is not far from the point where the

mean annual growth in volume culminates. For arriving at the amount of the annual cut, the preliminary field work supplied the following data: a total stand of saw timber amounting to 10,500,000 ft.; a tabulation of areas according to type and age. Being almost wholly second growth the stand was everywhere classifiable into blocks of uniform age. The growing stock could thus be summarized in three periods of twenty years each covering the duration of the rotation. The mean annual increment, as derived from the yield table, was found to be approximately 250,000 ft. From the summary according to age and area, it was possible to determine in which periods of the rotation, as compared with the normal representation of age classes, the growing stock was deficient and by how much. Considering the total volume of the stand and the surplus of volume in the third period, the theoretical allowable annual cut would have been about 325,000 ft. On account of the lack of tried silvicultural methods and the need of a good reserve of sizable timber for future scientific purposes, it was decided to put the annual cut at the conservative figure of 250,000 ft. or the annual increment of the pine-bearing lands of the forest. The succeeding cuttings in mature timber have been kept for ten years at this figure and a total of 2,500,000 ft. of lumber have been marketed. A reassessment of the growing stock and increment was undertaken in 1919. As a consequence of the absolute increase in productive forest area due to the planting of blank land and to release cuttings, and due to the inclusion of hardwood stands now merchantable but omitted in the first computation, the annual increment, exclusive of cordwood, is now found to be 380,000 board feet and the total volume of the growing stock 12,435,000 board feet. For additional data see Harvard Forest Bulletin No. 1, 1921.

APPENDIX C. EXAMPLE OF A PRELIMINARY POLICY STATEMENT FOR INYO NATIONAL FOREST.

The following is a discussion of existing conditions and the future timber policy of the Inyo:

Dependency and Local Demand: In the absence of transmountain transportation against which the high Sierras would seem to constitute a permanent barrier, the only local timber supply available for Owens Valley and vicinity is embraced in the Inyo (Mono Mills Block of the Mono National Forest).

The dependency area is defined as Owens Valley north of Owens Lake, Deep Spring and Fish Lake Valleys, and the mining camps in Nevada north to and including the mining camp of Candelaria. The bulk of the population of this area is located in the northern part of Owens Valley in the vicinity of Bishop and Big Pine, Bishop being the logical center for manufacture and distribution. The Southern Pacific narrow gauge railroad would make possible distribution to the entire population with the exception of a few ranchers in Fish Lake Valley and Deep Spring Valley. The dependency area has a population of 5,550 people with a present annual use of 4,000 M ft. of sawed material and 3,000 cords of fuel, fence posts and other similar cord materials. All cord material and approximately 15% of 600 M ft. B. M. of sawed material was supplied from the Forest, the remaining 3,400 M ft. B. M. sawed material being supplied from shipped in products largely from the Truckee region.

No material increases in the use of cord material is anticipated in the near future. The Southern Pacific Co. is contemplating standard gauging the present narrow gauge road through Owens Valley, which would probably lead to cheaper coal, with the result that less wood would be used as fuel, which decrease would probably in a short period of years be compensated for by the increased demand due to increase in population, further division of ranch property, etc.

The present demand for building material will probably remain more or less constant for a number of years. There is, however, a rapid development in the fruit industry apparent in the near future which will probably increase the demand by some two million feet of box material within the next fifteen to twenty years. According to

figures obtained from Mr. Dixon, County Horticulturist, the present use and increase for the next five years will be as follows:

Boxes of fruit shipped during 1920 (all fruits)   35,000 boxes
Estimated for 1923 ....   "   "   200,000   "
Estimated for 1925 ....   "   "   300,000   "

Also the shipment of honey from the Valley during 1920 required 10,000 boxes, making a total requirement for 1925 of at least 310,000 boxes, which it is estimated would require about 2,000 M ft. B. M. of box material in the rough.

When taken into consideration that the available stand of timber runs at least 50% of box and shop grades, this rapidly growing demand for box material is very fortunate as making possible practically 100% utilization of the entire product, a large per cent of which could not otherwise be utilized locally. In view of the above statements, it would appear that the local demand for lumber products within the dependent area would be increased to at least 7,000,000 ft. within the next twenty years, possibly consuming that much as an average for the period.

Available Supply of Commercial Saw Timber: The supply of commercial saw timber is confined to the northern portion of the Forest, the Casa Diablo block, the Mammoth and Summit blocks; the total stand according to cruise of 1907 by Mr. Eldridge is 670,000 M ft. B. M.

Timber cut during the past season showed an average age of approximately 130 years, which if taken as a basis of rotation would indicate that the local demand would exceed the annual yield of the available stand within the next twenty years.

Condition and Accessibility: The entire stand of timber is largely mature, the Mammoth Block particularly being over-mature as indicated by flat and spike tops and other indications common in an aged stand. Also this block shows unmistakable indications of a more or less general insect infestation. (Dendroctonus, according to reports by Mr. Hopping.) The only sawmill on the Forest is also located at the south edge of this block, being operated during the past summer to the extent of 622,000 board feet cut. The State Highway, which has been greatly improved during the past few years, connects this block of timber with Bishop, the distance being 48 miles from Bishop to the present plant. The Casa Diablo block is approximately 20 miles nearer to Bishop than the Mammoth block, but besides being a much younger, more thrifty stand which should not be cut at the present, is also shorter, poorer grade timber and though a shorter distance from market, the road is such that it is doubtful if transportation costs would be less than from the Mammoth block. Several attempts to market local lumber in competition with shipped in products were made prior to 1912, that season apparently being the last attempt, which was by the Home Lumber Company. The reason for this seems to have been due to three factors:

1. There was no market for box grades and no means provided for their manufacture.

2. Road conditions were extremely unfavorable as compared with present conditions and the motor truck as a means of transportation had not at that time developed to any extent, making its use impracticable.

3. The low prices of lumber prevailing at the time.

Present operators, F. M. and A. W. Hess, fully recognize the fact that to market their production, which is 50% box and shop grades, it will be necessary to provide means of manufacture in order to market those grades at a profit. The transportation problem has been greatly reduced through improvement of the road by the State, and the development of the motor truck as a means of transportation, and it is figured by Hess Brothers from the past season's experience that it will cost approximately $10.00 per thousand under present conditions, as cost of trucks and operating expense, to freight their product from the mill to the Bishop yard. Also the present price for lumber would justify a much greater expenditure to place the lumber on the market than was the case at the time the Home Lumber Company failed.

Sale Policy: 1. In recognition of the fact that Owens Valley and adjacent community must eventually be entirely dependent on the timber within the Forest for a local lumber supply, no timber should be sold in the future that will allow exportation beyond the limits of the dependent community.

2. The Mammoth block of timber showing signs of disease and insect infestation, besides being equally as accessible as any other block of saw timber, should be cut first and sales for the time being confined to this block.

3. The main object of our whole sales policy should be to build up a local lumbering industry that will eventually supply the needs of Owens Valley to the fullest extent possible from the local product without exceeding the annual yield of the available stand, which, exclusive of the Mono Mills block of the Mono Forest, would be approximately 5,000 M ft. B. M. of an annual cut.

The project is too small to hope to interest large lumbermen and must, therefore, in all probability start in a small way from local capital and build more or less gradually against strong competition from the outside, which at present controls the market. Therefore in order to assist the local operator to meet outside competition, which may or may not be based on the cost of production but rather with a view of eliminating the local operator, such sales as would tend to create competition in the manufacture of the local products should be discouraged until the local product has reached the proportions of an industry and established its market. Until such times as the local industry will have established itself there can be no necessity for limiting the selling price of the local operator when we cannot limit the selling price of the shipped in product in case the local operator is forced out of business. At such time as the local industry has firmly established itself we should then undertake regulation of selling price based on cost of production as we would have by that time sufficient information on the cost of production on which to base a fair selling price.

4. Our minimum annual cut required by contract has, it seems, in some cases, forced a local operator into bankruptcy, due to the fact that his competitors lowered the price of lumber to the extent that he could not market his production at a profit, his finances being limited, and our minimum cut requirement forcing him to operate at a loss. Therefore, for the time being at least, we should place our minimum annual cut at a very low figure, and if necessary, waive it entirely if it will assist the local operator in his fight to continue his business.

5. There is no question but that the present stumpage price of $2.50 a thousand for yellow pine and $1.50 a thousand for fir both red and white does not represent the full stumpage value of the timber, but in order to assist the local operator to meet competition from the outside, I do not believe this price should be raised until such time as the local operation has shown that to raise the stumpage price will not eliminate the operation entirely.

Timber Needed for Forest Development: All timber within the headwaters of Pine Creek, Bishop Creek, Rock Creek and north from Rock Creek to Mammoth Mountain, lying on the slope of the main Sierras, should be withheld from sale, commercial or otherwise, except for use within the area involved. This area has a very light stand of timber and great value for power development, irrigation, storage and recreation and it is practically certain that all of the timber within this area will be needed for its development.

Supply of Fuel, Fence Posts, and Similar Material: The present population of Owens Valley and almost the entire population dependent on the Inyo Forest for fuel, fence posts, and other similar materials, is located between Manzanar and Chalfant (see map). That portion of the Forest bordering the Valley on either side embraces a sufficient stand of timber to supply all future needs for cord material.

The best estimate of this timber being that given in connection with land classification, and which places it at some 380,000 cords, which is approximately 80% Pinon pine, 15% Foxtail pine and 5% other species. Taking into consideration present use and possible future development of both community and Forest, and the administration

of the Forest, the source of supply and the community are divided into three separate units of supply and dependency. This division is thought advisable for three reasons:

1. To prevent overcutting by the community as a whole within the area on which a portion of the community is logically most directly dependent, and thereby necessitating in later years, back haul of the same material.

2. Wagon roads and other means of access will be necessary in the near future in order to obtain fuel and post timber. To get the necessary improvements and to properly distribute the cost of same, it is thought that some form of organization will be necessary, and to reduce the size of the community to be dealt with in each case, and to properly assure them that what they develop will be available only for a limited community, will make it comparatively easy to promote the necessary development.

3. In the proposed division, one or more units in the dependency and use conform to administrative districts which gives the ranger the advantage of knowing his users and the opportunity by assisting them in a plan of development, to group his cutting instead of having them scattered as at present throughout the district.

In making these divisions, the pains was taken to obtain sufficient information regarding population and use of material by the different communities, to make sure that each community would be supplied indefinitely with timber suitable for fuel and ranch development; the amount of timber and population in each unit being as follows:

Area No. 1, or the Aberdeen Independence area: Has a population of 1,100 people with a wood supply provided of 88,882 cords.

Area No. 2, Big Pine-Tinnemaha area: Has a population of 1.200 people, 121,362 cords.

Area No. 3, population of 3,256 people, has a timber supply of 168,469 cords.

It is planned to confine both free use and sale of all cord materials within each community to the area on which that community is logically dependent, as outlined on the map.

Free use will be issued only for dead, insect infested timber.

Commercial sales to be made in any quantity, but only for delivery within the community.

S-22 sales will be issued for both dead and green material, being limited as near as consistent with the law under which these sales are made, to dead, diseased and insect infested timber.

There is at present no large demand for S-22 sales outside of the dependency areas as outlined, and we shall endeavor to confine sales of this nature to these areas.

Very truly yours,

(Signed)   T. J. JONES,

Forest Supervisor.

December 14, 1920.

APPENDIX D. RESULTS OBTAINED BY FRENCH WORKING PLANS IN SAVOIE FROM ORIGINAL FIGURES SUPPLIED BY A. SCHAEFFER (CONSERVATEUR, SERVICE DES EAUX ET FORÊTS).

* The recovery which this region has made under French forest management is a lasting tribute to the foresters of the Republic. This region was only ceded by Italy in 1860, and prior to that date the forest had been overcut and damaged, the prices were low, and there was a large amount of overmature diseased timber. A. Schaeffer, for many years chief of working plans, with headquarters at Grenoble, has studied the rotation, cutting period, stand per hectare, increment, and financial yield before and after past working plan revisions, and has proved that the conservative management

* See pages 37-38, "Studies in French Forestry," John Wiley & Sons.

NAME OF THE FOREST (All selection fellings)	Beginning of the present rotation		
	Average timber	Old timber	Total
		FIVE FIRST CLA	
Nancy sur Cluses (1st W. G.)	174	276	450
Habère Lullin	180	154	334
Thônes Ville	187	303	490
Vigny Mathonex (2d W. G.)	54	474	528
Vercland (1st W. G.)	99	200	299
Average (fractions omitted)	138+	231+	420
		FIVE SECOND CL	
Luzier	96	158	254
Petit Bornand (1st W. G. (pic)	102	88	190
St. Paul	118	83	201
Rognaix	136	123	259
Montgilbert	93	155	248
Average (fractions omitted	109	121	230
		FOUR THIRD CLA	
Bourg St. Maurice (1st W. G.	160	94	254
Macot (1st W. G.)	156	60	216
do (2d W. G.)	156	52	208
Villaroger (3d W. G.)	150	137	287
Average (fractions omitted	155	86	241
		SIX FOURTH CLA	
Ito Foy (2d W. G.)	73	92	165
do (3d W. G.)	100	63	163
do (5th W. G.)	93	34	127
Tignes (3d W. G.)	48	58	106
Val d'Isère (3d W. G.)	31	7	38
Villaroger (1st W. G.)	79	77	156
Average (fractions omitted	71	55	126

HECTARE meters)

introduced by the French is successful. These forests, classed according to yield production, may be grouped in four classes:

1. Those forests with a yield of over 6 cubic meters (211.9 cubic feet) per hectare (2.5 acres) per year. These are found on the sandstones, schists, warm calcareous soils, and alluvial soils near the lakes of Geneva, Annecy, and Bourget. Such yields are almost comparable with the famous Jura and Vosges.

2. The second- and third-class forests are yields between 4 and 6 meters (141.3 and 211.9 cubic feet) and between 3, 4, and 2 meters (141.3 and 70.6 cubic feet) respectively. Here, either the soil or the climatic conditions are naturally poor producers. Sometimes this intermediate yield is due to the mediocre combination of both climate and soil.

4. The fourth class of forests is where the production is less than 2 cubic meters (70.6 cubic feet) per hectare (2.5 acres) per year. These are located in the high valleys or rocky slopes where the climate is severe or relatively dry.

The table: Results of Forestry Management in Savoie, France, faces this page.

From a study of these figures the following conclusions can be made:

(1) *Under the fairly intensive conditions existing in Savoie the area of the working group increases with poorer soil conditions, except that towards the limit of tree growth the groups are small including only the slow growing Alpine forests.

(2) After the rotations are once correctly established there is little or no change. The length of the rotation increases with poorer soil quality.

(3) Without changes in local conditions the cutting cycles tend to remain the same.

(4) With forest management there is a tendency (in France) to increase the growing stock and with selection forests it is essential to have a mathematical check on the marking. With the French method of 1883 the average timber should be $\frac{3}{8}$ and the old timber $\frac{5}{8}$ the total volume. This is empirically true, so if at the revision of a working plan, it appears that the proportion is not being maintained this fact should influence the marking during the next cutting cycle. This also illustrates the necessity in selection forests of not cutting to a strict diameter limit, *but rather according to the needs of the stand as a whole.* It is also necessary to have in mind an empirically normal selection stand per acre to steer by before attempting to mark the stand.

(5) The present current yield is a useful check on the yield allowed; the relation between the current increment and the yield is *never* a fixed ratio unless the forest is normal.

(6) With wise forest management there is usually increased yield until the abnormal forest becomes more nearly normal but the silvicultural condition of the stand often precludes too rapid an economy in growing stock.

(7) With wise forest management the money yield is constantly increasing; and with the gradual increase in stumpage prices which is going on all over the world (and with the diminishing value of money) this increase will probably never cease if there is continued and wise management. This is one of the greatest arguments for forestry as a conservative investment where there is certain protection and permanent (public) ownership.

(8) As would be expected the expenses diminish with the less valuable soils but not in the ratio of diminished revenue.

(9) A change in the proportion of the species in a selection forest under natural regeneration is slow and difficult without artificial assistance. This indicates how futile it is for management officers to plan sweeping changes in species ratio without figuring the cost of planting or sowing—unless a radical and perhaps dangerous change in management is contemplated.

(10) After a term of years the effect of correct forest management on an understocked forest is very similar to the increase in capital assets of an industrial enterprise

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*The paragraph numbers refer to the column numbers of the foregoing table.

NAME OF THE FOREST (All selection fellings)	(1) AREA Hectares	(2) ROTATION (Years) Former	Present	(3) CUTTING CYCLE (Years) Former	Present	(4) STAND PER HECTARE (Cubic meters) — Beginning of former rotation Average timber	Old timber	Total	Beginning of present rotation Average timber	Old timber	Total	(5) Present Increment per hectare (cu. meters)	(6) YIELD (Cubic meters) Former	Present	(7) MONEY YIELD PER HECTARE (Francs) — Before the revision Chief products	Secondary products	Total	After the revision Chief products	Secondary products	Total	(8) EXPENSES PER HECTARE (Francs) Before the revision	After the revision	(9) PROPORTION OF SPECIES Before %	After
FIVE FIRST CLASS FORESTS																								
Nancy sur Cluses (1st W. G.)	121	162	162	18	18	198	207	405	174	276	450	6.2	3.08	6.2	37.5	1.0	38.5	64.0	1.0	65.0	3.0	3.0	Spruce 65, Fir 30, Beech 5	do
Habere Lullin	28	144	144	16	16	142	81	223	180	154	334	8.2	1.8	5.0	20.5	2.5	23.0	51.5	2.5	54.0	3.8	3.9	Spruce 85, Fir 8, Diverse 7	do
Thônes Ville	124	144	144	16	16	211	229	440	187	303	490	6.9	3.9	6.6	43.1	2.5	45.6	82.0	2.5	84.5	4.0	4.0	Spruce 55, Fir 35, Diverse 10	do
Vigny Mathonex (2d W. G.)	32	162	162	18	18	66	340	406	54	474	528	10.7	3.8	8.9	27.0	1.8	28.8	62.0	1.8	63.8	2.7	3.0	Spruce 85, Fir 15	do
Vercland (1st W. G.)	173	180	180	18	18	82	142	224	99	200	299	6.2	1.95	3.1	22.0	0.5	22.5	40.	0.5	40.5	2.6	3.0	Spruce 80, Fir 10, Beech 10	Spruce 85, Fir 10, Beech 5
Average (fractions omitted)	96	158	158	17	17	140	200	340	138+	231+	420	7.6	2.9	6.	30.	1.7	31.7	60.	1.7	61.7	3.2	3.4	Spruce .7, Fir .2, Diverse .1	
FIVE SECOND CLASS FORESTS																								
Luzier	26	180	180	20	20	81	117	198	96	158	254	4.9	2.0	3.8	8.3	0.2	8.5	21.9	0.2	22.1	2.1	3.4	Spruce 24, Fir 57, Beech 19	do
Petit Bornand (1st W. G. (pic))	137	144	176	16	16	62	83	145	102	88	190	4.3	1.2	3.2	9.9	0.5	10.4	23.6	0.5	24.1	3.5	4.0	Spruce 70, Fir 6, Diverse 24	Spruce 73, Fir 6, Diverse 21
St. Paul	428	180	180	20	20	87	48	135	118	83	201	4.1	0 8	2.0	5.3	2.4	7.7	15.6	2.4	18.0	3.4	4.0	Spruce 80, Fir 10, Diverse 10	Spruce 82, Fir 10, Diverse 8
Rognaix	74	162	162	18	18	74	67	141	136	123	259	5.8	0.9	3.0	7.8	4.0	11.8	17.6	4 0	21.6	3.3	3.8	Spruce 52, Fir 15, Diverse 33	Spruce 55, Fir 16, Diverse 29
Montgilbert	211	144	144	16	16	58	124	182	93	155	248	5.9	1.9	3.8	14.8	1.2	16.0	38.3	1.2	39.5	3.0	3.5	Spruce 25, Fir 72, Diverse 3	no change
Average (fractions omitted)	177	162	168	18	18	72	88	160	109	121	230	5.	1.4	3.2	9.2	1.7	10.9	23.4	1.7	25.1	3.1	3.7	Spruce .5, Fir .3, Diverse .2	
FOUR THIRD CLASS FORESTS																								
Bourg St. Maurice (1st W. G.)	284	162	162	18	18	176	60	236	160	94	254	2.9	1.75	2.6	10.0	2.0	12.0	19.1	2.0	21.1	1.0	1.3	Spruce 63, Larch 28, Diverse 9	Spruce 65, Larch 28, Diverse 7
Macot (1st W. G.)	306	162	162	18	18	143	34	177	156	60	216	3.4	1.2	1.5	6.0	1.2	7.2	12.0	1.2	13.2	1 2	1.4	Spruce 70, Larch 25, Pine 5	no change
do (2d W. G.)	200	162	162	18	18	142	30	172	156	52	208	3.2	1.1	1.3	5.5	1.2	6.7	10.4	1.2	11.6	1.2	1.4	Spruce 90, Fir/Pine and Larch 10	do
Villaroger (3d W. G.)	273	160 and 180	180	15	15	149	123	272	150	137	287	3.9	2.3	3.0	11.5	1.5	13.0	24.0	1.5	25.5	4.2	4 5	
Average (fractions omitted)	288	164	166	17	17	152+	61+	214	155	86	241	3.4	1.6	2.1	8.2	1.5	9.7	11.4	1.5	17.8	1.9	2.1+	Spruce .7, Larch .2, Diverse .1	
SIX FOURTH CLASS FORESTS																								
Ito Foy (2d W. G.)	133	Spruce Fir Pine 162 years, Larch 216	Spruce Fir Pine 162 years, Larch 216	20	20	63	97	160	73	92	165	1.9	1.6	1.7	9.6	1.4	11.0	13.6	1.4	15.0	2.6	2.7	Spruce 95, Pine and Larch 5	do
do (3d W. G.)	90	216	216	20	20	105	58	163	100	63	163	1.6	1.6	1.6	9.6	1.4	11.0	12.8	1.4	14.2	2.6	2.6	Spruce 90, Larch and Fir 10	do
do (5th W. G.)	171	216	216	20	20	80	30	110	93	34	127	1.7	0.8	1.2	4.0	1.4	5.4	9.6	1.4	11.0	2.6	2.7	Spruce 70, Larch 30	do
Tignes (3d W. G.)	193	Spruce 180, Larch 240	Spruce 180, Larch 240	20	20	38	39	77	48	58	106	1.8	0.5	0.77	2.6	0.4	3.0	4.6	0.4	5.0	1.9	2.1	Larch 80, Spruce 20	do
Val d'Isère (3d W. G.)	79	252	252	21	21	22	4	26	31	7	38	0.7	0.17	0.22	1.4	0.1	1.5	1.8	0.1	1.9	1.8	1.9	Larch 90, Cembro 10	do
Villaroger (1st W. G.)	31	160 and 180	180	15	15	83	60	143	79	77	156	1.7	0.9	1.3	7.2	1.4	8.6	10.4	1.4	11.8	4.2	4.5	Spruce 95, Larch 5	do
Average (fractions omitted)	116	272	270	19	19	65	48	113	71	55	126	1.6	.9	1.1	5.7	1.	6.7+	8.8	1.	9.8	2.6	2.7+	Spruce .6, Larch .3, Diverse .1	do

which is being continually strengthened by wise administration. Gradually as the company retires its indebtedness and expands, the value of the stock doubles or triples. Wisely administered forests fatten in the same manner.

APPENDIX E. EXAMPLES OF YIELD CALCULATIONS FROM NATIONAL FOREST MANAGEMENT PLANS, 1921.

On November 22, 1921, each District Forester of the Forest Service was written to as follows:

. . . . . . "In looking through the literature on working plans I find that there is a great dearth of material on actual working plans in the United States. The reason for this is obvious. If you have any plans in preparation or practically in final form, could you send me a sample of the method you used in calculating the yield, citing actual figures used? Could you also send me a sample of one of your most interesting policy statements where a working plan is not yet required?

What do you estimate to be the cost per acre of an extensive management plan, (A) for field work, including estimates and growth studies, and (B) office work, including report, maps, and computations."

The data received (up to March 1, 1922) is listed by districts:

District I. Missoula. No data received.

District II. Denver. The usual policy statements are in force and management plans are being prepared for the Harney and Black Hills National Forests.

District III. Albuquerque. "Policy statements have been prepared for most of the Forests." The Apache is an example of an extensive timber policy plan. It is divided into two parts: (a) South End (chiefly cordwood) and (b) North End (chiefly timber).

(a) The cordwood policy is to protect water sheds, supply local needs, increase yield for Clifton market, protect recreational requirements. Cordwood sales are to be confined "to dead material until accessible supply is gone." Cutting of green cordwood will be on a very conservative basis. Only improvement cuttings will be allowed along Clifton-Springerville highway and at recreation areas.

(b) Irrigation and recreation must be protected and enough timber to supply local market must be retained from export sales. Large scale sales will eventually be necessary to develop timber resources. Western yellow pine will probably be handled on a 200-year rotation, 100-year cutting cycles, and 70% to 80% of the stand will be removed. One hundred million feet in the northwest corner is withheld from sale for 20 years for the Apache Lumber Company now operating in bordering territory. About two billion feet is available for the general market.

For intensive working plan data see Part II of this volume for details taken from the Coconino working plan.

Costs have averaged .05 for field and .01 for office work.

District IV. Ogden. Under date of December 2, 1921 the District Forester writes: "The supervisors . . . . have been reading, thinking and talking about forest management for a long time . . . . A great dearth of usable data on actual regulation . . . The ease with which low grade coast timber comes into competition with our local supply has prevented exploitation of any but the most accessible stands . . . . No definite results are available to date." Up to now general policy statements have filled the need for regulation.

District V. San Francisco. See appendix C for a complete copy of the Inyo Forest Policy statement which is considered one of the best produced by any district in the Forest Service.

The data which follows for the Eastern Larsen Working Circle is from a rough draft not yet approved by the Forester. According to the District Forester: "Since our basic data is rough, we feel that it is a useless waste of time to make elaborate, detailed, technical calculations of yield." The cost of the field work, including growth studies,

was about $.13 per acre with 7/10 of a cent extra for office. The extra cost of management plans (working plans) is estimated at $.02 per acre above "preliminary timber survey work" . . . . The proposed rotation is 120 years, the net area 160,500 acres, the total merchantable stand 2,870,000 M feet of which 75% to 80% is cut at the first logging. The loss from the decadent trees is considered offset by the growth in younger age classes. If the cutting cycle is 60 years, cut = 36 million; if 50 years, 44 million; if 40 years, 55 million; if 30 years, 73 million. The timber is extremely decadent. A 40-year cutting cycle "is about the shortest period of return that would assure a sufficient stand to justify profitable logging" . . . .

"There are included within the confines of the proposed initial sale area to the Fruit Growers the greatest portion of the most decadent stands and also a body of timber that is the most isolated and the poorest in quality of any in the working circle. The argument for a rapid cut-over applies more particularly to this area than to the remainder of the working circle. A suggested compromise would therefore be to make an initial sale to the Fruit Growers upon conditions that would apply the conservative marking practice that cuts about 80% of the merchantable timber and which would allow an average annual cut of 40 to 50 million feet and at the termination of this sale, to make a second sale reducing the cut to about 25,000 M feet which would be comparable to a strictly sustained yield. It is believed that this compromise plan adequately protects the best interests of the Forest Service and fulfills the primary object of management to harmonize best the prescriptions of silviculture, sustained yield, and sound economics. I therefore recommend the adoption of this plan."

District VI. Portland. According to Hanzlik:

"Thus far in my calculations regarding the sustained yield, I have used what may be called arithmetical method, checked by some of the standard formulae, Von Mantel's and Hufnagl's coming about the closest, although I consider that both of these give too high a cut from our present type of forests in the Douglas fir region. It is difficult to explain clearly the arithmetical method used; it is what may be called a "cut-and-try" method starting with a cut based on one of the above formula and then carrying out through a rotation or two the theoretical stands resulting from a decrease of the mature stand and an increase, based on standard yield tables, in the present immature stands and the cut-over areas as development proceeds.

As an illustration, using the North Santiam Working Circle, Von Mantel's formula $Y = \dfrac{V}{\frac{1}{2}r}$, we get $Y = \dfrac{4,000,000 \text{ M}}{40}$, or $Y = 100,000$ M feet B. M., basing the cut on a stand of 4 billion feet and an 80-year rotation.

Hufnagl's formula takes into consideration the increment from the immature timber, and in this case we have the following to start with: $V = 4,000,000$ feet B. M. (mature volume). Immature growth:

$$
\begin{array}{lll}
31,000 \text{ acres} & 80 \text{ years old.} \\
6,000 \quad " & 40 \quad " \quad " \\
38,000 \quad " & 10 \quad " \quad "
\end{array}
$$

The increment for this circle is based on Site II, Douglas fir yield tables, and is estimated as being 60% stocked when compared to the stocking from which the Standard tables were constructed. It is obtained by a summation of the increments of the various immature age classes taken at one-half the rotation period, thus:

Present Age Years	Area Acres	M. A. I. 40 yrs. hence* feet B. M. per acre	Total M. A. I. 40 years hence—M. feet B. M.
10	38,000	258	9,800
40	6,000	375	2,200
80	31,000	404	12,500

Substituting in Hufnagl's formula:

$$
Y = \dfrac{V + \left(I \times \frac{r}{4}\right)}{\frac{r}{2}}, \quad Y = \dfrac{4,000,000 \text{ M} + 24,500 \text{ M} \times \frac{80}{4}}{\frac{80}{2}} =
$$

$$
\dfrac{4,000,000 \text{ M} + (24,500 \text{ M} \times 20)}{40} = \dfrac{4,400,000 \text{ M}}{40} = 112,250 \text{ M ft. B. M.}
$$

The yields, Y, as obtained by these formulae are used only as an indicative factor

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* Based on Site II, Douglas fir yield tables, present immature stands stocked 60% of standard stocking.

whereby the recommended yield is finally determined, this final yield being made by the arithmetical method as mentioned previously."

Costs have depended on the amount of intensive estimating (10 cents per acre), but the district plans to keep working plans simple and inexpensive. The Row River Plan will cost 7/10 cents per acre.

District VII. Washington, D. C. No data received.

APPENDIX F. COMMENT ON WOLFF FORMULA.

The above graph* is based on the figures of table 9. This is intended to depict the distribution in volume on 60 acres based on a 60-year rotation, to obtain a normal stock with the yields for each period. Up to the age 20, at which the first yield figure is given, the growth has been a straight line from the age zero. Then by the yield table method, the normal stock would equal in volume the shaded portion comprising the polygon A-B-C-D-E-F-L-G. The triangle A-O-G is necessarily omitted since the growth that it represents cannot be estimated. To make the yield table method comparable to the original unmodified $\frac{I \times R}{2}$ method of obtaining normal stock, this triangle would in theory have to be included. Now by Moore's method, the normal stock obtained would be included in the triangle G-F-L. The area therein included happens to be fairly close to that of the polygon above described, since the portions of the shaded area above the line G-F are almost great enough to balance the unshaded portions included below the line G-F.

On the other hand, by Wolff's formula, the area included is the trapezoid A-F-L-G. Here the growth is a straight line between A-F, as is the case in Moore's formula between G-F. It is patent, in this case, that there is vastly more of the unshaded portion included than there is excluded of the shaded portions; also, that the result would be still more in excess of the yield table method than Moore's formula gives.

Comparisons of the three methods will likely yield similar relative positions when the mean annual growth *before* rotation age is less than *at* rotation age, especially if the mean annual growth is constantly increasing to a maximum at the rotation age (giving a "concave" curve) and where the age, as in the example given, is very low.

While neither Moore's nor Wolff's formula gives the correct figure (as determined by the yield table) the method suggested by Wolff is mathematically the most correct.

It will be found that the nearer the "estimateable" age approaches the rotation age, the closer will be the results by the Wolff formula to those of the yield table method and the further away the results by the Moore formula. Vice-versa, the younger the "estimateable" age or the further away from the rotation age, the more closely will the results by the Moore formula and the yield table method approach, and in fact the more accurate will tend to be the original $\frac{I \times R}{2}$ method of obtaining the normal stock. As pointed out, if the lineaments of the yield curve change,—a not improbable possibility,—these relations will change. The Wolff formula will usually give the best figures because when approximating the curve by a straight line, the Wolff method is mathematically correct and the Moore formula is mathematically wrong.

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* See page 63 for this graph kindly supplied and discussed by Wolff. It was learned after this text was set up that H. H. Chapman had lectured on this problem as early as 1909, but had never published.

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* The numbers refer to pages and not to para-
graphs.