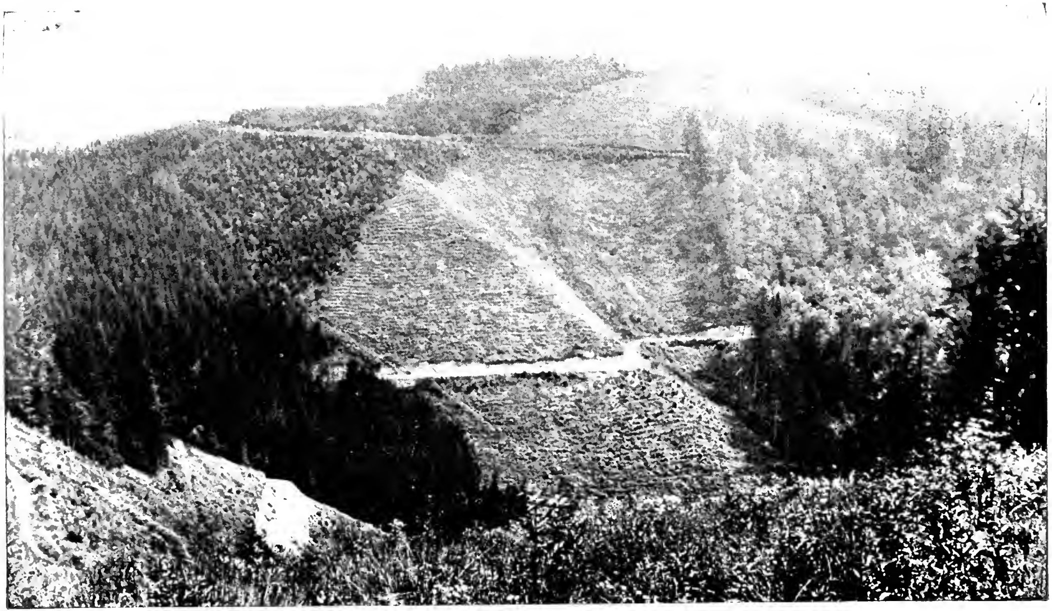
PLATE I.—Frontispiece.



Cutting Series and Compartment Lines in Spruce, Saxony.
Courtesy of Professor Frank F. Moon.

The Theory and Practice of Working Plans

(FOREST ORGANIZATION)

BY

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SECOND EDITION, THOROUGHLY REVISED
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PREFACE TO THE SECOND EDITION

THE reception accorded the first edition of this work has encouraged me to prepare a revised and enlarged second edition. In doing so I have profited from four main sources, not open at the time of writing the original text.

The first of these is the work of the Committee on Terminology of the Society of American Foresters, which has gone far to standardize the nomenclature. It has been my privilege to serve as chairman of the sub-committee on Organization, Mensuration, and Management, and I have derived the greatest help from the hearty coöperation of my colleagues both within and without the Committee. The terminology of the second edition has thus been brought into accord with the best usage of to-day.

The second great source of assistance is the helpful criticism engendered by the first edition. While it has not proved expedient to adopt all the suggestions, nevertheless, the faults noted have been corrected just so far as possible without destroying the originality and coherence of the work. In a text on forest organization, a detailed discussion of the application of silvicultural methods, of the pros and cons of various kinds of rotations and similar material of a general character does not seem in place, any more than would a didactic attempt to say: such and such a method of determining the cut should be used with such and such species, or forests. The time is not yet ripe for such generalizations; they must wait until the practice of forest management in America has advanced further than to-day. A new feature of this edition is the "Correlation of Silvicultural Methods and Methods of Determining the Cut," which is as far as the author feels justified in going along these lines.

The third source of assistance has been the experience of teaching forest management for the past four years. Nothing so quickly reveals the defects of a book as using it for a text. To this experience are traceable the new diagrams and the amplification of the section on the normal forest and its attributes.

Last but by no means least of the sources of assistance, has been the wealth of new data revealed in the forestry literature of the past four years. This has made it possible to diversify the examples used to illustrate the various methods of regulating the cut by introducing other species than the overworked western yellow pine of the first edition.

Throughout, I have endeavored to revise and improve the original text so as to embody all the recent developments in forest organization. In doing so I have drawn freely on the work of my colleagues in the profession of forestry and I take this occasion to acknowledge my indebtedness.

A. B. RECKNAGEL.

ITHACA, N. Y.
Jan., 1917.

PREFACE TO THE FIRST EDITION

This book does not pretend to present any original theories of Forest Organization, but merely the best of European efforts along this line adapted to the present needs of American forestry. The necessary data were gathered in the course of a year's study abroad, and, in their application, the experience gained in five years of similar work for the forest service in various parts of the United States was constantly kept in mind. The theoretical part has, therefore, been reduced to the minimum; similarly, the description of such intensive methods of regulating the yield as that by area and volume in periods has been merely sketched for the sake of completeness, since its application to America is of the far distant future, if ever. In a word, while sacrificing nothing to the completeness necessary in a text-book, the aim has been to make the book of value not only to the student, but also to the practising forester, and hence theory has in each case been subordinated to practice.

It will be ample reward for the time and labor spent, if this book takes its humble place in the growing list of American text-books on forestry.

Grateful acknowledgment is made to those who so unselfishly assisted in the collection of the subject-matter.

A. B. RECKNAGEL.

Dresden, September, 1912.

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INTRODUCTION

FOREST management may be broadly defined as the application of forestry in the conduct of the business of a forest. Forest organization, a subdivision of forest management, deals with the principles of organizing a forest for business. Forest organization may, therefore, be defined as that branch of forest management which concerns itself with organizing a forest property for management, ordering in time and place the most advantageous use of the property, usually with the ultimate aim of securing a sustained yield.*

In order to have a definite scheme for the conduct of operations on a tract so as to secure most effectively the objects desired by the owner, a *working plan* is formulated. This may be defined as the plan or plans under which a given forest property is to be continuously managed.

SCOPE OF WORKING PLANS

In its broadest sense a complete forest working plan deals not only with *silvicultural management* of the timber resources, but may cover any or all of the following subjects:

1. General administration.
2. Silvicultural management.
3. Grazing management.
4. Permanent improvements.
5. Forest protection.
6. Uses of forest land.

* The term forest regulation covers the same idea, but, since it suggests police and administrative prescriptions seems less desirable except for that part of organizing which concerns itself with regulating the cut.

Since the prime object of any forest is the growing of timber, the silvicultural management is the most important; it is also the most difficult. The present work will, therefore, confine itself to this phase.

SPHERE OF WORKING PLANS

The working plan is not confined to such forests as are managed with the idea of a sustained yield,* but is equally adapted to the exploitation forest; i.e., forests which are to be logged within the next ten or twenty years. As in every other business the advantages of systematization are obvious; the working plan secures these advantages. At the same time it is usually to the interest of the owner to leave the tract in as favorable a condition as possible for future growth without the undue expenditure of time, timber, or money. The working plan secures this by so organizing the logging operations that the natural reproductive powers of the forest are brought into full play instead of being nullified by the fortuities of haphazard and often unnecessarily destructive logging.

The sphere of forest organization therefore embraces all forests and is applicable to all classes of owners, large and small.

* Sustained yield: the yield or cut of timber from a forest which is managed in such a way as to permit the continuous removal of an approximately equal volume of timber annually or periodically (equal to the increment).

PART ONE

FOUNDATIONS OF WORKING PLANS

Foundations of Working Plans

CHAPTER I

PRELIMINARY BASIS

SECTION ONE

THE NORMAL FOREST AND ITS ATTRIBUTES

At the very root of forest organization lies the idea of a normal forest; that is, a standard with which to compare an actual forest to bring out its deficiencies for sustained yield management; a forest with normal age classes, in size and distribution, normal increment, and normal growing stock.

Normal distribution of age classes requires that separate age classes exist which will mature during each year, or longer period, of the rotation, occupying areas whose yield will equal the same per cent of the total yield of the forest for the rotation as the period bears to the rotation. Thus, for a given decade in a hundred-year rotation, the area maturing should yield one-tenth of the yield of the forest during one hundred years. Normal age class distribution in the strict sense of actual location means such distribution of age classes as will permit annual or periodic fellings to be made without damage to adjoining stands.

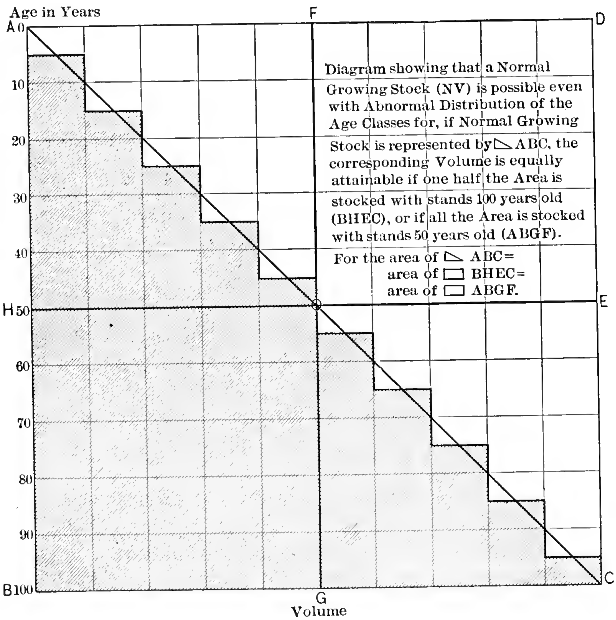
Normal increment is the best increment attainable by given species on given sites.

Normal growing stock is the amount of material represented by the stands in a normal forest.

Such a normal forest probably does not exist; it is merely a theoretical ideal towards which to strive. Assuming, therefore, that every forest is more or less abnormal, it is necessary to determine the degree of abnormality in the following directions:

1. Increment.
2. Growing Stock.
3. Distribution of the Age Classes.

Diagram A



In this connection it should be noted that while normality in 1 and 3 of themselves result in normality in 2, the reverse is by no means the case. A normal growing stock may exist in a forest with only a single age class. Valuable as its determination is, therefore, it should never be used as the sole criterion of regulating the cut. This may be shown diagrammatically as on page 2.

The Increment

Increment (syn. accretion, growth) may be defined as the increase in diameter, sectional area, height, volume, quality or value of a tree or a stand.

Three principal kinds of increment are distinguished:

Volume increment is the increase in volume of a tree or stand.

Quality increment is the increase in value per unit of volume due to its augmented intrinsic worth.

Price increment is the increment in the sale value of forest products independent of quality increment, due to market conditions.

Increment is further differentiated as *current annual increment* = the increment for a specific year (abbreviation " C.A.I."). Periodic increment = the increment during a specified period of years; *mean annual increment* = the total increment divided by the age (abbreviation " M.A.I."); *periodic annual increment* = the increment for a specified period of years divided by the number of years in the period, usually used in lieu of the current increment.

The determination of the increment is the province of forest mensuration; without trespassing on this subject, so admirably covered in Mr. Graves' textbook,* it is worth while to consider the matter solely in its relation to forest organization.

Not every method of regulating the cut requires the determination of the volume increment; e.g., the Method of Von Mantel or the Méthode de Masson. Again, it is possible to regulate the cut by increment alone (Swiss Method). But most methods of regulating the cut require a determination of the increment.

The normal increment is the increment of stands fully stocked

* " Forest Mensuration," Henry Solon Graves. John Wiley & Sons, New York, 1906.

or normal. However, regulation of cut is based upon actual, not normal increment, hence actual increment becomes the basis of the normal forest. Where the real increment is to be taken from yield tables,* the values given in the table must be reduced by the actual factor of density, since yield tables are always for fully stocked stands.

Where yield tables are not available, the increment must be determined on the ground, either by applying the increment per cent of representative trees of the stand, or else by calipering sample areas and figuring their increment by means of diameter-age and diameter-volume tables. The former (and yield tables) is better for nearly even-aged stands; the latter method for uneven-aged stands.

Where diameter-age tables are lacking, stump analyses can be made.

For determining current annual increment the use of an increment borer is deserving of wider popularity than it has heretofore enjoyed in America. Where no increment borer is obtainable, the representative trees, selected according to any of the standard methods (Draudt, Urich, etc.) can be cut into at breast height and the rings on the last inch of radius counted on the horizontal under-cut. Either Schneider's or Pressler's formulæ may then be applied.

Schneider's formula:

$p=\frac{400}{nd}$ (or 450 or 500 according as the height-growth of the tree is poor, average, or good)

where p = the current annual increment per cent;
n = number of rings of annual growth in the last inch of radius;
and d = diameter breast high, in inches.

---

* Yield table: A tabular statement of the volume of a stand of specified character per unit of area. This is usually constructed for units of one acre and for intervals of ten years.

The growth per cent must always be translated into figures of actual volume. For example:

A spruce tree 28 inches in diameter at breast height, of average height-growth, shows 8 rings in the last inch, bored at breast height. The increment per cent according to Schneider's formula is

$$p = \frac{450}{28 \times 8} = 2 \text{ per cent.}$$

Assuming a stand of 2400 feet board measure per acre, the volume increment (current annual) would be, if this were a sample tree:

$$\frac{2400 \times 2}{100} = 48 \text{ board feet per acre per annum.}$$

Pressler's formula:

$$p = \frac{V - v}{V + v} \times \frac{200}{n},$$

where p = the current annual increment per cent, V = the volume now, v = the volume n years ago, and n = the number of rings in the last inch of diameter. For example:

A hemlock tree 18 inches in diameter at breast height, of average height-growth, shows an average of twelve years to grow the last inch in diameter. The volume of a hemlock 18 inches d.b.h. is 230 board feet; of a hemlock 17 inches d.b.h. is 190 board feet.* The increment per cent according to Pressler's formula is

$$p = \frac{230 - 190}{230 + 190} \times \frac{200}{12} = 1.587 \text{ per cent.}$$

Assuming a stand in which there were, on an average, .25 hemlock trees 18 inches d.b.h. per acre, with a corresponding volume of 57.50 board feet per acre, the volume increment (current annual) would be, if this were a sample tree:

$$\frac{57.5 \times 1.587}{100} = .91 \text{ board feet per acre per annum.}$$

* Volumes based on U. S. Dept. of Agri., Bulletin 152, new series, Table 12.

Pressler's formula is exceedingly valuable for regulating the cut in mixed, selection forests.*

Whether the current annual or the mean annual increment is to be determined depends on the method of regulating the cut which is to be adopted. It is not usually necessary to determine painstakingly the exact increment of each stand, but rather correctly to approximate the increment in each Working Unit—i.e., the unit area for which the cut is to be regulated; for it is evident that in comparison with the volume of merchantable timber the increment is a relatively small amount. It is a useful fact that in stands approaching maturity (not overmature) the mean annual and current annual increment remains virtually the same for about ten years; since the former is simply the volume divided by the age $\left(\frac{Va}{a}\right)$, a simple way is thereby opened to approximate the current annual increment in mature, even-aged stands.

Dr. Fernow in an article on "The Sciences Underlying Forestry," † points out that the mean annual increment per cent. culminates when it is equal to $\frac{100}{a}$, in which a = age of the stand. This culmination occurs where the current annual increment curve crosses the *m.a.i.* curve. Current annual increment $= \frac{400}{nd}$ (Schneider), hence $\frac{400}{nd} = \frac{100}{a}$ or $a = \frac{nd}{4}$. This is a handy way to determine the age of maximum volume production.

The Growing Stock

Growing stock is a general term referring to the standing timber upon a unit of area. When used in relation to problems of management, it usually refers to the volume of standing

* See "A Practical Application of Pressler's Formula," Forestry Quarterly, Volume XIV, No. 2.

† Forestry Quarterly, Vol. VII. No. 1, pp. 23–33.

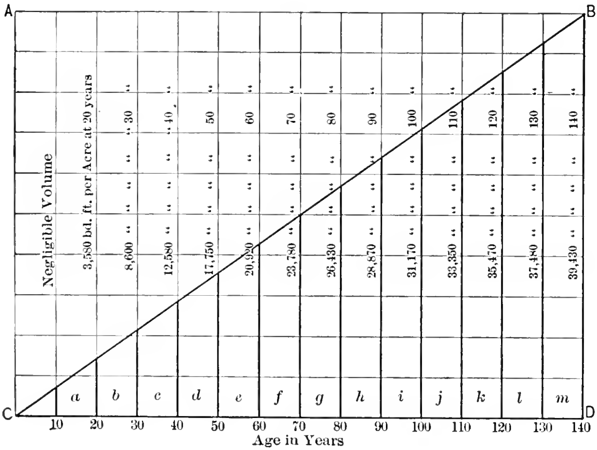
timber, but it may also be used with reference to the density of stocking, age classes, etc.

The normal growing stock (nv) is theoretically attained from normal age classes and normal increment, practically it results from normal age classes and actual increment.

The actual growing stock (v) is that which is present on a given forest. This is obtained by timber estimating.

The normal growing stock (nv) is obtained (1) by formula, (2) from yield tables.

Diagram B



(1) The normal growing stock is expressed by the formula:

$$nv = \frac{ri}{2}$$

where nv = normal volume of growing stock, r = rotation, and i = the mean annual increment.

(2) nv can also be determined directly from yield tables constructed by measurements of fully stocked stands.

$$nv \text{ then equals } n\left(a+b+c\ \ldots\ +\frac{m}{2}\right)$$

where n equals number of years in each age class (step of the yield table) and $a, b, c, \ldots m$ = the volume per acre given in the table for each age class.

The method and correctness of finding nv (1) by formula, (2) by summation from yield table, is illustrated on the accompanying diagram (Diagram B). For the values as given in this diagram, which is based on a yield table for white pine constructed by W. J. McCarthy, M. F., in the vicinity of Ithaca, N. Y., the normal growing stock would be as follows, assuming a forest of 1000 acres:

(1) $nv = \frac{ri}{2}$;

r = rotation = 140 years;

i = mean annual increment per acre = 281.64 board feet;

$$nv = \frac{140 \times 281.64}{2} = 19{,}715;$$

$$19{,}715 \times 1{,}000 = 19{,}715{,}000 \text{ board feet.}$$

(2) $nv = n\left(a+b+c \ldots + \frac{m}{2}\right)$;

n = number of years in each step of yield table = 10
$a, b, c, \ldots$ are volumes per acre in each step of yield table;
m is volume per acre at the rotation age (140 years);

$$nv = 10\left(3580+8600+12580 \ldots + \frac{39{,}430}{2}\right)$$

$$= 2{,}996{,}950 \times \frac{1000}{140 \text{ years}} = \frac{2{,}996{,}950{,}000}{140} = 21{,}407{,}000 \text{ board feet.}$$

A further comparison of the two methods of determining the normal growing stock is given in the following table. These calculations are based on Hanzlik's yield table for Douglas fir as given in Forestry Quarterly, Vol. XII, No. 3, pp. 442–445.

The rotations used were those given in table 6, p. 447 of the article cited. Premise: 100,000 acres of Douglas fir in western Washington.

COMPARISON OF TWO METHODS OF DETERMINING nv

Basis F. Q. XII, 3, pp. 442–5.	Rotation Age (Yrs.)	A. By Formula.		B. By Summation.		Per cent B is of A.
		Cubic Feet Whole Stand.	Board Feet Merch. Only.—M	Cubic Feet Whole Stand.	Board Feet Merch. Only.—M	
Table 1	52[1]	470,600,000	. . . .	334,134,615	. . . .	77.8
Table 1	110	. . . .	5,500,000	. . . .	4,161,400	75.6
Table 2	55	404,250,000	. . . .	397,000,000	. . . .	98.2
Table 2	110	. . . .	3,700,000	. . . .	2,890,900	78.1
Table 3	50	282,500,000	. . . .	216,900,000	. . . .	76.8
Table 3	115	. . . .	2,903,750	. . . .	1,979,451	68.1
Average	. . . .	. . . .	. . . .	. . . .	. . . .	79.1

1 For B it is necessary to find even decade values and then take proportional part of the difference.

From this table one might conclude that the formula values should be reduced by 20 per cent, *i.e.*, multiplied by .8, since summation is undoubtedly the more accurate method of the two.

Many authors have busied themselves with the problem of how to determine the normal growing stock most accurately and have suggested certain departures. Thus Flury * claims that the formula, $nv=\frac{ri}{2}$ to be more generally correct, should read:

$$nv=c\times r\times i,$$

in which c is a variable constant. To determine this constant, normal yield tables are necessary which may be summed up by the formula

$$nv=n\left(a+b+c\ .\ .\ .\ +\frac{m}{2}\right)=S,$$

* Schweizerische Zeitschrift für Forstwesen, March, 1913, briefed For. Quart., Vol. XIII, No. 1, pp. 108–113.

then, since $c \times r \times i = S$,

$$c = \frac{S}{r \times i}.$$

Flury has calculated c for the chief species of Europe and for various rotations as shown in the following table. These values are for timberwood only.

AVERAGE VALUE OF CONSTANT c

Species	Rotation in Years.			
	60	80	100	120
Spruce. Swiss foothills	.371	.463		
Swiss mountains	.316	.392	.453	.508
Prussia	.268	.354	.434	.519
Fir. Württemberg	.205	.267	.308	.359
Baden	.226	.317	.384	.437
Scotch pine. North German Plains	.387	.454	.503	.536
Prussia	.374	.456	.525	.596
Beech. Switzerland	.276	.341	.405	.467
Prussia	.219	.316	.379	.428

Applying Flury's constant c to McCarthy's white pine yields as given above, the factor is as follows: for rotation of 30 years, $c = .306$; for 40 years, .365; for 50 years, .378; for 60 years, .421; for 70 years, .452; for 80 years, .475; for 90 years, .493; for 100 years, .507; for 110 years, .518; for 120 years, .525; for 130 years, .536; and for 140 years, .542.

Thus the value for 140 years given above as 19,715,000 board feet would be corrected as follows:

$$nv = c \times r \times i = .542 \times 140 \times 281.64$$

$$= .542 \times 39{,}430 \times 1000 \text{ (acres)} = 21{,}371{,}000 \text{ board feet,}$$

which compares closely with the value 21,407,000 board feet found by summation of the yield table.

It is obvious that where the constant c is approximately .5 the error in finding nv by the formula method is least, since

$$nv = \frac{ri}{2} = .5 \times r \times i.$$

It is also obvious that finding c and using it in the formula is more correct than applying a general reducing factor such as found in the case of Douglas fir above.

To further illustrate the workings of c the average value of c has been found by and applied to the white pine yields as given in table 6, Bulletin 13, U. S. Dept. of Agriculture, new series, for site quality II, i.e., medium site quality. The values by formula, with and without use of c and by summation of yield table are also given.

AVERAGE VALUE OF CONSTANT c IN WHITE PINE, SITE QUALITY II
Based on Table 6, U. S. Dept. Agric. Bull. 13, N. S.

Rotation (Years).	c.	$nv = \frac{ri}{2}$.	$nv = n(a+b+c \ldots + \frac{m}{2})$.	$nv = c \times r \times i$.	Difference betw. Last Two Columns.
		Feet, Board Measure, per Acre.			
40	.227	11,750	5,337.5	5,334.5	3
50	.280	18,300	10,280	10,248	32
60	.330	23,450	15,525	15,477	48
70	.368	28,050	20,764	20,644	120
80	.399	32,000	25,588	25,536	52
90	.426	35,450	30,239	30,203	36
100	.449	38,500	34,610	34,573	37
110	.465	41,600	38,745	38,771	26
120	.484	44,050	42,654	42,650	4
130	.506	45,750	46,280	46,299	19
140	.549	47,050	51,604	51,660	56
Average					39.4

NOTE.—Values over one hundred years from prolonged curves.

The value of Flury's constant in finding the normal growing stock is evident since, as Flury says,* "the normal growing

* Grösse und Aufbau des Normalvorrates im Hochwalde, Mitteilungen der Schweiz. Centralanstalt für das forstliche Versuchswesen, XI, 1, 1914, pp. 97–148.

stock is the best, most pregnant, numerical expression of sustained yield management. To attempt an approach to normal stock conditions in some way, must be the aim of the manager for sustained yield."

Munger * has devised a formula for determining normal growing stock in selection forests. Munger conceives of the normal growing stock as consisting of the reserve left after cutting multiplied by the area, plus one-half the growth which take place on the entire forest for the entire cutting cycle. Expressed as a formula:

$$nv = \frac{i \times cc}{2} + \text{reserve for the entire forest,}$$

where i = the current annual increment on the entire forest and cc = the cutting cycle (period between cuts).

EXAMPLE: If for 50 acres $i = 5000$ board feet, $cc = 50$ years, that is, $\frac{1}{4}$ of the 200-year rotation, and reserve = 200,000 board feet, then

$$\begin{aligned} nv &= \frac{i \times cc}{2} + \text{reserve} \\ &= \frac{5000 \times 50}{2} + 200{,}000 \\ &= \frac{250{,}000}{2} + 200{,}000 \\ &= 325{,}000 \text{ board feet for the entire 50 acres} \\ &= 6500 \text{ board feet per average acre.} \end{aligned}$$

Using the formula $nv = \frac{ri}{2}$ and the same premises nv would figure out as 10,000 board feet per acre.

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* Proceedings Society of American Foresters, Vol. X, No. 1, pp. 18–21. The example which Munger gives on p. 20, is for 50 acres since $\frac{325{,}000}{50} = 6500$.

Munger's formula is undoubtedly well adapted for selection forest.

Fischer * has suggested the following modification of the formula for normal growing stock when applied to reproduction cuttings:

$$nv = (\text{initial gr. stock} + \text{final gr. stock}) \times \frac{\text{regen. period}}{2} \times .5.$$

The last figure varying according to the crown density.

For example: A pine forest which contains, on one acre, 14,600 board feet at rotation age (160 years) is cut by shelterwood method so that 66 per cent of the volume is removed during a twenty-year period of reproduction, whereby the density is reduced to .5. Substituting:

$$nv = (14{,}600 + 4818) \times \frac{20}{2} \times .5$$

$$= 19{,}418 \times 10 \times .5$$

$$= 194{,}180 \times .5$$

$$= 97{,}090 \text{ for } \frac{20}{2} \text{ years}$$

$$= 9709 \text{ board feet for any one year, per acre.}$$

By formula:

$$nv = \frac{ri}{2} = \frac{160 \times \frac{14{,}600}{160}}{2} = 7300 \text{ board feet per acre.}$$

Strzeleckis proposed † to figure $nv = \frac{r}{2}\left(V\frac{r}{2} + \frac{1}{2}Vr\right)$ where $V\frac{r}{2}$ = volume at $\frac{1}{2}$ rotation age and Vr = volume at rotation age.

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* Allgemeine Forst- und Jagd-Zeitung, March, 1914, pp. 100–102, briefed For. Quart., Vol. XII, No. 2, pp. 279–280.

† Allgemeine Forst- und Jagd-Zeitung, 1884, p. 88, p. 316.

Using the data in McCarthy's yield table for white pine, and a rotation of 140 years,

$$nv = \frac{140}{2}\left(23{,}780 + \frac{39{,}430}{2}\right) = 3{,}044{,}657 \text{ board feet,}$$

but this is for 140 acres,

$$\text{for the average acre} = \frac{3{,}044{,}657}{140} = 21{,}748 \text{ board feet}$$

per acre, which compares well with nv by yield tables, i.e., 21,407 board feet per acre.

Distribution of the Age Classes

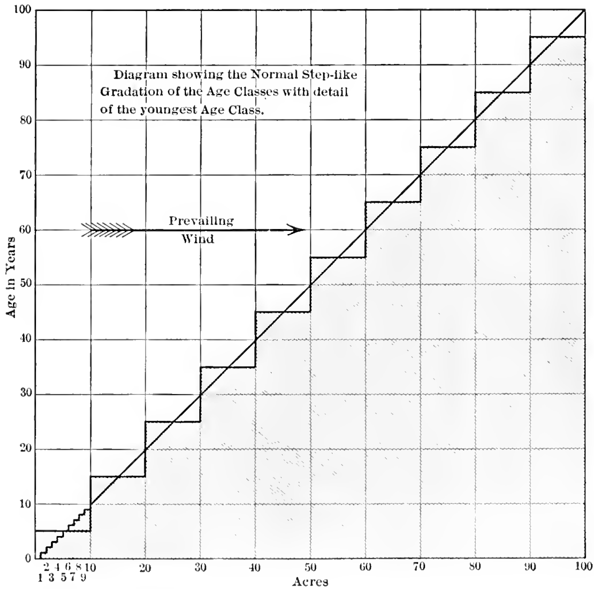
All the trees in a stand or forest whose age falls within stated limits are spoken of as being in the same age class. Age classes are usually divided in twenty-year periods, but in old stands may be of wider range. Age classes are stated in extent of area or in percentage of the whole stand; in selection forest in terms of number of trees. A stand where the ages of the majority of the trees fall between twenty-one and forty years, would, for twenty-year age classes, be referred to as being in "Age Class II."

In the selection forest, diameter classes take the place of age classes. A diameter class is a grouping of the trees of a stand on the basis of diameter, the intervals varying usually from 1 to 4 inches, fractions being rounded off to the nearest full inch of the limit. For example, with a 3-inch limit all trees from 22.6 to 25.5 inches in diameter would be assigned to the 24-inch class. The diameter classes may be stated by numbers of trees in each class on the unit of area or by the percentage of the total contents of the stand represented in each, or by area occupied or in any other way.

Distribution of age classes refers to either the *local* distribution of age classes (Verteilung der Altersklassen) or the percentic or absolute representation of the different age classes in area or amount, or (in selection forest) in number of trees (Altersklassenverhältniss).

Similarly, distribution of diameter classes in its strict sense means the location and area of each stand of a given diameter class in the forest. In a general sense it means the per cent of area occupied by each diameter class in the forest.

Diagram C



A table or diagram showing the proportion or amount of each age class in the forest is called an *age class record*. This may be expressed in percentages or in actual area. Similarly, there may be a *diameter class record*.

The correct distribution of the age classes is theoretically like a series of equal sized steps, growing higher along the prevailing storm direction. However, this theoretical ideal is never achieved; it suffices that each age class has an approximately equal representation on the area which is to have a sustained yield; in fact, without a fairly even distribution of the age classes sustained yield on a given area is impossible.

Twenty years is commonly taken as one age class, though sometimes ten and sometimes thirty-six years is used. In any case the rotation must be a simple multiple of the age class. It is customary to number the age classes from I up, beginning with the youngest.* Thus for an eighty-year rotation there are four age classes of twenty years each; a fifth age class would contain all stands older than r (the rotation).

It is of the utmost importance to get some conception of how the age classes are distributed.

In even-aged stands or stands even-aged in groups, the age may be determined by finding the average tree (any of the standard methods) and then getting the age from stump analysis or boring to the center at breast high with an increment borer, or from diameter-age tables (if available and *applicable!*).

Where stands are fairly even-aged, but conditions are too extensive to permit the exact assignment to definite age classes, the general classification into

> *O* overmature (more than rotation age);
> *M* mature (of rotation age down to $\frac{1}{2}$ thereof);
> *Y* young (from lowest age to $\frac{1}{2}$ rotation)

will serve the purpose.

The selection forest, of course, has all age classes inextricably intermingled. But where the age differences are not to exceed $\frac{1}{3}$ or $\frac{1}{4}$ of the rotation, the stand can be classified according to its average age, or, more exactly, according to the proportion of space each age occupies. For example: 320 acres of spruce might contain 160 acres of trees seventy years old, 100 of trees

* In Prussia this is reversed, I. is the oldest age class.

sixty years old, and 60 acres of trees only forty years old. The average age here would be 61 years; for:

$$\frac{160 \times 70 + 100 \times 60 + 60 \times 40}{320} = 61 \text{ years.}$$

Where, in uneven-aged forest, the age classes are so intermingled that they cannot be distinguished by area but only by volume (from the diameter-classes in the estimates), the average age = the $\frac{\text{volume}}{\text{increment}}$; e.g., if the uneven-aged forest has three main age classes:

100 year class with	2000	feet board measure
60	1200	
50	800	

then the average age would be $\dfrac{2000+1200+800}{\frac{2000}{100}+\frac{1200}{60}+\frac{800}{50}} = 71.4$ years.

Prof. Chapman of Yale has suggested a method of dividing the total volumes by the total number of trees, then finding the d.b.h. and height which, in the volume table, corresponds to this average volume and determining the average age from stump analysis, increment boring, or growth table. This method applies only to the merchantable classes.

The normal selection forest would show the following distribution of ages by area:

E.g., 900 acres of selection forest with a rotation of 150 years and a cutting cycle of 30 years would normally contain $\frac{150}{30} = 5$ age classes as follows:

Trees	1– 30 years old	$\frac{900 \times 30}{150} = 180$ acres
	31– 60	$= 180$
	61– 90	$= 180$
	91–120	$= 180$
	121–150	$= 180$
	Total,	900 acres

A convenient way to express the age limits and average age in an uneven-aged stand is by the expression $\frac{50-100}{71}$ where, in the example above, the age varies from 50 to 100 years and the average has been determined as 71 years (strictly 71.4 years). Where the average age has not been arithmetically determined the approximate age figures will, at least, serve as a valuable guide. Or even the letters *O*, *Y*, *M* may be used, e.g., $\frac{O\text{–}M}{O}$ would be a stand Mature to Overmature with the average Overmature, i.e., in excess of the rotation age.

Nor should it be forgotten that certain species, such as fir and spruce, often withstand decades of suppression during which their growth is almost nil. In determining their age this " core of suppression " should, therefore, be disregarded.

Areas that are being regenerated by shelterwood methods fall into two age classes, divided according to what remained of the original stand. For example, a shelterwood cutting in a ninety-year old stand covering 200 acres of which only 40 per cent of the stand remained uncut would be apportioned: 80 acres to the higher-age class and 120 acres to the lowest or to the " blanks " if no reproduction was on the ground. Where less than 20 per cent of the original stand remains on a cutting area or burn and the density of stocking is less than .3 and there is no reproduction the area, is temporarily at least, classed with the " blanks."

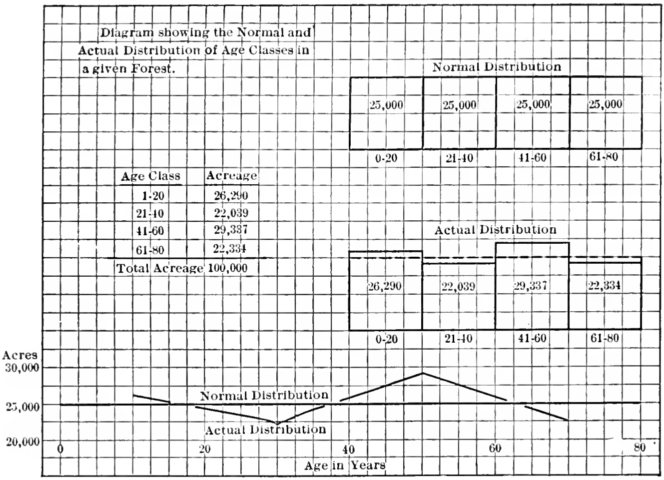
The age classes are differentiated by species only if there is a marked difference in their value.

There are two graphic ways of comparing the actual with the normal distribution of the age classes. One is by plotting the normal and the actual area of each age class on cross-section paper, using the ordinates for age and the abscissæ for area. The normal distribution will, of course, be a straight line; the actual a zigzag, now rising above, now falling below the horizontal line of normality.

The other method is that of rectangular blocks, the normal age classes being equal-sized and placed next to the unequal blocks showing the actual size of the various age classes.

It is always of advantage to compare the real and the normal age-class distribution; for it is a criterion of a sustained yield

Diagram D



and, in conjunction with the increment, determines the degree of approach toward a normal forest.

NOTE.—For a consideration of the value of the growing stock of a normal forest, see Roth: "Forest Valuation," Ann Arbor, Mich., 1916, pp. 65–70. See also, by the same author, "Normal Forest and Actual Forest, Normal Growing Stock and Actual Growing Stock, Normal Stand and Actual Stand," Forestry Quarterly, Vol. XIII, No. 2, pp. 154–162.

SECTION TWO

FOREST SURVEY

By forest survey is understood the gathering and tabulation of all data in regard to forest lands, including plane and topographic surveying, mapping, timber estimates, forest descriptions, grazing data and land classification, type and site determination, involving all the work of every kind (including the construction of volume, growth and yield tables) necessary for the making of the working plan.*

Here again forest organization touches upon the domain of forest mensuration and, in part, of engineering. Hence only the salient points affecting the working plan will be treated.

Preliminary Work

Before the field work is begun, all available data should be gathered from the records, along the following lines:

1. Area and boundaries of forest.
2. Best existing estimates of timber.
3. Approximate distribution of species.
4. Salient topographic features.
5. Past cuttings and their results; stumpage prices.
6. Classes of material utilized; prices obtained; market conditions.
7. Previous working plan or previous silvical studies; volume, growth, or yield tables.
8. Best maps available.

Armed with these data, the forest organizer should then make a preliminary trip over the forest so as to gain a general familiarity therewith and the better to formulate his plan of

* Forest surveys may be partial or complete, more or less intensive or extensive. A preliminary, extensive forest survey is often called a reconnaissance. This term may be applied to include one or more of the items constituting a complete forest survey. The term " intensive reconnaissance " is essentially contradictory in its component parts.

campaign. Wherever possible, he should be accompanied by the owner, the administrator, or both.

A conference should always be had between the owner or administrator, or both, and the forest organizer. The wishes and objects of the owner are basic in outlining a plan of silvicultural management and determine what data are requisite and what degree of detail is necessary in securing these data. The permissible cost of field work should also be decided. It is well if the results of this conference are put in writing and the document signed by each of the participants.

Survey of Area

A good map is an essential part of every working plan. The map need not be elaborate, but it must be accurate.

Where the land involved has not been surveyed, this must form a part of the field work, though it can often be done in conjunction with the estimating. In every case, it involves at least the retracement of the principal land lines and their fixation on the ground and on the map. Especial attention must be given to the boundary lines.

It is very serviceable to post boundary and interior corners with fire warnings, or similar placards, in pathless forests. These are most helpful in indicating the position of corners, especially if they are stamped with rubber stencils and indelible ink to show what corner it is. Thus, where the land is sectionized, the section corner would be posted and perhaps also where an important section or township line crosses a much-traveled road or trail. The object is to make the results of field surveys or retracement of old survey lines available not only on the map but on the ground.

The extent to which topography should be shown depends on the uses of the map. Where a detailed plan of logging is to be included, the topography must be shown in detail. For purposes of ordinary forest organization it suffices to show all drainage, all roads and trails, all houses, barns, and other "culture," and the topography in contours of 100-foot interval sketched in from aneroid barometer traverses.* In level country contours serve no useful purpose. In the matter of topography the object is to get a good working medium for orientation and for the subsequent division of the area.

The scale of the map must depend on the size of the area, the wealth of detail, and the intensity of the proposed management. Ordinarily a scale of 1 or 2 inches to the mile for the general map is quite sufficient. Where the forest is very large it is well to have a small scale location map, and then larger scale maps showing the various parts of the forest in greater detail.

No survey of the area—and no forest map—is complete which does not include a delineation of the forest types. This is usually done in conjunction with the estimating, but its importance must be emphasized here. Simplicity in type distinctions is essential for clearness. Only those type differences should be recognized which are sufficiently striking to be recognized instantly by every trained eye. Ordinarily, permanent types alone should be regarded, but often transitory types—e.g., aspen on old burns—must be recognized, since they demand a different treatment. Minor differences should never, for the purposes of a working plan, be made the basis of type distinction.

The mapping of all cut-over or burned areas, of swamps, barrens, etc., is a part of every forest survey.

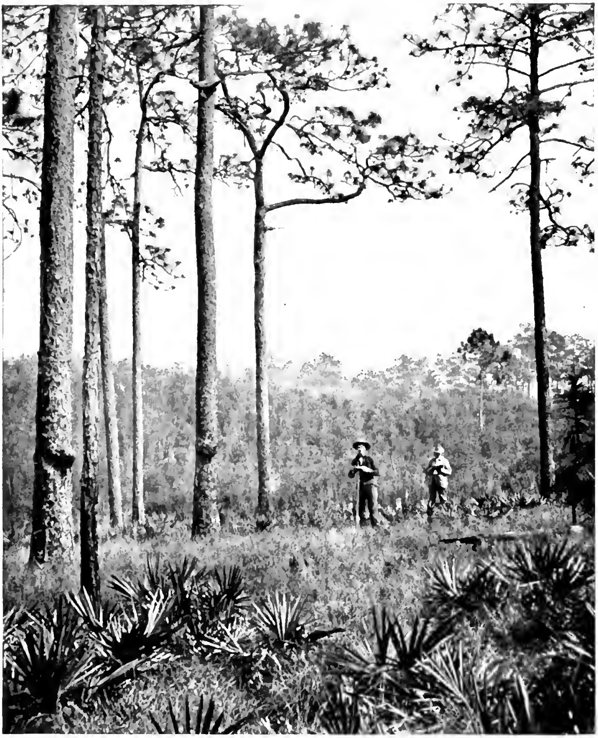
Timber Estimates

Requisites.—Without encroaching on the subject of forest mensuration, the requisites of the timber estimates for purposes of the working plan are:

1. Amount and species of timber.
2. Class of timber (saw timber, cordwood, etc.).

* The topographers of reconnaissance parties of the U. S. Forest Service prefer the Abney hand level to the barometer for any work except the making of very rough maps. See "The Abney Hand Level and the Chain on Intensive Forest Surveys," C. R. Anderson, For. Quart., Vol. XIII, No. 3, pp. 338–343.

PLATE II.



A Reconnaissance Survey Party, Florida.

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3. Condition of timber (soundness).
4. Approximate age of timber.

For purposes of combining the survey with the timber estimate, the strip method of estimating is undoubtedly the best. From a definite base line—such as a section boundary or, if in unsurveyed or very rough country, a base line previously run out—the strips are run out at right angles, at definite intervals.

Base Lines.—The section line serves as an excellent base, especially in fairly level country. Rough topography or the lack of suitable survey lines as a base make it necessary to establish base lines in advance of the actual estimating. They should be located in valley bottoms, along roads, or elsewhere so that they can be easily retraced; at the same time they give a preliminary topographic control. The distances must of course be measured accurately either by chain or tape or by stadia. The use of stadia—involving a mountain transit or a telescopic alidade—is advisable only in fairly open country or for the primary base lines. The chain or tape is much handier in timbered country; pacing is not accurate enough for this purpose.

Beginning at some known point, or at least tied thereto by definite triangulation, the base line system is developed over the whole forest like the stem and branches of a tree. The number of base lines must depend on the intensity of the work; better fewer and accurate than many and slipshod.

A traverse board and open-sight alidade are excellent for base-line work unless the timber is too dense; then chaining alone is possible, and the notes must be plotted not only upon return to camp, but immediately, in the rough, so as to determine where the equidistant strip stations are to be established. For the base line traverse will necessarily be a zigzag and the strip stations must be exactly equidistant. They are usually marked with a stake and a pile of stones or a blaze, scribed or blue-penciled with the number and the elevation of the station. For purposes of identification it is well to place the station close to some road, trail, stream, or other topographic feature. The elevation is determined by aneroid barometer readings carried from some point of known elevation. Where transit or telescopic alidade or a clinometer is used it can also be determined by the vertical angles. The crossings of all roads and trails, of creeks, etc., are noted, either directly plotted on the traverse board or else entered in the note-book; the elevation at these crossings is also noted.

If the forest is so large that the estimating will require several seasons, only so much of the base-line work need be completed in advance as will be used in that season. However, base-line work can often be done to advantage several months before the detailed estimates are begun.

Wherever possible, the forest organizer should himself be in charge of the base-line work. Three men constitute the ordinary base-line crew; two will suffice at a pinch, though it is better to have two to chain and one for the traverse board or to enter notes, take aneroid readings, etc.

The Strips.—The estimate strips should always run across the topography; only in that way will average conditions be secured. The size of the crew depends on the method of estimating employed. The ordinary strip survey crew consists of two caliper men, and a head and a rear chainman. The former runs the compass, the last named takes notes on topography and elevation and enters the diameters breast high as called out by the caliper men. Each strip is usually one chain wide.

Where the strip is not chained, the crew can be reduced to three, or even two, the compassman to pace and keep notes, two (or one) to caliper.

Where trained men are used, calipering is seldom necessary; here two men—one to pace and keep notes, one to estimate diameters—suffice.

In open timber the strips can be widened to one chain on each side of the line.

One man can run a strip, but he can scarcely manage compass, aneroid, note-book, and estimate all at the same time. Either he must make an ocular estimate of the whole stand or else confine himself to quarter-acre (or similar sized) sample areas at definite intervals. Only in cases of need is this sample-area method advised; it is usually better economy to use a two or more man crew. The work goes better, and is more accurate, the men check each other's judgment and, finally, in case of accident, the single man is not left helpless.

The strips must gridiron the forest. The interval between the grids depends on the purpose of the work. For a reliable estimate 5 to 10 per cent of the area should be covered.* This means:

For 5 per cent of area: chain-wide strips 20 chains apart.

For 5 per cent of area: strips two chains wide, 40 chains apart.

For 5 per cent of area: $\frac{1}{4}$-acre sample areas, $2\frac{1}{2}$ chains apart on strips 20 chains apart.

For 10 per cent of area: chain-wide strips 10 chains apart.

For 10 per cent of area: strips two chains wide 20 chains apart.

For 10 per cent of area: $\frac{1}{4}$-acre sample areas, $2\frac{1}{2}$ chains apart on strips 10 chains apart.

A very practical way of recording the estimates is by 2 or 3-inch diameter classes, beginning with the smallest merchantable diameter, supposing this to be 11 inches, as follows:

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* Margolin in an article on "Errors in Estimating Timber," For. Quart., Vol. XII, No. 2, pp. 167–176, says:

"Assuming that the method of estimating is correct and it is carefully applied, a 5 per cent estimate will give fairly satisfactory results for an area not less than about 1500 acres. A 10 per cent estimate may give fairly satisfactory results for an area as small as a section in extent, but for smaller areas than that even a 10 per cent cruise is not very reliable. Where more detailed estimates are desired more intensive cruises are essential. The practice of making 5 per cent or even a 10 per cent cruise and then giving out the estimate by 40-acre units is inaccurate and misleading and should be discontinued, especially so since such a detailed estimate seldom serves a useful purpose.

"The greater accuracy obtained by a 10-per cent cruise over a 5 per cent cruise is entirely out of proportion to the difference in the costs, and it appears to be good business, therefore, to make the more intensive cruise, especially where detailed figures are desired."

D. B. H. inches	SPECIES			
	Pine	Spruce	Fir	Etc.
12				
15				
18				
21				
24, etc				
Poles				
Saplings				
Seedlings				

Seedlings are all trees under 5 feet in height; these are usually counted on a quarter-acre circle at the end of every ten chains or so, to supplement the notes on reproduction.*

Saplings are from 5 feet in height to, say, 6 inches diameter breast high.

Poles are over, say, 6 inches diameter breast high up to the minimum merchantable diameter. Poles and saplings are usually counted and tallied just like the larger timber.

While the strip estimates, in combination with volume tables, usually give more accurate results than an ocular estimate, the greater expense of the former and the longer time required to cover a given area often decide in favor of the latter, especially where a rough estimate suffices and data on diameter classes are not requisite.

Various methods of ocular estimating have been devised; for purposes of forest organization the method of reconnaissance

* The Society of American Foresters recognizes the following tree classes:
Seedling: a tree, grown from seed, not yet 3 feet high.
Shoot: a sprout, not yet 3 feet high.
Small sapling: a tree from 3 to 10 feet high.
Large sapling: a tree 10 feet or over in height and less than 4 inches d.b.h.
Small pole: a tree from 4 to 8 inches d.b.h.
Large pole: a tree from 8 to 12 inches d.b.h.
Standard: a tree from 1 to 2 feet d.b.h.
Veteran: a tree over 2 feet d.b.h.

estimating practised by the Federal Forest Service since 1907 is probably the best.*

Topographic Notes.—Besides the timber estimating, it is a valuable feature of all strip surveys that the opportunity is offered to get excellent data on topographic features.

The estimator or tallyman carries an aneroid barometer and notes the elevation at each stream, divide, or similar feature; also at each corner to which he ties. Streams, ridges, roads, trails, etc., are sketched by him in a suitable note-book so as to show the exact point at which these features were crossed and their trend for a short distance to either side of the survey line. The same method applies to burned and cut-over areas. The boundaries of these and of the forest types should be noted where they are crossed and their trend for a short distance to either side of the survey line. These data should be sketched in on blanks or note-books provided for the purpose.

Time of Survey and Estimate.—The "field season"—i.e., that season when field work can be accomplished with the minimum of climatic difficulties—is usually the best for the work of estimating and mapping. In mountainous countries and in northern latitudes, this means the summer months; in southern latitudes winter is often preferable because of the excessive summer heat. Even in mountain regions the winter season may sometimes be chosen because the forest personnel is usually less heavily burdened with work in winter than in summer. That winter work is entirely feasible, if snowshoes or skis are used, is demonstrated by the winter reconnaissance in certain mountain forests of California.† One advantage of winter work is the ease with which the compassman's tracks can be followed by

* For detailed description see "The New Reconnaissance," Proceedings Society of American Foresters, Vol. IV, No. 1. Reprinted Yale Publishing Association, 1909. See also, for practical workings, cost, etc., "The Progress of Reconnaissance," F. Q., Vol. VIII, No. 4, pp. 415 to 418.

† See "Winter Reconnaissance in Californian Mountains," R. F. Hammatt, F. Q., Vol. IX, No. 4, pp. 557–562. Also "Winter Reconnaissance in the Rocky Mountains," G. Z. Mason, F. Q., Vol. XI, No. 4, pp. 516–518.

the cruisers and used by them as a check on the width of the estimating strips.

Use of Yield Tables.—The estimating of timber by means of yield tables unfortunately finds little or no application in America because of the lack of suitable tables. Yield tables are constructed for even-aged fully stocked stands of a single species for various site qualities. The age is usually given in five- or ten-year intervals. European yield tables are separated for final and intermediate yield (thinnings) and total. Normal yield tables preponderate, but local (empirical) yield tables are used as makeshifts. The methods of making yield tables is the province of forest mensuration, but for purposes of forest organization the data should comprise: Age, number of trees per acre, basal area, d.b.h. of average tree, height of average tree, yield per acre, current and mean annual increment, for each site quality.

The use of yield tables requires the determination in the field of the following data (presupposing nearly even-aged stands): Age, site quality,* density of stocking.† The corresponding value for the age and site quality is read directly from the yield table and this multiplied by the factor of density (1.0 to 0.0). Where there are several species in the stand, the percentage of each is determined and the corresponding value in the various yield tables multiplied thereby; these values are then added and their sum multiplied by the factor of density (1.0 to 0.0).

Cost.—The cost of estimating (field work only) averages between the following figures:

Ocular estimates	1 to 2	cents per acre
$2\frac{1}{2}$-per cent strip estimates	$2\frac{1}{2}$ to 5	
5-per cent strip estimates	5 to 10	
10-per cent strip estimates	10 to 15	

* Site quality is most accurately gauged by the height of the trees. See Roth: "Concerning Site," Forestry Quarterly, Vol. XIV, No. 1, pp. 3–13.

† The density or degree of stocking is most accurately gauged by considering it as = area of cross-section of trees of the stand divided by normal area of cross-section (basal area). See Roth: "Forest Regulation," Ann Arbor, Mich., 1914, pp. 54–56.

PLATE III.

A Reconnaissance Survey Camp, Florida.

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Forest Description

It is of the utmost importance for the working plan that the silvical data secured in gridironing a forest be made a matter of record. In order that the observer may put down his observations while they are fresh in his mind it is well to provide a note-book or blanks with appropriate headings, such as those in the following outline:

Outline for Forest Description

1. Locality. Name of tract or owner, township, county, state. (Govt. Survey give Sec., T., R., and M.)
2. Situation and altitude. Reference to mountain, ridge, road, stream, camp, trail, etc. Elevation above sea level.
3. Boundaries and area. Adjoining property.
4. General topography.
   - *a*. General character—level plain to steep mountain.
   - *b*. Percentage of level land, gentle slopes, steep slopes, etc.
   - *c*. Height of the hills above the neighboring streams.
   - *d*. Drainage.
5. Slope and aspect (aspect = exposure).
   - *a*. Slope.

Level..........	0 to 5%	0 to 3°
Gentle.........	5 to 15	3 to 8.5
Medium........	15 to 30	8.5 to 16.5
Steep..........	30 to 50	16.5 to 26.5
Very steep......	50 to 100	26.5 to 45
Precipitous.....	over 100	over 45

   - *b*. Aspect, eight principal points of the compass.
6. Underlying rock, outcroppings; the quantity and size of boulders.
7. Soil.
   - *a*. Physical composition: gravel, sand, loam, clay and intermediate forms; also the amount of organic matter, and possibly of lime.

b. Depth:

Depth:	Very shallow...........	less than 6 inches
	Shallow...............	6 to 12 inches
	Moderate..............	12 to 24
	Deep..................	24 to 36
	Very deep.............	over 36

c. Color and consistency (light, binding, stiff, etc.)

d. Soil moisture:

Wet: when water drips from a piece held in the hand without pressing.

Moist: when water drips from a piece pressed in the hand.

Fresh: when no water drips from a piece pressed in the hand, though it is unmistakably present.

Dry: when there is little or no trace of water.

Very dry: when the soil is parched. Such soils are usually caked and very hard, sand being an exception.

e. Agricultural value.

8. Forest floor (the deposit of vegetable matter on the ground in a forest).

a. Litter (the upper, only slightly decomposed portion of the forest floor). Deep, moderate, scant, etc.

b. Humus (the portion in which decomposition is well advanced). Give the depth in inches.

9. Ground cover (all small plants growing in a forest, except young trees; such as ferns, mosses, grasses and weeds). Specify as herbaceous, woody, grass, ferns, moss, etc., and state amount.

10. Underbrush (all large woody plants, such as laurel, striped maple, witch-hazel and devil's club, which grow in a forest but do not make trees).

NOTE.—Undergrowth includes ground cover, underbrush, seedlings, shoots, and small saplings.

11. Reproduction (trees less than 10 feet high, from sprouts or from self-sown seeds). State whether the repro-

duction is from seed or sprouts; for each of the principal species give the approximate age, size, amount, condition and occurrence of the reproduction (by occurrence is meant in groups or singly, on raised ground or in depressions, on decaying logs, etc.); mention which species are most productive.

12. Stand (all growing trees in a forest or in part of a forest).
   a. Forest types, the topographic location of each, and the approximate proportion of the total area occupied by each. (A forest type is a forest or a part of a forest possessing distinctive characteristics of composition or habit of growth.)
   b. Composition: leading species, associated species, nature of mixture (singly or in groups); give approximate percentages of the leading species.
   c. Origin: seedling, sprouts.
   d. Density of crown cover (density of the crowns of the trees in a forest); it is usually measured by the extent to which the ground is shaded; express in decimals.
   e. Age: calculated from stumps or by judgment; approximate range of average ages, or age classes. Age class I, one to twenty years; II, twenty-one to forty years, etc.
   f. Diameter and height development: (I) general range of the breast-high diameters and of the heights of the larger trees, e.g., 8 to 14 inches, 70 to 90 feet. (II) Are the various tree or size classes well represented? The tree classes are:

   Seedling—a tree grown from seed not yet 3 feet high.

   Shoot—a tree not yet 3 feet high grown from a sprout (sprout = a tree which has grown from a stump or root).

   Small sapling—tree from 3 to 10 feet high.

   Large sapling—a tree 10 feet or over in height and less than 4 inches d.b.h.

   Small pole—a tree from 4 to 8 inches d.b.h.

Large pole—a tree from 8 to 12 inches d.b.h.
Standard—a tree from 1 to 2 feet d.b.h.
Veteran—a tree over 2 feet d.b.h.

g. Form of trees: long or short boles; clear or limby; straight or crooked. If saw timber, the number of sawlogs (16 feet long) per tree and per M. feet, board measure.

h. Condition: health, and apparent vigor of growth.

13. History of the stand: treatment by man; damage by fire, grazing, insects, diseases and atmospheric agents.
14. Merchantable condition of the trees. Reductions for defect; per cent of probable output of different grades of lumber.
15. Site class (forest-producing power of the locality). Use five grades, I, II, III, IV, V. I is best site. Should express the capability of the tract rather than the present production.

NOTE.—Many American authors use only three grades, I, II, and III, I being the best site and III the poorest site.

These subjects need not be treated exhaustively; the forest description must, above all, be practical and brief.

The unit of area in forest description depends, of course, on the degree of intensity possible in the working plan. The ideal unit of description is the stand. The stand is that portion of the forest which is so essentially different in forest type, in method of management, in component species, in age, in density of stocking, or in quality of site, that is clearly distinct from the surrounding forest. The stand as a unit of forest description is ideal, since it is at the same time the true unit of silviculture and forest organization. But the necessity of pushing the reconnaissance work and the size of the working plan area often makes it more feasible to confine the description to the survey unit—such as the section—or to an entire watershed (in unsurveyed and very mountainous country), leaving it to the forest organizer to combine the various descriptions and smooth out their differences and discrepancies into a general forest description for the working plan. At the same time the forest organizer is helpless if these specific forest descriptions are inadequate or inaccurate. Nor need the description contain many words; for mere stereotyped repetition is both tiresome and futile.

The outline given above for forest description must, of course, be supplemented by a report on logging and milling methods and costs if an appraisal of stumpage values is to be a part of the working plan. The following outline is suggested:

Lumber:

I. Stump to pond.
 (*a*) Logging operations with equipment used.
  1. Felling, limbing and sawing into logs.
  2. Brush disposal.
   a. Piling.
   b. Scattering.
   c. Dragging from trees.
  3. Skidding or bunching.
  4. Hauling to railroad.
   a. Big wheels.
   b. Wagons.
   c. Go-devils.
   d. Sleighs.
   e. Steam skidders (several types).
   f. Electricity.
  5. Loading on cars.
   a. Horse power.
   b. Steam power.
 (*b*) Transportation to mill.
  1. Trucks.
  2. Chutes.
  3. Flumes.
  4. Railroads.
  5. Tramways.
  6. Traction engines.

7. Sleighs.
8. Streams—driving.
9. Ponds—hot and cold.

(*c*) Logging administration.

1. Camps.
2. Commissary.
3. Labor.
4. Supervision.
5. Scaling.
6. Animals.

II. From pond into cars.

(*a*) Milling and equipment by types of mills.

1. Sawing.
    a. Hoisting logs from pond to mill deck—scaling.
    b. Steam nigger.
    c. Log carriages (shot gun or cable feed).
    d. Saws (sash, gang, circular or band).
    e. Re-saw.
    f. Saw filing.
2. Edging.
3. Trimming.
4. Conveyor system.
5. Power.
6. Transmission.
7. Electricity (lighting system).
8. Hog.
9. Refuse burner.

(*b*) Yarding by types of mills.

1. Grading and grading rules.
2. Conveying from grading table to piles in yard, or kiln.
3. Dry kilns—types, etc.
4. Loading on cars.

(*c*) Planing.

(*d*) By-products.
1. Lath.
2. Shingles.
3. Boxes.

(*e*) Milling administration.
1. Supervision.
   a. Mill.
   b. Office.
2. Labor.
   a. Mill.
   b. Office.

III From cars to consumer.
1. Methods of selling.
2. Transportation.
3. Markets.

Hewn railroad ties:
1. Specifications.
2. Cutting.
3. Hewing and peeling.
4. Delivering.

Telephone poles:
1. Specifications.
2. Cutting and peeling.
3. Delivering.

Fence posts and stays:
1. Specifications.
2. Cutting and peeling.
3. Delivering.

Mining timbers:
1. Kinds and specifications.
2. Cutting and peeling.
3. Hauling to cars.

4. Transportation.
5. Markets.

Cordwood:

1. Specifications.
2. Cutting and stacking.
3. Hauling.
4. Loading on cars.
5. Transportation.
6. Markets.
7. Supervision and labor.

Cooperage stock:

1. Specifications.
    a. Heading stock.
    b. Stave material.
2. Felling and making bolts.
3. Disposal of brush.
4. Hauling bolts to mill and piling in yard.
5. Manufacture of staves and stacking in yard.
    a. Heading.
        1. Sawing.
        2. Sorting.
        3. Stacking.
    b. Staves.
        1. Equalizing.
        2. Sawing or "bucking."
        3. Listing.
        4. Grading.
        5. Stacking.
6. Transporting staves to railroad.

In addition to logging and milling methods and costs, the logging conditions should be summarized for each logging unit, that is for each part of a forest which can conveniently be made the basis of an individual logging operation. The following headings, taken from the outline on pp. 222–225 of Chapman's

"Forest Valuation," John Wiley & Sons, N. Y., 1915, will be found useful for this purpose.*

A. Modification of logging required by silvicultural demands.
  1. Amount and character of merchantable timber to be left standing.
  2. Methods of brush disposal and precautions required, for protection of young timber.

B. General conditions affecting appraisal.
  1. Market value of lumber.
  2. Size of mill and cost of milling, with profits.
  3. Cost of main transportation system.

C. Specific conditions affecting appraisal.
  1. Specific costs of logging the unit.
  2. Specific appraisal of value of standing timber per unit of log scale.

D. Appraised value of standing timber, by species, for specific units of product, modified for overrun to apply to standing timber.†

Division of Area

In order to facilitate the management of a forest, it is systematically divided into units of area. A forest may be divided from various points of view into units, either localized in the field, or differentiated in the working plan, or both.

The division of area for purposes of forest organization is in Europe considered the prerequisite of any working plan. For the extensive conditions prevailing in many parts of America the elaborate divisions of area used in Europe can well be waived. Indeed it is conceivable that a useful working plan

* More detailed outlines for studies of lumber operations have been published by the Yale Forest School (Prof. R. C. Bryant), and by the N. Y. State College of Forestry at Syracuse University (Vol. XVI, No. 7.)

† For detailed methods of determining the value of merchantable standing timber, see Chapman: "Forest Valuation," Chapter XI; also Roth: "Forest Valuation," Chapter VI; also, "Manual of Stumpage Appraisals," U. S. Forest Service, November, 1914.

could be constructed without any systematic division of the area. The need for these divisions grows with the refinements in management, and while it would be mere play in most American forests to mark each compartment and subcompartment in the map or on the ground, a skeleton outline of the salient divisions will often serve to facilitate and to systematize the working of a forest. Unnecessary divisions must be avoided.

For these divisions topographic features, roads, trails, etc., should be made the boundaries; even in flat country the hewing through of compartment lines is justified only under most intensive conditions.

The customary subdivisions of a forest are:

The working unit (syn. working plan unit. Ger. Wirtschaftsganzes).

The working group (syn. management class, working block, working circle, working section, Ger. Betriebsklasse).

The block.

The compartment.

The lot or subcompartment.

These may be defined as follows:

Working Unit.—The forest area managed under an individual working plan and by means of the plan of regulation of the cut, usually with the idea of a sustained yield. It may or may not coincide with an administrative unit.

Working Group.—A unit of forest organization, comprising an aggregate of compartments or stands to be managed under the same silvicultural method and rotation.

Block.—A major division of the working unit, being a permanent land subdivision in the forest, intermediate in size between the working unit and a compartment. A block is usually based on topography, such as the whole or portion of a drainage, containing from 1000 to 100,000 acres.

Since the division of a block is usually topographic, a suitable local name can generally be taken from some salient topographic or cultural feature contained therein.

Compartment.—A unit of forest organization for purposes of orientation and silvicultural operation. It is a permanent subdivision. It may or may not coincide with the public land survey. There may be an indefinite number of compartments in a block. The limits of a compartment are rectilinear in the plains and follow topographic features in hill and mountain country. The area of a compartment varies with the intensity of management and seldom exceeds 500 acres.* In a forest under complete management, the compartment boundaries are shown on the forest maps and are permanently marked on the ground by blazed lines, durable monuments, posting, roads, trails, streams or other well-defined natural features.

The compartment is created for purposes of easier orientation in the woods and for facilitating and systematizing the keeping of detailed forest records. Where the boundaries of compartments are hewn out or made into roads, these serve the additional purposes of fire lines, logging roads, points of attack in cutting series, and as convenient units where game is beaten from cover.†

The Forest Service apparently favors the use of chance or logging chance in place of compartment. This is a term in common local use, more or less synonymous with logging unit. It is not favored as a term in forest management.

Lot or Subcompartment.—A permanent or temporary subdivision of the compartment based upon differences in stand, necessitating a different method of silvicultural treatment. An example of permanent subdivision is the case of swamp in the midst of pine land. An example of temporary subdivision is the case of a severe burn in the midst of uninjured, mature forest.

Designation of Divisions.—Working units and blocks are given names: compartments are numbered; subcompartments

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* Roth: "Forest Regulation," p. 38, says: "It is feasible even in high mountain districts to stay below 200 acres in the average size of the lot."

† Hence in the plains, e.g., in the Prussian pineries, the compartment is called a "Jagen" i.e., a "hunting." The average size in Prussia is 25 hectares = $61\frac{3}{4}$ acres.

are lettered; e.g., a paper-birch thicket in midst of spruce compartments on the lower slopes of Mount Tecumseh block in the Waterville, N. H., basin, would be designated as *29a*, Tecumseh Block, Waterville Unit.

Boundaries of Divisions.—Before designating the boundaries of any working-plan divisions, either in the field or on the map, the forest organizer, in consultation with the owner and the administrator of the forest, or both, should decide just what divisions are to be made and on what basis. The determination of working units is a *sine qua non*, but whether blocks, compartments, and subcompartments are also to be segregated depends entirely on the specific needs of the forest. Large forests should almost always be divided into blocks. The further subdivision into compartments and subcompartments is necessary only where intensive working plans are practicable.

Having decided just how far to go in the matter of divisions, the forest organizer keeps this in mind during his preliminary reconnaissance and during the entire progress of the field work. The details of forest description and the unit described depend on the extent of subdivision. That is, if blocks are the minimum divisions possible, the organizer needs only the briefest descriptions by sections or other survey units and a more detailed general description by watersheds or other appropriate units. If, on the other hand, the refinements of compartments and subcompartments are possible the unit of description must be the stand, and the forest description of each stand must be sufficiently detailed so that the forest organizer can determine therefrom whether to make it a subcompartment, and its function in regulating the cut.

Obviously, therefore the provisional boundaries of the minimum unit of division decided upon must be noted in the progress of the forest survey and noted on the map.

As the work of gathering the data progresses, the forest organizer keeps always in mind the possible division of the forest and, map in hand, goes through the area to determine its most advantageous arrangement. His task will be the easier if the forest description data are well and carefully gathered.

Where artificial lines are cut through, those running with the prevailing storm direction are called, in Germany, "Haupt-Gestell" (Main Frame) or "Wirtschafts streifen" (Management Stripe), those running at right angles thereto, "Neben-Gestell" (Accessory Frame) or "Schneussen" or "Schneisen."* The former average 15 to 30 feet in width, the latter $6\frac{1}{2}$ feet to 15 feet; in this way they serve as a network of logging roads and fire lines. The "Schneisen" serve also to strengthen the stand against windfall; for along them develops the "wind-mantle"—i.e., the crowns of the trees on the border form an impenetrable mantle and protect the interior of the stand from windfall. This is especially important in spruce and similar shallow-rooted species. As the lower branches show signs of dying off, the strip is widened so as to let in the necessary additional light and keep the wind mantle intact, until it reaches a maximum width of 30 or 40 feet. These "Schneisen" are then made the points of attack for the cutting series,† since the stand to leeward of them has through its wind mantle ample protection against the storms.

Block divisions are always natural and are chosen on a large scale—watersheds, drainage basins, are suitable units. The single block may contain many thousand acres; its shape is immaterial; the governing considerations are logging and market conditions. The block is usually a main logging unit or

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* In Prussia the "Hauptgestelle" are 700 to 800 yards apart; the "Nebengestelle" are 350 to 400 yards apart.

† *Cutting Series.*—A cutting series or felling series is an aggregation of stands into a proposed or actual sequence of felling areas—that is, areas on which cutting operations are being conducted or areas designated for cutting. The object of such a series is a distribution of felling 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 felling area. It is intended to interrupt a regular sequence of age classes. It is quite generally used abroad in spruce to prevent windfall and pine to prevent insect damage.

It is not used in broadleaf forests or in any selection forest.

group of logging units. Its segregation requires a complete knowledge of such matters as present market conditions, lines of transportation, outlets for the timber, and the probable changes and developments in all three.

How far, if at all, the blocks should coincide with the administrative divisions, such as ranger districts, must depend on local conditions. It is often convenient to have block and ranger district coincide, and in level country, such as the Prussian pineries, this is entirely feasible. But the purposes of administrative division are so different from those of the working plan that the coincidence should never be secured at a sacrifice of either forest administration or forest organization.

The boundaries of blocks and subcompartments need not be marked on the ground. Compartments must be marked on the ground by blazed lines, durable monuments, posting, roads, trails, streams or other well-defined natural features. A convenient way is stencilling the number of the compartment in white paint on the bark of a tree nearest to the corner thereof. Where the lines are not actually cut through, their intersections with roads, trails, streams, etc., should be similarly designated. Where road or trail or stream itself serves as the boundary, this is not necessary, but merely corner monuments or occasional guide-monuments are placed.

On the map the boundary of the working unit is marked by heavy dot and dash —.—.—.—; the blocks by dashes — — — — — — — — — — —; the compartments by a dotted line . . . .; and the subcompartments by a thin unbroken line ————————.

References.—Roth, "Forest Regulation," pp. 34–43, Illick, "The Subdivision of Forests," F. Q., Vol. XIII, No. 2, pp. 183–198.

Maps and Tables

The various data collected in the field should, as far as possible, be entered on maps and summarized in tables. In this way they are made available at a glance.

Maps, or, at least, some map of the forest, however crude, are indispensable in forest organization. The forest map should contain:

(*a*) Essential topographic features; contours are seldom necessary in level country; hachures are not ordinarily advisable.

(*b*) Roads and trails, railroads, houses, barns, and other "culture."

(*c*) Boundary (exterior) of the forest; also all other interior holdings by other owners.

(*d*) The forest types; also all burns and cut-over area; all barrens and all land under cultivation or pasturage (non-forest land) within the exterior boundaries.

a, *b*, *c*, and *d* may form one base map, or they may be made into separate maps as the wealth of detail necessitates or convenience dictates. Where the area is too large to be shown completely on one map of ordinary scale ($\frac{1}{2}$ or 1 inch to the mile), a small scale location map can be made and as many large scale detail maps as are desired. In surveyed country a separate map of each township, compiled from section sketches, is advisable.

Armed with this base map the forest organizer sketches in from survey notes, detail sketches, and forest description the following additional points:

(*e*) Provisional division of area into

Blocks,
Compartments,
Subcompartments,

all depending on the divisions previously decided upon. Where the forest is approximately even-aged and the method of regulation is to consider age classes, these should be entered on the map by writing the age class of the subcompartment in Roman numerals, and coloring or shading it accordingly. Barrens and treeless land are left blank. Often the organizer must go over the area, map in hand, in order to settle some uncertainty on the ground. The boundaries had best be sketched only in pencil. If the original maps are made on tracing linen

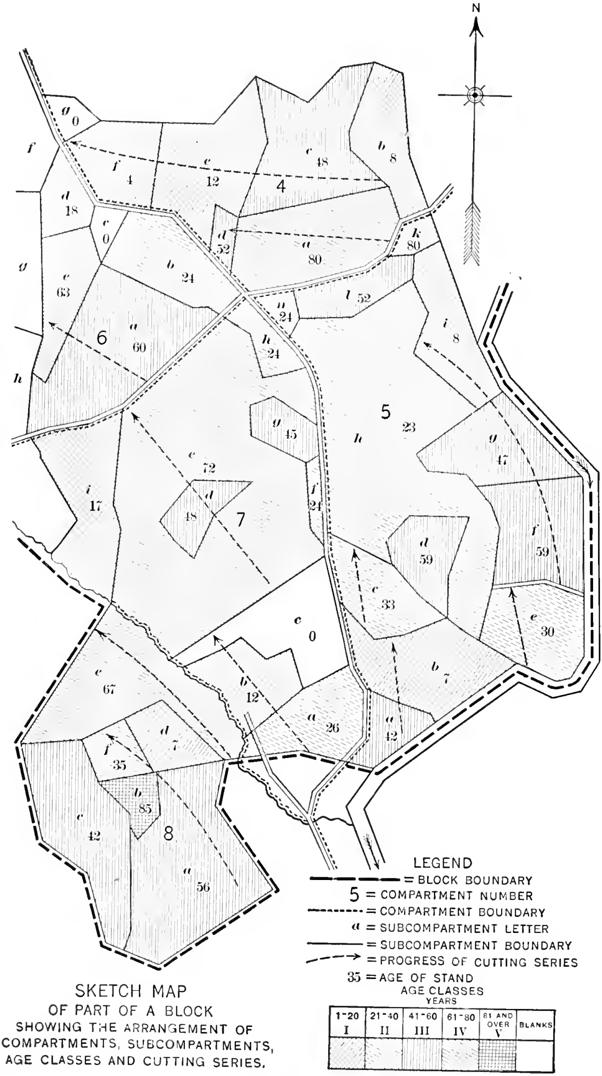
N
LEGEND
= BLOCK BOUNDARY
5 = COMPARTMENT NUMBER
= COMPARTMENT BOUNDARY
a = SUBCOMPARTMENT LETTER
= SUBCOMPARTMENT BOUNDARY
= PROGRESS OF CUTTING SERIES
35 = AGE OF STAND
AGE CLASSES
YEARS
1-20 I
21-40 II
41-60 III
61-80 IV
81 AND OVER V
BLANKS
SKETCH MAP
OF PART OF A BLOCK
SHOWING THE ARRANGEMENT OF
COMPARTMENTS, SUBCOMPARTMENTS,
AGE CLASSES AND CUTTING SERIES.

Fig. 1.

or on thin bond paper, blue-prints, or, still better, Van Dyke copies can be used for this provisional division of the area.

This provisional map quite suffices until the final working-

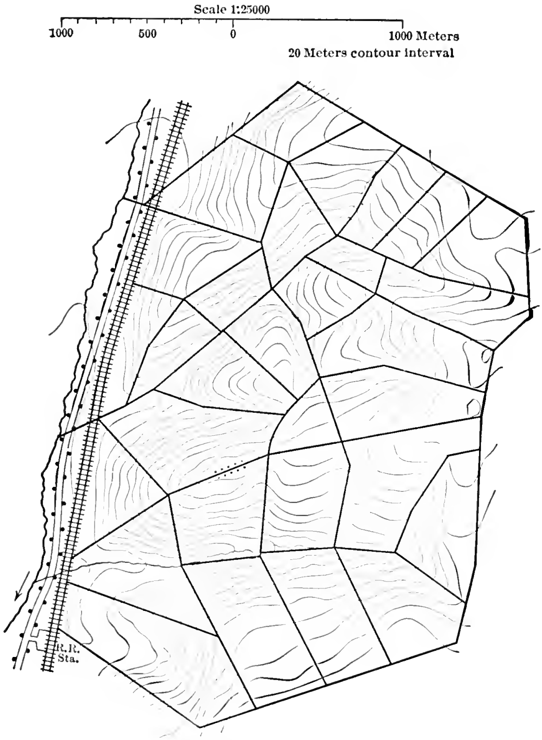

Fig. 2.—Division of a Prussian Forest into Compartments. (After Schilling.)

plan document is prepared, when the maps may be elaborated as much as is desired. E.g., the age classes can be shaded or colored, the type colored or symbolized, etc.

The prevailing local storm direction is entered (where it is not known already it must be determined; in a mountainous region the storms often follow the direction of the main drainage) by means of long dotted arrows (see Fig. 1).

The next step is to obtain the areas of the various divisions, types, alienations, etc. This is most easily done by means of a planimeter. One decimal place usually suffices. The larger areas are always measured first—e.g., the blocks before the compartments—the sum of the smaller divisions, e.g., of compartments, should check with the area of the larger unit (block) containing them. Minor errors can be proportioned. Roads, streams, boundary lines which have been cut through, etc., are seldom calculated as separate areas unless they are excessively wide, e.g., more than 20 feet.

Tables are now drawn up to contain these and other data which can be summarized. These may be:

(*a*) *Stand Table.*—A tabular enumeration showing separately for each diameter class and species, the number of trees on a given unit of area, usually an average acre. The corresponding volume may or may not be given.

Obviously, this form of table is most useful in the uneven-aged forest. The following example of such a table is taken from Bulletin 11 of the N. Y. State Conservation Commission,* based on virgin stands of hardwoods in the Catskill Mountains.

(*b*) *Stock Table.*—A tabular enumeration showing separately for each diameter class and species, the volume of timber upon a given unit of area, usually an average acre.

This form of table is best adapted to the uneven-aged forest. It serves as an excellent basis for computing the estimates, by simply multiplying the values given in the table by the total acreage. The following example of such a table is taken from Bulletin 11 of the N. Y. State Conservation Commission.†

* Bulletin 11, "Forest Survey of a Parcel of State Land," Albany, N. Y. 1915.

† *Ibid.*

Example of Stand Table

Slope Type.—Average number trees per acre based upon 84.86 sample acres.

D. B. H. Inches.	Balsam.	Hemlock.	Beech.	Birch.	Maple.	Ash.	Basswood.	Miscellaneous	Total.
7	.35	.34	4.07	3.88	2.17	.60	.60	.78	12.79
8	.18	.31	3.75	2.95	1.62	.46	.44	.64	10.35
9	.06	.29	3.91	1.79	1.06	.54	.31	.36	8.32
10	.07	.31	4.13	1.51	1.07	.34	.29	.24	7.96
11	.06	.33	2.85	1.14	.90	.14	.17	.18	5.77
12	.01	.31	3.31	1.32	.75	.11	.17	.14	6.12
13	. . . .	.23	2.66	1.24	.74	.07	.18	.07	5.14
14	. . . .	.15	2.07	1.06	.72	.12	.12	.01	4.25
15	. . . .	.09	1.41	1.17	.63	.07	.08	. . . . .	3.45
16	. . . .	.09	1.20	1.15	.61	.04	.12	. . . . .	3.21
17	. . . .	.09	.67	1.13	.64	.05	.06	. . . . .	2.64
18	. . . .	.07	.44	.94	.49	.02	.11	. . . . .	2.07
19	. . . .	.04	.24	.69	.53	.01	.08	. . . . .	1.59
20	. . . .	.02	.16	.67	.30	. . . .	.06	. . . . .	1.21
21	. . . .	.04	.09	.61	.31	.01	.07	. . . . .	1.13
22	. . . .	.04	.05	.55	.29	.02	.05	. . . . .	1.00
23	. . . .	.05	.02	.47	.27	. . . .	. . . .	. . . . .	.81
24	. . . .	.02	.01	.54	.22	. . . .	.01	. . . . .	.80
25	. . . .	.02	.02	.44	.11	. . . .	.04	. . . . .	.63
26	. . . .	. . . .	. . . .	.39	.09	. . . .	. . . .	. . . . .	.48
27	. . . .	.02	.01	.21	.11	. . . .	. . . .	. . . . .	.35
28	. . . .	.05	. . . .	.19	.07	. . . .	. . . . .	. . . . .	.31
29	. . . .	. . . .	. . . .	.09	.04	. . . .	. . . .	. . . . .	.13
30	. . . .	. . . .	. . . .	.09	.02	. . . .	.01	. . . . .	.12
31	. . . .	.01	. . . .	.11	.01	. . . .	. . . .	. . . . .	.13
32	. . . .	. . . .	. . . .	.06	.03	. . . .	. . . .	. . . . .	.09
33	. . . .	. . . .	. . . .	.04	.03	. . . .	. . . .	. . . . .	.07
34	. . . .	.01	. . . .	.01	.01	. . . .	. . . .	. . . . .	.03
35	. . . .	. . . .	. . . .	.04	. . . .	. . . .	. . . .	. . . . .	.04
36	. . . .	. . . .	. . . .	.01	. . . .	. . . .	. . . .	. . . . .	.01
37	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . . .	. . . .
38	. . . .	. . . .	. . . .	.01	. . . .	. . . .	. . . .	. . .	.01
39	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . . .	. . . .
40	. . . .	. . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . . .	. . . .
Total	.73	2.93	31.07	24.50	13.84	2.55	2.97	2.42	81.01
Per cent. .	.9	3.62	38.35	30.24	17.08	3.15	3.66	3.00	

Example of Stock Table

Slope Type.—Average volume per acre based upon 84.86 acres, board feet.

D.B.H. Inches.	Balsam.	Hemlock.	Beech.	Birch.	Maple.	Ash.	Basswood.	Miscellaneous.	Total.
7....	4.55	6.80	......	......	......	....	....	....	11.35
8....	3.78	6.41	......	......	......	....	....	....	10.19
9....	1.74	12.18	......	......	......	....	....	....	13.92
10....	2.73	17.98	......	......	......	....	....	....	20.71
11....	1.06	24.09	......	......	......	....	....	....	25.15
12....	.65	28.83	......	......	......	....	....	....	29.48
13....	....	26.68	220.78	73.16	59.94	4.90	12.60	5.81	403.87
14....	....	21.45	238.05	100.70	85.68	11.04	11.04	1.15	469.11
15....	....	15.48	200.22	146.25	89.46	8.19	9.36	....	468.96
16....	....	18.36	200.40	167.90	98.82	5.76	16.06	....	507.30
17....	....	22.23	126.63	184.19	117.68	8.65	10.38	....	469.76
18....	....	20.51	92.84	174.84	101.43	4.20	23.10	....	416.92
19....	....	13.60	57.60	149.73	122.96	2.54	20.32	....	366.75
20....	....	7.78	44.00	167.50	76.50	....	17.70	....	313.48
21....	....	17.56	28.26	181.17	87.73	3.45	24.15	....	342.32
22....	....	19.68	17.95	181.05	92.51	8.00	20.00	....	339.19
23....	....	27.15	8.28	170.61	95.58	....	....	....	301.62
24....	....	11.86	4.73	209.52	84.04	....	5.20	....	315.35
25....	....	12.80	10.66	179.52	45.10	....	23.40	....	271.48
26....	....	....	......	169.26	38.70	....	....	....	207.96
27....	....	14.50	7.13	58.70	48.95	....	....	....	129.28
28....	....	38.25	......	95.95	32.20	....	....	....	166.40
29....	....	....	......	49.05	19.00	....	....	....	68.05
30....	....	....	......	52.92	9.80	....	9.50	....	72.22
31....	....	8.85	......	68.09	5.05	....	....	....	81.99
32....	....	....	......	38.94	15.60	....	....	....	54.54
33....	....	....	......	27.16	16.00	....	....	....	43.16
34....	....	10.05	......	7.09	5.50	....	....	....	22.64
35....	....	....	......	29.56	......	....	....	....	29.56
36....	....	....	......	7.69	......	....	....	....	7.69
37....	....	....	......	......	......	....	....	....	......
38....	....	....	......	8.29	......	....	....	....	8.29
39....	....	....	......	......	......	....	....	....	......
40....	....	....	......	......	......	....	....	....	......
Total	14.51	403.08	1,257.53	2,698.84	1,348.23	56.73	202.81	6.96	5,988.69
%...	.25	6.73	21.00	45.05	22.52	.95	3.38	.12	

(*c*) *Area tables* (by types, by divisions of area).

(*d*) *Age-class table* (comparison with the normal).

Any or all of these tables may be constructed as the data warrant and as there is occasion for them. An age-class table is necessary only where the distribution of the age classes plays a part in the regulation of the cut.

Tables (*a*), (*b*), and (*c*), together with abbreviated notes on site, density, age, and salient silvical characteristics, can be combined into a general stand table, that is, a tabulation showing something of the condition of the stand on the several units of area. Only the more important items respecting the stand are included, such as merchantable and total volume by classes of material (sawtimber, cordwood, ties, etc.), species, age, stock density, etc. Such a table is usually supplemental to map records. It is compiled from the forest description and from the stand and stock tables of individual units of area. The particular form which this table takes should be varied to meet the needs of the working plan in question. The purpose is to give the essential data for the regulation of the cut; these essential data vary with the method of regulation which is chosen. In the example the table has been made as complete as is necessary even under intensive conditions. The hypothetical data would have required a correspondingly intensive forest survey.

These data will be required for only those forests which permit of an intensive management. However, the same form of table, with minor modifications, applies to even the most extensive conditions. For example:

If the estimate and description is by survey units, e.g., by sections, quarter-sections, or even forties, the arrangement of the columns would be varied so that Col. 2 would be township and section, Col. 3 the quarter-section or forty, Cols. 5, 7, 9, 11, 13, and 15 would give the area, not in acres, put in per cent of total, Cols. 6, 8, 10, 12, 14, and 16 would usually indicate the age only as Over-mature (*O*), mature (*M*), or young (*Y*). Cols. 23–29 would usually be recorded separately for each type.

If the estimate and description are lumped for the entire area of one type within the same watershed, Col. 2 would be the name of the type, Col. 3 would be blank, Cols. 5 to 22 inclusive would be as in the paragraph above, Cols. 23 and 26 would be very general, Cols. 24 and 25 would fall away, but Cols. 28 and 29 would be retained.

From the above data, a rough age-class table can, and, for all methods of regulating the cut by the distribution of the age classes, should be constructed. Assuming in the hypothetical data of the general stand table above that the rotation is 160 years, the form of age-class table would then be as follows: See Age-Class Table A.

In the above example if only the symbols "*O*," "*M*," and "*Y*" are used, the comparison would be as in Age-Class Table B.

Were the intermediate steps *O/M* and *Y/M* used also to designate the approximate age of the stands, the table would read as in Age-Class Table C.

NOTE.—In addition to the maps and tables listed, status records are often desirable. These are records showing the ownership of lands. Complete status records will show in detail the chain of title for each parcel of land and also all servitudes and easements attaching to the land. In addition, they usually show the location and extent of all qualified or temporary alienations such as unpatented mineral claims, leased areas, or lands otherwise specifically under permit or affected by outstanding contracts, as for the sale of timber, etc. Status records usually consist of sets of maps, often called "tract books," and of written or tabulated records supplemental to the map records.

AGE-CLASS TABLE A.

Block	Compt.	Subcompt.	Area	Area by Age Classes—Acres										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name	No.	Letter	Acres	I 1-20	II 21-40	III 41-60	IV 61-80	V 81-100	VI 101-120	VII 121-140	VIII 141-160	IX 161 +	X Blank	XI Uneven Aged
Tecumseh	1	....	104.27	..	104	..	..	..	..	..	..	..	Natural .. Restockable ..	....
....	2	....	96.	..	..	..	96	..	..	..	..	..	.. ..	....
....	3	....	93.73	..	..	..	..	..	..	..	..	..	.. ..	94
....	4	....	106.	..	..	..	..	..	106	..	..	..	.. ..	....
....	5	....	99.20	..	..	..	..	..	..	..	..	..	9 (rock)	90
....	6	....	103.	..	..	..	..	..	..	..	100	..	(cut) 3	....
....	7	....	97.	..	..	..	..	..	..	..	..	..	17 (pasture)	80
....	8	....	99.50	60	..	..	..	..	..	..	40	..	....	....
....	9	a	40.	..	..	40	..	..	..	..	..	..	....	....
		b	61.	..	..	..	..	..	..	..	..	61	....	....
....	10	....	100.30	..	..	..	..	..	..	..	..	..	(cut) 50 (burnt) 50	....
Totals...............			1,000	60	104	40	96	..	106	..	140	61	129	264
Comparison with Normal			Normal	88.75	88.75	88.75	88.75	88.75	88.75	88.75	88.75	..	of which 26 natural	Prtcn. Belt
Distribution of			Deficit	28.75	..	48.75	..	88.75	..	88.75	..	..	....	....
Age Classes:			Surplus	..	15.25	..	7.25	..	17.25	..	51.25	61	103 restockable	....

AGE-CLASS TABLE B.

	Overmature (160+)	Mature (81–160)	Young (1–80)	Restockable Blanks	Natural Blanks	Protection Belt (uneven aged)
Total, 1,000 acres	61 acres	246 acres	300 acres	103 acres	26 acres	264 acres
Normal	....	355 "	355 "	....	26 "	264 "
Deficit	....	109 "	55 "	....	....	....
Surplus	61 "	....	....	103 "	....	....

AGE-CLASS TABLE C.

	O (160+)	*O–M* (120-160)	*M* (80-120)	*M–Y* (40-80)	*Y* (1-40)	Restockable Blanks	Natural Blanks	Protection Belt (uneven aged)
Total, 1,000 acres	61 acres	140 acres	106 acres	136 acres	164 acres	103 acres	26 acres	264 acres
Normal	....	177 "	178 "	177 "	178 "	....	26 "	264 "
Deficit	....	37 "	72 "	41 "	14 "	....	....	....
Surplus	61 "	....	....	....	....	103 "	....	....
		(Merchantable)	(Near-Merchantable)	(Intermediate)	(Young Growth)			

SECTION THREE

DETERMINATION OF METHOD OF TREATMENT

Governing Conditions

The method of treatment of any given forest depends on the wishes and purposes of its owner. It is very necessary that these fundamentals be decided in consultation between the owner and administrator, and the forest organizer; for the working plan must be arranged accordingly.

Four main issues must be decided before any complete working plan is possible:

1. The unit of regulation.
2. Object of management.
3. The silvicultural method of management.
4. Rotation.

The Unit of Regulation

The unit of regulation or working unit, as defined above, is that area which is to be managed under an individual working plan, and usually for a sustained yield. The working unit may or may not coincide with the administrative unit, e.g., the single national forest.

In creating working units, the doctrine of sustained yield must be treated broadly. A sustained yield presupposes three things:

(1) A sustained market with attendant transportation facilities rendering every part of the forest accessible now or progressively so in the near future.

(2) An area ample, under the silvicultural methods chosen, to supply this sustained market.

(3) Stable market prices for the lumber and other forest products.

These three factors do not always coincide with the administrative units. The boundary of the administrative unit is purely for convenience in the management of the forest; the boundary of the working unit is, as far as limitations of ownership permit, an economic one within which the marketing of timber is controlled by certain factors of consumption or distribution. Economic reasons may warrant the over-cutting on one administrative unit and the under-cutting on another, but if a sustained yield from the entire market unit is maintained it is of small moment if the stand on one or more of the administrative subdivisions is over-cut.

This broad construction is of course adapted to the extensive conditions existing in most parts of America. In Europe, e.g., in Prussia, it has long been customary to require a sustained yield by administrative units—i.e., for each oberförsterei or supervisor's area—recently it has been extended in Prussia to cover each ranger's district! But in America the unit of regulation, the working unit, must be practical, must be the *market unit,* just as the subdivision, the block, usually is the main *logging unit.*

Where administrative unit areas belonging to the same owner are far apart or exceedingly large, they are not included in the same working unit. E.g., it would be preposterous to make a single working plan for the two divisions of the Florida National Forest or for the whole complex of contiguous national forests in Washington and Oregon. But it is entirely correct and logical to combine, e.g., the contiguous and similar Coconino and Tusayan National Forests in northern Arizona. The administrative boundary separating these two national forests is a purely arbitrary one; they are essentially the same in character and composition, and are parts of the same market unit.

The working unit is given some convenient local name which is simple and characteristic.

Object of Management

At the working-plan conference between owner, administrator, and organizer, the object for which the forest is to be managed must be decided, i.e., whether

1. For sustained yield,
2. For exploitation,
3. For protection,
4. For æsthetic purposes,
5. For a game preserve,

or how far each or all of these or any other considerations are to govern.

If the forest is to be a continuously productive one, the next point to decide is the class of product desired:

1. Sawtimber,
2. Cordwood,
3. Mining timber,
4. Turpentine, etc.

It must also be decided, if the yield is to be sustained, whether it is to be periodic or annual.*

The satisfactory solution of all these questions demands a thorough knowledge of forest finance and forest policy on the part of the organizer.

Silvicultural Method of Management

Having decided upon the unit of regulation and the object of management, the organizer, in conference with owner and administrator, should decide, provisionally, upon the silvicultural method of management; for the method of regulating the cut varies with the silvicultural system chosen.

The first point to determine is whether the forest is to be managed as:

High forest, i.e., a forest originating from seed;

Coppice, i.e., a forest in which reproduction is secured by sprouts;

or Coppice with standards, i.e., a forest in which seedling trees or selected sprouts (standards) are maintained above the coppice or sprouts;

* For excellent comparison of properties with yearly and with intermittent income, see Roth: "Forest Valuation," pp. 82–84.

or is to be converted from one of these forms to another. If high forest is chosen, the method of reproduction must be determined provisionally, that is, an orderly procedure or process, either natural or artificial, by which a forest is renewed or established. The following methods are distinguished: *

1. Clearcutting with artificial reproduction. Removal of the entire stand in one cut with artificial reproduction by direct seeding or by planting. See also seed tree methods (*b*). G., Kahlschlagwirtschaft. F., Méthode par coupe unique.

2. Clearcutting with natural reproduction. Removal of the entire stand in one felling, reproduction taking place by seed from the marginal stand or from seed in the ground. This method may be applied to the stand by cutting a strip and, when reproduction has taken place, seaming off an additional strip, called *strip method*. G., Saumhieb. F., Coupe par bandes.

When applied by removing groups of trees and enlarging these openings until the entire stand is removed it is called *group method*. G., Kesselhieb, Löcherhieb. F., Coupes par trouées.

3. Seed tree methods. (*a*) Removal of the entire stand at one cut excepting a small number of seed trees left singly on the area, or small groups or blocks of seed trees, which are expected to seed the area thus exposed.

(*b*) Removal of the entire stand excepting a few chosen individuals, reserves, left uncut for a period, usually for a second rotation, after the stand is reproduced. The primary purpose is to secure increment of the reserves and incidentally seed. This is known as *reserve seed tree method*. It is applied to forests naturally reproduced and to those artificially reproduced also. G., Ueberhaltbetrieb. F., Traitement en futaie avec réserve sur coupe définitive.

4. Selection method. That method of cutting in which single trees, usually the largest and ripest, or small groups of such trees, are removed and reproduction secured under the

* The terminology is that prepared by the Society of American Foresters.

FIG. 1.—A Compartment Reproduced by Shelterwood Cutting, Baden.
Courtesy of Mr. Lincoln Crowell.

Fig. 2.—A Compartment Reproduced by Selection Border Cutting Württemberg.
Courtesy of Mr. Lincoln Crowell.

[To face page 56]

remaining stand and in the openings. It is usually applied in selection forests. When groups of trees are taken it is termed *group selection method*. G., Plenterbetrieb, Femelbetrieb. F., Jardinage, régime de la futaie jardinée.

A special form of the selection method is termed *selection border cutting* when cuttings are made in narrow strips, in most instances beginning on the north border and progressing southward, varying in character from a selection cutting farthest in to a clear cutting on the edge of the forest. The resulting forest is unevenaged in narrow lines. G. Blendersaumschlag.

5. Shelterwood method. A method of securing natural reproduction under the temporary shelter of the seed-tree crown cover, by means of a series of cuttings throughout the stand, aimed to admit a gradually increasing supply of light to the seedlings.

The principle of the method lies in the protection (shelter) which the seed trees (nurse trees) afford the young growth during its youth. G., Schirmschlagbetrieb (Gayer & Lorey) in part Femelschlagbetrieb (Lorey). F., Régime de la futaie régulière. The number and severity of the cuttings and hence the duration of the entire removal period, depends upon the rate of establishment and upon the early growth of the reproduction. In theory the series of cuttings is divided into four parts as follows:

Preparatory cuttings fit the stand for its reproduction by the removal of dead, dying, or defective trees and prepare the ground for the germination of seeds. A stand in which one or more preparatory cuttings have been made is in the preparatory stage. G., Vorbereitungschlag. F., coupe préparatoire.

Seed cuttings encourage seed production by the further opening of the stand, and admit light in quantity favorable for the development of young growth. A stand in which one or more seed cuttings have been made is in the seeding stage. G., Besamungsschlag. F., coupe d'ensemencement.

Removal cuttings gradually remove the mature stand which would otherwise retard the development of the young trees.

A stand in which one or more removal cuttings have been made is in the removal stage. G., Lichtschlag. F., coupe claire.

The *final cutting* is the last of the removal cuttings, in which all of the old stand still remaining is cut. G., Abtriebsschlag, Endhieb. F., coupe définitive. In practice a two-cut shelterwood method has been used, including the seed-cutting and final-cutting stages. The shelterwood method may be applied to a stand in narrow strips, from the leeward side, at such intervals that reproduction cuttings are generally going on in three strips at one time, one strip being in the removal stage, one in the seeding stage, and one in the preparatory stage. This manner of application is termed *shelterwood strip method.*

Another modification of the shelterwood method of reproduction is that in which groups of valuable advance growth, if present, form the starting points for the cutting which radiates from these centres. Such an application is termed *shelterwood group method.*

The determination of the silvicultural method to be practised will require the best judgment and experience of the forest organizer. Complete forest descriptions and frequent observations within the forest will assist greatly in determining the best silvicultural system to pursue.*

The Rotation

By rotation is meant the predetermined time period during which it is intended to cut over a working group; the predetermined, *approximate* felling age of stands. Rotation refers to the forest as a whole and is expressed not by a definite year, but a period of ten to twenty years; *felling age* refers to a stand and a definite year.

Rotations are determined by (1) technical, (2) economic,

* It does not seem expedient to enter into a discussion of the specific application of various silvicultural methods. Such a discussion will be found in Roth: "Forest Regulation," pp. 90–107, in books on silviculture and in Recknagel and Bentley: "Forest Management," John Wiley & Sons, N. Y., 1917.

and (3) financial considerations, silvicultural considerations exercising a limiting influence.

Technical Rotations.—These attempt to produce the maximum amount of material suitable for a certain purpose, such as railroad ties, mine timbers, saw logs of given size and the like.

For example, railroad ties can not be made from trees less than 10 inches in diameter breast high. If, therefore, an owner in southern Connecticut desired to grow chestnut sprouts for this purpose it would require fifty * years for the average tree to reach 10 inches d.b.h. on the best sites. At this age † there would be 435 standard ties produced per acre besides 35 cords of cordwood.

Another example may be taken from the Pacific Coast. To produce suitable sawtimber from Douglas fir, the tree should be at least 16 inches d.b.h. If, therefore, an owner in western Washington desired to grow Douglas fir for this purpose it would require ‡ seventy years for the average tree to reach 16 inches d.b.h. on the best sites. At this age § there would be 56,500 feet, board measure, produced per acre.

This rotation is the one most commonly used in the United States. It is easily applied and, if conservatively chosen, will give satisfactory results. In this, as in all rotations, the silvicultural considerations exercise a limiting influence. For example, where reproduction is by natural methods, such as the shelterwood method, some of the trees will have to be left beyond the rotation age in order that the seed from them may restock the area cut. This space of time required for the renewal of a stand constitutes the *reproduction period* and must be added to the rotation age.

Economic Rotations.—These attempt to secure either the

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* According to Table 17 of Bul. 96, Forest Service, U. S. Dept. of Agriculture, "Second Growth Hardwoods in Connecticut."

† Table 28, ibid.

‡ Table 1, Forestry Quarterly, Vol. XII, p. 442.

§ Ibid.

maximum average volume production, or the maximum average value production.

The higher the average yearly production of a piece of woodland, the greater, of course, will be its continuous producing value if cut over repeatedly. For example, in the second-growth hardwoods in Connecticut * the average annual growth in cubic feet and cords culminates as follows:

Chestnut type: best sites and medium sites..........	35	years
Chestnut type: poorest sites......................	40	"
Oak-chestnut type: best sites and medium sites......	30	"
Oak-chestnut type: poorest sites..................	35	"
Oak type: best sites and medium sites..............	35	"
Oak type: poorest sites..........................	40	"

These lengths of rotation are so nearly similar that it is safe to place the cordwood rotation for second-growth hardwood stands at from thirty to forty years. To illustrate how silviculture enters in as a limiting factor, the rotation for stands containing much red, black, or scarlet oak should be thirty or even twenty-five years in order to secure successful sprout reproduction of these species.

Another example of the economic rotation may be taken from Douglas fir on the Pacific Coast. According to published tables † the economic rotation for cubic volumes and board-foot volumes for best, medium and poor sites, in western Washington and Oregon is as follows:

Site Quality.	Cubic Volume.		Board-Foot Volume.	
	Rotation Years.	Yield per Acre, Cu.ft.	Rotation Years.	Yield per Acre, Bd.ft.
Best......................	52	9,050	110	100,000
Medium....................	55	8,110	110	74,000
Poor......................	52	5,650	115	58,000

* Bul. 96, Forest Service, U. S. Dept. of Agri. Tables 30, 32, and 33.
† For. Quart., Vol. XII, p. 447, table 6.

From this, a rotation of fifty to fifty-five years could safely be chosen for maximum production in cubic contents and of 110 to 115 years for maximum production in board-foot contents.

Unlike the technical rotation, this rotation finds but little application to-day, since it usually takes quantity of material as the goal. It is satisfactory from the silvicultural standpoint hence it is sometimes spoken of as a "silvicultural rotation."

Financial Rotations.—These introduce considerations of cost and attempt to secure either the maximum *forest rent* or maximum *soil rent.*

The doctrine of *forest rent* considers the soil and forest jointly as capital and chooses that rotation which, in the form of a normal forest, would produce the maximum net annual income after subtracting the annual cash expenses. The rotation age which yields this maximum income for the entire forest coincides with the year of maximum mean annual net income from an even-aged crop of timber, found by dividing total gross income, minus actual cash expenses, by number of years in the rotation.

In other words it is "a mere bookkeeper's balance of income and outgo, under annual management, without consideration of time of income or outgo, forest and soil representing the capital producing the rent as an annual receipt, like a house and lot producing the annual rent." *

The Norway spruce will serve as an example of financial rotation based on forest rent. According to European tables (Endres, after Schwappach) the gross income, expenses and net income per acre for different decades is as follows for medium sites.†

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* From letter by Dr. B. E. Fernow to the author under date of February 23, 1914.

† Taken from "Forest Valuation," Roth, Ann Arbor, Mich., 1916.

Years.	Gross Income per Acre.	Expenses per Acre.			Net Income per Acre.	
		Initial (Planting).	Current (at $0.90 per Year).	Total Expense.	Total.	Average.
30	$ 87	$12	$27	$ 39	$ 48	$ 1.60
40	210	12	36	48	163	4.00
50	402	12	45	57	354	6.90
60	654	12	54	66	588	9.80
70	923	12	63	75	848	12.10
80	1212	12	72	84	1129	14.10
90	1474	12	81	93	1382	15.30
100	1710	12	90	102	1609	16.00
110	1919	12	99	111	1808	16.40
120	2087	12	103	120	1967	16.30

From this table it is evident that the highest net income occurs at 110 years and this, accordingly, would be the financial rotation chosen on the basis of *forest rent.*

The doctrine of *soil rent* considers the soil as a capital and the value of the growing timber as the interest on that capital. Such interest is compounded and is calculated at a predetermined rate. The interest so calculated is considered as rent (" soil rent ") and the rotation chosen which yields the highest soil rent per acre.

In other words it " considers the soil alone as capital, the forest stand representing the accumulated interest on that capital. It is, therefore, based on intermittent returns and hence requires a compound interest calculation: it is a financier's balance as compared with a bookkeeper's balance." *

A good example of financial rotation based on soil rent is found in European tables. The following figures are taken from Endres' " Valuation " and Schwappach's " Tables of Growth." Assuming an interest rate of 3 per cent compounded, the income value per acre for different decades and different species is as follows: †

* Letter from Dr. Fernow.

† Taken from " Forest Valuation," Roth, Ann Arbor, Michigan, 1916.

Years.	Norway Spruce.			White Fir.		Scotch Pine.		Beech.	
	Best Sites.	Medium Sites.	Poor Sites.	Best Sites.	Poor Sites.	Best Sites.	Poor Sites.	Best Sites.	Poor Sites.
	Dollars per Acre.								
30	51	10	−14	−10	−30	43	−3	4	−19
40	100	47	13	67	−5	59	7	25	−4
50	139	77	38	134	25	66	13	32	6
60	159	98	53	156	38	67	13	35	7
70	166	105	59	156	44	64	13	35	7
80	161	105	59	145	44	59	10	34	4
90	151	99	56	130	41	53	8	31	2
100	138	91	51	114	36	48	5	27	2
110	126	83	46	99	30	43	4	24	−2
120	117	75	41	86	25	40	2	21	−4

From this table it is evident that for Norway spruce, medium sites, the financial rotation chosen on the basis of *soil rent* would be 70 or 80 years; for white fir 70 years; for Scotch pine 60 years; and for beech 60 or 70 years.

The financial rotation will undoubtedly be used more and more in the future especially as the necessary data become available. "In any ordinary forest business the aim is to keep the forest and land in best possible condition and at the same time make the largest income. Assuming the silvicultural conditions cared for, the best rotation is the one furnishing the best income for the longest time. There are two distinct ways of judging this income.

"(1) . . . the largest net income per acre of established forest." (Forest rent.)

"(2) . . . the largest per cent on the money invested in the forest." (Soil rent.) *

The kind of rotation to adopt depends on matters of policy, to wit:

1. Conditions of ownership, wishes and purpose of owner.
2. The market and logging conditions.

* Roth: "Forest Valuation," p. 85.

3. The site.

4. The character of the stand.

1. The state can afford a higher rotation than can the private owner; furthermore, it is the duty of the state to grow timber not only for profit, but to supply future demand, especially in sizes requiring long rotations.

2. The market conditions influence the rotation, inasmuch as good markets and easy accessibility permit shorter rotations, whereas forests further from market and more difficult of access necessitate a longer rotation to make logging at all profitable. The decreasing area of virgin forest and the rapidly increasing population justify the consideration of *future* as well as *present* market conditions. It is reasonable to expect that the price of larger timber will increase proportionately more than that of smaller sizes, and hence it may be good economy, in view of future market prices, to adopt a longer rotation and plan to grow larger sizes of timber than present market prices would warrant.

3. The more the site is adapted to a certain species, the longer can the rotation be. Conversely the more rapid growth on good sites will often tend to shorten the rotation.

4. The character of the stands influences the rotation in respect to their *quality* and *species*. The better the *quality* of the stand, the longer can the rotation be; the less thrifty stands will often have to be cut before the regular rotation age. As Meinecke says: * "The time at which a tree or a stand is to be cut may range from a comparatively low age to the age of maximum production of lumber, according to the special needs the forester has in view; but the upper limit of this range should not lie beyond the period at which the gain from the increment is offset by loss from decay, irrespective of the ideal amount of timber a sound tree or stand might produce under favorable conditions . . . the age of decline forms the basis for what

* U. S. Dept. of Agri., Bulletin No. 275 "Forest Pathology in Forest Regulation," Contribution from the Bureau of Plant Industry. Professional paper by E. P. Meinecke. Reviewed Proc. Soc. Am. Foresters, Vol. XI, No. 2.

might be termed the 'pathological rotation.'" The *species* in mixed stands can usually be worked on the same rotation unless they mature at different ages or are markedly different in value, e.g., a mixed forest of Engelmann spruce and white fir (*A. concolor*) will often require a higher rotation for the spruce than for the fir; because the fir deteriorates at an earlier age and becomes almost valueless at a time when the spruce is just fully matured.

Where the species are not intermingled but form pure groups or stands in the same working group, the rotation is determined separately for each species comprising more than one-third of the total volume, and the results are then averaged.

NOTE.—In connection with rotations involving financial calculations, see chapter in Roth: "Forest Valuation," on "Relation of Capital and Income in Forestry," pp. 73–82; also, Chapter VIII, pp. 100–119 in Chapman: "Forest Valuation."

CHAPTER II

REGULATION OF CUT *

DEFINITION

Regulation of the cut is the fixation, in advance, of the annual or periodic cut, which, in the normal forest, would be equivalent to the annual or periodic increment. The regulation of cut is necessarily preceded by a determination of the amount to be cut and by the location of the areas to be cut over.

The space of years for which the cut is regulated depends on the frequency of accurate revisions of the working plan. Ten years is the customary minimum period for which the cut is regulated; at the end of that time † the working plan is revised and the cut regulated for the following decade. Where period methods (see below) are used, the cut is regulated in detail for the first period—twenty years in advance ‡—or even for the first two periods—forty years in advance§—in detail for the first period of twenty years and roughly for the second period. Despite this regulation, so far in advance, exhaustive revisions are undertaken at the end of each decade. Frequent revisions are an absolute essential, and the regulation of cut for many years in advance, or even for the whole rotation, is little better than a useless play.

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* Yield in the sense of the allowable cut from a forest has been abandoned, in the terminology of the Society of American Foresters, in order to prevent ambiguity. The terminology defines yield as " the timber or wood volume that is (actually) or can be (normally) produced by a stand of a given composition at a given age under given site, conditions and treatment—the actual, or normal product of the stand."

† In Saxony the revision is undertaken every five years; the plan is for ten years.

‡ Prussia. § Austria.

The allowed cut is fixed: *First,* in respect to *how much* can be cut, i.e., the determination of cut; *second,* in respect to *where* it is to be cut, i.e., the distribution of cut. This chapter is accordingly divided into sections to correspond with these two divisions of the subject and a third to treat special cases of regulation.

SECTION ONE

DETERMINATION OF CUT

The determination of the cut is either by area, by volume, or by both. In this determination the bases are the foundations of working plans already considered namely:

1. Increment.
2. Growing stock and distribution of the age classes.
3. Object of management.
4. Silvicultural method of management.
5. Rotation.

Of these, increment is the most important, i.e., the increment as it *actually* is.* No sustained yield is possible which disregards the increment.

According as the determination of cut is to be by area, by volume, or by both, the following methods have been evolved:

1. *A*. By area.
   B. By volume.

      I. Based solely on growing stock.
2. 1. Von Mantel's method.
3. 2. Méthode de Masson.

      II. Based solely on increment.
4. 1. By current annual increment (Swiss method).

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* "The main task for the regulation of cut, here as well as abroad, is doubtless the determination of the annual or periodic increment—the increment as it actually is. This is under all circumstances the most important basis and standard of comparison for the cut."—Prof. Dr. Martin, Tharandt, in letter to the author, January 21, 1912.

III. Based on growing stock and increment.

5. 1. Austrian formula (Kameraltaxe).
6. 2. Karl's method.
7. 3. Hundeshagen's method. “Formula Methods.”
8. 4. Breymann's method.
9. 5. Heyer's method.

IV. Based on diameter classes.

10. 1. French method (Méthode de 1883).
11. 2. Indian method.
12. 3. Diameter class method (Hufnagl).

C. By area and volume.

I. For entire forest.

13. 1. Méthode du Contrôle (Gurnaud).

II. Based on age classes.

14. 1. Direct method (Hufnagl).
15. 2. Hufnagl's method.
16. 3. The stand method (Judeich's “Bestandswirtschaft”).

III. Based on periods (“Fachwerks Methoden”).

1. Area-period method (“Flächenfachwerk”).
17. 2. Volume-period method (“Massenfachwerk”).
3. Area-and-volume period method (“Kombiniertes Fachwerk”).
18. 4. American method (Chapman).

These eighteen methods of determining the cut will be considered *seriatim;* for each will be given (*a*) the description of the method, (*b*) an example of its working, and (*c*) an estimate of its value and application, with especial regard to American conditions. The following symbols are used: V = volume, r = rotation, A = area, a = age, M. = thousand feet board measure, *cds* = cords, *c.a.i.* = current annual increment, *m.a.i.* = mean annual increment.

1. BY AREA.

(a) **Description of Method.**—The forest or main divisions thereof (working groups, blocks) is divided into a number of cutting areas—annual or periodic—corresponding to the rotation age. These annual or periodic cutting areas are marked on the ground; annually or periodically, a cutting area is logged. The size of the cutting areas is either exactly equal or else is equal to the reduced area corresponding to the varying site qualities. In order to give more accurate expression to the distribution of the age classes, Hufnagl has suggested that each annual cutting area be multiplied by the factor: $\frac{\text{average age}}{\text{half the rotation}}$ or $\frac{a}{\frac{r}{2}}$ thus securing the maximum sustained annual cutting area.

In selection forest, i.e., a forest through all parts of which many different age classes are represented, the individual area is cut over several times during the rotation, the interval between cuts on the same area being the cutting cycle (*cc*). Hence in forests managed under the selection method, the annual cut $= \frac{\text{total area}}{cc} \times$ amount to be removed per acre under the selection cutting.

(b) **Example**:—I. Area not reduced. II. Area reduced. III. Hufnagl variation.

I. A block contains 10,000 acres. It is to be managed on a rotation of 60 years. The annual cutting area $= \frac{A}{r} = 166.7$ acres. If the cutting period is twenty years, then the periodic cutting area will be $166.7 \times 20 = 3334$ acres.

II. BY REDUCED AREA: Each site quality produces for a fully stocked stand a varying volume at the rotation age. These volumes can either be secured empirically or by means of normal yield tables. E.g., for white pine it has been determined * that the maximum yield (Site I) for a sixty-year

* Table 6, Bulletin 13, U. S. Dept. of Agric., new series, "White Pine under Forest Management."

rotation is 60,200 board feet per acre, the minimum (Site III) 33,600 board feet per acre.

	Per acre
Site quality I	60,200 board feet
II	46,900 "
III	33,600 "

On the basis of site quality I the per cents of the other site qualities would be:

Site quality I	1.00
II	.78
III	.56

These are the factors of reduction to the common site quality (I).

If, in the above instance, the actual area of 10,000 acres was composed equally of each site quality (I to III), then the reduced area would be:

Site quality I, original 3,334 acres, reduced 3,334 acres.
Site quality II, original 3,333 acres, reduced 2,600 acres.
Site quality III, original 3,333 acres, reduced 1,866 acres.

Total, 10,000 acres, reduced 7,800 acres.

The annual or the periodic cutting area is, therefore, varied according to the site quality or qualities in the area allotted. E.g., the annual cutting area $= \frac{\text{reduced area}}{\text{rotation}} = \frac{7800}{60} = 130$ acres. Similarly the periodic cutting area $= 130 \times 20 = 2600$ acres. If these 2600 acres were all to be distributed among site quality II it would actually require:

$$2600 \times 1.28 = 3328 \text{ acres;}$$

for, from the above table of percentages, it requires:

1.28 acres of site quality II to equal 1 acre of site quality **I.**
1.79 acres of site quality III to equal 1 acre of site quality **I.**

III. Hufnagl variation: Hufnagl multiplies the annual cutting area by the $\dfrac{\text{average age}}{\frac{r}{2}}$.

For example, if the stand shows the following distribution of the age classes:

Total Area acres	I 1–20 yrs.	II 21–40 yrs.	III 41–60 yrs.	IV 61–80 yrs.	V 81 and over	Blanks unst'k'd
2160	510	496	465	443	214	32

then the average age would be:

$$
\begin{aligned}
32 \times 0 &= 0 \\
510 \times 10 &= 5,100 \\
496 \times 30 &= 14,880 \\
465 \times 50 &= 23,250 \\
443 \times 70 &= 31,010 \\
214 \times 90 &= 19,260 \\
\hline
\text{Total, } 2160 \quad & \quad 93,500
\end{aligned}
$$

$93,500 \div 2160 = 43$ years = the average age.

Area	= 2160 acres.
Rotation	= 80 years.
Average age	= 43 years.

$\therefore$ the annual cutting area $= \dfrac{2160}{80} \times \dfrac{43}{40} = 29$ acres.

(c) **Value and Application.**—The area method is the oldest of regulation, dating from the sixteenth century. It enables the transition from mere exploitation to a conservative management.

Its great advantage is simplicity.

Its great disadvantages are:

1. The rotation is assumed as a fixed value, whereas in reality it is a mere approximation and varies with the interior (management, accidents, etc.) and exterior (markets, desires of owner) changes to which every forest is subjected.

2. The method is too strait-laced to permit the free play necessary for the best silviculture, e.g., natural reproduction.

It is, therefore, restricted in its direct application to forests with fairly uniform conditions, i.e., to coppice, coppice with standards, and well-developed selection forests. As an "area check" on volumetric determinations, however, it finds a wide use. (See Method No. 14 for examples.)

2. BY VOLUME.—BASED SOLELY ON GROWING STOCK. VON MANTEL'S METHOD.

(a) **Description of Method.**—This is the simplest of the "formula methods." Indeed it is hardly to be ranked with them except in having the same underlying principle, namely, that the actual cut must bear the same relation to the actual growing stock as the normal cut (or, what is the same, the normal increment) bears to the normal growing stock.

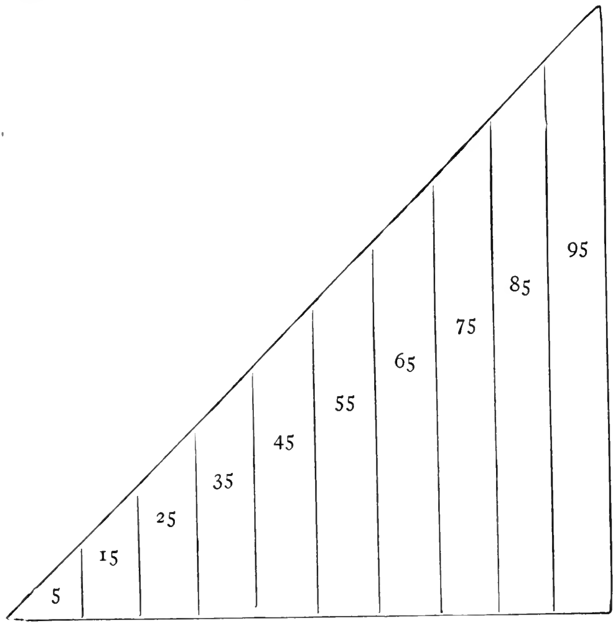
Von Mantel considers that the growing stock = the real increment (mean annual) multiplied by half of the rotation $\left(i \times \frac{r}{2}\right)$ for under normal conditions the volume present (growing stock) in any one year equals one-half of the total volume produced during the entire rotation. This is shown diagrammatically on the next page. Since the volume present (growing stock) need be but one-half the total volume produced, therefore the annual cut = volume present ÷ by half the number of years in the rotation, or, as Von Mantel puts it:

$$Y \text{ (annual cut)} = \frac{V}{\frac{r}{2}}.$$

(b) **Example.**—A forest contains 6810 M. feet board measure of spruce and fir to be managed on a 160-year rotation. The annual cut $= \frac{V}{\frac{r}{2}} = \frac{6{,}810}{\frac{160}{2}} = \frac{6{,}810}{80} = 85{,}125$ feet, board measure.

(c) Value and Application.—The greatest advantage of Von Mantel's formula is its utter simplicity; for it requires only the total volume and the rotation. It is thereby adapted to the most meagre data.

Its disadvantages are: 1. That it assumes a definite rotation which is altogether impossible in view of the disturbing emer-



gencies which always arise. 2. While it does automatically reduce any surplus or deficit in the growing stock, it requires unduly long to do so. The annual cut is apt to be over-conservative.

Its use is, therefore, restricted to determining the cut provisionally before detailed data can be obtained, and as a check on the results obtained by other methods.

3. BY VOLUME.—BASED SOLELY ON GROWING STOCK. MÉTHODE DE MASSON.

(a) **Description of Method.**—Masson's formula closely approximates that of Von Mantel, but is claimed by the French to have been developed independently, although based on the same principles. The formula is:

$$\text{Annual cut} = \frac{2V}{r}.$$

(b) **Example.**—A forest contains 6810 M. feet board measure of spruce and fir to be managed on a 160-year rotation. The annual cut $= \frac{2V}{r} = \frac{13,620}{160} = 85,125$ feet, board measure.

(c) **Value and Application.**—Precisely as in Von Mantel's method (No. 2).

4. BY VOLUME.—BASED SOLELY ON INCREMENT. BY CURRENT ANNUAL INCREMENT (SWISS METHOD).

(a) **Description of Method.**—This method is described in an anonymous article on Selection Forest Management in the Swiss Forestry Periodical for 1913,* briefed in Forestry Quarterly, Vol. XIII, No. 2, pp. 260–262, as follows:

" Divide the volume of the oldest size classes by the annual increment of the entire stand. This will give the number of years during which the volume of the oldest size classes must last. If this be forty-five (45) years, then the cut for the next decade would be from one-fifth to one-quarter of the volume of the largest size classes."

Expressed mathematically:

Let X = the volume of the size classes below the diameter limit;

Xi = the current annual increment thereon;

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* " Die Betriebsordnung im Plenterwald," Schweizerische Zeitschrift für Forstwesen, August, Sept., Oct., Nov., 1913, pp. 234–238, 265–272, 307–313, and 339–346.

Y = the volume of the size classes above the diameter limit but within a satisfactory current annual increment;

Yi = the current annual increment thereon;

Z = the volume of the size classes beyond a satisfactory current annual increment—that is overmature timber—surplus growing stock;

Zi = the current annual increment thereon;

CC = the cutting cycle.

Then $$CC = \frac{Y+Z}{Xi+Yi+Zi}.$$

and annual cut $$= \frac{Y+Z}{CC}.$$

This is the strict interpretation of the method as described, but since Z is surplus growing stock it should play no part in determining CC, neither should the increment thereon (Zi).

Then $$CC = \frac{Y}{Xi+Yi},$$

and annual cut $$= \frac{Y+Z}{CC}.$$

The current annual increment can be easily determined by Pressler's or by Schneider's formulæ. Where reliable diameter growth figures are available, these can be used as well as increment borings or stump analyses, since what is wanted is the number of years required to grow from 1 inch class to the next.

The chief data required are an exact determination of the current annual increment and stand and stock tables. The diameter-class distribution must approach the normal relation. It is a further essential of this method that the increment and growing stock be redetermined, by identical means, at frequent regular intervals of not to exceed ten years. If the growing stock then shows an unintentional diminution, the cut was set at too high a figure; if, conversely, the growing stock, at the time of revision, shows an unintentional increase, the cut was set too low.

(b) **Example.**—It is desired to determine the cut of hemlock in the slope type of Catskill forest illustrated by the stand and stock tables quoted above from Bulletin 11 of the N. Y. State Conservation Commission.* A breast-high diameter limit of 12 inches is to be observed which, according to U. S. Dept. of Agriculture Bulletin 152, new series, "The Eastern Hemlock," table 10, corresponds to a rotation of 160 years. The current annual increment per cent has been determined from increment borings and Pressler's formula. The complete data are as follows:

D. B. H., Inches.	C. A. I., Per Cent (Pressler).	Volume on Average Acre (Stock Table).		C. A. I. per Acre.	
	Per Cent.	Board Feet.		Board Feet.	
7	7.19	6.80		.488	
8	4.30	6.41		.276	
9	4.00	12.18	x	.487	xi
10	2.69	17.98		.484	
11	2.68	24.09		.645	
12	2.26	28.83		.652	
13	2.08	26.68		.555	
14	1.75	21.45		.376	
15	1.55	15.48		.240	xi
16	1.69	18.36	y	.310	
17	1.48	22.23		.329	
18	1.24	20.51		.254	
19	1.10	13.60		.150	
20	.97	7.78	z	.076	zi
21	.89	17.56		.156	
		(Cont. in st'k table) See p. 48,		Total 5.478	

To summarize:

$$Y = 138.31 \text{ board feet per acre}$$
$$Z = 168.48$$
$$Y + Z = 306.79$$

* Bulletin 11, "Forest Survey of a Parcel of State Land," Albany, N. Y., 1915, Tables 4 and 5.

$$Xi = 3.032 \text{ board feet per acre}$$
$$Yi = 2.214$$
$$Zi = .232$$
$$Xi + Yi + Zi = 5.478$$

Then $CC = \frac{Y+Z}{Xi+Yi+Zi} = \frac{306.79}{5.478} = 56$ years, and the annual cut $= \frac{Y+Z}{CC} = \frac{306.79}{56} = 5.478$ board feet per acre, or, for the 1730 acres in this type, $= 9477$ board feet of hemlock.*

Eliminating Z and Zi in figuring CC:

$CC = \frac{Y}{Xi+Yi} = \frac{138.31}{5.246} = 26$ years, and the annual cut $= \frac{Y+Z}{CC} = \frac{306.79}{26} = 11.797$ board feet per acre, or for the 1730 acres in this type $= 20{,}409$ board feet of hemlock.

(c) **Value and Application.**—This method is well adapted to finding the allowed annual cut in a selection forest. It should be used, however, in conjunction with some other methods, such as Method 12, Var. II, Method 2, and the area check as indicated for selection forest in Method 1.

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* By Von Mantel's method, the cut of hemlock figures out 9965 board feet. The cut by the Swiss method for the other species in the stock table is as follows:

Beech, above 16 inches d.b.h. = 10.878 board feet per acre; 18,819 board feet for 1730 acres.

Birch above 16 inches d.b.h. = 29.183 board feet per acre; 50,487 board feet for 1730 acres.

Maple above 16 inches d.b.h. = 17.345 board feet per acre; 30,007 board feet for 1730 acres.

Others above 16 inches d.b.h. = 14.610 board feet per acre; 25,275 board feet for 1730 acres.

For further details see, "A Practical Application of Pressler's Formula," F. Q., XIV, 2.

5. BY VOLUME.—BASED ON GROWING STOCK AND INCREMENT. AUSTRIAN FORMULA (KAMERALTAXE).

(a) Description of Method.—This, and the other so-called " formula methods " (" Vorrats methoden "), is characterized by the fact that the allowed annual cut is determined, apart from any plan of management, by mathematical calculation based on a formula. The main factors in this calculation are the growing stock and the increment. The aim in regulating the cut is to have the actual growing stock (V) and the actual increment (i) approach the normal forest characterized by a normal growing stock (nV) and a normal increment (ni). The period of time in which the actual growing stock is to be brought to point of normality is taken as the whole rotation. This is to be accomplished by heavier cutting if the actual growing stock is greater than the normal growing stock, and lighter cutting if the actual growing stock is less than the normal growing stock.

The normal growing stock is calculated by the formula $\frac{ri}{2}$ where i = the *actual* mean annual increment.* In even-aged stands it can also be calculated from yield tables by the formula $n(a+b+c+\ .\ .\ .\ \frac{m}{2})$, where a, b, c . . . m are the values

* Barrington Moore, in an article on " Methods of Regulating the Cut on National Forests," Proceedings of the Society of American Foresters, Vol. VII, No. 1, has suggested that: " If, as is almost always the case, the real growing stock (Gr) is made up of only merchantable trees, it will be manifestly unfair to compare with this real growing stock a normal growing stock, which includes the small as well as the large trees. The result would be too small a surplus or too large a deficit. To obtain a more correct surplus or deficit a normal growing stock which includes only the merchantable trees should be used. This can be found by substituting for R in the expression $\frac{I \times R}{2}$ a quantity, R' equal to the difference between the age of the merchantable trees and the rotation. For example, if the rotation is 200 years, and trees become merchantable at 60 years the growing stock of merchantable trees necessary to leave on the area would be $\frac{I \times 140}{2}$ instead of $\frac{I \times 200}{2}$."

given in the table for each age class, n the number of years in each of the age classes, and m the volume at the rotation age.

The main formula then follows: $y(\text{annual cut}) = i + \frac{V - nV}{r}$.

Here again i is the *actual* mean annual increment, *not* the normal.*

(b) Example.—An uneven-aged forest of Western yellow pine contains 3,500,000 feet board measure of timber 12 inches diameter breast high and over on 1000 acres. The actual mean annual increment is assumed as 0.7 per cent, or 24,500 feet board measure; the rotation as two hundred years. The normal growing stock $\frac{ri}{2} = \frac{200 \times 24,500}{2} = 2,450,000$ feet board measure. The annual cut (y) then $= i + \frac{V - nV}{r} = 24,500$ $+ \frac{3,500,000 - 2,450,000}{200} = 24,500 + \frac{1,050,000}{200} = 24,500 + 5250$ $= 29,750$ feet board measure. In this case there appears to be an excess growing stock. Adopting Mr. Moore's variation (see footnote), the result would be:

Normal growing stock $= \frac{r'i}{2} = \frac{140 \times 24,500}{2} = 1,715,000$ feet board measure.

The annual cut $(y) = i + \frac{V - nV}{r} = 24,500 + \frac{3,500,000 - 1,715,000}{200}$ $= 24,500 + 17,850 = 42,350$ feet board measure.

This, however, is not strictly accurate, due to the failure to consider the increment per acre of young growth. "If the area of young growth below merchantable size is known, the increment can be found by determining the number of merchantable trees per acre which there would be if the stand were about normally stocked and contained no other age classes. The volume of such a stand divided by the average age of merchant-

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* There has been some dispute about this, but the matter seems settled by the authoritative pronouncement of Judeich, "Forsteinrichtung," 6th Edition, p. 360, and Martin, "Forsteinrichtung," pp. 216–217.

able trees will give the increment per acre of the young growth below merchantable size." *

E.g., area of young growth under 12 inches diameter breast high = 6 per cent of total area (1000 acres) or 60 acres. A normally stocked stand of Western yellow pine 12 inches in diameter (about sixty years old) contains 5850 board feet; † $\frac{5850}{60} = 97.5$ board feet = the increment per acre of the young growth below merchantable size. There are 60 such acres, hence $97.5 \times 60 = 5850$ feet board measure. But the average density of stocking is only .7, so the real increment $= 4095$. The increment of the merchantable timber has already been figured at 24,500 feet; this + the 4095 increment on unmerchantable timber $= 28,595$. Then $\frac{r'i}{2}$ ‡ $= \frac{140 \times 28,595}{2} = 2,001,650$ feet board measure.

The annual cut $(y) = i + \frac{V - nV}{r} = 28,595 + \frac{3,500,000 - 2,001,650}{200}$ $= 36,087$ feet board measure.

(c) Value and Application.—Dating from a decree of the Vienna Hofkammer in 1788 (whence the name "Kameraltaxe"), this method has won the cognomen of "Austrian," although in Austria it is now used only as a check on other methods of determining the cut (see Part Two). Adapted to rather primitive conditions, especially to irregular, uneven-aged forests, the Austrian formula has grave disadvantages in that it assumes both i and nV as constants, whereas in consequence of cutting and unforeseen contingencies they are always changing, e.g., becoming better by correct cutting, becoming worse by storms, windfall, etc. In view of these changing constants the formula cannot secure even an approach to normal during the next rotation unless the cut is revised at least every ten years.

* Barrington Moore, ibid.

† From Tables 10 and 19, Bulletin 101, Forest Service, U. S. Dept. Agri.

‡ E. J. Irish has suggested that r and not r' be used, since the increment of the young growth is included.

This revision is not a part of the original Kameraltaxe any more than is a plan of cutting (distribution of cut) so essential to a well regulated forest; for, as shown in Chapter I, Section 1, no forest can be normal unless increment and age-class distribution are normal. The normal increment and normal growing stock alone do not suffice. Hence this and the other "formula methods" are all makeshifts (except as a check on other methods) and must be replaced by other and better methods as soon as conditions warrant.

Realizing these deficiencies, Huber varied the Austrian method by using the current annual instead of the mean annual increment and distributing the surplus or deficiency in growing stock over the whole rotation in a decreasing series instead of equally. This variation is, therefore, a transition to the methods of Karl and of Hundeshagen, which are considered below (6 and 7).

6. BY VOLUME.—BASED ON GROWING STOCK AND INCREMENT. KARL'S METHOD.

(a) Description of Method.—This method was probably suggested by the Austrian formula just described (No. 5) with Huber's modification. Karl takes the allowed annual cut as equal to the real current annual increment plus or minus the excess or deficiency of the actual growing stock when compared with the normal growing stock, distributed over a period of A years instead of over the entire rotation, as in the Austrian formula. The formula for the cut for the first year therefore

$$=i+\frac{V-nV}{A}.$$

This formula would apply accurately to subsequent years only if i were determined anew each year; for it changes constantly (see Method 5 above). In order to accomplish the approach to normal without an annual recalculation of i, a third expression is added to the formula, namely: $\frac{i-ni}{A}\times n$ where ni = the normal current annual increment and n = the number of years which have elapsed since the estimates were made. In the first year $n=O$, and hence the entire expression $=O$. In consequence of the increase of n the annual cut would really have to be redetermined each year, but, for convenience, Karl presupposes the adoption of ten-year periods and makes $n=5$, i.e., the middle of the ten-year period during which the annual cut is to be equal. At the end of the ten-year period a revision of the cut takes place.

This third expression of the formula is always given the sign opposite that of the preceding expression.

The entire formula is therefore:

$$y \text{ (annual cut)} = i \pm \frac{V - nV}{A} \mp \left(\frac{i - ni}{A}\right) n.$$

In addition a simple plan of cutting (distribution of cut) is drawn up as a guide in the management of the forest. However, this plan of cutting plays no part in the determination of the cut, which is by formula alone.

(b) **Example.**—An uneven-aged forest of Western yellow pine contains 3,500,000 feet board measure of timber 12 inches and over diameter breast high, on 1000 acres. The actual mean annual increment is assumed at .7 per cent, the rotation at 200 years. nV then $=\frac{ri}{2}=2{,}450{,}000$ feet board measure.* A, the period of distribution, is assumed as one-quarter of the rotation, or fifty years.† i, the actual current annual increment, is averaged (see Method No. 4) for the whole stand and, reduced for the density of stocking, is assumed as $=1$ per cent or, in volume, $=35{,}000$ feet board measure. The normal current annual increment is obtained from fully stocked sample plots (or from yield tables in even-aged stands), and is assumed as 1.2 per cent, or 42,000 feet board measure. (With

* It can also, in even-age stands, be calculated from yield table (see Method No. 5).

† This period of distribution is chosen according to local exigencies; it had best be somewhat longer than seems necessary, in order to avoid possible errors and to remain on the side of conservatism.

a density of .85 this would = an actual increment of $1.2 \times .85 = 1.02$ or, roughly 1 per cent.)

The annual cut by the formula then $= i \pm \frac{V-nV}{A} \mp \left(\frac{i-ni}{A}\right)n$ $= 35{,}000 + \frac{3{,}500{,}000 - 2{,}450{,}000}{50} - \left(\frac{35{,}000 - 42{,}000}{50}\right)5 =$ $35{,}000 + 21{,}000 + (140)5 = 56{,}700$ feet board measure equals annual cut.

Adopting Mr. Moore's variation of r' instead of r in developing nV (see No. 5), $nV = 1{,}715{,}000$ feet board measure. The annual cut then equals $i \pm \frac{V-nV}{A} \mp \left(\frac{i-ni}{A}\right)n = 35{,}000 +$ $\frac{3{,}500{,}000 - 1{,}715{,}000}{50} - \left(\frac{35{,}000 - 42{,}000}{50}\right)5 = 35{,}000 + 35{,}700$ $+ 700 = 71{,}400$ feet board measure equals annual cut.

Calculating the increment on the area of young growth, as was done under No. 5, the result would be: for nV, 2,001,650 feet board measure. The annual cut then equals $i \pm \frac{V-nV}{A} \mp$ $\left(\frac{i-ni}{A}\right)n = 35{,}000 + 4{,}095$ (the mean annual increment on the unmerchantable young growth, conservative since less than the current annual increment) $+ \frac{3{,}500{,}000 - 2{,}001{,}650}{50} -$ $\left(\frac{35{,}000 - 42{,}000}{50}\right)5 = 35{,}000 + 4{,}095 + 29{,}967 + 700 = 69,$ 762 feet board measure equals annual cut.

(c) **Value and Application.**—Karl's method, which dates from 1838, shows an advantage over the Austrian formula in so far as it uses the current annual instead of the mean annual increment, and in that it distributes the excess or deficit over a period adapted to local conditions instead of arbitrarily over the whole rotation. However, it is incorrect in making the third expression $\left(\frac{i-ni}{A}\right)n$ always bear a sign opposite that of the expression $\frac{V-nV}{A}$ directly preceding it. This would presume that an increase or decrease of the actual growing stock is always followed by an increase or decrease in the actual current annual increment. But the exact opposite can happen, e.g., if overmature stands are replaced by thrifty young growth or if, contrariwise, the overmature stock is allowed to accumulate. Karl's error probably arose through considering the volume of a forest's growing stock as comparable to a sum of money which bears more interest as it increases in size. Judeich * therefore considers the third expression $\left(\frac{i-ni}{A}\right)n$ not only incorrect, but unnecessary in view of the ten-year revisions; which would reduce the formula to $y=i\pm\frac{V-nV}{A}$ and would make the values in the above three examples 56,000, 70,700, and 69,062 feet board measure respectively, the expression $\left(\frac{i-ni}{A}\right)n=700$ falling away in each case. The only remaining difference between Karl's formula and the Austrian formula is, then, the use of current instead of mean annual increment and of a suitable period for distributing the surplus or deficit—fifty years in this case. There seems to be no reason why the latter modification can not be applied directly to the Austrian formula (No. 5) so that it reads: $y=i+\frac{V-nV}{A}$,† whereupon the values in three examples under (5) would become:

(1) $24{,}500+\frac{3{,}500{,}000-2{,}450{,}000}{50}=45{,}500$ feet, board measure.

(2) $24{,}500+\frac{3{,}500{,}000-1{,}715{,}000}{50}=60{,}200$ feet, board measure.

(3) $28{,}595+\frac{3{,}500{,}000-2{,}001{,}650}{50}=58{,}562$ feet, board measure.

* Lorey's "Handbuch der Forstwissenschaft," 2d Ed., Vol. III, pp. 421–2.

† This is Heyer's formula as given by Martin's "Die Forsteinrichtung," 2d Ed., p. 67, but Judeich, who made a special study of this point, considers it as under 9 below, and his precedent has been followed, although the results are exactly identical. (See example under No. 9.)

With Judeich's suggested modification, the value of Karl's formula is as a rough method in irregular stands or as a check upon other methods of regulating the cut. For this purpose either it or the just suggested modification of the Austrian formula may be used according as the current or the mean annual increment has been determined.

7. BY VOLUME.—BASED ON GROWING STOCK AND INCREMENT. HUNDESHAGEN'S METHOD.

(a) Description of Method.—Hundeshagen conceives of the increment or allowed cut as the interest on the growing stock and assumes that the actual cut is to the actual growing stock as the normal cut is to the normal growing stock, or: $\frac{y}{v}=\frac{ny}{nv}$ transposed this is $y=v\frac{ny}{nv}$ which is the Hundeshagen formula.

Hundeshagen calls the factor $\frac{ny}{nv}$ the "use per cent" ("Nutzungs prozent"). If nv is calculated by means of the mean annual increment $\left(nv=\frac{ri}{2}\right)$ and ny is taken as $=i$, then $\frac{ny}{nv}=\frac{2}{r}$ and $y=v\times\frac{2}{r}$ which is the same as Methods Nos. 2 and 3. Hundeshagen, however, calculates nv by means of yield tables. v is the volume actually present in the forest.

Hundeshagen suggests a short-cut method wherein for calculating nv and v only those stands are to be considered whose age exceeds $\frac{r}{2}$ and thereby a "partial use per cent" obtained.

(b) Example.—An uneven-aged forest of Western yellow pine contains 3,500,000 feet board measure of timber 12 inches and over diameter breast high, on 1000 acres. The mean annual increment (i) is assumed at .7 per cent, the rotation at 200 years. Disregarding Hundeshagen's method of determining nv by means of yield tables and taking $\frac{ny}{nv}=\frac{2}{r}=\frac{2}{200}=.01$, the formula gives:

$y = v\frac{ny}{nv} = v \times .01 = 3,500,000 \times .01 = 35,000$ feet board measure equals annual cut.

This result is identical with that obtained by Von Mantel's formula (No. 2) or by the Austrian formula (No. 5) modified (as suggested under No. 6) by making the period of distribution of excess or deficit equal half the rotation.

(c) **Value and Application.**—This method, published by Hundeshagen in 1821, was really discovered by Paulsen in 1795, though Hundeshagen never knew of the latter's work until 1830. It presents no advantages over the methods already described and some very substantial disadvantages:

(1) The assumption that the actual cut is to the actual growing stock as the normal cut is to the normal growing stock is not always correct, especially not where there are overmature and deteriorating stands in the forest.

(2) The value of v changes constantly, hence, to be strictly accurate, y would have to be redetermined annually.

(3) The method provides for no definite period for the distribution of surplus or saving of deficit in the growing stock. A cutting plan is permissible, but does not affect the volume of the cut as determined by the formula. Hence under the method, overmature stands can be held through many years if the growing stock is excessive, or immature stands cut off though the growing stock is already deficient.

The only real use of the formula in irregular, uneven-aged stands is as a check on other methods. Its use in even-aged stands presupposes normal yield tables and regulated conditions, neither of which exist in America at present nor are apt to exist for some time to come.

8. BY VOLUME.—BASED ON GROWING STOCK AND INCREMENT. BREYMANN'S METHOD.

(a) **Description of Method.**—Based on Hundeshagen's formula, Breymann assumed that the actual cut is to the normal cut as the actual average age is to the normal average age of a stand. Hence $y = ny\frac{a}{na}$ (a = age). Now $ny = ni$ (mean annual increment) and $na = \frac{r}{2}$. The average age can be determined either by area according to the formula:

$a = \frac{f_1a_1 + f_2a_2 + f_3a_3}{f_1 + f_2 + f_3}$ wherein f_1, f_2, f_3, etc., equal the area of the various age classes and a_1 a_2, a_3, etc., equal their respective average ages, or else the average age can be determined by volume according to the formula:

$a = \frac{v^1 + v^2 + v^3}{\frac{v^1}{a^1} + \frac{v^2}{a^2} + \frac{v^3}{a^3}}$ wherein v^1, v^2, v^3, etc., equal the volumes of the various age or diameter classes and a^1, a^2, a^3, etc., their respective ages.

(b) **Example.**—A forest of Western yellow pine containing 3,500,000 feet board measure of timber 12 inches and over diameter breast high, on 1000 acres, is essentially uneven-aged, but shows three distinct diameter classes: 12 to 18 inches, average 14 inches ("Black Jacks"), and 20 inches and over, average 26 inches ("yellow pines"). The volume of the former is 20 per cent of the total, or 700,000 feet board measure, the volume of the latter is 80 per cent of the total, or 2,800,000 feet board measure. The average age of a 14-inch "Black Jack" is 70.5 years, of a 26-inch "yellow pine" 285 years.* Then by the formula,

$$a = \frac{v^1 + v^2}{\frac{v^1}{a^1} + \frac{v^2}{a^2}} = \frac{700{,}000 + 2{,}800{,}000}{\frac{700{,}000}{70} + \frac{2{,}800{,}000}{285}} = \frac{3{,}500{,}000}{10{,}000 + 9{,}818} = 176 \text{ years.}$$

The adopted rotation is, however, only 200 years, hence $na = \frac{r}{2} = \frac{200}{2} = 100$. The mean annual increment is placed at 0.7 per cent, or 24,500 feet board measure. By the formula

* From Table 9, Bulletin 101, Forest Service, U. S. Dept. of Agric.

$y = ny\frac{a}{na} = 24{,}500\left(\frac{176}{100}\right) = 24{,}500 \times 1.76 = 43{,}120$ feet board measure, equals annual cut.

(c) **Value and Application.**—This method, promulgated by Breymann in 1854, aims in common with the other "formula methods" to secure an approach of the actual growing stock toward the normal growing stock. However, in addition to the employment of data which are difficult and subject to error in irregular stands and extensive conditions (e.g., normal increment and average age calculations), it has the strong drawback that the adjustment of the excess or deficit in the growing stock is spread over the whole rotation, whereas the exigencies of the occasion usually warrant this adjustment in a fraction of that time.

The method is, therefore, of little practical value except as a check upon other methods of regulating the cut.

9. BY VOLUME.—BASED ON GROWING STOCK AND INCREMENT. HEYER'S METHOD.

(a) **Description of Method.**—Heyer bases his formula on the following premises:

(1) If a stand is normal, then an amount equal to the mean annual increment can be cut each year so long as the three requisites of normality are maintained, i.e., (*a*) normal growing stock, (*b*) normal increment, and (*c*) normal distribution of the age classes.

(2) If normality in (*a*) and (*b*) exists, but (*c*) is abnormal, it can be made normal if the normal increment is cut annually or periodically, and the cut-over stands immediately regenerated.

(3) If the actual increment is less than the normal increment (the contrary can scarcely ever occur), then, even if the growing stock is normal, only the actual, not the normal, increment can be cut.

(4) If the growing stock is abnormal it can be brought toward normality by either cutting less than the actual incre-

ment if the growing stock is too small, or cutting more if it is too large.

(5) The period of equalization (x) of excess or deficit, i.e., the time during which an abnormal stand is to approach normality, can be determined only with regard to local exigencies, it must be developed out of a general plan of management which is in consonance with the wishes of the owner. If $v < nv$ then x must equal at least a period of years sufficient so that the sum of the actual increments during that period equals the difference between v and nv; where this is exactly the case then y (the annual cut) equals o.

On these premises Heyer develops the formula:

$$y=\frac{v+ix-nv}{x};$$

i is the actual mean annual increment, and hence really varies from year to year. Hence as i improves, the approach toward normality is accelerated to less than x years, as it grows smaller the approach toward normality is retarded to more than x years. This variation of i Heyer meets by calculating i not solely according to its present condition, but by conceiving of the expression ix as the increment during the period of x years, with regard to all the probable changes in increment during the x years. This is facilitated by the drawing up of a plan of cutting (distribution of cut) as outlined further on in the present chapter.

nv is found by the formula $\frac{ri}{2}$ in which Heyer takes i as the normal mean annual increment, but at the same time raises the question whether taking i as the actual mean annual would not be equally correct.* (It has now come to be universally considered as the correct method.)

(**b**) **Example.**—An uneven-aged forest of Western yellow pine contains 3,500,000 feet board measure of timber 12 inches

* Judeich, "Forsteinrichtung" in Lorey's "Handbuch der Forstwissenschaft," 2d edition, Vol. III, p. 425, foot-note.

and over diameter breast high, on 1000 acres. The mean annual increment equals .7 per cent, equals 24,500 feet board measure. The rotation is taken at 200 years. The normal growing stock equals $\frac{ri}{2}=\frac{200\times 24,500}{2}=2,450,000$ feet. v is, therefore, $>nv$ by 1,050,000 feet. This excess is, in view of local exigencies and the wishes of the owner, to be distributed over $\frac{r}{4}$ years $=\frac{200}{4}=50$ years $=x$. By the formula:

$$y=\frac{v+ix-nv}{x}=\frac{3,500,000+(24,500\times 50)-2,450,000}{50}$$

$$=\frac{3,500,000+1,225,000-2,450,000}{50}=45,500 \text{ feet board measure}$$

equals annual cut, which is exactly the same result secured by the Austrian formula (No. 5) modified as suggested under 6, (c), i.e., $y=i+\frac{v-nv}{x}=24,500+\frac{3,500,000-2,450,000}{50}=45,500$ feet board measure. The only difference is if ix is modified to correspond with expected changes during the next x years—as outlined above.

(c) **Value and Application.**—Carl Heyer's formula dates from 1841, and is perhaps the only one of the formula methods in active use to-day. Gustav Heyer, in the revised edition of Carl Heyer's work,* adds a complete period distribution of the cut similar to that described under No. 17 below. However, this is possible only under regular conditions and in even-aged stands, and in no way destroys the effectiveness of Heyer's formula in irregular, uneven-aged stands, although it correctly emphasizes the importance of adding to the mere volume determination of the cut a "when" and "where" by means of a careful cutting plan (distribution of cut) as described below in Section 2 of the present chapter.

With this in mind, Heyer's formula is directly applicable to

* Carl Heyer, "Die Waldertrags-Regelung," 1841. Second and third editions edited by Gustav Heyer, 1862 and 1883.

the majority of American forests, especially to those where, as in virgin forests, the actual growing stock is far in excess of the normal growing stock and a reduction to normal is of prime importance.

Summary and Comparison of the "Formula Methods"

The "formula methods," or, more properly, the "growing stock methods" ("vorratsmethoden"), for there are other methods employing formulæ to determine the cut, all aim to have the actual growing stock approach the normal. This is secured by a purely mathematical ratio of increment and growing stock, whereas, oftentimes, the character of the stands and other conditions of management which do not admit of mathematical expression are of more importance.

In combination with a careful cutting plan (distribution of cut) the Heyer formula serves as a useful determinator in irregular, uneven-aged forests. It is better than the other formulæ for the reasons already detailed under (c) "Value and Application," although the other formulæ will serve as a useful check. The superiority of the Heyer formula is still further evident when the results of the examples based on identical premises are compared:

Current No. Method	y (annual cut) in feet board measure		
	If $nv = \frac{ri}{2}$	If $nv = \frac{r'i}{2}$*	Including young growth, etc.
5 Austrian Formula	29,750	42,350	36,087
6. Karl's Formula	56,700	71,400	69,762
Karl's Formula without $\left(\frac{i-ni}{a}\right)$	56,000	70,700	65,786
7. Hundeshagen Formula	35,000	......	......
8. Breymann's Formula	43,120	......	......
9. Heyer's Formula	45,500	60,200	58,562
For Comparison:			
2. Von Mantel's Formula / 3. Méthode de Masson	35,000	......	......

* See explanation under No. 5: (a) "Description of Method" and (b) "Example" of Austrian formula.

10. BY VOLUME.—BASED ON DIAMETER CLASSES. MÉTHODE DE 1883 ("FRENCH METHOD").*

(a) **Description of Method.**—Instead of constructing a stand table, the total volume of each diameter class should be determined. Some figures should also be obtained showing the number of trees of the diameter desired at the end of the rotation (exploitable diameter) which there would be per acre in a normally stocked stand, if no other age classes were present. Since these figures must be taken in the field, sometimes before the exploitable diameter has been decided upon, several diameters should be taken.

When the desired exploitable diameter has been decided upon, determine from the growth figures the number of years necessary to produce this diameter. This number of years, lengthened by a few years to allow for a possible delay in reproduction, will be the rotation.

Divide the trees shown by the estimates into three groups as follows:

First group, old trees. Those containing two-thirds of the exploitable diameter and above; e.g., if the exploitable diameter is 30 inches, this group would contain trees between 20 inches and 30 inches.

Second group, medium trees. Trees having a diameter falling between one-third and two-thirds of the exploitable diameter; e.g., trees between 10 inches and 20 inches.

Third group, young trees. Everything with a diameter less than one-third of the exploitable diameter.

The calculation of the cut is based on groups 1 and 2, and is made in the following manner:

Find the volume of each of the first two groups. Then if the volume of the old trees is to that of the medium trees as 5 is to 3 the proportion of the two groups may be considered

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* Adapted from Barrington Moore's article "Methods of Regulating the Cut on National Forests," in Vol. VII, No. 1, "Proceedings of the Society of American Foresters."

normal.* If the proportion is normal it will be possible to cut the group of old trees, plus their increment, during the first third of the rotation, the increment, of course, being figured for only half of the third of the rotation.

But, first of all, it is necessary to ascertain whether or not the volume as a whole is too great or too small. This is done by finding the total volume which there would be if half of the entire area were covered with trees of just exploitable size † (not of very large mature trees). In obtaining this volume the number of exploitable trees per acre, called for above, is used. The result should be approximately equal to the sum of the old and medium trees. If the result is less the forest contains a surplus; if more, it contains a deficit. There are five distinct possibilities:

(1) The volume of the old and volume of the medium trees may be in the proportion of 5 : 3, and sum of their volumes normal. In this case nothing further is necessary before the actual calculation of the cut.

(2) The volume of old and medium trees may be in the proportion of 5 : 3, but their sum less than normal. In this case it will be necessary to increase the growing stock. This can be done by cutting, during the first third of the rotation, only the old trees, without their increment, or, if the area is very badly understocked, by cutting less than the old trees.

(3) The volume of old and medium trees may not be in the proportion of 5 : 3, and their sum nevertheless normal. This is adjusted by transfers from the group which is too large to that which is too small.

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* This ratio is based on the relative age of the old group and the medium group; it will vary with the length of the rotation, the conditions of growth, and the species. In the present instance, if the rotation age is 150, each group covers 50 years, i.e., the old group 100–150, average 125; the medium group 50–100, average 75. Then the old group is to the medium group as 125 : 75 = 5 : 3.

† In dealing with open stands, such as Western yellow pine in the Southwest, the area must be considered as fully stocked with exploitable trees, but due allowance must be made for natural openings and bare places.

(4) The volume of old and medium trees may not be in the proportion of 5 : 3, and their sum less than normal. This will probably mean that the volume of old trees is deficient, and must be increased by cutting less than the otherwise allowable volume of old trees.

(5) The volume of old and medium trees may not be in the proportion of 5 : 3, and their sum more than normal.

This could occur only with an excess in the old group. To correct this, find the volume of old trees necessary to make the ratio 5 : 3 with the volume of the medium trees, and which, added to the volume of medium trees, will give a normal growing stock. The difference between this volume and the actual volume of old trees is surplus. This surplus must generally be removed during the first third of the rotation, for the entire area will be cut over once during that time. Even though it were desirable to distribute this surplus over a longer period, such a course would generally be impossible, because in virgin forests, most of them of difficult accessibility, the first cut must be heavy per acre to justify logging. Later cuttings may, without hardship to purchasers, be made lighter.

When several species occur in mixture all are regulated together without affecting the method. If one species has a more rapid growth and is shorter lived, requiring a shorter rotation, its exploitable diameter should be made lower than that of the other species.

The whole calculation is checked by figuring what per cent of the total volume is represented by the allowable cut. This per cent, after subtracting the surplus, should be approximately the growth per cent of the group of old trees.

The area check on this method is applied as follows:

The whole working unit is to be gone over in one-third of the rotation. Since the rotation may be long, this third is further divided into periods during which the plan is to run without revision. If these periods are too short an unnecessary expense will be incurred by frequent forest surveys, whereas if they are too long there is danger that the effects of original errors may accumulate. A period of about twenty years seems reasonable. Thus if the rotation is 180 years, the whole working unit will be cut over in sixty years. If the period during which the plan is to run be twenty years, the area is divided on the basis of topography into three parts, each containing about an equal volume, and each to be cut over in twenty years. In some cases, where the working unit does not lend itself to a division into parts containing equal volumes, it may be divided into unequal parts, each part to be cut over in a period bearing the same relation to the one-third of the rotation as the part bears the whole working unit. The part containing the largest proportion of overmature and deteriorating timber should be cut during the first period. This part may be further subdivided for convenience into watersheds forming natural logging units or groups of units (blocks).

(b) **Example.**—Total area of working unit = 200,000 acres.

Minimum merchantable d.b.h. = 10 inches.

Size of material desired: Sugar pine and yellow pine = 30 inches. Incense cedar = 24 inches.

The group of old trees will include those 20 inches and over d.b.h. The medium trees will include those between 10 inches and 20 inches d.b.h.

The average length of time required to produce a tree 30 inches d.b.h., considering the important species, is 160 years. The period of reproduction is approximately twenty years. Hence the rotation will be 160+20, or 180 years. Incense cedar is shorter lived and more rapid growing, hence will be considered exploitable at 24 inches.*

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* This exploitable diameter for incense cedar will cause a slight inaccuracy in that the medium trees should be taken to 8″ instead of 10″ to correspond with the 24″. On the other hand, the volume between 8″ and 10″ will be small, and if desired can be allowed for by sample tallies over a small percentage of the strips. The cutting of a short-lived species to a lower diameter limit is desirable in this case because the area is gone over only once in 60 years.

Table of Estimates

Medium Trees					*Old Trees*			
Volume M. Feet					Volume M. Feet			
Sugar pine	Yellow pine	Incense cedar	Total	D. B. H. inches	Sugar pine	Yellow pine	Incense cedar	Total
Volume of sugar pine and yellow pine for each diameter class up to 19″, inclusive.		Volume of incense cedar for each diameter class up to 15″, inclusive.	200,000	10 11 12 13 etc.	Volume of sugar pine and yellow pine for each diameter class 20″ and over.		Volume of incense cedar for each diameter class 16″ and over.	1,800,000

From the table we find the actual proportion of old and medium trees to be:

Old trees = 1,800,000 M. feet
Medium trees = 200,000 M. feet

Total, 2,000,000 M. feet

The normal proportion should be:

Old trees, $2{,}000{,}000 \times \frac{5}{8} = 1{,}250{,}000$
Medium trees, $2{,}000{,}000 \times \frac{3}{8} = 750{,}000$

But the normal growing stock over the whole area, considering half of the area stocked with 30-inch trees, should be 1,120,000 M. This should be divided between the two groups as follows:

Old trees, $1{,}120{,}000 \times \frac{5}{8} = 700{,}000$ M.
Medium trees, $1{,}120{,}000 \times \frac{3}{8} = 420{,}000$ M.

1,120,000 M.

Hence although there is a surplus of $1{,}800{,}000 - 700{,}000 = 1{,}100{,}000$ M. feet of old trees, there is a deficit of $420{,}000 - 200{,}000 = 220{,}000$ M. in the medium trees. If all the old trees were cut during the first third of the rotation the growing stock would be depleted. Therefore 220,000 M. feet will be taken from the lower diameters of the large trees, chiefly from the more valuable species, and added to the medium trees.

The resulting surplus will be 1,100,000 − 220,000 = 880,000 M. This surplus is to be removed during the first third of the rotation. The cut for the first third of the rotation will therefore be the 880,000 M., surplus and the 700,000 M. normal volume of old trees, plus the increment on their sum. This increment will be 12,000 M. per annum, or 12,000 × 30 = 360,000 for the sixty-year period.* Therefore the annual cut for the first third of the rotation will be:

$$Y = \frac{880,000 + 700,000 + 360,000}{60} = 32,333 \text{ M. feet.}$$

This amounts to 1.61 per cent of the total volume. Not counting the surplus or increment on the surplus, there will be a cut of only 853,000 M. feet for the sixty-year period, or an annual cut of only 14,216 M. feet. This is but .71 per cent of the total volume, or approximately the increment on the group of old trees.

In carrying out this method, site qualities producing very marked differences in growth must be distinguished in the field work and kept separate in the computation. For instance, in some of the very dry limestone soils of the Western yellow-pine belt of the Southwest the trees are small and stunted, and even when mature hardly reach the diameter of poles on ordinary sites. Such areas if small and unimportant may be thrown out and ignored; but if of some extent they should generally receive a separate calculation and proper consideration in the final allotment of the cut.

(c) **Value and Application.**—A disadvantage of the French method is that it requires the tallying of trees down to one-third of exploitable diameter. This means that if the exploitable diameter is 24 inches, everything above 8 inches must be tallied. It is, therefore, best adapted to a high diameter limit and long rotations, which is, however, generally the case in many of our selection forests. The advantages of the method

* The increment is taken for only half of the period because cutting is going on.

are elasticity and a degree of accuracy not attainable with formulæ.

11. BY VOLUME.—BASED ON DIAMETER CLASSES. INDIAN METHOD.*

(a) **Description of Method.**—This method is based on the principle that a certain number of trees reach a size suitable for cutting every year or period of years. The aim of the method is to cut just this number of trees.

The data required are:

1. A careful enumeration of the growing stock. For this purpose five or six broad classes are made from seedlings up to mature trees.

2. Growth figures, particularly showing the number of years required to pass through each class.

3. Figures showing the percentage of mortality suffered by each class as it passes into the next class above and into the final or mature class.

The rotation is generally the sum of the number of years required to pass through each age class till the exploitable size is reached, with generally a few years added on to make it conservative. The felling period is a convenient subdivision of the rotation and should be at least the length of time required to produce enough material to justify the next cut.

The annual cut is calculated in the following manner: The number of trees in each class is multiplied by the percentage which will survive till maturity. The results are added and then divided by the rotation plus one-half of the felling period.†

In order to find the growing stock of Class I trees the average

* Adapted from Barrington Moore's article, "Methods of Regulating the Cut on National Forests," in Vol. VII, No. 1, "Proceedings of the Society of American Foresters."

† Half of the felling period is added to the rotation to allow for the number of Class I trees (the largest class) which should always be on the ground, because there should always be a number of Class I trees equal to the $\frac{\text{Felling period}}{2} \times$ average annual cut.

annual cut as found above is multiplied by half of the felling period. In order to allow for mortality this number is raised by multiplying by

$$1 \times \left(\frac{\text{Mortality per cent}}{2} \right).$$

The growing stock thus found is compared with the actual growing stock to find whether there is a surplus or deficit. The annual cut is allotted accordingly, distributing this surplus or deficit over a certain period according to the proportion of lower classes and reproduction.

The area check is applied by prescribing the order of the fellings through the different subdivisions of the working unit A table is drawn up showing for each year the subdivision on which the cut is to be located and number of trees to be removed.

(b) Example.—

TOTAL GROWING STOCK

Class

Species	I 28″ and over d.b.h.	II 24″ to 28″	III 18″ to 24″	IV 2″ to 18″	V 6″ to 12″	VI Below 6″ d.b.h.
Yellow pine....	13,178	11,366	19,770	42,577	117,590	215,667

Rotation = 150 years
Felling period = 15 years

From a table showing per cent of each class, reaching Class I, and the per cent of Class I surviving fifteen years, the following calculation is made: Average annual cut

$$= \frac{(13,178 \times .95) + (11,366 \times .83) + (19,770 \times .66) + (42,577}{150 + \frac{15}{2}}$$

$$\frac{\times .50) + (117,590 \times .30) + (215,667 \times .10)}{150 + \frac{15}{2}}$$

$$= \frac{12,519 + 9472 + 13,180 + 21,288 + 35,277 + 21,567}{157.5}$$

$$= \frac{113,303}{157.5} = 719 \text{ trees per annum.}$$

The growing stock of Class I trees, which there should always be, is therefore $719 \times \frac{15}{2} \times 1.025 = 5532$.

Since there are 13,178 Class I trees, a surplus of $13,178 - 5532 = 7646$ trees exists.

The cut for the period over which it is desired to distribute the surplus will be: The present Class I trees, plus the total number of trees reaching Class I in the period, minus the growing stock, all divided by the period.

A modification may be made by calculating the annual cut on the basis of only the upper classes (the first three or four) instead of on all classes. The sum of these classes is then divided by the number of years which the lowest class used will take to become Class I instead of by the rotation.

(c) **Value and Application.**—Practically the only place where the single tree method is used is in India. There it is used almost to the exclusion of all other methods. It is particularly well adapted to mixed tropical forests in which only one or two of the many species found is merchantable.

The disadvantages of the method are its lack of elasticity, its complexity, and liability to error; it also requires as many data as better methods. Hence it should be used only in exceptional cases.*

12. BY VOLUME.—BASED ON DIAMETER CLASSES. DIAMETER-CLASS METHOD (HUFNAGL).

(a) **Description of Method.**—*Variation I.* For uneven-aged (selection) forests the cut can be determined if all stands or trees more than $\frac{r}{2}$ years old are known and their increment. This presupposes the fixation of the rotation age. By means of ring-counts on stumps of average diameter or from other

* An attempt to modify this method for application in the United States was made by Walter J. Morrill in an article "Method for Regulating the Yield in Selection Forests," For. Quart., Vol. XI, No. 1, pp. 21–27. This method, while rather ingenious, is not of great practical importance since it rests on the very dubious basis of average crown spread.

data, it is then determined at what diameter breast high the trees have an age equal to $\frac{r}{2}$. All trees of this diameter and over are next estimated—preferably in 3-inch diameter classes—and their volume and current annual increment determined.

Annual cut = volume of trees or of diameter classes $\frac{r}{2}$ years and over, plus increment thereof in $\frac{r}{4}$ years; this sum divided by $\frac{r}{2}$. (For underlying theory see Formula Methods above.)

Variation II. Going a step further, diameter can be substituted for age. After determining at what diameter, and upwards, the trees are most merchantable, it follows that all trees of this diameter and larger are merchantable and should, other things being equal, be cut in the near future, i.e., during a period of years required for the next lowest diameter class or classes to produce an equal number of merchantable stems. But the lower diameter classes contain more trees than the higher classes, therefore more than replacing those cut in the higher class.

To express this numerically, the period of years separating the diameter classes must be known, i.e., the average age of the average tree in each diameter class. Let this value equal a_1, a_2, a_3, etc. The volume of the average tree in each diameter class must be also known (volume tables, measurement of representative trees, etc.). Let this value equal v_1, v_2, v_3, etc. Let, finally, the number of trees in each diameter class equal n_1, n_2, n_3, etc., and the formula follows:

$$\text{Annual cut } (y) = \frac{n_4}{a_4 - a_3} v_4 + \frac{n_3 - n_4}{a_4 - a_3} v_3 + \frac{n_2 - n_3}{a_3 - a_2} v_2 + \frac{n_1 - n_2}{a_2 - a_1} v_1.$$

The formula indicates the cut in number of trees of each class as well as in volume.

Hufnagl further advocates the comparison of y obtained by this method with y obtained by current annual increment (method No. 4 above) and, if necessary, the use of only the first one or first two of this series of expressions so as to make the results comparable, and also periodic revisions of the data on which the method is based. The class represented by a_1, v_1, and n_1, is usually the one just below the diameter limit of cutting.

Since the method is particularly intended for selection forests it is Hufnagl's theory that the cutting cycle shall equal approximately $a_4 - a_3$ years, i.e., the time required for the highest merchantable diameter class to be replaced by the one next below it.

In its practical application it is customary to choose a *maximum* as well as the usual *minimum* diameter limit; that is, the maximum diameter of trees which it is practicable to produce. This usually leaves a surplus of still larger trees produced under virgin conditions. This surplus may well be distributed over the cutting cycle or disposed of more rapidly or more slowly as local exigencies dictate.

(b) **Examples.**—*Example of Variation I.*—It is desired to determine the cut of hemlock in the slope type of Catskill forest, illustrated by the stand and stock tables quoted above from Bulletin 11 of the N. Y. State Conservation Commission.* A breast-high diameter limit of 12 inches is to be observed which, according to U. S. Dept. of Agriculture Bul. 152, n. s., "The Eastern Hemlock," table 10, corresponds to a rotation of 160 years. The same table shows that at eighty years $\left(\frac{r}{2}\right)$ a diameter breast high of 4 inches is attained.

The volume of all hemlock trees over 4 inches is 403.08 board feet per acre (Table 5, Bul. 11). The current annual increment thereon is 5.478 board feet per acre (see example of method No. 4.) The annual cut then

* Bulletin 11, "Forest Survey of a Parcel of State Land," Albany, N. Y., 1915, Tables 4 and 5. See pages 47 and 48.

$$=\frac{403.08+\left(5.478\times\frac{r}{4}\right)}{\frac{r}{2}}$$

$$=\frac{403.08+(5.478\times 40)}{80}$$

$$=\frac{403.08+219.12}{80}$$

$$=\frac{622.20}{80}=7.778 \text{ board feet of hemlock per acre}$$

or, for the 1730 acres in this type, =13,456 board feet of hemlock.

Example of Variation II.—It is desired to determine the cut of hemlock in the slope type of Catskill forest, illustrated by the stand and stock tables quoted above from Bulletin 11 of the N. Y. State Conservation Commission.* The number of years required to grow from one diameter class to the next has been determined by increment borings and the current annual increment per cent has been worked out by Pressler's formula (see data in example under Method No. 4). These show that trees of 20 inches d.b.h. and over have a c.a.i. of less than 1 per cent and so may be regarded as surplus stock (z in method No. 4). The d.b.h. limit chosen is 12 inches. This leaves a merchantable stand of trees from 12 to 20 inches, d.b.h., as the basis of computation. It is simpler to group these in 3-inch classes, as follows: 17 to 19 inches equals 18-inch class; 14 to 16-inch equals 15-inch class; 11 to 13-inch equals 12-inch class. To this must be added the class immediately below the diameter limit class, that is, 8 to 10 inches equals 9-inch class. From table 9 of the aforesaid Bulletin 11 are taken the volumes of 18, 15, 12, and 9-inch trees, respectively. The years required

* Bulletin 11, "Forest Survey of a Parcel of State Land," Albany, N. Y., 1915, Tables 4 and 5. See pages 47 and 48.

to grow from one class to the next are found by working up the increment borings.* The complete data are as follows:

D. B. H. Class (Inches.)	Volume per Tree. Board Feet. (Table 9, Bul. 11.)	Number of Trees per Average Acre. (Table 4, Bul. 11.)	Years Required to Grow from One Class to Next.
9.	$42(v_1)$	$.91(n_1)$	$27(a_2-a_1)$
12.	$93(v_2)$	$.87(n_2)$	$32(a_3-a_2)$
15.	$172(v_3)$	$.33(n_3)$	$35(a_4-a_3)$
18.	$293(v_4)$	$.20(n_4)$	
			$cc=a_4-a_3$ $=35$ years

Applying the formula, y, the annual cut,

$$=\frac{n_4}{a_4-a_3}v_4=\frac{.20}{35}\times 293=1.674 \text{ board feet per acre,}$$

$$+\frac{n_3-n_4}{a_4-a_3}v_3=\frac{.13}{35}\times 172=\ \ .637 \quad \text{“ “ “ “}$$

$$+\frac{n_2-n_3}{a_3-a_2}v_2=\frac{.54}{32}\times\ 93=1.569 \quad \text{“ “ “ “}$$

$$+\frac{n_1-n_2}{a_2-a_1}v_1=\frac{.04}{27}\times\ 42=\ \ .062 \quad \text{“ “ “ “}$$

$$\text{Total} \qquad =3.942 \quad \text{“ “ “ “}$$

$$+\frac{z}{cc}=\frac{168.48 \text{ bd. ft. per ac. of surplus}}{35 \text{ years, the cutting cycle}}=4.814 \text{ board feet per acre,}$$

$$\text{Total annual cut} \qquad =8.756 \quad \text{“ “ “ “}$$

or, for the 1730 acres in this type = 16,117 board feet of hemlock.

Comparing this with the results obtained from similar data by method No. 4, the annual cut does not appear excessive. If, however, the result were much higher than those

* See “A Practical Application of Pressler's Formula,” F. Q., XIV, No. 2.

by method No. 4, the formula should be cut down to the first one or two expressions of the series; e.g., if to the first expression, then $y = \frac{n_4}{a_4 - a_3} v_4 + \frac{z}{cc} = 1.674 + 4.814 = 6.488$ feet b.m. per acre or, for the 1730 acres in this type = 11,224 board feet of hemlock.

The cutting cycle equals $a_4 - a_3 = 35$ years.

(c) **Value and Application.**—This method, first published by Hufnagl in 1893,* is excellently adapted, especially in its second variation, to the irregular and overmature selection forest which is so commonly encountered in all parts of America. It is especially well suited to virgin stands, tending to cut the excess growing stock (of overmature timber) within the first cutting cycle, and yet providing ample material for a second cut at the end thereof.

The data which are required are those of every thorough forest survey preliminary to a working plan, namely, data on diameter-class distribution, on number of trees in each (in representative stands), of volume, and of diameter growth or, in the first variation, of increment (current annual). If it is not feasible to tally diameter classes for the entire tract, carefully chosen, fully stocked sample plots of varying site qualities will suffice, but when applied to the total stand must be reduced to correspond with the average density of stocking. All data should be revised at least once in ten years.

When accompanied by a plan of cutting (distribution of cut) for the next decade, the method is perhaps the most practical yet invented for irregular selection forests. Indeed, it is intended for just such conditions in the more remote parts of Austria.

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* "Oesterreichische Vierteljahrschrift für Forstwesen," 1893, pp. 177 and following.

13. BY AREA AND VOLUME.—FOR ENTIRE FOREST. MÉTHODE DU CONTRÔLE (GURNAUD).

(a) **Description of Method.***—This method, intended for selection forest, was originated in France by M. Gurnaud. It has been tried successfully in France and in Switzerland. It consists in making successive measurements of the whole forest, going over the whole area at short intervals of six to ten years. The remeasurements are all made under absolutely like conditions. The amount of increment is obtained by deducting from the volume found at the last measurement that of the preceding. A stand table is made. The stand is divided roughly into three main diameter classes. The first class includes all trees below .30 meter in diameter (about 12 inches), the second, between .30 and .50 meter (approximately 12 to 20 inches), the third, over .50 meter (over 20 inches). The cut is taken in per cent of the material on the area; based on the vigor of growth at different ages.

The method seeks the proportion of trees in the different classes at each remeasurement. Growing stock and increment must be determined by some measure common to both, to be determined by the parties concerned. Muret advocates the use of basal area for estimating the cut, rather than the estimate of the actual cubic contents, since the cubic contents vary in exact proportion with the basal area.

One cannot establish a sustained annual yield by this method until the beginning of the second period. The more frequently inventories are taken, the more accurately can this yield be determined.

"The sustained and annual yield will fix and will justify:" 1. Whether the cuttings ought to cover all the increment, more than the increment, or less than the increment; 2. How and

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* Adapted from M. Muret's article: "A Method of Yield Regulation, Méthode du Contrôle," translated by K. O. Ward, in Forestry Quarterly, Vol. XIII, No. 1, pp. 43–46.

where the allowed cut ought to be distributed among the different classes, and what proportion of the old, medium, and young trees it should contain. The most favorable distribution among the different classes of the whole, according to M. Gurnaud, is 50 per cent in the old tree class, 30 per cent in the medium class, 20 per cent in the young class. In the following cases, it may be advantageous to change these proportions; for example, to increase the proportion of older trees if the soil needs protection, or to lessen the older classes according to species and exposure, if more sunlight is needed for the appearance of natural reproduction. This method is much less a method of absolutely mathematical results, applicable to all forests, than a simple process allowing the finding of all necessary information in the forest.

(b) **Example.**—A typical stand of Western yellow pine of 456 areas * was measured in 1909 and remeasured five years later with the following results:

	1909	1914	Increase in five years.
Number of trees 4 inches or over, d.b.h.	8,255	8,400	145
Total volume, ft. b. m., 12 ins. or over, d.b.h.	1,550,910	1,756,328	205,418

Total increment for five years = 13.2 per cent = 2.64 per cent per year. The current annual increment per cent of this stand is therefore 2.64 per cent. The annual cut would therefore be taken as 2.64 per cent of 1,756,328 board feet = 46,367 board feet. This is an equivalent of 102 board feet per acre. By Von Mantel's method the cut, assuming a rotation of 160 years, would be $\frac{1,756,328}{80} = 21,954$ board feet, which is far lower than the circumstances warrant. By method No. 4, including

* Data from "A Preliminary Report on the Progress in the Remeasurement of Sample Plots on the Coconino and Tusayan National Forests, Arizona," by G. A. Pearson, briefed For. Quart., Vol. XIII, No. 1, pp. 60–63.

z and zi in figuring cc, the cut would be 41,084 board feet. The cut would be distributed among the different size classes as dictated by silvicultural and market conditions.

(c) **Value and Application.**—The method's chief advantage is that an exact account of what is done can be kept, and of the effect produced by the operations carried on, so as to modify future proceedings to suit the object in view. The short period between surveys allows checking, and lessens the chance of overestimating. However, forest management in America is seldom intensive enough to apply the method since it involves too much time and expense by requiring such frequent re-measurements of the whole forest.

14. BY AREA AND VOLUME.—BASED ON AGE CLASSES. DIRECT METHOD (HUFNAGL *).

(a) **Description of Method.**—If the volume and the area of the oldest stands which, presumably, will be cut in the next ten or twenty years is known the average volume per acre equals $\frac{v}{a}$. This volume multiplied by the allowed annual cut in area equals the allowed annual cut in volume.

(b) **Example.**—Referring to example of method No. 1 above: *Variation I. Area not reduced.* Annual cutting area equals 166 acres. The volume of the oldest stands to be cut in the next twenty years (oldest age class) equals 140,000 M. feet board measure, their area is 3500 acres.

Then the average volume per acre $=\frac{v}{a}=40$M. feet board measure.

The volume of the annual cut $=40\text{M.}\times 166=6640\text{M.}$ feet board measure.

Variation II. Area Reduced. Using the figures given in the example of Variation II, Method No. 1 above: Annual

* Hufnagl, "Praktische Forsteinrichtung," is the source of this and the subsequent method (No. 15).

cutting area reduced to terms of Site Quality I equals 130 acres. The stands ripe for cutting in the next twenty years (oldest age class) show an average stocking of .7 and an average site quality II, and hence (from yield tables or from measurements of sample plots of mature fully stocked stands of varying site qualities) an average volume of $46,900 \times .7 = 32,830$ feet board measure per acre. 130 acres are to be cut per annum. This is equivalent (see example method No. 1, Var. II) to 166 acres of site quality II. Hence the annual cut $= 32,830 \times 166 = 5,449,780$ feet board measure.

Variation III. Hufnagl. Using the figures in the example under method No. 1:

$$\text{The volume of the annual cut} = \frac{v}{a} \times 29.$$

(c) **Value and Application.**—As noted under similar heading in method No. 1, the method has all the disadvantages of a fixed value for the rotation, instead of a naturally adjustable one, and allows none of the free play so necessary for the best silviculture. Variations I and III are exceedingly simple, and hence quite well adapted to forests with fairly uniform conditions, i.e., coppice and coppice with standards. Variation II is too complex for all but the most intensive conditions, and requires all the data, while possessing none of the advantages of other and better methods. Obviously the method presupposes an age-class table, and hence a forest composed of fairly even-aged stands. It is therefore essentially *not* a method for selection forests.* Its chief use is as an area check on the figures obtained by other methods.

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* In selection forest the area-volume calculation, as stated under Method No. 1, is based on the cutting cycle and not on the rotation. It may be expressed as a formula: annual cut $= \frac{\text{total area}}{cc} \times$ amount to be removed per acre. In this form it is useful as an area check on other methods of calculating the cut in selection forests.

15. BY AREA AND VOLUME.—BASED ON AGE CLASSES. HUFNAGL'S METHOD.

(a) **Description of Method.**—Hufnagl's premise is that the sustained yield can be determined directly if the volume and the increment of the stands now more than $\frac{r}{2}$ years old is known. This method presupposes a tabulation containing the volume and area of all stands of over $\frac{r}{2}$ years. To this volume is to be added, also, the increment of these stands in the next $\frac{r}{4}$ years; for since the area of these stands diminishes each year, and in the year $\frac{r}{2}=o$, the increment can only apply, on an average to half the area.

As to the increment, Hufnagl distinguishes two variations of his method according as I the current, or II the mean annual increment is used.

I. The current annual increment of each stand over $\frac{r}{2}$ years old having been determined (by yield tables or by field measurements, Chapter I, Section 1), the sum of these increments is used in the formula which follows:

II. The mean annual increment equals $\frac{v}{r}$. It can be determined from yield tables or, empirically, by measuring average stocked stands of average site quality whose age approximates r years. $\frac{v}{r}$ then equals the mean annual increment.

Hufnagl's formula then follows (letting v equal the volume of stands $\frac{r}{2}$ years and over, a their area, i the increment in board feet per acre per annum, current or mean):

$$Y=\frac{v+a\times i\times\frac{r}{4}}{\frac{r}{2}}$$

If i equals mean annual increment it will usually be 10 to 20 per cent less than the current annual increment. This makes its use the more conservative of the two.

(b) **Example.**—In a white pine forest of 2160 acres, site quality II, with a rotation of sixty years, the stands thirty years and older have a volume of 33,041,000 feet board measure on 1120 acres. The mean annual increment for the rth (sixtieth) year equals 782 board feet per acre.* Then by formula:

$$Y=\frac{v+a\times i\times\frac{r}{4}}{\frac{r}{2}}=\frac{33{,}041{,}000+(1120\times782)15}{30}$$

$$=\frac{33{,}041{,}000+13{,}137{,}600}{30}=1{,}539{,}287 \text{ feet board measure}$$

$$=\text{annual cut.}$$

(c) **Value and Application.**—Hufnagl's method shows much originality and is applicable to even-aged stands of only moderate regularity, the very conditions encountered in many American forests. Its age-class differentiation is very simple, as is also the volume and increment determination. The latter had best be the mean annual increment, and can readily be calculated from sample plots if yield tables are lacking.

A disadvantage of the method is the rigid fixation of the rotation age, which should really be a flexible quantity; but if this is offset by frequent revisions at regular intervals the method will pass muster, especially in the irregular stands common to most parts of America. If this method is adopted, it must always be supplemented by a careful cutting plan (distribution of cut).

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* Table 7, Bul. 13, U. S. Dept. of Agric., n. s., "White Pine under Forest Management."

16. BY AREA AND VOLUME.—BASED ON AGE CLASSES. THE STAND METHOD (JUDEICH'S "BESTANDSWIRTSCHAFT").

(a) **Description of Method.**—Judeich* bases his method on the undoubted fact that no method of determining the cut for a period of years in advance—some even attempting to do so for the whole rotation or a substantial part thereof—is accurate without frequent revisions which recognize the unexpected changes inevitable in every stand no matter how carefully managed. He therefore makes no attempt to regulate the cut for more than a decade in advance, but prescribes not only a revision, but a new plan at the end of the decade.

In order to secure a sustained yield the annual cut is calculated with the following three regulating factors:

(*a*) The yearly cutting area or volume;

(*b*) The distribution of the age classes;

(*c*) The results of previous cuttings.

The more the results of previous cuttings, especially with regard to their effect on the distribution of the age classes, are available, the greater is the justification in regulating the cut for only a decade in advance. Where there has been no previous working plan nor adequate record keeping (with especial respect to volume, area, and distribution of age classes) the cut must be determined two, three, or at most four decades in advance.

Judeich does not give any certain method of ascertaining the cut—either in volume or in area—but adapts this to the peculiar exigencies of each forest. The object of the working plan is the attainment of normality in the distribution of the age classes; this is secured by a correct cutting series and cutting policy.

The cutting policy selects for the next decade or two, or, at most three or four, all the stands or groups of stands which require cutting for one or more of the following reasons:

* Adapted from Lorey, "Handbuch der Forstwissenschaft," 2d edit. Vol. III.

1. Administrative necessity.
2. Disease and decadence (overmaturity).
3. Maturity.
4. Inferiority, slow growth.

The sum of stands ready to cut for reasons 1 to 4 gives in area and volume the cut for the next period, subject to the following regulating factors:

(*a*) The yearly cutting area or volume.

(*b*) The distribution of the age classes.

(*c*) The results of previous cuttings.

(*a*) Can be determined by any of the methods already described, by area if the distribution of the age classes is not too abnormal (e.g., method No. 1), by volume, preferably, if the distribution of the age classes is far from normal and there is a preponderance of overmature timber (e.g., method No. 9).

Judeich expressly states that his method is not restricted to a financial rotation, but is equally well adapted to rotations on other bases.

(**b**) **Example.**—Assuming a general stand table such as that given in Chapter I, Section 2, from this it appears that the following stands * are in need of cutting during the next ten years:

Reason.	Compt. No.	Sub-compt Letter.	Area Acres.	Stand Species and M. ft. b.m.	
1. Administrative necessity	.....	......	......	....	....
2. Disease and decadence..	9	*b*	61	Spruce 900	
	10	......	50	....	Fir 100
3. Maturity............	6	......	100	Spruce 1100	Fir 75
	8	......	100	Spruce 440	Fir 60
Total............	.....	......	311	Spruce 2440	Fir 235

= 2675 M. feet.

* The selection forest in compartments 3, 5, and 7 is necessarily omitted, since it obviously requires a different method of computing the cut.

The distribution of the age classes (see age-class table, Chapter I, Section 2) shows a considerable abnormality, as follows:

	Overmature (160 +)	Mature (81–160)	Young (1–80)	Restockable Blanks.
Actual....................acres	61	246	300	103
Normal..................	....	355	355	
Deficit....................	....	109	55	
Surplus...................	61	....	....	103

The rotation is 160 years; the total area 710 acres exclusive of natural blanks, and the protective belt of selection forest (see foot-note p. 113).

Despite the abnormality, the annual cutting area is here calculated for the sake of an example, e.g., by method No. 1, variation I, the annual cutting area $= \frac{A}{r} = \frac{710}{160} = 4.43215$ acres. For ten years $= 44.3125$ acres.

The cutting for the next ten years would, therefore, be confined entirely to compartment 9*b*.

But where stands are so irregular in age classes, site quality and density of stocking, it is not well to resort to area as the regulating factor, but rather to use some volume method, such as Heyer's, of comparison with the normal growing stock (method No. 9).

This would give:

i (increment) = 5,840 M. feet of spruce × (say) .007 = 40,880 ft.b.m.
970 M. feet of fir × .01 = 9,700 ft.b.m.

Total, 50,580 feet.

$$r = 160$$

$$nv = \frac{ri}{2} = 4{,}046{,}400 \text{ feet b. m.}$$

$$v = 6{,}810{,}000 \text{ feet b. m.}$$

$$\therefore \quad v > nv \text{ by } 2{,}763{,}600 \text{ feet b. m.}$$

Let x (the period of equalization) $=\frac{r}{4}=\frac{160}{4}=40$ years.

Then by the formula:

$$y=\frac{v+i\times x-nv}{x}=\frac{6{,}810{,}000+(50{,}580\times 40)-4{,}046{,}400}{40}$$

$$=119{,}670 \text{ feet board measure.}$$

The annual cut therefore equals 119,670 feet board measure.

The cut for the decade equals 1,196,700 feet board measure.

There is within compartments 9*b*, 10, and part of 6 and 8 ample (2,675 M. feet) for the cutting within the next decade. Compartments 6 and 8 need scarcely be touched, which is just as well, since they are barely mature now. If, however, in view of the proportionately large amount of mature and overmature timber it is desired to reduce the period of distributing the surplus to ten years, the result would be:

$$\frac{6{,}810{,}000+(50{,}580\times 10)-4{,}046{,}400}{10}=326{,}940.$$

The annual cut therefore equals 326,940 feet board measure.

The cut for the decade equals 3,269,400 feet board measure.

There are within compartments 9, 10, 6, and 8 only 2,675,000 feet, hence the management must either be conservative and content itself therewith or add compartment 4, with 945,000 feet to the cutting areas for the decade, which would make 3,620,000 feet board measure, or ample whereon to draw for the 3,269,400 feet board measure to be cut.

(c) **Value and Application.**—This method is without doubt the most rational of all the methods of determining the cut; for it attempts no iron-clad rule or framework—such as the "period methods" next to be considered—but depends entirely on the silvicultural and economical requirements of the forest. By means of frequent revisions the amount cut can never endanger the continuity of the forest's productiveness, while it allows full play to the skill of the officer in charge of the management of the forest. The forest moves steadily toward a normal distribution of the age classes, but this very desirable goal is attained without undue sacrifices.

It is a method of great freedom and adaptability. Freedom in so far as the cutting of certain stands is not prescribed far in advance for a certain time, but entirely according to the exigencies of the situation. It is adaptable to all methods of high forest which result in even-aged or fairly even-aged stands, i.e., to all but the selection system.

The method in its simple application is well suited to American conditions where it is often of prime importance to dispose of the overmature and decadent timber within the reasonable check of a sustained volume yield aided by the corrections of decennial redetermination of the cut, and to work toward the distant goal of a normal age-class distribution.

17. BY AREA AND VOLUME.—BASED ON PERIODS ("FACHWERKSMETHODEN" *).

(a) **Description of Method.**—The rotation is divided into a number of equally long periods of time. Usually these periods comprise twenty years. Every compartment or subcompartment is assigned to a period corresponding with its age, so that each part of the entire area of the working unit, with the exception of certain areas reserved for selection forest, protective belt, or other special purpose, is used once during the rotation.

The sums of the individual periods must be approximately equal, or somewhat higher for the later periods. If this is not the case, adjustment is necessary, by transferring certain stands or subcompartments to an adjacent period. According as this adjustment emphasizes equality of area, or equality of volume, or equality in both, different kinds of period methods are recognized as: I. Area-period method (" Flächenfach-

* The name " Fachwerksmethoden " comes from the German " Fächer " or pigeon-holes into which the various parts of the forest are placed by these methods. A " Fächerwerk " or " Fachwerk " is, therefore, a framework consisting of many pigeon-holes, and these methods are " Framework " methods.

werk "); II. Volume-period method (" Massenfachwerk "); III. Area-and-volume-period method (" Kombiniertes Fachwerk ").

I. In the area-period method (" Flächenfachwerk ") the areas are assigned to various periods either as actual areas or as reduced areas (see method No. 1 above) of equal productivity. The method aims to cut each year, or each period, an equally productive area containing an approximately equal volume. The age-class table is the basis of the assignment to periods, however these must then be shifted to secure equality of utilization in each period. Knowing the area to be cut in the first (immediate) period and (from yield tables or empirical measurements) the volume yield thereof, the annual cut is found by dividing this volume by the number of years in the period. This volume calculation is usually confined to the first period. Final cuttings are restricted to this period.

In a rotation of 120 years there are, e.g., $\frac{120}{20}=6$ periods. Were the age-class distribution normal, the periods and the age limits of the stands comprised therein would be as follows:

I Period........................	Age of Stands 100–120 years
II Period........................	80–100
III Period........................	60– 80
IV Period........................	40– 60
V Period........................	20– 40
VI Period........................	0– 20

In practice this method is restricted to simple, regular conditions with artificial reproduction after clearcutting.

The area " framework " has the advantage of simplicity and ease of application. Within the rotation, if no unforeseen disturbances occur, the normal age-class distribution is attained. But the method has the great disadvantage that no due regard is paid to existing conditions (age-class distribution, growing stock, increment). In the case of an overmature, broken stand more should be cut than a strict period method permits; in the case of immature stands, less should be cut than this period method provides. Equality of periods is secured, often, only at a tremendous sacrifice.

II. In the volume-period method (" Massenfachwerk ") the aim is to have an equal cut in each period. The various periods are, therefore, given approximately equal volumes, although the younger periods are sometimes endowed with slightly higher volumes (" Massen ") than the older periods. The annual cut is found by dividing the volume of the first period by the number of years therein (usually twenty).

The individual stands (compartments and subcompartments) are assigned to the periods corresponding to their age. Their volume is then prorated by means of yield tables or, at least, increment tables so as to determine the volume they will have at the time of reaching the middle of the I period (i.e., the cutting period). These volumes are then compared and the necessary adjustments made; the stands are shifted from one period to another, e.g., if the II period were deficient, the IV period excessive, some stands would have to be shifted from the IV into the III period, and from this into the II period, until the proper balance was secured. Since this " shifting " carries with it a recalculation of the final yield because of changed increment, the method involves an enormous amount of calculation.

This method was founded by G. L. Hartig in 1795. It finds no application in practice to-day.

It has the advantage over the area " framework " of cutting an equal volume each year, and hence more nearly approaches the desires and needs of timber owner and timber buyer. But it has the glaring disadvantage of attempting to regulate the cut for a whole rotation. The future treatment of stands must depend on eventualities which cannot be foreseen in the present. Nor can the method be used in the extensive, irregular conditions for which it is intended because of the lack of adequate volume and increment data. Furthermore, an equal annual cut may disregard overmature stands in need (financial and silvicultural) of cutting, or, conversely, cut stands which are not yet mature. It is an unnecessarily narrow concept of sustained yield; it does not even secure normality, for volume, i.e., growing stock, alone is no criterion of normality.

III. The area-and-volume period method (" Kombiniertes Fachwerk ") aims to combine the area " framework " and the volume " framework " so that each period will contain approximately equal areas and volumes.

Theoretically this distribution of volumes is for the whole rotation and is achieved for the I period by means of volumetric surveys, for the other periods by means of yield tables. Areas and volumes are then adjusted as in the area " framework " and the volume " framework." The annual cut is then obtained by dividing the area and the volume of the I period by the number of years contained therein (usually twenty) and letting the two factors of area and volume act as a mutual check.*

In practice the difficulty of predicting volumes for a whole rotation and of equalizing volumes and areas, led to an important modification whereby the volumes are calculated for only the I period or, at most, the I and II periods; the areas, however, delineated, roughly, for the whole rotation so as to insure a sustained yield.

This method was founded by Heinrich Cotta in 1804. The important modification of restricting the volumes to the I or I and II periods dates from von Klipstein in 1823 and von Grebe in 1867.

This method possesses the combined advantages of the area and the volume " framework "; it secures a greater regularity of volume yield than does the former and a quicker approach toward normality than does the latter. Combined with a proper distribution of the age classes and a liberal interpretation of equality in the periods, the method secures good results. But

* A number of variations have been suggested, *e.g.*, annual cut = volume of period ÷ years of period (Prussian practice); annual cut = area of period ÷ years of period (Auhagen); annual cut = area of (I or I and II) periods ÷ years and reduced to volume (von Stockhausen and von Grebe). In practice both factors are regarded as local conditions demand.

with too strict construction it results in crass errors, such as the needless leaving of overmature stands simply because they are in the *sacrosanct* II period and can not be touched,* or the cutting of immature stands which were placed in the I period merely to " fill in."

(b) **Example.**—Since, from what has gone before and what follows (c) these methods are so obviously unsuited to American conditions, it would serve no useful purpose to elaborate them by examples.†

(c) **Value of Application.**—In most of the German States the " framework " methods were the foundation of regulated management and thus exerted a mighty influence on German forestry. But under the conditions of modern times they have steadily diminished in importance for the following reasons:

(1) The silvicultural method of management, to which the method of regulating the cut must conform, is often in direct disagreement with the " framework " method. The latter demands that the cutting on a given parcel (e.g., compartment) be completed within the period (twenty years). This is often impossible without silvicultural mistakes and economic sacrifices. The natural reproduction of many species requires more than an arbitrary period of, say, twenty years. Even with artificial reproduction there are often unavoidable and unforeseeable events which make complete regeneration impossible within the period.

(2) The concept of sustained yield which endows each period with an equal area or volume, or both, is unnecessarily narrow. For practical purposes it suffices that the area or volume, or

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* This has led to the growing demand for the " Opening of the II Period."

† These may be found in Judeich's or Martin's " Forsteinrichtung," or in Lorey's " Handbuch der Forstwissenschaft," 2d ed., Vol. III, pp. 411, 415, and 423, or in Roth: " Forest Regulation," pp. 142–145, 147–150, who gives, what he calls the " Allotment Methods," a strong endorsement, despite the fact that most of the European countries have outgrown them. This endorsement is all the more strange since Roth values Dr. Martin so highly as an authority and Martin himself repeatedly declares against the period methods.

both, of the next working period be in reasonable ratio to the total area or volume, or both, of the entire working unit. Modern economic conditions have greatly changed the concept of sustained yield and often demand the cutting of other than the exact period area; the zone of economic influence has extended tremendously.

(3) Cutting series are not dependent on a period method; indeed the latter often resulted in cutting series of excessive length.

(4) The assignment of every compartment or other parcel of the forest to a certain period presumes a certainty of judgment on the part of the forest organizer amounting to prescience. As a result the cumbersome calculations are often valueless.

(5) These calculations of cut for the whole rotation in advance are the more unnecessary since, under proper administration, there are frequent revisions of the working plan at regular intervals.

Taking all these together, it is a just cricitism of the " framework " methods to say that they are too hide-bound, adapted only to even-aged stands, to intensive conditions, and to methods of clearcutting with artificial reproduction. The realization of this has brought about a revulsion from these methods. Most of the German States have definitively abandoned the " framework "; in others it still persists, but without any weight on the determination of cut for future periods (see Part Two, Chapter I).

18. BY AREA AND VOLUME.—BASED ON PERIODS. AMERICAN METHOD.*

(a) **Description of Method.**—Professor Chapman offers this method as a possible standard for regulation in all forests whose increment per acre and age classes can be determined and as

* Adapted from " Coördination of Growth Studies, Reconnaissance, and Regulation of Yield on National Forests," H. H. Chapman, Proc. Soc. Am. Foresters, Vol. VIII, No. 3, pp. 317–326.

such it has been termed by him for convenience the "American" method of regulation.

Step 1.—The forest is grouped into four or five rough age classes such as:

1.	Decadent	(overmature)..........	O
2.	Mature	(mature)............	M
3.	Young merchantable	(young).............	Y
4.	Immature poles	(poles)..............	P
5.	Immature saplings	(saplings)............	S
6.	Seedlings	(reproduction).......	R

The rotation age may coincide with the upper limit of class 3.

Step 2.—Find the average age of each age class either by area or by volume (as described under method 8) or by drawing a curve of height on diameter for the type, and thus securing a type volume table based on diameter alone. The average volume of the trees in the age class is found from knowing the total volume and total number of trees. The diameter, which corresponds to this average volume, is taken direct from the volume table, but interpolated to one-tenth of an inch. The age of a tree of this diameter is found from the growth curve of diameter based on age, prepared on a similar site by analyzing the growth on stumps. This age is accepted as the average age of the class.

Step 3.—The volume in each group, or age class, is computed from reconnaissance.

Step 4.—From the yield table (which may be constructed by any of the accepted methods) read the current annual increment per cent for stands of each age class. The increment in decadent stands (overmature) may be a minus quantity.

Step 5.—Plan to remove the volume of the decadent class within a given period (I) corresponding to the quantity and condition thereof, the distribution of the age classes * and the

* The presence of large areas of immature timber of good size should permit the more rapid cutting of the older stands.

possibility of heavy cutting. The total cut for the period will be the volume of the decadent class plus half the growth (or minus half the loss) for the period as found in step 4. The annual cut equals the cut for the period divided by the number of years.

Step 6.—Plan to remove the volume of the mature class in a period (II) beginning in the year when the volume of decadent timber is exhausted and stretching over a number of years according to its acreage and volume. The total cut for Period II equals present volume of the mature class plus the growth during Period I plus one half the growth (or perhaps minus one half the loss) during Period II.

Step 7.—Treat group 3 the same way, remembering that the calculation becomes increasingly uncertain the more remote the period.

Step 8.—Determine for groups 4, 5 and 6 the per cent of total area occupied and assign to it a period at the end of the rotation equaling this per cent of the total rotation.

Step 9.—The sum of the periods should equal the number of years in the rotation, since before the expiration of the full rotation all timber now growing, from seedlings up, will pass the exploitable age.

Step 10.—Should the first arbitrary assignment of periods give very irregular yields, alter the lengths of the periods and recompute the yields, until the desired equalization of yield is approximated.

(b) **Example.**—The complete figures of an example are too extended to be given here; however, as worked out by the author for Western yellow pine on the Coconino National Forest in Arizona in 1913, this method gives, for an area of 100,000 acres, an annual cut of 12,160 M. feet b.m. or, on a basis comparable with the data used in figuring the cut by other methods, of 4,053,333 feet b.m., as against 6202 M. feet b.m. by Heyer's formula (No. 9), and 5457 M. feet b.m. by Hufnagl's method (No. 12, Var. II). This bespeaks a thorough conservativeness of regulation by the American method.

(c) **Value and Application.**—This is an adaptation of Hartig's volume—period method (see method No. 17, Var. II) but greatly simplified. Some of the disadvantages of the period methods adhere to it, but it has the following substantial advantages: The commercial factors of demand and markets, as well as the conditions of the stand, can be given full weight in fixing the limits of the annual cut, actual increment is fully recognized, and sustained yield is assured by recognition of the amount and relation of the actual age classes.

It is applicable to even-aged forests and to those uneven-aged by groups of even age. It is not suited for the true selection forest unless a satisfactory yield table, based on age and area, can be made.

REVIEW OF THE METHODS OF DETERMINING THE CUT

No single one of the methods described above will be adapted to all varieties of conditions. The choice of method depends: 1, on the intensity of management possible; 2, the kind of forest, and 3, the silvicultural method adopted. In the light of these considerations, the methods may be valued as follows:

Method No. 1 is chiefly adapted to coppice and coppice with standards. It is also useful as an area check on calculations by volume alone.

Methods Nos. 2 and 3 for provisional determination of the cut under rough conditions, and as a check on other methods.

Method No. 4 for selection forest.

Methods Nos. 5–9 (" formula methods "): Of these all but No. 9 are restricted to rough calculations in irregular stands and as checks on other methods. No. 9 (Heyer's formula) finds a wide application in uneven-aged, virgin stands when supplemented by a careful cutting plan.

Method No. 10 is adapted to high diameter limits and long rotations.

Method No. 11 is adapted to mixed tropical forests where only one or two of the many species are merchantable.

Method No. 12 is excellently suited for irregular and overmature selection forests.

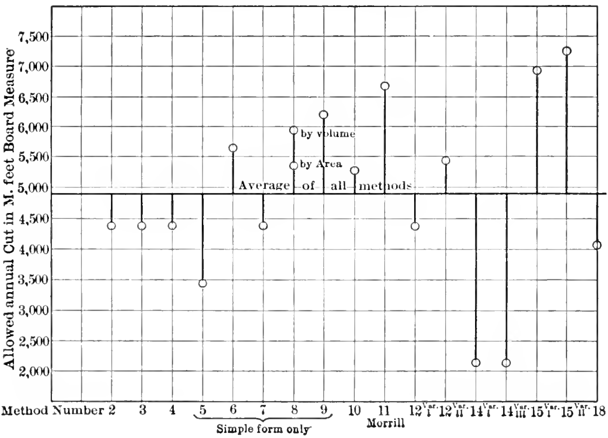
Method No. 13 is restricted to very intensive conditions.

Method No. 14, variations I and III, for coppice and coppice with standards, Var. II for intensive conditions. Chiefly used as area check.

Method No. 15, for even-aged stands of only moderate regularity.

Diagram E

DETERMINATION OF CUT BY 18 DIFFERENT METHODS
BASED ON THE SAME PREMISES



Method No. 16, the ultima ratio of fairly regular, even-aged stands.

Method No. 17, the strait-laced period method of Europe; not adapted to American conditions.

Method No. 18, an American adaptation of the period method for even-aged stands and those uneven-aged by groups of even age.

It is always advisable to calculate the annual cut by a variety of methods so as to have a check on the figures. Both volume and area should be figured wherever possible in order to have an "area check." *

The accompanying diagram (Diagram E) shows the relative numerical results of computing the cut by the different methods, using the same data as premises.

CORRELATION OF SILVICULTURAL METHODS AND METHODS OF DETERMINING THE CUT

In general it should be borne in mind as Roth points out in his "Forest Regulation," page 159: "Regulation of the cut in amount is very important in development of any forest property to prevent unreasonable overcutting which could defer any desired regularity of income for a long time and bring permanent injury to parts of a forest. But it is not as important as is good protection and silviculture and a suitable division of the forest, for these together with any degree of orderly sequence of cutting will in themselves work in the direction of regularity and will in all forest properties largely replace regulation of the cut in time.†

"But in the present beginning stages of forestry, such simple and satisfactory procedure is not possible. More than 75 per cent of our large forest areas are not even accessible and assigning an area here to a particular time, can have no meaning. For this and other reasons it is necessary to use other methods."

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* "To learn what the condition of the whole forest is with reference to continuity of the determined felling budget, the average age of the entire forest is found by dividing the stock by the increment $\left(\frac{v}{i}=a\right)$. This should be equal to one-half the rotation; if it turns out to be much less, it may be an indication not to cut the entire increment during the working period, or vice versa, in order to come nearer to normal age." Oberforstrat Frey in "Vereinfachung des Waldertragsregelungs-Verfahren," Allgemeine Forst- und Jagd-Zeitung, July, 1905, pp. 232–236.

† Cotta, a century ago said: "A proper division of area, orderly sequence in cutting, and frequent revisions of the plan, are far more important than a mere calculation of the permissible amount of timber to be cut."

1. **Selection Method.**—The cutting cycle—i.e., the period of return—is of more real importance than the rotation. The cutting cycle, in turn, depends on the time required for reproduction and on the growth.

Regulation must be simple to fit the extensive conditions. Volume with an area check is suggested. For volume use:

Von Mantel's method (No. 2) or
Swiss method (No. 4) or
Heyer's method (No. 9) or
Hufnagl's diameter class method (No. 12, especially Var. II).

The choice of methods depends on the available data. Methods 4, 9, and 12 may often be employed as a check on each other. For area check use $\frac{\text{total area}}{\text{cutting cycle}} \times$ volume per acre to be cut.

2. **Shelterwood Method.**—In its strict form, this leads to even-aged stands, but may exhibit quasi-cutting cycles if the period of reproduction is long. The determination of the age classes is important.

In the former case—even-aged stands with rapid reproduction—regulation can be by volume with an area check or by volume and area. For volume use Heyer's formula (No. 9) or even Von Mantel's method of "glorious simplicity" (No. 2). For area use $\frac{\text{total area}}{\text{rotation}} \times$ volume per acre. For volume and area use Hufnagl's method based on age-classes and the mean annual increment (No. 15) or Chapman's "American method" (No. 18).

The distribution of age-classes, actual and normal, is of great value in judging the needs and the progress of the management.

If the period of reproduction is so long as to constitute a quasi-cutting cycle, the regulation will be like that for selection method.

3. Clearcutting and Seed-tree Methods.—These invariably lead to even-aged stands. Regulation can be by area with a volume check or by volume and area. The distribution of age-classes is very important.

For area use $\frac{\text{total area}}{\text{rotation}} \times$ volume per acre.

For volume use Heyer's formula (No. 9) or even Von Mantel's method (No. 2).

For volume and area use Hufnagl's method based on age classes and the mean annual increment (No. 15) or Chapman's "American method" (No. 18) or, where conditions are sufficiently intensive, Judeich's Stand method (No. 16).

4. Coppice.—Use area or area and volume.

For area use method No. 1.

For area and volume use Hufnagl's direct method (No. 14).

5. Coppice with Standards.—Coppice regulated as above. Standards regulated similarly except that the rotation of the standards is a multiple of the coppice rotation.

*In all cases, if possible, the cut should be determined by more than one method in order to be sure of the results. The cut adopted should be a conservative average of the results by different methods.**

In using area of high forest as a means of determining the cut it may either be the area unreduced, reduced, or based on average age; according as the data warrant. (See method 1, variations I, II and III.)

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* For example, in the accompanying diagram, the cut, figured by eighteen methods, averages 4,914.66 board feet. The cut for the next ten years would, therefore, be taken as not to exceed 50,000 M. feet board measure.

SECTION TWO

DISTRIBUTION OF CUT

To make the actual annual cut conform directly to the cut as determined, i.e., to cut yearly the exact amount specified in the working plan, is neither possible nor desirable. Unforeseen contingencies, both silvicultural and economic, often necessitate an overcut one year, an undercut the following. If the working plan must be flexible even under European conditions which allow the forester to decide the " where " and " when " of cutting, how much more is it necessary in America, where the " where " depends on profitable accessibility and the " when " on market conditions.

It therefore suffices entirely to keep within the allowed cut for the working period of ten or twenty years—the period of years during which the working plan is intended to apply—and to make no attempt to cut one-tenth or one-twentieth thereof each year. In other words: a periodic sustained yield rather than an exact annual sustained yield should be the aim.

For similar reasons, a great flexibility must be allowed in the selection of the actual cutting areas. The working plan properly lists certain areas to be cut within the working period of ten or twenty years—the time before the next revision of the working plan—but these cannot be rigidly adhered to, cannot in Europe, and much less so in America. European experience has brought about a great liberality in this regard—the executive officer in charge of the forest is given freedom of choice as to what areas he wishes to cut each year of the working period,* this yearly cutting plan is *viséed* and approved by his superior officers, otherwise he has *carte blanche* to exercise his judgment.

* With due regard, of course, to supplying local needs for timber and to a proper distribution of classes of timber so as to keep values from fluctuating and to provide industries dependent on the forests with the timber they need.

No other course is possible in America, where conditions are far more extensive. The working plan designates certain areas, certain cutting series even; beyond this it cannot go. It must help and not hamper the managing officer. It is merely a frame within which he exercises his individual ingenuity.

Selection of Stands to be Cut

The conditions which govern the selection of stands to be cut are: market, maturity, damage (insects, fungi, etc.), windfall, fire, and the like.

Under *market* are contained all the manifold considerations of logging accessibility, of profit in cutting and marketing, and the sizes and species which can be logged. For example, a spruce stand on top of an isolated mountain like Mt. Graham in Arizona may be fully mature and in need of cutting, but unless there are adequate logging devices which can market the timber at a reasonable profit, it is useless to designate this as the sole cutting area of the next working period. Similarly, there may be large amounts of fir (*abies*) in mixture with other species such as spruce and Douglas fir, but unless the fir is accepted as lumber and as ties it cannot be counted on the same basis with the other species. Finally, where material below a certain diameter cannot be marketed at a profit it should not be considered a part of the cut of the next working period. In other words, the cutting plan must deal first with actualities confronting the administrative officer and put hypothetical utilization in a subordinate place.

Other things being equal, the cutting plan provides for the logging of all *mature* and *overmature* stands, i.e., such as have attained or passed the rotation age. If the forest is even-aged or fairly so, these stands are those of the highest age class or classes.

Stands which show *damage* by insects, fungi, etc., should usually be cut; they are therefore included in the cutting plan for the next working period.

Stands which have suffered severe *windfall* must often be cut speedily so as to prevent further damage.* But, further than this, the lessons of past windfall must be applied in distributing the cut—e.g., to remove a certain stand may expose the one behind it and subject it to almost certain windfall. This can best be regulated by the formation of cutting series, described below. The windfall danger varies, of course, with species and character of stand, with soil and site, and with the prevailing wind direction. Spruce is exceedingly subject to windfall and often requires especial precautions.

Stands damaged by *fire* enough to necessitate reproduction, but not enough to be rendered unmerchantable, must be disposed of speedily before further deterioration.

Mapping of Stands to be Cut

The type and age-class map of the forest is of the greatest value in deciding on the areas to be included in the cutting plan for the working period, especially when supplemented by complete and reliable forest descriptions of each unit. Referring to Fig. 1, and presuming that it is possible to log and market where, when, and what one wishes, but that the windfall danger is great, making many "points of attack" preferable to extensive consecutive cutting areas, the following stands would be chosen:

4*a*, 7*e*, and 8*a* can be cut without in the least endangering any other stands.

6*e*, however, though it is sixty-three years old, cannot be cut before the larger, but only sixty-year-old 6*a*, because this would immediately subject 6*a* to heavy windfalls. Hence 6*e* must wait until 6*a* is cut. This involves a balancing of whether it is the more desirable to cut 6*a* and 6*e* now or to wait until 6*a* is fully mature. Other things being equal, 6*e* must wait, since it is the smaller.

The stands or blocks in which it is intended to cut during the coming working period should be indicated on the working

* In the spruce stands of the Black Forest, Germany, it is not uncommon to have most of the annual cut taken up by unexpected windfalls. (F. Q., XI, 333.)

map either by color, or shading, or symbol. The kind of cutting intended, e.g., shelterwood, can also be indicated by using the symbols given in the "General Stand Table," Chapter I, Section 2, above.

Cutting Series

When one cutting area is purposely joined to another and this to a third, etc., they form a cutting series. In its perfect form it is a silvicultural unit, usually consisting of several compartments, in which the age classes are arranged so that they form a complete series, thereby permitting each cutting series to be handled independently. The object is to interrupt the regular sequence of the age classes and thereby to interrupt the continuity of cutting areas. This tends to reduce the damage due to windfall and insects. (See frontispiece for illustration.) Cutting series always progress from some initial "point of attack" against the prevailing wind direction. They are shown on the map by arrows. The formation of cutting series is a tremendous safeguard against windfall, especially where at the point of attack a wind-mantle has formed on the edge of the stand to leeward. This mantle consists of the persisting middle and lower branches of the trees on the edge of the stand. It is artificially stimulated during the youth of the stand by the cutting through of compartment lines, or forms naturally along a road, stream, or other topographic interruption. It can also be created by heavy thinning along the edge of a stand or compartment whereby the crowns remain deep and hence the trees windfirm.

Cutting series can seldom be arranged without some minor sacrifices. For example, in Fig. 1 the small, forty-eight-year old stand *7d* lies in the midst of the nearly merchantable seventy-two-year old stand *7e*: *7d* would be sacrificed to the cutting series, the lesser good to the greater. Only if the borders of *7d* had been liberated so as to form a mantle, could it be left after *7e* has been cut. This would be done in the case of *7f*, since it is a much younger stand.

GENERAL STAND TABLE,..................................

1	2	3	4	5	6	7	8	9	10	11	12	13	14
DIVISION			AREA										
			Total Area	Even Aged		Uneven Aged		Cut Over				Burnt	
								Regulated		Unregulated			
Block (name)	Compt. (No.)	Sub-compt. (ltr.)	Acres	Area	Average and Age Limits	Area	Age Limits	Area	* Silvicult. Method Date and % Left	Area	Date and % Left	Area	Date and % Left
Tecumseh	1	..	104.27	104	20-40	..	..	..	..	..	..	..	..
......	2	..	96.	96	60-80	..	..	..	..	..	..	..	..
.....	3	..	93.73	..	....	94	1-150	..	..	..	..	..	..
......	4	..	106.	106	100-120	..	..	..	..	..	..	..	..
......	5	..	99.20	..	....	90	1-150	..	..	..	..	..	..
......	6	..	103.	100	140-160	..	..	..	..	3	1900 clean	..	..
......	7	..	97.	..	....	80	1-150	..	..	..	..	..	..
......	8	..	99.50	100	{ 1-10 140-160	..	..	100	Sh. '02 40%	..	..	..	..
......	9	a b	40. 61.	40 61	41-60 160-200	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
......	10	..	100.30	..	(160-200)	..	..	..	..	50	1895 10% Culls.	50	1906 None
Totals....	..	..	1,000.	607	....	264	..	See Col. 5		53	..	50	..

* The silvicultural methods may be designated by the symbols:

- *C* = Clear cutting (indicate whether artificial or natural reproduction).
- *C str* = Clear cutting in strips.
- *C g* = Clear cutting in groups.
- *C ss* = Clear cutting with scattered seed trees. (Seed tree method.)
- *Sh* = Shelterwood cutting.
- *S* = Selection cutting.
- *Sh–S* = Shelterwood selection cutting.
- *S–G* = Group selection cutting.
- *S–B* = Selection border cutting.

† M. = thousand feet, board measure.

ORKING UNIT, AREA.................................ACRES

16	17	18	19	20	21	22	23	24	25	26	27	28	29
	STAND						DESCRIPTION					INCREMENT	
oductive	Stand by Species											Curr. Annual	
	Species Spruce		Species Fir		Miscellaneous Hardwoods		Pure, Mixed, Kind of Mixture	Density of Stocking	Site Quality	Young Growth sufficient to Restock?	Remarks		
Reasons	M. †	Cds.	M.	Cds.	M.	Cds.						%	Vol.
..	200	..	25	..	..	..	P.	1.0	I	Yes	Thrifty	1.5	3.4 M.
..	400	..	35	..	..	..	P.	.9	I-II	No	"	1.7	7.4 M.
..	700	..	30	..	..	..	P.	.8	IV	Yes	"	1.	7.3 M.
..	900	..	45	..	..	..	P.	.8	II	No	"	1.	9.5 M.
Rock	600	..	300	..	..	..	M. singly	.7	IV	Yes	"	1.	9.0 M.
..	1,100	..	75	..	..	..	P.	.6	III	Half	Mature	.5	5.5 M.
Pasture	600	..	300	..	..	..	M. singly	.8	III-IV	No	Grnd. fire	.7	6.3 M.
..	440	..	60	..	..	..	P.	.3	III	Half	Mature	.5	2.5 M.
..	..	..	..	..	Birch	80	P.	1.0	II-III	No	Old burns	1.	.8 cds.
..	900	..	..	..	..	..	P.	.5	II-III	Yes	Decadent; fire scars	.3	2.7 M.
..	..	..	100	..	Aspen	20	M. Grps.	.1	II	No	Bad shape old burn	.2	.2 M.
..	5,840	..	970	..	..	100	..	..	..	..	......	..	....

Cutting series must be decided upon by the forest organizer during the progress of the field work in order to gauge the sacrifices properly. They can be provisionally entered on the working map by using dotted arrows.

Theoretically the cutting series are like steps, actually they are always somewhat irregular even under favorable conditions. In the map, 5*d* and *h*, and 5*e*, *f*, *g*, and *i* obviously belong to two cutting series. But 5*l* is a separate proposition because it must be cut before 5*h* since it is more than twice as old (5*h* = 23 years, 5*l* = 52 years).

Cutting series must be planned decades in advance, and require careful thought and accurate judgment. The cutting of such a series may require many years; early mistakes are difficult to correct.

Cutting series are most necessary in even-aged stands of shallow-rooted species, and there they are of tremendous importance.* Their regular adoption in America is still of the future, but the principle can be utilized now.

Plan of Cutting

Having determined "how much" and "where" to cut during the ensuing working period, this is reduced to a documentary plan of cutting or "felling budget."

Two kinds of cutting plans should usually be drawn up: I, a general one for the entire working period—i.e., for the number of years during which the working plan is intended to apply, generally ten years; and II, a specific plan for the ensuing year.

I. The general cutting plan provides cutting areas sufficient to yield (if the working period is ten years) at least ten times the volume of the allowed annual cut or ten times the area, as the case may be. It should, however, provide for somewhat more, so as to furnish additional cutting areas in case of

* By this means windfall is checked and controlled in the spruce forests of Saxony; the lack of cutting series is largely accountable for the tremendous windfall in the spruce stands of the Black Forest in Baden.

GENERAL CUTTING PLAN, WATERVILLE WORKING UNIT

Decade 1912–1921, inclusive

Block (name)	Compt. (no.)	Sub-compt. (letter)	Silvicult. Method (symbol) *	Present Age (1912) or age lmts.	Area acres	Volume to be Cut and Per Cent of Total							Remarks (reason for cut, etc.)
						Spruce		Fir		Hdwds.		Total	
						M.	%	M.	%	M.	%	M. ft. b.m.	
Tecums'h	9	b	Sh	160–200	61	540	60	..	..	..	..	540	Overmature. Seed cutting.
Tecums'h	10	..	CSS	160–200	50	...	...	85	85	...	...	85	Old stock, to be replanted.
Tecums'h	6	..	Sh	140–160	100	660	60	53	70	...	...	713	Mature. Seed cutting.
Tecums'h	8	..	Sh	140–160	100	440	100	60	100	...	...	500	Removal cutting, repro. complete. 60 per cent cut in 1902 by Sh.
Totals..					311	1,640	...	198	...	...	...	1,838	
Allowed cut for decade†..........					...	...	...	...	...	...	...	1,197	

* The symbols are those used in the General Stand Table, Chapter I, Section 2, above.

† This figure is taken from the examples under Method No. 16.

unforeseen contingencies making the cutting of certain areas impractical or allowing a higher cut than was originally intended. Under fairly regular conditions the cutting plan may cover the next twenty years, or even forty years, but under average American conditions this is little better than a useless play. Nor, under most American conditions, is it necessary or advisable to prorate the increment to the middle of the cutting period. Such corrections had best be left to frequent revisions of the working plan at regular intervals.

The general cutting plan should take the form * on preceding page:

II. The specific cutting plan for the ensuing year, calendar or fiscal, is drawn up by the administrative officer in charge of the forest and submitted by him to his superior officers (if he has any) for approval. Thus it is really a part of administration and not of forest organization, yet it is closely linked thereto. The administrator, through his intimate knowledge of the forest and of the exact status of local conditions of logging, market, etc., selects from out the general cutting plan those areas which in his judgment should be cut during the ensuing year. On large forests he usually consults each ranger on the subject.† A convenient form for the annual cutting plan is as follows: This can be printed or otherwise manifolded and serve as a permanent record. (See next page.)

In the following table, column 4 contains the estimated volume to be cut during the year. If instead of compartment 10, compartment 9*b* had been chosen, with its 540 M. of spruce, the value in column 4 would have been set as directly equal the allowed annual cut, or 120 M. Column 5 is always the volume actually cut. Column 6 is merely for convenience in checking the results of estimates as a guide to their accuracy. When

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* The figures are taken from the General Stand Table, Chapter I, Section 2, above.

† In Prussia the Oberförster (supervisor) calls on each Förster (ranger) for an annual cutting plan for his district. These he then combines for the whole forest.

ANNUAL CUTTING PLAN, WATERVILLE WORKING UNIT
Decade 1912–1921, Year 1912

1	2	3	4				5				6			
Block (name)	Compt. (no.)	Sub-compt. (ltr.)	ESTIMATED VOLUME TO BE CUT				ACTUAL VOLUME CUT				DIFFERENCE			
			Spruce	Fir	Hdwd.	Total	Spruce	Fir	Hdwd.	Total	Plus		Minus	
			M.	M.	M.	M.	M.	M.	M.	M.	M.	%	M.	%
Tecumseh....	10	..	..	85	..	85	..	100	..	100	15	17.6	..	..
Totals..................			..	85	..	85 M.	..	100	..	100 M.	15	17.6	..	..
Allowed annual cut.........			..	..	..	120 M.	..	..	..	120 M.				
Balance: Plus...........			..	..	..	35 M.	..	..	..	20 M.	..	..	..	..
Minus.........			..	..	..	......								

Reasons: Weak market makes small cut advisable.

column 4 contains only part of a compartment, column 6 must be deferred until the entire compartment has been cut over.

Where conditions are sufficiently intensive the table may include areas as well as volumes.

Descriptions and further explanations can always be added if advisable for clearness.

It is obvious that the cutting plan proper consists only of columns 1, 2, 3, and 4 and the comparison of column 4 with the allowed annual cut. But for purposes of convenience columns 5 and 6 are added, thus making the record complete, though they cannot be filled until after cutting is finished. Based on this record, the cutting plan for 1913 is computed. Having saved 20 M. in 1912, the administrator would not hesitate to cut 120+20=140 M. in 1913. Indeed, considerable leeway is customary in this respect, so as not to tie the administrator's hands.*

At the end of the decade, if that is the working period, the annual cutting plan sheets are added up and the results compared with the general cutting plan; they then serve as most valuable data for the revision of the working plan.

SECTION THREE

REGULATION IN SPECIAL CASES

This section considers the methods of regulating in special cases, such as, I abnormal forests, II transition forests, III wood-lots, and IV turpentine forests. Much of what has gone before will apply directly; it is only necessary here to note the exceptions and departures.

I. Regulation of Abnormal Forests

Strictly speaking all forests are abnormal which do not have a normal growing stock, a normal increment, and a normal distribution of the age classes. But in current usage the term

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* In Prussia the Oberförster (supervisor) may exceed the allowed cut by 10 per cent without first seeking permission from his superiors.

"abnormal" is restricted to those forests which show striking irregularities—e.g., a very sparse, patchy stocking, or a marked excess of a single-age class. In the former case the chief aim is to secure a good stand. In the latter case it is sometimes possible, if the entire stand is mature or past maturity, to cut it all off at once, invest the resulting capital, and let the interest thereon take the place of the sustained timber yield.

But ordinarily the timber owner needs timber rather than money in order to supply his saw-mills, pulp-mills, etc. In the case of the government it is obviously the correct political economy to be able to supply without undue interruption the necessary raw material to the timber-using industries dependent on the national or state forests. Furthermore, it is usually to the interest of the private owner to lumber conservatively and to plan for a second cut rather than to slash and abandon. By so doing he may, under favorable conditions, reasonably expect a 5 or 6 per cent return upon his investment* and, if the shortage of lumber becomes as great as is freely predicted, stumpage values will increase prodigiously and profits proportionately.

Assuming, therefore, that the abnormal forest of a single age class is not to be exploited, but to be managed with a liberal construction of sustained yield, the regulation is as follows:

If the age is less than $\frac{r}{2}$ only thinnings are possible.

If the age is more than $\frac{r}{2}$ cutting is permissible, usually less than the allowed annual cut up to the age of $\frac{3}{4}r$, usually more than the allowed annual cut beyond the age of $\frac{3}{4}r$.

The object is to replace the excess of slow-growing mature and overmature stands by young, thrifty stands of rapid incre-

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* See "Possibilities of Private Forest Management in New York State," by C. H. Guise, Cornell University, Bulletin 375. See also "The Cost of Growing Timber in the Pacific Northwest," etc., by B. P. Kirkland, Seattle, Wash., 1915, reprinted from the University of Washington, Forest Club Annual. See also Chapman: "Forest Valuation," pp. 115–117, for excellent statements of the relative importance of profits in private versus public forestry.

ment. This reduction of excess growing stock must never be brought about at the expense of glutting the timber market and forcing down prices. In America the silvicultural needs must, for the present at least, be subordinate to the economic demands. "In spite of the loss from deterioration, the country as a whole may be benefited more by reserving a considerable portion of these stands against the time of critical need than by cutting them off too rapidly, under present market conditions, in order to put the growing power of the soil to work." *

II. Regulation of Transition Forests

Forests in transition from high forest to coppice or, which is more frequently the case, from coppice to high forest, or from crude selection to even-aged forests, require special regulation.

The transition from coppice to high forest involves the replacing of sprouts by seedlings. The process of conversion is, briefly, as follows: Instead of cutting the coppice at the thirtieth year or thereabouts, as is usually done, it is allowed to grow until the sixtieth year or thereabouts. If the coppice does not already contain sufficient seedling trees in mixture, these must be supplied artificially. During the last decades, it is necessary to free the crowns of the seed-bearing standards from the encroaching coppice. This is done by means of preparatory cuts at intervals of about ten years.

When the coppice is about sixty years old, the reproduction cutting begins. This aims to open up the stand by cutting most of the coppice, allowing the seed from the standards to regenerate the area. The reproduction cutting is repeated four or five times at intervals of about five years, and gradually changes from cuts to seed up the area (or plant, if artificially) to cuts giving light to seedlings obtained, and at last to final

* W. B. Greeley in "National Forest Sales on the Pacific Coast," "Proceedings of the Society of American Foresters," Vol. VII, No. 1, p. 46. B. P. Kirkland takes a different view in "The Need of Working Plans on National Forests and the Policies which should be Embodied in them," Proc. Soc. Am. Foresters, Vol. X, No. 4, pp. 341–375.

removal cuttings. The last two cuts (light giving and final removal) operate not only in the coppice, but also in the seed-bearing standards which may be present (coppice with standards).

The period of transition is thus thirty years' additional coppice plus twenty years of reproduction cutting if the coppice contains standards; otherwise extensive planting is necessary. The transition from coppice with standards to high forest is cheaper and easier than is the transition from straight coppice. Fifty years is the usual transition period, or about one-fourth to one-third the high-forest rotation. Even by planting the seedlings the time can only be shortened by greatly heightened annual expense unless the area to be transformed is small. There is also the danger of creating large areas of even-aged stands if too much is planted each year.

The forest regulation consists of a general cutting plan for the whole period of transition. This cutting plan designates for each of the stages of transformation the approximate amount to be cut and how the cut is to be conducted. Where the seedlings have to be introduced artificially, this must be supplemented by a careful planting plan, showing species, kind of stock, spacing, etc., and the amounts and areas to be planted in each stage of the transformation.

It is obvious that the sustained yield suffers temporarily because of the cessation of coppice yields and the delay in securing high-forest yields. To minimize this delay it is often advisable to plant species of fairly rapid growth and hence low rotation age, such as chestnut, ash, pine, European larch, etc.

The transition from selection forest to even-aged forest is comparatively simple, but requires one or two rotations. The object is secured by a change in the silvicultural method employed, and can be brought about in a variety of ways.

The quickest and most useful is by means of shelterwood-selection cuttings, whereby the period of reproduction, that is, the space of time required for the renewal of the stand, is reduced from the entire rotation to thirty to fifty years.

With the next rotation the method can still further approach the shelterwood system, if conditions are favorable, and the period of reproduction reduced to from ten to fifteen years, resulting in virtually even-aged stands.

Where the selection forest is already even-aged in groups, the transition can take advantage of this by employing the shelterwood-group method.

The forest regulation consists in modifying the general cutting plan to meet the changed conditions—i.e., a high cut during the reproduction period followed by a cessation of cutting until the young growth is merchantable, instead of the more frequently recurring cutting cycles of the selection forest. The general cutting plan is also extended so as to cover the entire reproduction period (thirty to fifty years) instead of merely a decade or so.

III. Regulation of Wood-lots

Wood-lots are seldom managed by a technically trained forester, hence the prescribed regulation must be so simple, clear, and direct that any layman can carry it out. The owner of the wood-lot is interested chiefly in having a sustained yield. This feature should, therefore, be emphasized by determining the allowed annual and periodic cut as exactly as possible by area or volume, or both. This should be incorporated in a detailed general cutting plan and the cutting areas for the next working period indicated on a map of the wood-lot.

Where frequent revisions are possible, the prescriptions can be confined to the next decade or so, but where frequent revisions are out of the question the progress of management should be sketched for the whole rotation as a guide to the owner.

The regulation of cut in wood-lots must conform primarily to the wishes and desires of the owner, but it can usually accomplish these without the waste incident to haphazard management, and hence it is of the greatest value to draw up simple working plans even for small wood-lots.

IV. Regulation of Turpentine Forests

The imminent dearth of timber available for naval stores * emphasizes the urgent necessity of abandoning wasteful, destructive methods of turpentining in favor of a more conservative utilization and a regulated yield.

The field data necessary for the regulation of the turpentine yield are, besides a thorough acquaintance with the general and local turpentine business:

(1) The distribution of the diameter classes on each management or survey unit.† This need not be by inch classes, but according to the cupping limits, explained below. Strip surveys, two chains wide, are excellent for this purpose.

(2) The local turpentining quality of each stand, gauged by the number of cups per acre.

(3) The amount and character of young growth below the minimum turpentining diameter for each management or survey unit, supplemented by detailed figures from sample areas more carefully measured, i.e., calipered instead of estimated ocularly.

(4) The board measure contents of stands. The cord-wood contents of undergrowth, etc.

(5) The silvical characteristics—maturity, height, thriftiness, etc.

(6) Diameter increment tables showing time required to grow from one diameter class to the next.

For conservative turpentining, the use of a system of cupping is basic. Scarcely less so is the cupping to a diameter limit—e.g., no cups on trees below 11 inches in diameter, and never more than three cups on any tree. Furthermore, in order to prolong the productivity of the tree and minimize the injury, the chipping must be shallow and light.

A definite rotation must be adopted for the working of the

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* See "The Naval Stores Industry," Bulletin 229, new series, U. S. Dept. of Agriculture.

† E.g., blocks, compartments, subcompartments, or townships, sections, quarter-sections, etc.

crops *—e.g., by shallow and light chipping the first faces can be chipped for three years, when the faces will be about 45 to 50 inches in height, the cups being moved up each year. Then the faces are worked with a "puller," a chipping tool with a long handle, for another three years, which makes the faces from 7 to 8 feet high. The tree is then allowed to recuperate for three years, when "back cups" are placed *between* the old faces and worked for three years. The final period of three years' working is secured from the high-face back cups. Thus each tree is worked for twelve years, extending over a period of fifteen. When the trees have been completely worked, they are cut for saw-timber, ties, or other material.† Certain of them are left as seed trees if that form of reproduction is sought, or else the seeding is from the side by the clearcutting strip method. In case of artificial reproduction, the worked and logged area is seeded or planted. When the young growth has reached sufficient size, the larger trees are turpentined, and thus the cycle is completed.‡

* A "crop" is commonly considered as containing 10,000 cups.

† The turpentined trees of France are highly prized in England as mine timbers.

‡ For further details, see "The Administration of a National Forest for Naval Stores," I. F. Eldredge, Proc. Soc. Am. Foresters, Vol. IX, No. 3, pp. 310–326.

CHAPTER III

THE WORKING-PLAN DOCUMENT

SECTION ONE

CONTENTS AND FORM

The working-plan document is the vehicle for recording the salient features of a forest bearing on its organization and the detailed prescriptions of that organization for the next working period. Simplicity and brevity are the key-notes. The descriptive portion is usually confined to such short statements as suffice to bring to the trained forester's eye the picture of the forest as it is in its essentials, but, occasionally, a more detailed description is warranted so as to make the plan comprehensible to a layman, e.g., where the plan is to be executed by a layman-owner.

In the interests of clearness and brevity data should be tabulated wherever possible, e.g., estimates, stand tables, age-class tables, etc. Maps, also, are a powerful aid in graphic presentation of the data.

The working-plan document may be confined to the silvicultural management, or it may cover all the activities of a forest such as general administration, grazing management, permanent improvements, forest protection, and use of forest land; in other words, be a complete forest plan. The desirability of including these sundry subjects depends on their importance and the purpose of the plan. National forests usually require complete plans. Where other subjects than that of silvicultural management are to be included, the descriptive data preceding the plan proper must be amplified accordingly.

The essential contents of a working plan confined to silvicultural management are (1) *Orientation*, i.e., location, size, history of forest with important changes, salient physiographic, social, and industrial features, time, method, and personnel of forest survey and work of organization, period for which made (working period), digest of working-plan conference, if had; (2) *Foundation*, i.e., growing stock (estimates) and increment, and (if even-aged) distribution of the age classes, stand and stock tables, maps, forest description, division of area; (3) *Recommendation:* method of management, past, present, and proposed, i.e., governing conditions, object of management, silvicultural method, rotation, etc.; (4) *Regulation*, i.e., determination and distribution of the allowable cut, general and annual cutting plan, corresponding general and annual planting plans.

These essentials may be presented in various forms, some of which are given in the following section, varying with the needs and desires of the administrative officers. The form of the working-plan document is comparatively unimportant. It may be typewritten or not, bound or unbound. If typewritten it can be manifolded more easily; if plainly bound it resists handling better, and the working-plan document is meant to be used constantly, not put away on a library shelf for the admiration of visitors. To facilitate this use a 2-inch margin should be left at the side of the text throughout the document, excepting tables, for the purpose of allowing notes to be made from time to time by officers charged with the execution of the plan. This simple device keeps a plan alive and up to date and greatly facilitates the work of revision.

The field work in connection with forest organization often results in the collection of many interesting and valuable silvical and other data which, while germane to the working plan, are not a cognate part thereof. Such data, including volume growth, and yield tables, silvical notes, notes on climate, geology, soil, etc., should be placed in the appendix or elsewhere convenient, in order that everything in the plan may be confined to the actual scheme of management for the forest.

1. Orientation

(a) **Location and Size.**—The briefest mention suffices.

(b) **History of Forest with Important Changes.**—Past and present ownership and administration, boundaries, past object of management, past revenues and expenditures.

(c) **Physiographic Features.**—The physiographic features include topography, drainage, geology, soils, and climate. Detailed observations and statistics should be reserved for the appendix, and only the salient characteristics which influence the forest organization stated briefly.

(d) **Social and Industrial Features.**—The social and industrial features include population, labor supply, local industries such as lumbering, grazing, mining, agriculture, etc., all in their bearing on the problems of forest organization. For it is evident that without adequate labor no forest resources can be developed, without lumbering facilities no regulation of the cut can be maintained or executed, and the very term "accessible" is modified by the degree of skill exercised in logging and the kinds of appliances used to get the timber. Again, the need of the local population for timber is the root of the theory of sustained yield. These fundamental phases require no detailed discussion, but brief statements of conditions in explanation of the plan proper.

(e) **Digest of Working Plan Conference.**—If a conference was had between the forest organizer and the owner or administrator of the forest, as suggested in Chapter I, Section 1, this should be digested and added to the working-plan document with the names of the participants.

(f) **Time, Method, and Personnel of Forest Survey and Organization.**—These statements should be exceedingly brief—a tabular form is advisable for time and personnel, since they are of purely historical interest. The method used should, however, be set forth in sufficient detail so that there can be no question as to how much weight attaches to the accuracy of maps and estimates.

2. Foundation

(a) **Growing Stock (Estimates).**—The estimates should be in form of a table by species and classes of timber, either separate stand and stock tables or as part of the general stand table. The details of this estimate table depend on the intensity of the entire plan. It will usually suffice to give the totals by compartments (if any) and blocks, or else by survey units such as sections, or even townships. Separate estimates may be given for each forest type. The estimate for the entire working unit must always be given. It must also be stated to what minimum diameter trees were estimated, and if available, what average deduction must be made for defect. Estimates in greater detail, e.g., section sheets showing the stand on each "forty," should be reserved for the appendix or for the files. Volume tables should be placed in the appendix.

(b) **Increment.**—The increment, either current or mean annual, or else both, is given, and is expressed either in increment per acre or as a per cent or both. Growth and yield tables on which the calculation of increment may be based should be included in the appendix.

(c) **Distribution of the Age Classes.**—If the stand is even-aged or approximately so, a table of age-class distribution, like the example already given, should be included. Not only does such a table show at a glance the relation of young, mature, and overmature timber, but, in the revisions of the working plan, it shows by means of graphs or blocks what progress has been made toward the attainment of normality in this direction.

(d) **General Stand Table.**—A table approximating, as far as possible, the example in Chapter I, Section 2, should be included as a convenient tabular summary of areas, volumes, and conditions of timber.

(e) **Maps** can be elaborated to almost any extent according to the kind and importance of the data to be shown thereon. The following are the most important:

(1) A *topographic map* showing topography in contours,

seldom hachures; roads, trails, railroads, saw-mills, and all other "culture"; drainage. This map is the "base" and should be of a convenient scale, such as $\frac{1}{2}$, 1, 2, 4, or even more inches to the mile, depending on the size of the tract and the amount of detail to be shown. It should be drawn so as to permit of being manifolded in order that all officers charged with the administration of the forest and the execution of the working plan may be furnished with copies. On this "base" can be added any or all of the following special data in so far as the wealth of detail will not confuse the whole.

(2) *Boundary map* showing the ownership (status), the forest boundary or boundaries; survey lines, if any; boundary or boundaries of the working units, blocks, compartments, and subcompartments.

(3) *Forest-type map*, showing the various forest types, also cut-over areas, burns, open "parks," etc.

(4) *Age-class map*, showing the distribution of the various age classes on the ground.

(5) *Site-quality map*, showing the distribution of the various site qualities.

(6) *Soil map*, showing the various soils and geologic formations of the forest.

(7) *Reproduction map*, showing areas of good, fair, and poor reproduction.

(8) *Cutting map*, to accompany the general cutting plan, showing areas to be cut over within the next working period, also those already cut over.

(9) *Planting map*, to accompany the general planting plan, showing areas to be restocked artificially during the next working period, and areas already planted or sown, all nurseries and proposed nursery sites.

If the plan is to be a complete forest plan, and not confined to the silvicultural management, there may be the following additional maps:

(10) *Fire map*, to accompany the fire plan, showing all lookout points, watch towers, lines of patrol, ranger headquarters,

fire-guard stations, location of fire-fighting tools, and places whence assistance in fighting fire may be obtained. The base should be maps 1 and 3 combined.

(11) *Permanent improvement map*, to accompany the permanent improvement plan showing all improvements, existing or proposed, such as ranger stations, fire cabins, telephone lines, etc.

(12) *Grazing map*, to accompany the grazing plan showing the grazing types, condition of the range, the portions grazed (and by what class of stock) or ungrazed, the winter, summer, or year-long range, corrals, pastures, drift fences, water tanks, etc.

Lest too many data be placed on one map, it is better to have separate maps than to combine too much and cause confusion. For ordinary purposes, however, the following maps may well be combined:

Nos. 1, 2, 3, and 4. Topography, boundaries, types, age-classes.*

Nos. 1, 2, 3, 7, and 8. Topography, boundaries, types, reproduction, cutting.

Nos. 1, 2, 3, and 9. Topography, boundaries, types, planting.

Various methods of regulating the cut require special data on the map, e.g., if the regulation is to be by area reduced according to site classes (method No. 1, variation II; method No. 14, variation II; method No. 16, variation II, also method No. 17, Nos. I and III), then a site-class map (No. 5) is necessary.

Detailed maps of survey units or of small areas which it is desired to show in greater detail should be placed in the appendix, as should also special maps showing areas of insect or fungus attacks, etc.

(f) **Forest Description.**—Must be concise and free from burdensome details. Silvical details, methods and costs of logging and milling, etc., had better be placed in the appendix

* If even-aged or approximately so.

or in a special file. The forest description of the entire working unit should be a careful summary of the description for each block.* The aim is to present a lucid picture of the forest as it is in the essential silvical factors bearing on the plan of management adopted. The description must be ample reason for the provisions of the working plan. The description is the premise; the recommended management the logical deduction from that premise.

(g) **Division of Area.**—On the basis of the forest description, the division of area should be so evidently logical as to require very little special justification. However, it is well to explain briefly what considerations governed in the choice of working unit, block, compartment, and subcompartment, in so far as this was not already covered in the digest of the working-plan conference. Since the working unit usually has a sustained yield, its adequacy from this viewpoint should be considered along the broad lines already laid down.

3. Recommendation

The recommended management should be the logical sequel of the data given under " Orientation " and " Foundation." The basic considerations of object of management, of silvicultural method of management, and of rotation are contained in Chapter I, Section 3. This part of the working-plan document should review the governing conditions which determine the recommended management. These are:

(a) **Object of Management.**—*i.e.*, the wishes and purpose of the owner (in so far as not already contained in the digest of the working-plan conference).

(b) **Practical Restrictions** of market, logging accessibility, fire danger, erosion danger, etc.

(c) **Silvicultural Method of Management** which can best fulfill the object of management with the given silvical conditions

* A good example of such a forest description will be found in Bulletin 11 of the N. Y. State Conservation Commission, " Forest Survey of a Parcel of State Land,'' Albany, 1915.

and under the practical restrictions imposed. Past management and its mistakes and lessons should be reviewed and the proposed method of management given in detail. The best silviculture is not always possible under existing conditions, and the organizer must seek to combine the three divergent factors of object of management, practical restrictions, and silvical requirements into a harmonious scheme of management. This should cover:

(1) *Silvicultural method* for each type with brief description thereof.

(2) *Rotation* chosen, with reasons for its adoption. The period of reproduction, cutting cycles, etc., should be given and made entirely clear.

(3) *Marking rules* to be followed in the execution of the cuttings for natural reproduction. They should be clear and concise, simply put so as to be readily intelligible to the non-technical man charged with their execution, sufficiently elastic to cover all cases. Good marking rules will do much toward insuring the actual execution of the silvicultural method decided upon, especially when backed by sample areas marked by the forest organizer as a concrete illustration.

(4) *Brush disposal rules* are a necessary concomitant of the marking rules. Here too actual examples of what is desired should reinforce the written rules.

4. Regulation

As the recommended management (3) is the logical outgrowth of the data given under Orientation (1) and Foundation (2), so the regulation of the cut itself is but the carrying out of the Recommendation (3).

The chief phases of regulation are:

(a) **Determination of the Allowable Cut** by one or more of the methods already described. Where working groups are formed, each requires a separate determination of the cut.

(b) **Distribution of the Allowable Cut.**—Selection of stands to be cut, formation of cutting series, etc., with concise reason for the choice; cutting policy in so far as not covered already in the digest of the working-plan conference.

(c) **General Cutting Plan** for the next working period according to the example given above. It should contain in addition recommendations in regard to stumpage rates, methods of logging, rules of cutting to prevent waste, and other features of practical utilization such as probable purchasers, uses and markets, etc. An annual cutting plan for the ensuing year is usually drawn up by the administrative officer in charge of the forest, and does not as a rule form a part of the working-plan document.

(d) **General Planting Plan** for the next working period according to the example given below. A description of the methods and cost of nursery, planting, and seeding practice to be employed. An annual planting plan for the ensuing year is usually drawn up by the administrative officer in charge of the forest, and does not, as a rule, form a part of the working-plan document.

NOTE.—In addition to the general working plan, 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.

SECTION TWO

OUTLINES FOR WORKING PLAN

Three typical outlines for working-plan documents will be given. A. The Prussian outline, typical of forest organization in countries based on forest-rent.* B. The Saxon outline, typical of forest organization in countries based on soil-rent,* and, C, an outline typical for the average extensive conditions existing in America. This last includes all the phases of a complete forest plan.

* See "Rotation," p. 61.

A. Prussian Outline

Introduction.—Working period (two decades). Revision (every decade). Name of forest organizer and assistants.

1. Letter of minister (secretary) putting plan into effect.
2. Plan of management.

    Digest of working-plan conference.

    Introduction. Time and scope of work.

    General position and history of the forest.

    The measurements.

    a. Maps.

    (1) Special maps (large scale).
    (2) Location map (small scale).
    (3) Map of servitudes.

    b. Record of measurements.

    (4) Boundaries.
    (5) Table of measurements (survey notes).
    (6) Record of changes in area.
    (7) Record of changes in servitude.

    Division of area.

    (8) Ranger districts and blocks.
    (9) Compartments.
    (10) Subcompartments.

    Condition of stand.

    (11) Site.
        (*a*) Exposure.
        (*b*) Soil.
    (12) Stand.
        (*a*) Species.
        (*b*) Distribution of the age classes.
    (13) Injuries.
        (*a*) Fire.
        (*b*) Storm (wind).
        (*c*) Frost.
        (*d*) Drought.

(*e*) Fungus.
(*f*) Insects.
(14) Market conditions.
(15) Labor conditions.
(16) Servitudes.

Regulation of cut and plan of management.
(17) Former management.
(18) Basis of present regulation of cut.
(*a*) Rotation.
(*b*) Plan of cut.
(*c*) Calculation of cut.
(19) Method of cutting.
(20) Method of reproduction.

Miscellaneous.
(21) Financial yield.
(22) By-products.
(23) Hunting and fishing.
(24) Forest protection and policing.
(25) Fiscal matters.
(26) Communal relations, i.e., with communally-owned forests.
(27) Other matters of interest.

3. Boundary register (status records).
4. General stand tables.
5. Area tables.
6. Table of servitudes.
7. Plan of thinnings.
8. Résumé of communal conditions.

B. Saxon Outline

Part One. Introduction. Working period (one decade). Revision (every five years).

General stand tables (areas and volumes).

Site-quality * table and comparison of increments.

* "Standorts bonität."

Comparison of age classes and volume (growing stock).
Table of age-class distribution in per cents and area.*
Stand-quality table.†
Results of past management.
(1) Final cuttings.
(2) Intermediate cuttings.
(3) Total yield.
(4) Yield by cutting areas.
(5) Money yield from cuttings.
(6) Plantations, also care of plantations and of the stand.
(7) Road and trail building.
(8) Summary of net soil rent (Boden reinertrag).
Determination of the allowable cut for the five years until the next revision.
General rules of management.

Part Two. General cutting plan.
Part Three. General planting plan.

C. American Outline (*suggested*)

1. *Orientation.*
   a. Location and size of forest (working unit).
   b. History of forest with important changes.
   (1) Past and present ownership (status).
   (2) Boundaries. Interior surveys.
   (3) Past object of management and general administration.
   (4) Past revenues and expenditures.
   c. Physiographic features.
   (1) Topography.
   (2) Drainage.
   (3) Geology (formation).

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* Diagrammatically by means of blocks. See Diagram D, p. 19.
† "Bestands bonität."

(4) Soils (depth, fertility, etc.).

(5) Climate (maximum, minimum, and average temperature, rainfall, prevailing wind direction).

d. Social and industrial features.

(1) Population. Dependence on forest for work and fuel and timber supply.

(2) Labor supply.

(3) Local conditions—lumbering, grazing, mining, agriculture, etc. Interrelation with forest.

e. Digest of working-plan conference.

f. Time, method, and personnel of field work. Cost, if desired.

2. *Foundation.*

a. Growing stock (estimates). Tabulation. (Stand and stock tables if uneven-aged.)

b. Increment per acre or per cent or both.

c. Distribution of the age classes. Tabulation. (Diameter classes if uneven aged.)

d. General stand table. Tabulation.

e. Maps. Statement of maps prepared. The maps themselves should go in the back of the plan or else be kept on file separately.

f. Forest description.

g. Division of area. Working unit, block, compartment, subcompartment. Working group if necessary.

3. *Recommendation.*

a. Object of management. Wishes and purpose of the owner (policy, if national or state forest). Exploitation or sustained yield (annual, periodic). Production of cordwood, sawtimber, pulpwood, turpentine, etc.

b. Practical restrictions. Market, logging accessibility, special danger from fire, erosion, avalanches, etc.

c. Silvicultural method of management.

(1) Silvicultural method or methods, their proposed application.

(2) Rotation (period of reproduction, cutting cycle, etc.).
(3) Marking rules.
(4) Rules for brush disposal.

4. *Regulation.*
   a. Determination of cut.
   b. Distribution of cut. Formation of cutting series, etc.
   c. General cutting plan for working period.
   d. General planting plan for working period.
5. *Administrative plan.*
   a. Scheme of field administration.
      (1) Administrative districts and area.
      (2) Field and office force, year-long and temporary.
   b. Forecast of receipts and expenditures and net income for working period.
6. *Grazing plan.*
   a. Description of forage types and condition of range.
   b. Protection and development of range.
      (1) Range improvements. Watering facilities.
      (2) Treatment of overgrazed and partly stocked areas.
      (3) Measures for fuller use of range.
      (4) Control and eradication of poisonous plants.
      (5) Control and extermination of predatory animals, prairie dogs, and other pests.
   c. Grazing control. Capacity of range. Grazing districts and allotments.
7. *Permanent-improvement plan.*
   a. General.
   b. Telephone.
   c. Look-out towers.
   d. Fire cabins and tool-boxes.
   e. Roads and trails.
   f. Ranger stations.
8. *Forest-protection plan.*
   a. Fire control.
      (1) Nature of fire problem.
      (2) Past fires. Bearing on the plan.

(3) Hazards. Danger zones, extra fire risks, necessity of special measures.
(4) Coöperation. Desirable and proposed coöperation.
(5) Scheme of protection.
(*a*) Primary control by look-outs.
(*b*) Secondary control by patrol and actual combat.
(6) Organization. Look-outs and patrolmen. Action in case of fire.
(7) Mobilization.
(*a*) Fire-fighters, regular and volunteer, available.
(*b*) Transportation. Logging railroads, pack trains, teams, etc.
(*c*) Tools, equipment, and supplies. Location of tool-boxes. Bases of supplies.
(8) Improvements. Additional headquarters, telephone lines, trails, etc., required.

b. Insect control } and other special problems warranting inclusion.
c. Fungus control }

9. *Uses of forest land.*
a. Settlement.
(1) Classification of lands, whether of relatively greater value for agriculture or for forest purposes.
(2) Sale prices of land. Comparative land values.
(3) Cost of clearing land for agriculture and probable profits of agriculture thereon.
b. Special uses.
c. Water-power sites. Present and future development. Stream measurements.

10. *Appendix* (observations not properly a part of the main working plan).
a. General data—geology, soils, climate, occurrence and protection of fish and game.
b. Silvical data.
(1) Volume, growth, and yield tables.
(2) List of component species.
(3) Silvical characteristics of component species.

(*a*) Soil and moisture requirements.
(*b*) Influence of elevation and aspect.
(*c*) Tolerance.
(*d*) Reproduction.
(*e*) Injuries: fire, storm, frost, drought, fungus, insects, etc.

c. Detailed estimates, maps, forest descriptions, etc., of survey units or other units, unless filed elsewhere for greater convenience.

SECTION THREE

THE PLANTING PLAN

This is properly an integral part of every working plan, but in order to avoid confusion, and not to encumber the subject of timber regulation, detailed mention has been reserved for this section.

Some planting operations are necessary in every well-regulated forest, whether it be to eke out a too scanty natural reproduction or to restock former forest areas where natural reproduction is out of the question.

Just as a general cutting plan is drawn up for the intended cuttings in the ensuing working period, so a general planting plan is drawn up to cover all the operations of artificial reproduction which are contemplated during the ensuing working period. From out this general planting plan the administrative officer in charge of the forest selects those areas whose restocking he deems of the most immediate importance and incorporates them into an annual planting plan which, with the approval of his superior officers, becomes the planting schedule for the ensuing year.

As a preamble to the general planting plan should come a general discussion of the areas needing artificial reproduction, the extent to which it is expedient to go in replanting commensurate with the results to be obtained, and other phases of the policy to be pursued in the choice of areas. In general, it is advisable to restock first those areas on which success seems most assured, leaving for the future with its greater experience and presumably greater capital those areas where immediate success is less certain. For most administrations profit by making a good initial "showing" and once the way is paved the more difficult operations can be undertaken even though they fail to make so good a "showing." Other things being equal, the money return from a planting is surer, larger, and sooner the better the site and the quicker the success of the operation.

This should be followed by a full discussion of the methods of reproduction to be employed. First the results of past plantings and sowings, accentuating the reasons for failure or success, and then the policy for future planting and sowing. The source of plant material—seeds, seedlings, and transplants should be considered; the seed should be shown to be from reliable and appropriate sources (sources suitable to the climatic and site conditions), and the planting stock preferably grown in nurseries on the forest or else secured from outside nurseries whose site corresponds approximately to that of the intended planting site. If there are to be nurseries on the forest, the preamble of the general planting plan gives full provisions for their location, creation, and maintenance, and should contain the area thereof in seed-beds and their capacity, the area thereof in transplant beds and their capacity, and the proposed annual production by species and classes of stock.*

The areas which it is intended to plant or sow during the coming working period should be indicated on the working map of the forest either by color, or shading, or symbols.

The annual planting plan may conveniently take the forms on pages 162 and 163, a separate head being used for plantings and seedings.

The general planting plan may conveniently take the form shown on page 161.

* See Toumey: "Seeding and Planting," John Wiley and Sons, N. Y., 1916.

GENERAL PLANTING PLAN, ... WORKING UNIT

Decade* 1912–1921, inclusive

Location Block, Compt. and Subcompt. or Survey Unit	Area acres	Forest Type. abbrev.	Character: soil and topog.	Reason (Blank or Repro. Area)	METHOD								Remarks
					PLANTING				SEEDING				
					Season	Species	Stock	Spacing	Season	Species	Amt.	Mthd.	
Total............													

* Working period.

ANNUAL PLANTING PLAN, ...WORKING UNIT

Decade* 1912–21, Year 1912

PLANTING														
Location	Type	PRESCRIPTION						EXECUTION						Remarks
		Area	Season	Species	Stock	Spacing	Cost	Area	Season	Species	Stock	Spacing	Cost	
		acres						acres						
Total.......														

* Working period.

SEEDING

Location	Type	Prescription						Execution						Remarks
		Area	Season	Species	Amt.	Mthd.	Cost	Area	Season	Species	Amt.	Mthd.	Cost	
		acres			per ac.			acres			per ac.			
Total.......														

SECTION FOUR

CONTROL AND REVISION OF WORKING PLAN

No working plan can remain alive and useful unless it is revised at frequent, more or less regular intervals. These revisions incorporate all the changes which have taken place during the working period. Such renewals may be made at fixed intervals of say ten years, or at irregular intervals, as is commonly the case where revised data or changes in prevailing market conditions, etc., necessitate modification of the original plan.

Since the working period is usually ten years, the working-plan document is usually revised every decade. But under very intensive conditions more frequent revision may be justified, even to the extent of every five years. On the other hand, a plan should not, ordinarily, go without revision for more than a decade, even though the working period be longer, e.g., two decades, or even four, as in Prussia and Austria, respectively.

Especially under the kaleidoscopically changing conditions in most parts of America is it desirable to have frequent revisions so that the working plan may really " work " and not become obsolete within the working period. Special revisions before the end of the working period are, of course, necessitated whenever, through storm, purchase, or the like, a substantial change is caused in the size, character, or composition of the forest.

The record of the progress of the work on the forest as outlined by the working plan is called the working plan control. This control operates as a check on the execution of the working plan. In European practice these records are kept by maps and books. The entries are made periodically or at the time of completing each of the various projects. The books (called " Control Books ") may conveniently be divided into two parts: I, the cutting and planting record; II, the general or " history " book. The former may conveniently take the following form (page 165).

CONTROL BOOK, PART I, ... WORKING UNIT

Block	Compartment	Subcompartment	Cut					Planted					
			Year	Estimate	Mthd.	Actual	Left	Year	Mthd.	Species Stock	% of area	% of Success	Cost per ac.
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Column 1. Name of block, or township number if by survey units.

" 2. Number of compartment, or section number if by survey units.

" 3. Number of subcompartment, or subdivision of section if by survey units.

" 5. By species and classes of material, using separate lines.

" 6. Method: use abbreviations given in the general stand table, Chapter I, Section 2.

" 7. The actual amount cut (from the annual cutting plan, see Chapter II, Section 2) by species and classes of material to correspond with the estimate.

Column 8. The amount left by species and classes of material.

" 10. Abbreviations suffice. State whether direct seeding or planting, amount of seed per acre or spacing.

" 11. Abbreviations, such as "D.F. 2-1," means Douglas Fir, three-year-old stock, two years in the seedbed, one year in the transplant bed.

" 12. Give the per cent of area actually seeded or planted sufficient for purposes of reproduction.

" 13. Success gauged by actual counts after the plantation or the seeding area is well established.

It is obvious that this Part I of the control book is built up from the annual cutting and planting plans. It embodies their essentials in convenient form as a permanent record. It can, of course, be extended to cover all the activities of the forest besides "timber," e.g., grazing. A column for areas can also be added between columns 3 and 4 if desired.

A separate page is kept for each convenient unit—be it block or compartment, township or section, depending on the needs of the administration.

All areas cut or planted are to be entered on the map of the forest.

Part II, the "history" book, contains convenient headings for a general record of the various forest activities. Such are:

1. *Forest survey and boundaries:* a running record of the forest surveys made and proposed, be it for timber, grazing, or what not, and of the changes in boundaries and the demarcation in the field of the boundaries.*

2. *Methods of cutting and planting:* a running record of silvical observations in natural and artificial reproduction.

3. *Forest protection:* a running record of all important forest menaces; the method and success of the combat with them. Such are:

(*a*) Fire.
(*b*) Storm.
(*c*) Frost.
(*d*) Drought.
(*e*) Fungi.
(*f*) Insects, etc.

Chapters can be added at will for the other forest activities covered in a forest plan, such as:

* This may also include the Status Records, that is, records showing the ownership of newly acquired lands. Complete status records will show in detail the chain of title for each parcel of land and also all servitudes and easements attaching to the land. In addition, they usually show the location and extent of all qualified or temporary alienations such as unpatented mineral claims, leased areas, or lands otherwise specifically under permit or affected by outstanding contracts, as for the sale of timber, etc.

4. *Administration.*
5. *Grazing.*
6. *Permanent improvements.*
7. *Uses of forest land.*
8. *Utilization of forest products.*
    (*a*) Methods and costs of logging.
    (*b*) Methods and costs of saw-milling.
    (*c*) Markets and prices of stumpage and lumber or other products.
    (*d*) Utilization of by-products.
    (*e*) Impregnation of wood (wood preservation), etc., *ad lib.*
9. *Game and the chase.*
10 *Money returns of management.*
    (*a*) Gross income and expense.
    (*b*) Net income.
11. *Personnel relations.*
12. *Miscellaneous data.*

Such a control book, together with the summarized annual cutting and planting plans, corrected maps, and the marginal notes and corrections in the plan itself, forms a perfectly adequate basis for undertaking the periodic revision.

The thoroughness of the revision depends on the correctness of the original plan. Only rarely should it be necessary to rewrite the entire plan. Those portions which come under "Orientation," such as physiographic features, social and industrial features, and under "Foundation," such as forest description, division of area, etc., can either be incorporated directly in the new working plan, or else reference made to the original working plan covering these portions in detail.

In matters of determination and distribution of the cut as embodied in the general cutting and planting plans, the revision is essentially a recalculation and reallotment.

The preliminary of every revision should be a working-plan conference to review the plan for the working period just passed and to make suggestions for the ensuing period. The digest of this conference should be incorporated in the revised working plan.

If the forest is essentially even-aged, the revised working plan should contain under " Orientation ": " History of forest with important changes," a diagrammatic presentation of the distribution of the age classes, showing graphically the gradual approach (presumably) towards normality in this respect. This may be shown either by means of a graph or by means of proportionate blocks (see Diagram D, p. 19).

PART TWO

PRACTICE OF WORKING PLANS

Practice of Working Plans

CHAPTER I

IN EUROPE

SECTION ONE

GERMANY

THE chief States of Germany from the standpoint of forestry are: Prussia, Bavaria, Saxony, Württemberg, Baden, and Alsace-Lorraine. For each of these will be given, after a summary of the salient conditions, such as size of country and forests, topography, species, markets, etc., a brief review of the history of working plans, the chief foundations of plans, the methods of regulating the cut, and the prescriptions for control and revision of the working plan. The same scheme will be followed for the data about France and Austria (Sections 2 and 3).

I. PRUSSIA

Prussia is by far the largest of the German States, with 86,118,526 acres, or about 65 per cent, of the total German Empire. Of these 86,118,526 acres, 20,427,179 acres, or 23.72 per cent, are in forest.

Prussia contains widely varying topography, from the very characteristic plains of the northeast to the lesser ranges along the Austrian frontier (Riesengebirge) and in the east-central portions (Harz, Teutoburger Wald, Taunus, etc.).

If one considers Germany as roughly divided into three main forest regions by a line from the corner of Bohemia, at Eger, northward through Hannover into Lübeck on the Baltic, and another line from Hannover westward to Amsterdam, the large northeast block may be called the pine region, the small northwest block the heath region, and the remaining southwest block the hardwood-spruce-fir region. Practically all of the pine region is contained within Prussia, and this explains the preponderating percentage of Scotch pine—60 per cent as against 12 per cent of spruce and fir, 5 per cent of oak, 15 per cent of beech, and 4 per cent of birch and alder—in Prussia.

The markets for Prussian forests products are so excellent as to admit of the profitable placing of all classes of timber with only minor exceptions.

During the nineteenth century the period method of regulating the cut ("Fachwerksmethoden," i.e., "Framework Methods"—see method No. 17) predominated in Prussia. At first, owing to the influence of G. L. Hartig, it was a strict volume-period method ("Massenfachwerk," i.e., volume framework). The official instructions of 1819 provide a detailed allotment by volume and classes of material for each of the six periods of the 120-year rotation. The impracticability of such calculations without adequate bases soon brought a change from Hartig's strict method, the more so since such slow progress was being made toward the goal of having working plans for each forest. Therefore, in 1836, after a provisional regulation of the cut had been accomplished between 1826 and 1835, a new order for regulating the cut was issued which remained in force almost to the end of the century. Though still based on the volume-framework method, the calculation of cut was simplified, and the equality of area was also taken into consideration together with a correct distribution of the age classes and the formation of cutting series. With the introduction of the factor of area, the volume-period method (Massenfachwerk) fell into abeyance and the combined period method (Kombiniertes Fachwerk) came to be used for less regular stands, the area-period method (Flächenfachwerk) for the more regular conditions.*

Of late the calculation of cut has been more and more confined to the ensuing period (the I period), paying little or no attention to the periods following (periods II, III, IV, V, and VI). This is especially marked in the instructions for 1912,† which go a long way toward ameliorating the strict "framework" methods. Wagner considers them an abandonment of the "framework" methods.‡

The general cutting plan takes the following form:

Column 1*a*	Block and compartment.			
1*b*	Subcompartment.			
2	Soil description.			
3	Site quality. Average height.			
4	Average age and age limit.			
5	Percentage of stocking (density).			
6	Form of mixture (scattered, groupwise, etc.)			
7	Percentage of chief species in mixture.			
8	Species (repeated between columns 18 and 19).			
9	Defects and diseases.			
10	Area of the whole compartment.			
11	Area by Age Classes	I	over 120 years	area in hectares.
12			101–120	
13		II	81–100	
14		III	61– 80	
15		IV	41– 60	
16		V	21– 40	
17		VI	1– 20	

* For outline of Prussian working plan, see p. 153.

† "Anweisung zur Ausführung von Betriebsregelungen in den Preussischen Staatsforsten vom 17. März, 1912."

‡ Wagner, in the third edition of Lorey's "Handbuch der Forstwissenschaft," Vol. III, p. 463, takes the position that the new instructions (1912) "entirely abandon the 'framework' methods (No. 17) and go over to the method by age classes (No. 16); one must not be deceived by the retention of the 'framework' terminology . . . An assignment of areas and volume, to all the periods of the rotation no longer takes place; under difficult conditions only 'are the first and second periods to be provided for.'"

18 Unstocked blanks.
19 Cutting area of the I period. in hectares.
20 Cutting area of the II period in hectares.
21 Silvicultural method to be used.
22 Species to be reproduced.
23 Remarks. Explanations of measures adopted. Reasons for departures from the usual rotation age.

The block and the ranger district usually coincide. Working groups (" Betriebsklassen ") are segregated whenever there are salient differences in species, rotation, or method of management.

The block is subdivided into rectangular units called " Jagen " (" hunts ") in the plains, " Distrikte " (" districts ") in the mountains. The boundaries are roads or topographic features (ridges, streams, etc). The average size in pine stands is from 49.4 to 74.1 acres; in spruce stands, from 24.7 to 49.4 acres.

Subcompartments are not segregated for minor differences, and never for less than 2.47 acres (1 hectare).

To insure continuity of records the numbers and boundaries of blocks, compartments, etc., are not changed except for urgent reasons.

The soil and rock description is usually taken directly from the geological survey maps.

The site quality is usually gauged by means of the average height as given in yield tables published by the experiment station. The average height is determined by hypsometer measurements of trees in representative stands or, where less important, merely estimated.

In uneven-aged stands in which the age classes blend one into the other, the age limits and average age are indicated; where the age classes are widely divergent (e.g., very young and mature) they are entered separately. Great weight attaches to the age class and area table.

The criterion of cutting the sustained yield is the normal area of the period. This is determined by the proportion of the period to the rotation which is usually $\frac{20}{120}=\frac{1}{6}$. An annual sustained yield is not required, but, under regular conditions, the periodic yield must be sustained even for the individual blocks; under irregular conditions more than the normal area can be cut if there is an excess growing stock, and vice versa. With species requiring a long period of reproduction (e.g., natural reproduction by shelterwood-selection method often requires forty years) the areas are allotted in detail for the I and II periods, but not the volumes.

The cutting is virtually restricted to the stands indicated for the I period. The manifest impossibility of selecting such stands twenty years in advance and then barring all the others has led to a universal demand for the "Opening of the II Period." This is met by providing for an intermediate revision in the eleventh year which may lead to the preparation of a new cutting plan.

The choice of stands for the I period, i.e., the stands to be cut during the next twenty years, is prescribed as follows: Mature stands and defective stands are chosen first. Without undue sacrifices the object to attain is the equalization of the age-class distribution by smoothing out the age differences between subcompartments (unless they are extreme), but not having too large adjacent areas of the same age class, because of the increased danger from fire, insects, windbreak, etc., in coniferous stands especially. Cutting series are, therefore, advised and so many points of attack that each cutting area will have become stocked with young, thrifty growth before the adjacent area is cut. This usually means a wait of twenty years.

The rotation for the chief species is determined for all Prussia, hence only departures therefrom need detailed explanation and justification.

The yield or allowed cut for the twenty-year period is the growing stock on the cutting areas of the I period plus the increment thereon during ten years (half the period). This growing stock is estimated by calipering, either all the trees, or certain representative stands, if conditions are sufficiently uniform. The volumes are then calculated from basal area, average height and form factor. The volume of stands of the younger age classes is, if sufficiently regular, taken directly from yield tables, or by means of sample areas.* The increment per cent is usually taken directly from the yield tables.

The allowed annual cut is then found by dividing the volume of the entire I period by twenty.

A separate cutting plan for thinnings is drawn up. The cut in thinnings is approximated from past experience. This in cludes the accidental yield through drought and windfall.

The regulation of selection forests is purposely simplified, since these uneven-aged stands are primarily intended for protection. The division into subcompartments is usually waived; the age classes are only approximated, and the calipering of every single stem is not necessary. The allowed cut for the I period is estimated for each working unit according to the ripeness for cutting. Where the selection forest is a distinct unit of sufficient size (e.g., a block) the average annual increment of the whole is determined and taken directly as the allowed annual cut in so far as there is not a marked excess or deficiency in the growing stock or the condition of the forest or other cogent reasons demand a heavier cutting or vice versa. Where the selection forest has been under regulated management for some time past, experience will dictate the approximately correct annual cut.

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* The preparation of the working plan is one of the regular duties of the forest supervisor; where necessary, he is aided in the field-work by younger members of the Service (forest assessors, etc.); the rangers do the calipering, etc. It is preceded by a working-plan conference between the district officer and the supervisor. This conference discusses ways and means, is digested and incorporated in the working-plan document (called the "Abschätzungswerk," a bound volume of some 125 pages, manuscript or typewritten, with ample margins for additional notes.) The working plan must be submitted through regular channels, to the Minister of Agriculture, whose letter putting the working plan into effect is incorporated in the bound volume.

Control and revision of the working plan are provided for by means of the control book, the chief note-book (Hauptmerkbuch), and the area register.

The control book serves the double purpose of checking the estimate and the allowed annual cut. For the allowed cut must be adjusted according as the estimates are shown to be too high or too low. If too high, there will be a deficit at the end of the period; if too low, there will be a surplus. The allowed annual cut is not strictly maintained; silvicultural or market conditions may necessitate a higher or lower cut.* Of course this must be offset by reducing or increasing the cut in the years following.

Each cutting is entered in the control book, Part A, where for each Jagen, or District (compartment), there is a page whereon to show the time and kind of cutting, the species, and the amount obtained by classes of material.

When the cutting of a stand is finished the result is compared with the estimate and the difference entered in control book, Part A1, which is arranged as follows:

Column 1. Block.
2. Compartment.
3. Subcompartment.
4. Year in which cutting is completed.
5. Estimate in cubic metres by species.
6. Actual cut in cubic metres by species—from control book, Part A.
7. Plus difference in cubic metres between columns 5 and 6.
8. Minus difference in cubic metres between columns 5 and 6.

At the end of each year † a balance is struck, and the result of this comparison between the estimate and the actual cut is

* An Oberförster (supervisor) may not exceed the allowed annual cut by more than 5 per cent without the consent of the district office; over 10 per cent requires the consent of the central office in Berlin.

† Formerly every three years.

applied to the allowed cut as entered in control book, Part C,* which is arranged as follows:

Year		Cut by Species, in Cubic Metres				
	Allowed Actual Balance ±					

This balance, be it a plus or a minus sum, is carried forward and used as the basis of the cutting plan for the year following, taking into account the plus or minus divergence of the estimate. At the same time Part C serves as a current record of the annual cuts. It is customary to add brief marginal explanations of the cuts larger or smaller than the calculated amount.

The chief note-book (Hauptmerkbuch) is a running history of the forest showing the occurrences, management, measures taken, observations made, etc., to form the basis for a new organization of the forest † and as a guide to new administrative officers just taking charge of the forest. It is divided in two parts—the first, a general part, divided into various headings for the recording of events connected with the history of the forest, observations, and also recommendations, under the following headings:

* Part B has long since been abandoned.

† This is sometimes supplemented by a "Taxatorische Notizbuch," i.e., a note-book containing data especially concerning the field-work and operation of the working plans.

1. Surveying and estimating.
2. Methods and results of cuttings and plantings.
3. Forest protection.
4. Status and servitudes.
5. Miscellaneous: markets, utilization, by-products, the chase, money returns, personnel, etc.

The second part of the chief note-book is specific, and contains a page for each compartment whereon to record the events and changes affecting it. It is in tabluar form, as follows:

Column	1	Compartment.		
	2	Area.		
	3	Cuttings.	Year.	
	4		Area.	
	5	Plantings.	Year.	
	6		Method of planting or seeding.	
	7		Species.	
	8		Plant material used.	Amount of seed.
	9			Num. of plants.
	10		Area restocked.	
	11		Cost aside from cost of plant material.	
	12	Remarks.		

As a supplement to this, all changes in boundaries, soil utilization, in the character of the stands through cutting or planting, new constructions such as roads, etc., are entered on a map of the forest.

The register of area consists of four parts:

(A) The index to all extant maps, estimates, and working plans for the forest.

(B) A record of all changes in area.

(C) A record of all changes in ownership, servitudes, etc.

(D) A record of the changes in the area devoted to the growth of timber.

Since the year 1852 there have been detailed instructions for the revision of working plans. Until recently this included not only the regulation of the cut, but also the actual administration of the forest. With the advent of frequent statistical reports and inspection trips, this last fell into abeyance. Regular revisions come at the close of the twenty-year period, however, as explained above, an intermediate revision is provided for during the eleventh year of the period.

The work of revision is similar to that of a new working plan; the degree of revision necessary depends on the changes which have occurred. Preparatory to the revision, each portion of the forest is carefully gone over to determine its present condition as compared with the condition at the time the estimate was made, in order to form an adequate basis for judging the effectiveness of the measures of the working plan, their further usefulness, and extent to which they require revision. The results of this examination are presented in brief—oftentimes tabular—form, especially as concerns cuttings, plantings, financial results, changes in area, servitudes, and the like.

Revisions are made by the Oberförster (supervisor) himself, aided, where necessary, by men especially detailed, as in the case of the original estimates. All revisions are based on a conference between the officials concerned, following the precedent of the working-plan conference; this conference decides upon the further usefulness of the working plan as it stands, just what revisions are to be undertaken, and along what lines.

The following are given as the chief considerations in the revision of a working plan:

(1) The correction of the surveys and estimates. The area register and the second part of the chief note-book together with the forest maps posted to date are aids in this.

(2) Review of the accomplished cutting and reproduction. The bases of this are the control-book and the chief note-book. As an index to the results of management, the cut is totaled for the period; in addition there is compiled from Part A1 of the control-book a comparison of the estimated cut with the actual cut; the areas planted or sown during the period are also summarized.

(3) Review of the silvicultural method of treatment, the rotation, division of area, etc.

(4) Review of the regulation of the cut both in determination and distribution. This may involve a partial or even complete revision of the estimates.

(5) The drawing up of new general cutting and planting plans according to the revised regulation.

(6) The correction or even redrafting of the forest map.

II. Bavaria

Bavaria is the second largest of the German States. Of its 18,739,890 acres, 32.51 per cent (6,072,386 acres) are in forest.

Bavaria presents widely varying topographic and forest conditions, from the rugged spruce and fir-clad northern ranges of the Alps along the southern boundary, through the varied spruce, fir, and Scotch pine stands mixed more or less with hardwoods, of the central and northern portions, to the extensive stands of pure spruce on the east—the famous "Bohemian woods," low ranges not exceeding 5000 feet elevation, which form the boundary with Austria—and the magnificent oaks of the Spessart in the north-west corner.

The market for timber in Bavaria is very variable. In the more remote localities, such as the Alps on the south or the "Bohemian woods" on the east, utilization is necessarily still incomplete. In the northern and central portions of the kingdom intensive agriculture has brought with it the profitable possibility of complete utilization.

Systematic forest organization in Bavaria dates from 1830, when the combined period method (see method No. 17) was adopted by a governmental order.* The period was taken as twenty-four years instead of the customary twenty years. The cut was regulated for three periods—seventy-two years—in advance.

The end of the nineteenth and beginning of the twentieth

* "Instruktion für Forstwirtschaftseinrichtung," June 30, 1830.

century witnessed a revolution in the forest policy of Bavaria, away from the often excessive conservatism of the early days, toward a more liberal interpretation of the State's economic duty, especially in regard to the increasing tendency to manage the State forests for profit as well as for a future timber supply.

This change in general policy has manifested itself in the new instructions for forest organization.* These working-plan instructions because of their absolute modernity deserve somewhat detailed mention.

The objects of forest organization are given as:

(1) To give a clear conception of existing conditions in the forest.

(2) To deduce from these conditions and the purposes which the forest is to serve the object and methods of management and the determination of the cut.

(3) To regulate the cut in detail for the ensuing working period.

(4) To control the execution of the plan and to secure statistical data thereon.

The working unit usually coincides with the administrative unit (forest), but this is not essential; if conditions on two or more adjacent forests are sufficiently similar one working plan may suffice.

The working unit ("Betriebsverband") is divided into districts, and these into compartments. This division is primarily for the purpose of orderly arrangement and easier orientation.

The basis of division into districts (blocks) is usually topographic; sometimes, however, matters of status and of servitudes cause the segregation of a district.

The basis of division into compartments is chiefly silvicultural, i.e., differences in elevation, exposure, opening of logging means, formation of a mantle against windfall, etc. The

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* "Anweisung für die Forsteinrichtung in den Königlich Bayrischen Staatswaldungen," Munich, 1910, Verlagsbuchhandlung Oskar Beck.

actual boundaries are usually topographic—ravines, ridges, etc.—with artificial boundaries—roads, trails, cut-out lanes, etc.—as needed. For mere division of area a width of 3 metres (9.84 feet) * suffices; where protection from fire or wind also comes into play (formation or wind-mantles), the width must be increased accordingly.

The determination of existing conditions (the first task of forest organization) begins with the division of each compartment into forest and non-forest soil; the latter includes not only those areas unsuited for forest, but also those suited for forest but used otherwise. Where accurate measurements are impossible, as in the Alpine zone, estimates of the relative area suffice.

Of the forest areas, those are to be distinguished whose yield is naturally very slight (Alpine type) or, for reasons of protection, cost of logging, etc., do not permit of complete, regular utilization.

The compartment is divided into subcompartments. The basis of this division is the individual stand. On the stand as the ultimate unit is built up the entire management.†

The stand, or subcompartment, must be a unit as regards site, soil quality, species, age, and character (growth, density, health, etc.). A stand must differ in at least one of these features in order to be made into a subcompartment. However, all minor differences are to be disregarded. The minimum size of a subcompartment is usually 1 hectare (2.47 acres).

In coppice and in selection forest the segregation of stands (subcompartments) is often impossible, and the compartments must suffice.

Wherever possible the subcompartment boundaries are to

* In Saxony the main compartment lines running north and south (Wirtschaftsstreifen) average 9 metres (29.52 feet); the secondary compartment lines running east and west (Schneisen) average $4\frac{1}{2}$ metres (14.76 feet).

† "Die ausgeschiedenen Bestände—die Unterabteilungen—sind die Wirtschaftseinheiten. Sie bilden die Grundlage für die Ordnung der Wirtschaft und für die Nutzung des Waldes, sowie für die Buchung der Erträge und des Aufwands."

be topographic features or roads, trails, etc. Where these do not suffice, lines are cleared to a width of 1–2 metres (3.28 to 6.56 feet) and rings of white paint put on the border trees.

In uneven-aged stands the average age as well as the age limits is to be given. Throughout the greatest attention is given to the presentation of the age classes in their relation to area by 1, species, singly and in mixture; 2, site qualities; and 3, density of stocking. These are shown graphically by means of diagrams. The reason of this attention to the age-class distribution is that in even-aged high forest it is made, in conjunction with data on the thriftiness of stands and their suitability to the chosen site, the basis of regulating the cut and of judging the progress towards a normal forest. In coppice with preponderating standards ("Oberholzreicher Mittelwald") and in selection forest a presentation of the age classes is seldom practicable; the most that could be done would be a summary of the area occupied by each age class within the same (uneven-aged) stand, and this gives no adequate basis for judgment.

Detailed estimates are confined usually to those stands intended for cutting during the ensuing working period of ten years. Ocular estimates suffice if conditions are regular and there are available data on cuttings of, or yield tables for, similar stands. In all other cases caliper measurements either of sample plots or of every tree, as the irregularlity of the stand may necessitate, are required.

The increment is to be determined for the next twenty years, because it is a fundamental principle that, at the end of twenty years at the latest, the working plan is to be completely revised, growing stock, increment, and allowed cut redetermined. However, only half the increment for the twenty years is to be added to the present volume of the stands to be cut, since at the end of the first decade half of the stands so designated will have been cut and be without further increment.

The increment is taken either from suitable normal yield tables or as the current annual. The former is simple; the latter, in irregular and overmature stands, more reliable. The mean annual increment can be used if, by investigation, it has been determined what relation with increasing age and on different site qualities the current annual increment bears to the mean annual.

A peculiarity of Bavarian forest organization is the "Character Index" ("Charakterzahl") of the stand: $\frac{N}{d}$ or the number of stems per hectare divided by the average diameter. This index figure is determined separately for each stand.

In the description of existing conditions, special attention is paid to the methods of getting out the timber and suggestions for the development of roads, and other logging methods. Forests only partially accessible demand a plan of logging which includes portions now inaccessible as well as those already opened to management. This plan is usually indicated on a contour map.

The real and the normal growing stock are determined (the latter from yield tables), since they show whether there is an excess or a deficit. The relation of normal increment to normal growing stock gives the normal yield by which the actual yield can be judged (see Hundeshagen's formula, method No. 7).

On this basis of conditions as they exist, the general rules of management are then formulated according to the objects which the forest is to serve. A decision must therefore be reached as to species, form of stands desired, silvicultural methods, and the rotation to be adopted. Finally the cutting area for the next working period must be fixed.

A working unit may be divided into groups ("Betriebsklassen") that is, portions of one or more administrative units varying sufficiently from conditions on the rest of the area to warrant a separate age-class table and calculation of the cut. These variations can be in silvicultural method; in different age of maturity in the species (i.e., different rotations); in marked difference of increment, especially in widely varying elevations; and in important servitudes which influence the course of management.

It is to be remembered, however, that too many divisions of the working unit make the plan unwieldy and difficult of execution, hence only considerable differences are to be taken into account.

The instructions for determining the rotation age are a declaration of principles for the new Bavarian forest policy. The rotation age is to be governed by the objects of management: " Without violating the sustained yield and with the regard to rights of user, to secure the highest possible production of those classes of timber best suited to the needs of the community and of the country as a whole. In addition, the administration is bound to manage the state property entrusted to it in an economic manner, and from the management to secure the highest possible money revenue.

" According, therefore, as a forest is not exclusively or preponderatingly intended to satisfy servitudes or to be a protection or a recreation forest, the management must aim at the largest possible production of most demanded timber and at the economic securing of a maximum money revenue."

The rotation age must be determined from this standpoint. This determination is not to be confined to the other stands, but must extend to the younger classes whose origin and growth are often different from that of the older timbers; * for in fixing the rotation age, the period of years required for these younger stands to reach maturity is the most important.

The possible rotation period is bounded on the lower side by the merchantability of the sizes secured, on the upper side by the age at which the forest rent ceases to increase. The time of maximum forest rent is therefore the extreme rotation age. As a rule the rotation is to be fixed at that age which

* This difference is well illustrated by the Western yellow pine. Measurements made by the author near Flagstaff, Arizona, in 1907, show that the mature yellow pine, when in the " blackjack " form, grew much slower than the present " blackjack " of the same size; e.g., at 100 years of age the present " yellow pine " were 13.2 inches diameter breast high; the present " blackjack " 17.95 inches diameter breast high. See Forest Service Bulletin 101, " Western Yellow Pine in Arizona and New Mexico," tables 9 and 10.

produces the maximum amount of timber of medium size, provided the site quality permits. On poorer sites the growth is slower, and there the management must be satisfied with the production of smaller sized timber if the rotation is not to be unduly prolonged.

Some sacrifices, however, of mere income to the production of larger timbers is proper, since it is the duty of the state to provide for these. But where this can be secured only at the sacrifice of a satisfactory income per cent the prolongation of the rotation is unwarranted.

Besides the mathematical calculations of timber and money yield certain other factors come into play, i.e., the influence of the rotation age on the condition of the soil and on the capacity of the stand for natural reproduction, the increased danger of windfall, the decreased vigor with increasing years, the possibility of intensive thinnings, and other partly economic, partly silvicultural, partly administrative considerations.

Where there are several species with considerable variance in their rotation age, but the working unit is not subdivided into working groups, the rotation age is taken as the average of the respective areas and rotations.

In selection forest a rotation age is difficult of determination because of the widely varying conditions of growth. Diameter is a better guide, i.e., the diameter of greatest productivity determined by measurements of sample trees. Trees which have reached the diameter so determined are merchantable.

For every working unit the area must be determined which is to be cut over in the ensuing twenty-year working period. The fundamental consideration is to gauge the cutting areas so that overmature stands and cutting of immature stands are both avoided, but at the same time so that undue vacillations of area cut over do not occur with their bad effect on local market for and needs of timber, employment for men in the woods, and also delayed normality in the distribution of the age classes.

If the cutting areas are gauged properly and if, in addition, by means of prompt reproduction, care of soil and growth, the increment in volume and in value is furthered, then the demands of a sustained yield are fully met.

In the normal forest the periodic cutting area is constantly equal to $\frac{\text{Total area}}{\text{Rotation}} \times 20$. Where the age-class distribution is abnormal this figure can serve only as a means of comparison. In such a case the periodic cutting area is the sum of the stands requiring cutting for silvicultural reasons ("hiebsbedürftig"), stands now mature ("hiebsreif") or becoming mature in the next twenty years.

Where the distribution of the age classes shows a marked departure from the normal, the progress of the cuttings must be gauged for several decades in advance, so as to foretell the progress which the cutting of the present working period will make toward a normal distribution of the age classes. This is to be done schematically according to the following form:

Premise.—Rotation = 100 years. Area = 982.2 acres.

Normal periodic cutting area $= \frac{982.2}{100} \times 20 = 196.4$ acres; for silvicultural reasons (overmaturity and poor growth) this has to be increased to 258 acres. This overcutting is then equalized in ensuing periods. (See p. 189.)

The distribution of cutting areas for the ensuing working period is not confined to assigning half the periodic area to the ten years elapsing before the intermediate revision. The administrative officer in charge of the forest requires leeway in the choice of where to cut; for he must vary his points of attack, use to the full each seed year, secure a mixture of species by advance reproduction of certain ones (e.g., of fir in spruce-fir type; of beech in pine-beech type), take thought of the fluctuations in the demand for timber, aim to secure each year an approximately equal revenue, etc. This is possible only if the field of operations is larger than the mere ten-year cutting area. This is secured by allowing the administrative officer in charge of the forest to pick from the periodic (twenty-year)

Age Classes Years	Area in 1911 acres	Less the Period. Area of 258 acres.	Average Cutting Age	Area in 1931 acres	Less the Period. Area of 240 Acres	Average Cutting Age	Area in 1951 acres	Less the Period. Area of 162 Acres	Average Cutting Age	Area in 1971 acres	Less the Period. Area of 162 Acres	Average Cutting Age
			(9×145)									
141–150	9.0	9.0	1305.0	......	......	......	......	......	......	......	......	......
			(9.1×135)									
131–140	9.1	9.1	1228.5				......	......	......	......	......	......
121–130	34.4	34.4	4300.0	17.8	17.8	2225.0	......	......	......	......	......	......
111–120	58.8	58.8	6762.0	5.2	5.2	598.0	......	......	......	......	......	......
101–110	44.0	26.2	2751.0	......	......	......	......	......	......	39.1	39.1	4105.5
91–100	61.6	56.4	5358.0	15.5	15.5	1472.5	134.5	134.5	12777.5	99.4	99.4	9443.0
81– 90	41.1	41.1	3493.5	137.3	137.3	11670.5	66.6	27.5	2337.5	39.0	23.5	1997.5
								162.0	15115.0		162.0	15546.0
71– 80	38.5	23.0	1725.0	198.7	64.2	4815.0	99.4		÷162.0	48.2		÷162.0
		258.0	26923.0		240.0	20781.0						
61– 70	137.3		÷258.0	66.6		÷240.0	39.0		= 93	96.5		= 96
51– 60	198.7		=104	99.4		= 87	48.2		+ 10	129.0		+ 10
			+ 10			+ 10			103 yrs.			106 yrs.
41– 50	66.6		114 yrs.	39.0		97 yrs.	96.5			129.0		
31– 40	99.4			48.2			129.0			120.0		
21– 30	39.0			96.5			129.0			120.0		
11– 20	48.2			129.0			120.0			81.0		
1– 10	96.5			129.0			120.0			81.0		
	982.2			982.2			982.2			982.2		

cutting area those areas for the cutting in the ensuing decade which he deems most expedient for reasons of silviculture, cutting sequence (cutting series), administration, and maturity.

If the sum of the stands so chosen greatly exceeds the allowed ten-year cutting area, those stands are to be excluded and saved for a future decade whose growth is the most thrifty and valuable.

By dividing the entire periodic cutting area into the merchantable volume thereon, the cut per acre is obtained. This multiplied by the annual cutting area gives the allowed annual cut in volume.

In coppice with preponderating standards and in selection forest regulation by area is not desirable, since it does not do justice to the complicated and varying needs of the tree in such uneven-aged stands.* In such stands the cut for the ensuing working period consists of all trees above a fixed diameter (determined as stated above), in addition the volume of those trees which during the next ten years will reach this diameter and such as have to be removed for silvicultural reasons (" wolf-trees," " snobs," etc.). In the case of coppice with standards there is, also, of course, the volume of the coppice. A tenth of the total amount for the next decade is the allowed annual cut, this is checked by the current annual increment per cent—the sum of the current annual increment per cents of each diameter class, and by the result of past cuttings. Order and progress of the cuttings are insured by the observance of a cutting cycle.

The provisions for renewal of the working plan are as follows: Each plan is drawn up for a period of twenty years, but at the end of the first decade an intermediate revision—or review—is had; at the end of the twenty years a complete revision is had resulting in a new plan. Exceptional circumstances may necessitate a complete revision before that time, as when unforeseen changes have occurred in the very founda-

* Where the undergrowth is too dense to permit calipering, it may be necessary to regulate the cut, even of coppice with standards, by area.

tions of the plan. Often, however, it suffices in such cases to make provisional changes for the remainder of the working period. Natural calamities—wind, fire, etc.—always require some time before the measure of the catastrophe can be properly judged.

The intermediate revisions are to cover the following points:

a. Necessary corrections of the methods of determining the cut (checking of estimates, etc.).

b. Determination of the cutting areas for the past decade, comparison with the allowed area, and determination of the area for the ensuing decade which again is really that for a period of twenty years.

c. Emendation of the plan of management.

d. Determination of the volume yield of the next working period (based on *a*, *b*, and *c*).

e. The making of a new map of the forest.

In the main revisions the task is a similar one, but more exhaustive. The results of the management during the past period—twenty years—are to be compiled and the whole structure of the working plan renewed as may be necessary.

Bavaria, in common with many of the German States,* has a separate section of working plans in the central office at Munich. This section is charged with the field-work and the office preparation of the plans. The supervisor of the forest concerned is consulted in every feature of the plan; he and his subordinates are charged to assist in the preparation thereof.

The bases of the plan as well as the completed plan require the approval of the royal ministry of finance, forest section.

The procedure in working plans is as follows:

During the working period the supervisor is supposed to keep careful record of such results of management as aid in judging of the volume and value yield. The underlying field data can often be supplemented by him during slack periods of the year.

* E.g., Saxony, Baden and Württemberg; Prussia is a notable exception.

In the last year of the twenty-year working period the supervisor has to report about the execution of the working plan, the experiences gained thereby, and about the essential results of the management, the changes in the condition of the forest, to express himself about the fundamentals of the working plan and to base suggested changes on detailed data.

The district inspection officer has to express himself as to this report and these recommendations of the supervisor. The working-plans officer assigned for the task has then, in company with the district officer and the officers of the forest, to go over the forest in detail. On the basis of this trip over the forest, and after due consideration of the proposals made by the district officer and the supervisor,* the working-plans officer draws up the fundamentals of the new working plan, and the scheme of field-work. Often, of course, some of these fundamentals must await, at least in part, certain investigations in the field; for such points a supplement is to be prepared.

The fundamentals as agreed upon at the working-plan conference and any supplement thereto, must be approved by the state ministry of finance.

In the last year of each decade, also, the supervisor must anticipate the intermediate revision or review by a report on the correctness and applicability of the methods of regulation and of the rules of management.

A working-plan conference and consequent drawing up of the fundamentals of the proposed plan are not necessary in the intermediate revisions.

The field-work is done by assistants of the working-plans officer in so far as the forest force cannot be used therefor. The party may be divided into sections, each under the direction of a section chief versed in working-plans procedure. These section chiefs and their workmen are instructed (if necessary in writing) by the working-plans officer acting in conjunction with the administrative officers of the forest.

* If their advice is refused the reason for such refusal must be stated by the working-plans officer.

The supervisor has to keep in touch with the progress of the work and the manner of execution. The section chief, on demand, must report thereon to the supervisor.

The working up of the field data and the preparation of the working-plan document is the task of the section of working plans in the central office at Munich. As soon as the essentials of the plan are ready in rough draft, they are to be submitted to the supervisor of the forest for his review and written recommendations and memoranda. These last are to be incorporated in the working-plan document. Then the draft of the plan is submitted to the officers of the district and central offices, who must also record any divergent opinions in writing.

Finally, all new working plans or main revisions have to be laid before the ministry of finance for its approval, which puts the plan in force. In intermediate revisions it suffices to notify the ministry of departures necessitated from the original plan, before submitting the revised plan to the supervisor for execution.

A map of the forest forms an indispensable part of every working plan.

No special document is necessary for the intermediate revisions; the existing plan is merely amended in the text, if necessary by the insertion of extra pages.

A part of every revision is a résumé of the management during the working period just concluded.

III. Saxony

Although small in size—3,703,271 acres—Saxony is, because of its dense population and great industrial development, the state of third importance in Germany. Despite its dense population, 949,813 acres, or 25.65 per cent of the total area, is forested.

Saxony is a compact unit, roughly triangular in shape, the low mountains of the Erz Gebirge forming the base and the city of Leipzig the apex. The stands in Saxony are, overwhelmingly, pure spruce with Scotch pine stands in the nortnern, plains portion.

The Saxon markets are pluperfect, which explains the success of the Saxon spruce management with such a low rotation and resulting small diameter.*

Forest organization in Saxony is under the control of a central bureau of forest organization (Forsteinrichtungsanstalt) in Dresden. This has worked well, since it has secured uniformity of methods and results and an experienced, well-drilled personnel. It also established for forest organization a definite and correct interrelation with the other branches of forestry—administration, experimentation, etc.

As in most of the German states, the regulation of cut was first by the period method. Heinrich Cotta, who systematized the working plans for the Saxon state forests in the years 1811 to 1831, endorsed both the area period and the combined period methods. Frequent, regular revisions soon obviated the necessity of determining the cut for several periods of twenty years each in advance. The period method was therefore abandoned and the determination of cut confined to the next decade by means of the stand method (" Bestandswirtschaft ") (method No. 16).†

The division of area is as far as possible rectilinear, the boundaries being used as roads. Because of the imminent danger of windfall in spruce, the lines are run parallel with and at right angles to the prevailing wind direction.

Stands (subcompartments) are segregated down to a minimum area of half an acre. The prevalent uniformity of conditions permits of tabulated forest descriptions. Site quality is gauged both according to the intrinsic quality of the soil (Standortsbonität) and according to the quality of the stand growing thereon (Bestandsbonität). The two by no means always coin-

* See " Management of Spruce in Saxony," Forestry Quarterly, Volume XI, No. 2, pp. 143–148.

† For outline of Saxon working plan, see page 154.

PLATE V.

Road Forming a Compartment Boundary Line, Saxony.
Courtesy of Director James W. Toumey.

[To face page 194]

cide; for the stand growing on a certain site is not necessarily the one best suited to it.

The age classes are in twenty-year gradations—each age class is again divided in half so that the age-class distribution is recorded by decades.

Owing to the great regularity of the stands, calipering is not ordinarily necessary. Stands less than half of the usual rotation of eighty years are estimated from yield tables; stands over forty years old are estimated ocularly and reëstimated at each ten-year revision.

Where clear cutting preponderates, the normal annual cut is taken roughly as the total area divided by the rotation. The proper rotation age is determined by applying the index per cent (Weiserprozent) to the individual stand.* Tables of value increment have been prepared for the whole kingdom of Saxony, based on the prices secured in the open market for the various classes of timber.

Saxon forestry foots on the soil-rent basis. In order to show the profits of management on this basis, the net income for the whole forest is compared with the total cost of production. This is done, for purposes of forest organization, by determining the timber and soil capital which the forest represents and then showing in tabular form the rate of interest returned thereon for each year by the forest management (Reinertragsübersicht).

The normal annual cutting area is maintained as nearly as may be. Under irregular conditions, departures therefrom are necessary. The table of age-class distribution serves as an index to the degree of departure necessary. If the higher age classes are in excess, the annual cutting area is increased; con-

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* The index per cent, W, is determined by the formula $W=(a+b\pm c)\dfrac{A}{A+S}$ where a = volume increment, b = quality increment, c = value increment or depreciation, A = the arithmetical mean of present and future yield, and S = the soil capital with interest thereon. (For details see Roth: "Forest Valuation," pp. 76 to 78.)

versely it is diminished. Hence, a careful exposition of the age-class distribution is of vital importance.

The Saxon system, of maximum money returns on the investment, demands that those stands whose index per cent is lowest be cut first. The next most important consideration is the cutting series; for with the preponderance of spruce, the danger from windfall demands that the cutting areas progress toward the prevailing wind direction. Since the cutting strips are narrow and an interval elapses before the adjacent strip is cut, it follows, as a general rule, that the cutting series are short. However, in order to accomplish this and to avoid the joining together of large areas of practically equal age, it is necessary to have many points of attack. To secure these, the edge of a stand exposed by the removal of the sheltering stand to windward, must betimes be accustomed to the exposure by the formation of deep crowns—the so-called forest mantle or wind mantle.

The most important task of the forest organization, as regards arrangement of area, is the selection of these points of attack for the cutting series. The further development of the cutting series can, however, be only sketched, since it depends on circumstances which the organizer at the time of drawing up the plan cannot know.

The volume of the cut for the working period of ten years is found by ocular determination of the stand on the area to be cut over. The cut to be expected from thinnings is gauged according to the results of the decade past, aided by yield tables, and, of course, with special regard to the needs of the stands.

Stress is laid on the continuity of statistical records *in re* age-class distribution, volume of growing stock, yearly cuts in amount and classes of material, the gross income, the expenses, the net income (Reinertrag), the forest capital, etc. These records have been kept in Saxony since 1817 and are invaluable aids for purposes cf forest organization.

In addition to the revisions at the end of the ten-year working period, there are, in Saxony, intermediate revisions in the middle of the working period. The most important features of revision are the entry of cuttings and plantings on the map of the forest; the comparison of the actual cut with the estimate; the necessitated departures from the prescriptions of the working plan.

For purposes of forest organization the usual stand map (scale of 1 : 20,000 or 1 : 15,000) showing species, age classes, and cutting series, is used as a base whereon to show the intended cutting areas of the next decade, special planting areas, the cutting series, etc.

IV. Württemberg

Württemberg and Baden between them contain the Black Forest, that long line of low ranges flanking the Rhine on the east. Württemberg has an area of 4,819,958 acres, of which 30.77 per cent or 1,483,025 acres are forested.

Württemberg is traversed by various low ranges which give to the whole kingdom a rolling topography. The species corresponding thereto are preponderatingly spruce and fir.

The splendid development of the timber market in Württemberg and of the road system necessary to get the timber on the market puts Württemberg on a par with Saxony as regards financially profitable management.

Württemberg's systematic forest organization dates from the year 1878. The experience gained during the years following led to a sweeping revision in 1898. Since then there has been a second, tentative, revision of the working plans instructions in 1911.* The period method has been dropped, with the impractical endowment of areas in advance for each twenty-year period of the rotation. Attention has been centred on the segregation of stand units, i.e., subcompartments and the regulation of cut based thereon rather than on the area of arbitrary divisions (compartments). The condition of the individual

* "Vorläufige Anleitung zu den Vorarbeiten der Wirtschaftseinrichtung u.s.w. in Württemberg," 1911.

stand has been made the criterion of regulation; the cut is no longer determined in advance for the whole rotation, but usually for only the first period of twenty years, exceptionally for the second period also.

Normally, the cutting area of the I period $= \frac{\text{Area}}{\text{Rotation}} \times 20.$

Exceptions are necessitated under abnormal conditions such as an excess or deficit of merchantable timber, etc. With thrifty stands and a proper distribution of the age classes (in ten-year gradations) the sum of the merchantable stands will automatically aggregate the periodic cutting area.

In the choice of stands for reproduction, great attention is paid to the formation of proper cutting series, just as in Saxony (see above).*

The process of forest organization is summarized as follows: After rotation, silvicultural method, and species have been settled upon and the actual condition of each stand (subcompartment) accurately determined, the first period of twenty years is endowed with the proper area of subcompartments according to the principles outlined above. Then for the next decade the stands on half the period area are accurately estimated (calipered). Since there are always unlooked-for contingencies requiring cutting of areas aside from those provided for in the plan, an amount based on past experience is allowed for such emergencies.

A separate area plan is drawn up for thinnings.

Forest organization in Württemberg is in a state of transition from the period method to that by stands; it is not quite "off with the old" as yet nor "on with the new."

V. Baden

The Grand Duchy of Baden is the neighbor state of Württemberg. It has a total area of 3,725,007 acres, of which 1,402,454 acres, or 37.65 per cent, are forested, the highest

* "Oberster Grundsatz die Bildung geeigneter Hiebszüge."

percentage of any of the German states, only excepting the petty principalities of Waldeck and of Reuss.*

The Black Forest range traverses Baden from north to south like a backbone. The preponderating species are therefore spruce and fir (whence the name "Black Forest") except in the northern plains and along the Rhine, where there are stands of hardwoods (mostly coppice) and of Scotch pine.

As in Württemberg, a magnificent road system makes accessible every portion of the forests; a ready market exists for almost every class of products.

In Baden, too, forest organization developed from the volume period method (Massenfachwerk). But under the prevailing forest conditions of the Grand Duchy, which is characterized by splendid natural reproduction,† especially of fir, the method did not prove feasible; for the process of natural reproduction requires a much longer time than the twenty-year period (usually from thirty to fifty years).

In 1846 a combined area and volume "framework" method was prescribed, first worked out for a whole rotation, then determining volumes only for the first decade. This met with difficulties on account of the selection forests, so that, in 1869, an adaptation of Heyer's formula (method No. 9) was prescribed.

Since 1860 thoroughgoing revisions of the working plan are undertaken every ten years. They are based on the results of the past decade; the actual cut, as compared with the estimates; the effect thereof on the condition of the forest, etc.

The present working-plan procedure dates from 1912,‡ its characteristic features are as follows: §

* These have 38.18 and 37.74 per cent, respectively. The average for the whole German Empire is 25.88 per cent.

† See "Natural Regeneration in the Black Forest," Forestry Quarterly, Volume XI, No. 3, pp. 330–339.

‡ "Dienstanweisung über Forsteinrichtung u.s.w. in Baden (Forsteinrichtungsordnung)" 1912.

§ Adapted from "Die Neue Dienstanweisung für Forsteinrichtung," Allgemeine Forst- und Jagd-Zeitung, Dec., 1912, pp. 420–425, briefed For. Quart., Vol. XI, No. 1, pp. 111–114.

Before the working-plan data are secured, the forest is carefully gone over by the officials who are concerned in the organization of the forest. This also involves the critical scrutiny of the existing working plan in all its parts. This examination lays stress on the division of area, the descriptions of site and of stands, the estimates of growing stock and of increment, the results of the previous management, and the basic provisions of the proposed future management.

The new prescription makes the stand (subcompartment) the unit of management; as far as according to species, age, and site it will probably remain permanently an area for independent treatment.

The minimum size of such a stand is not prescribed. Site classes are determined by use of average height and age according to Eberhard's site-class tables. For determining stock the same tables are used reduced by 10 per cent. Only the volume of the main stand is used, the intermediary stand, 5 to 10 per cent of the total, is neglected, which opens up the possibility of great variety of opinion as to what to count to main and intermediary stand, and to likely underestimates.

The increment, however, is to be ascertained on both final and intermediary yield; namely, a total average increment for the rotation under normal stock conditions, and a current increment for the first decade. Also the mean annual felling age increment for each working group is to be ascertained by use of the tables checked by sample areas. These latter are to be made permanent, so that the progress of increment can be studied.

Age-class distribution according to area and volume, and comparison with normality is to be specially looked after, but the normal stock is to be figured from the yield tables, not as hitherto according to formula.

The forest capital is to be ascertained for comparison with the annual net yield according to most modern valuation methods. Stands up to forty years of age are to be calculated at actual cost value, older stands at sale values; soil values as soil-rent values checked by actual sale values. The prescribed interest rate is 2.5 per cent. While—quite properly—the management is not to be based upon a strict calculation, the principle is laid down, that the aim of the management is to be to secure the highest forest net income possible under sustained yield management besides at the same time attempting to secure an adequate interest rate on the capital involved in the management.

Hence, stands are to be considered ripe when the periodic increment of the forest net yield begins to decline considerably, and to determine this rotation, forest net yields and average interest calculations are to be made, also soil expectancy values with interest rates of 1.5 to 3 per cent are to be calculated to exhibit the time of culmination.

If then the rotation based on the forest rent and the financial rotation based on an "adequate" (if no special considerations, 2.5 per cent) interest rate coincide, it is accepted. If not, then investigation is to be made to see by what changes in management coincidence can be secured.

In this way, for the first time, at least a financial check is introduced.

Where the determination of the rotation in this way leaves uncertainty, the index per cent, or with very valuable stands only the value increment per cent, is to be used for judging ripeness.

Rules of management for districts of similar conditions of production are to be formulated to stop the continual experimenting of each manager.

For regulation of the cut the stand method (method No. 16) has been adopted.

The securing of normal age-class distribution in area and volume is to be especially attempted.

In very uneven-aged stands or with long periods of reproduction, a comparison between actual and normal stock is to be used as a check with Heyer's formula (method No. 9), or else the volume rate per cent may be used as a check.

($p = \frac{c}{v} \times 100$, where c = the actual annual cut and v = the actual growing stock.)

In the selection forest the current annual increment furnishes the principal index for the allowed cut, as well as other considerations, like market and labor conditions, etc.

A large number of forms for gathering the necessary data accompany this instruction; the control book is to furnish a complete chronicle by stands. Besides the sample areas mentioned, so-called special typical "index stands" are to be used to accumulate data of yield and finance, and these are to be specially booked.

The map work is also to be improved by stand maps showing species, age class, site.

The working plans are to be made by a special bureau, as hitherto, except that the head of the bureau is now made a member of the central direction.

Statistical Record has, since 1869, been in intimate conjunction with forest organization so as to have systematic data on conditions and results, to simplify the working-plan documents and to be applied as precedents, good or bad.

The vital statistical records are: The history of the particular administrative unit (origin, composition, status, etc.); the description of the forest according to the subheads: forested area, topography, management, forest utilization, logging methods, forest protection, the chase, money returns, etc.

These data are compiled for the first time by the administrative officers of a forest, but the continuation and supplementing thereof is done by the forest organizer at revision of the working plan.

VI. Alsace-Lorraine

These provinces, conquered from the French in 1870–71, contain the major part of the Vosges Mountains, a long line of low ranges flanking the Rhine on the west. Together they have an area of 3,584,711 acres, of which 1,086,385 acres, or 30.31 per cent, are forested.

The topography is rolling, becoming mountainous in the southern portion of the Vosges. The species correspond closely to the topography: coppice hardwoods and Scotch pine in the more level portions; fir and beech and some spruce in the mountains, with oak on the foothills.

The road development and the timber markets of these provinces are rapidly approaching the same degree of perfection as already exists in the neighboring state of Baden.

When Germany gained control of these provinces in 1871 it became necessary at once to have provisional working plans for each administrative unit. These were made by the administrative officer in charge of the forest, passed upon by the inspecting (district) officer, and finally approved by the minister. The essentials of these provisional plans are the division of area, plan for roads and trails, determination of the method of silvicultural management, fixation of the rotation, etc.

As soon as possible following thereupon, regular working plans were constructed, based on these provisional plans. Revised plans are also prescribed at the expiration of each twenty-year period, after substantial changes in area or growing stock, and in cases of transition as from high forest to coppice and vice versa.

The regulations of 1910 lay stress on the following features of forest organization.*

Division of Area.—The segregation of compartments is done in conjunction with the laying out of the logging and wagon roads and the trails. The area in coniferous stands is not to exceed 24.70 to 37.05 acres, in hardwood stands from 37.05 to 49.40 acres. For coppice and coppice with standards the forest is divided into annual cutting areas; for there the regulation is by area alone. In communal forests one-quarter of the area is set aside as reserve, dating from the ordinances of Colbert in 1669, which provide that in forests owned by the church, or alienated in mortmain, or owned by communities or by

* "Vorschriften für die Aufstellung und Revision der Forstbetriebseinrichtungswerke," Strassburg, 1910.

parishes, one-fourth of the area is to be reserved from cutting; the balance to be divided into regular cuts (" coupes régulées ").

There are no binding prescriptions for the division into subcompartments. In larger forests with various species the minimum size is to be 2.47 acres (one hectare). For segregation on the basis of age differences or differences in density of stocking, a minimum of 4.94 areas suffices. Subcompartments are segregated only if the area requires distinctive treatment. Stands in process of reproduction are to be segregated down to a minimum size of 2.47 acres.

The subcompartments are indicated on the ground by means of stakes and ditches at the corners and are entered in the maps.

Maps.—Field surveys are usually confined to interior lines, since reliable geodetic maps are available for both provinces.

The forest map is usually on a scale of 1 : 25,000 and shows the species by different colors. The cutting areas are indicated on the map for the I and II period—i.e., for the next forty years—by means of cross hatching, unbroken lines for the I period, broken lines and dots for the II period.

Forest Description is to be short and confined to the characteristic features such as status, boundaries, surveys, etc.; stand and site conditions; the occurrence and interrelation of the chief species; past management and results; future, intended management, expecially species, silvicultural methods, rotations, formation of cutting series, roads, markets, by-products, the chase, etc.

Regulation of Cut.—The criterion is the normal periodic cutting area. If the same rotation applies throughout the forest this area = the total area of the forest $\times$ 20 $\div$ the rotation. Where there are several rotations, the normal periodic cutting area is determined for each species according to the ratio of the period to the rotation The total cutting area is then secured by adding together those of each species. Since, as a rule, the forests are not normal, the actual periodic cutting area must be modified to accord with the distribution of the age classes. This modification is predicated on the area of mature and overmature stands, i.e., those of or over the rotation age, on the area of the next youngest age class, and the ratio which the area of all stands less than half the rotation age bears to the area of all stands more than half the rotation age. Where there is an excess of mature stands more than the normal area is cut over; where there is a deficit less is cut over.

Stands of the I period in which reproduction cuttings have begun are entered with reduced areas in proportion to the percentage of the stand removed. A distribution of cutting areas for the III, IV, V, and VI periods is obsolete; these stands and their areas are merely entered in the column headed "later periods." In deciding on stands for the I and II period especial regard is paid to age and thriftiness, volume and value, and, in coniferous stands, on the formation of small cutting series.

The period method, strictly speaking, is therefore no longer used in Alsace-Lorraine.

The long period of reproduction—often thirty to fifty years—requires the assignment of stands for two periods—forty years—in advance. The stands intended for cutting in the I and II period are usually calipered; those of the II period, if sufficiently uniform, may be estimated by means of sample areas; thereto must be added the increment calculated to the middle of each period.

The volume of the allowed annual cut is one-twentieth of the period volume calculated separately by species. In communal forests one-fourth of the allowed cut is to be subtracted (see above).

In selection forest the cut is determined from the actual increment and the relation of the actual to the normal growing stock according to Heyer's formula (method No. 9). In order to determine the actual growing stock, all the trees above $3\frac{1}{6}$ inches (8 centimetres) in diameter are calipered. The actual increment is determined by increment borings of trees of various diameter classes; the normal growing stock according to the formula $\frac{ri}{2}$, where i = the mean annual increment. The number of years in which the excess or deficit of the growing stock is to be equalized is determined for each individual case according to the particular circumstances. The cutting cycle (period between cuts) is not to be placed too high: usually seven to nine years.

Planting and Road Plans are to form a part of every working plan. The planting plan embraces not only the methods of artificial reproduction, of nursery practice, and the source of plant material, but also the care of cutting areas and of young plantations.

Revisions of the Working Plan are to take place in the middle of the twenty-year period. The kind and degree of the revision to be undertaken follows from the demands made on the plans and the changes which, through the methods of management pursued or through outside influences, have occurred during the first half of the working period (ten years). At the end of the working period (twenty years) an entirely new working plan is drawn up.

The essential points to be considered in revision are: Changes in area, the actual annual cut as compared with the allowed annual cut as regulated, the comparison of the volume yield of stands cut over with the estimated volume thereof, the unforeseen cuttings not provided for in the plan, the yield from thinnings, the execution and cost of planting and seeding, the changes in servitudes, the relation of by-products to the scheme of management, the completion of road and trail buildings, etc.

An interesting feature is the instruction that a financial valuation of the forest must be made when a new working plan is prepared or an old one revised. The data for local yield tables are to be gathered by establishing carefully chosen, typical, permanent sample plots to serve as " index stands."

SECTION TWO

FRANCE

The total area of France is 132,492,776 acres, of which * 18.17 per cent are covered with forests: 5,187,000 acres, or 77 per cent, hardwoods; 1,583,270 acres, or 23 per cent, conifers. Of these 6,770,270 acres the state forests comprise only 12 per cent; the communal forests under state management, 20.2 per cent.

The forests of France proper may be divided roughly into (1) plain and (2) mountain forests. Under (1) may be included the Parisienne zone, the Gironde, the Provençale; under (2) the Vosges, Jura, Alpes, Plateau Central, and the Pyrénées.† Corresponding to the topography the chief species are either oak, beech, birch, elm, chestnut, and pine, or, in the mountains, fir, spruce, pine, larch, and beech. La Savoie is the only region of France where the spruce dominates in the forests. In the Pyrénées and along the Mediterranean coast species are found distinctive of the region, such as hook pine, d'Alep pine, maritime pine, cork oak, live oak, etc.

The timber markets of France, while not so intensively developed as those of Germany, are still almost as omnivorous as those of the neighbor state on the east because of the relatively smaller per cent of forest land.‡

The methods of forest organization in France are in striking contrast to those in Germany. The conditions of forest ownership have strongly influenced French forest organization or "Aménagement," as it is called. Hitherto it has been generally assumed that privately owned forests are not suited to a sustained yield management. It was thought that the difficulty

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* From Hüffel: "Économie Forestière."

† For further details see article: "European Study for Foresters," by A. B. Recknagel and Theodore S. Woolsey, Jr.; "Forestry Quarterly," Volume X, No. 3, pp. 417–439, especially pp. 429–430, 436–438.

‡ In France 18.17; 25.88 per cent in Germany.

of foretelling future needs and the uncertainty of predicting yields were in contravention to the basic principles of forest management for private ends and that, furthermore, the growing of timber, especially of the larger sizes, is primarily the duty of the state and of the communities. These views coincided with the actual conditions of forest ownership: in the forests owned by the state high forest is the rule with a long rotation;* the forests owned communally are usually coppice with standards; and the forests privately owned, simple coppice. But of late conditions have changed substantially: the increased prices of forest products and the decreased interest rate have made the growing of the larger sizes of timber profitable also for the private owner.

The chief features of French forest organization are the division of area, the methods of regulating the cut, the distribution of the periodic cutting areas, and the determination of the allowed annual cut.

Division of Area.—The state forests and the forests under state control are divided into series. These series are adjacent forest areas with uniform market conditions and a sustained yield; they often coincide with the ranger districts (triages). " By a series is understood a portion of the forest intended to be covered by a special plan of utilization and consequently to furnish a series of annual cutting areas." †

The series are subdivided into sections. " By a section is understood a portion of the forest distinct from the rest by the general method of management " (coppice, regular high forest, selection high forest, etc.). Accordingly, the segregation into sections is based, preferably, on the general method of management (régime) and on the specific silvicultural method of reproduction (mode de traitement).

The series are further divided into periodic cutting areas called " affectations."

The division by silvical units, i.e., stands, is called the par-

* 140, 160, 200, and even 240 years.

† Tassy: " Études sur l'aménagement des forêts."

celle. These parcelles are the basis of the whole forest organization and of the course of the management. In each forest district (canton) those portions are to be segregated which differ in species or in age, or in site, exposure, growth or density of stocking, in such a way that each portion or parcelle can be handled identically throughout. In the records the parcelles are classed as divisions if they are permanent, as subdivisions if only temporary. The parcelles are marked by stones at the intersections of the boundary lines; the boundaries themselves by narrow cleared lines or by signs.

The forest description of the individual parcelles is according to the following form.*

Column 1. Cantons, i.e., forest district, or block.
2. Divisions and subdivisions.
3. } Volume { subdivisions.
4. } Contents of the { divisions.
5. Site and elevation.
6. Exposure.
7. Slope.
8. Soil.
9. Percentage of each species in the mixture.
10. Age.
11. Character of the stand.
12. Growth.
13. Remarks.

Method of Determining the Cut.—The cut is determined by the area period method as appears from the following tabulated form for working plans.†

Column 1. Number of the affectation.
2. Names of the cantons.
3. Divisions and subdivisions.

* Called "État descriptif des divisions et subdivisions."

† Réglement général des exploitations par période pendant la première révolution (révolution equals rotation). See also Méthode de Masson, Méthode de 1883 (French Method), Méthode du Contrôle, Nos. 3, 10, and 13, respectively.

Column			
4.	Area in hectares of the		subdivisions.
5.			divisions.
6.	Site, exposure, soil.		
7.	Percentage of each species.		
8.	Density and growth of the stand.		
9.	Age	present.	
10.		at the time of cutting.	
11.	I period	final cuttings in hectares	ordinary.
12.			extraordinary.
13.		Thinnings, in hectares.	
14.	II period	final cuttings in hectares	ordinary.
15.			extraordinary.
16.		Thinnings, in hectares.	
17.	III period cuttings, in hectares		final.
18.			thinnings.
19.	IV period cuttings, in hectares		final.
20.			thinnings.
21.	V period cuttings, in hectares		final.
22.			thinnings.
23.	VI period cuttings, in hectares		final.
24.			thinnings.
25.	Remarks.		

The number and length of the periods vary with the species and the locality. For oak in central France eight periods of twenty-five years each are formed; for beech usually six periods of twenty years each; for fir four or five or more periods of thirty years each. The number of the periods and their length require the approval of the minister.*

The rotation age is only fixed tentatively "without attempting to fix it definitely by applying experiences whose value is often only specious." †

For the state forests a rotation age is chosen which corre-

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* Formerly of the Emperor himself by a decree.

† From a French working plan.

sponds to the maximum possible yield of the most useful classes of materials. This has resulted in a conservative tendency showing itself in the present conditions of the forests of France and of Alsace-Lorraine. In general the adopted rotations are distributed as follows:

	Rotation Age		
	Under 100 years	100-150 years	150-200 years
Reg. high forest	35.7% of total area	43.1% of total area	21.2% of total area
Select. high forest	9.8% of total area	43.7% of total area	46.5% of total area

Distribution of the Periodic Cutting Areas.—This is the most characteristic feature of French forest organization. The periodic cutting areas are to be so arranged that they comprise the area of each period without a break or interrupting area of another period. This is in direct contradiction to the aim of the German forest organization, particularly of the Saxon. The reasons given for this distribution are simplicity in reproduction cuttings; of regularity of formation of the periodic cutting areas with their narrow side toward the prevailing storm direction and bounded wherever possible by roads. Tassy in his "Études sur l'aménagement des forêts" lays especial stress on the undesirability of breaking up the periodic cutting areas into cutting series.*

This principle has been followed in the working plans for the state and communal forests. The periodic cutting areas are systematically grouped in the maps and on the ground. The immediate consequence is that many stands are cut not at the time of their maturity, but too soon or too late; furthermore, the reproduction cuttings become very large and thus, in the future, there will be extensive stands of even age. Both consequences are attended with drawbacks of management (in-

* Tassy, troisième étude, Chapter IV, Section 3, "Formation des affectations conformément aux règles d'assiette."

creased danger of windfall, fire, insects, fungi, etc.), even though these are less in France by reason of the prevalence of the natural reproduction and the predominance of hardwoods than they would be, for example, under German conditions.

Determination of the Allowed Annual Cut is both by volumes and by values. For the cuttings of the first period a special cutting plan or felling budget is drawn up (Réglement special des exploitations pour la première période) in which the cutting areas and volumes are entered, arranged according to the divisions and subdivisions and according to final cuttings (Coupes principales) further divided into Coupes ordinaires and Coupes extraordinaires, and thinnings (Coupes intermédiaires).

The volume of the Coupes principales is determined first by caliper measurements entered separately by species; the volumes are then computed from volume tables based on the contents of sample trees of the various diameter classes.

The increment for the years elapsing between the estimate and the cutting is disregarded in the computation.

Thinnings are regulated by area; their volume is taken from the experience of the preceding decade.

To the determination of the allowed annual cut by volume is added one by values (Évaluation en argent de la possibilité). This is based on the estimate of the classes of timber which is made for each species and for each class on the value according to the prevailing prices (prix sur pied par nature de marchandises). Adding the values of each class gives the total value of the felling budget.

The regulation of cut in coppice and in coppice with standards is by area. Coppice systems have reached a point of development in France far in advance of that in other European countries. The regulation of coppice dates from the ordinances of Colbert in 1669. The division of area depends on the rotation age of the coppice under the standards. In the State forests 50 per cent have a coppice rotation of twenty to thirty years; 46 per cent have a rotation of over thirty years in the communal forests 77 per cent have a rotation of twenty to thirty years, 20 per cent a rotation of over thirty years.* The standards are arranged by age classes and distributed equally on the area. These standards are either two, three, or four times the rotation age (baliveaux de l'âge, modernes, and anciens, respectively). The cut of standards is determined by the number of stems of each class and is usually accomplished with the utmost regularity.

SECTION THREE

AUSTRIA

Austria, exclusive of Hungary,† contains 74,101,976 acres, of which 24,125,888 acres or 32.6 per cent are forested.‡ This puts Austria fourth in the rank of timbered countries of Europe, preceded only by Sweden with 49 per cent forest area, Finland with 46 per cent, and Russia with 39 per cent. The ownership of Austrian forests, which has profoundly influenced the development of forestry there, is as follows: State forests 11 per cent of the total area, communal forests 14 per cent, church forests 17 per cent, private forests 59 per cent.§

Austria can be conveniently divided into five great districts; these, with their percentage of forested area and the per cent of timber tracts over 2500 acres in size, are as follows:

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* For simple coppice 56 per cent of the State forests and 76 per cent of the communal forests have a rotation age of twenty to thirty years.

† The differences of race and language have resulted in all but the political separation of the two countries.

‡ In Hungary it is 27.8 per cent, in Germany 25.88 per cent, in France 18.17 per cent.

§ Data from "Die Holzproduktion Oesterreichs. K. K. Ackerbauministerium, 1907. See also "A Glimpse of Austrian Forestry," by Theodore S. Woolsey, Jr., Proc. Soc. Am. Fsters., Vol. IX, No. 1, pp. 7 to 37.

District and included Provinces	% of forest area	% of tracts 2,500 acres and over
Danube (Niederösterreich, Oberösterreich)	34.2	44.6
Alps (Salzburg, Tirol, Steiermark, Kärnten, and Krain)	41.8	41.1
Coast (Küstenland, Dalmatia)	29.6	37.7
Northwest (Bohemia, Mähren, Schlesien)	29.1	65.7
Northeast (Galicia, Bukowina)	27.7	69.6
Totals	32.6	54.3

of which nearly one-half are tracts of 7500 acres in size or more; nearly one-quarter, or half of the half are tracts of 25,000 acres or more.

This division corresponds fairly well with the general topography and the forest conditions. The Alps and the northeast districts (Carpathians) comprise tremendous mountain ranges; the Alps continue in diminished form through the coast district to the southeast and break down northward into the rolling plains and foothills of the Danube district, this foothill character is preserved through most of the northwest district adjoining thereon, grading gradually into the main ranges of the Carpathians, the divide of which forms the boundary between the northern districts of Austria and Hungary.

The coniferous species in Austria cover over 60 per cent of the total forest area; 21 per cent are hardwoods; the balance of 19 per cent are mixed stands. Spruce predominates with 44 per cent of the total forest area, it occurs at almost all elevations from the plains up to timber line, only in Dalmatia is it lacking. Scotch pine is next, with 7 per cent of the total forest area, chiefly occurring on the plains. The remainder of the 60 per cent of coniferous stands are mixtures of various species —fir, Austrian and other pines, and larch.

Of the hardwood stands which cover 21 per cent of the total forest area, beech leads the list with 10 per cent, the remaining 11 per cent are stands of oak with beech, or hornbeam with beech, or of aspen, alder, birch, etc.

The 19 per cent of mixed stands are admixtures of larch, Pinus cembra (" Zirbe "), ash, elm, maple, chestnut, etc.

Austria shows within its boundaries the greatest variety of forest conditions.* All phases of vegetation are encountered from the semi-tropical shores of the Adriatic grading through the sandy and often rocky coastal plains, through the mounting foothills to the dolomitic or archaic fastnesses of the Alps and Carpathians, where all tree growth is dwarfed and even the lower stands are constantly threatened with rock slides and avalanches. The forest products vary accordingly from the finest timbers with high rotations down to mere fuel woods with the shortest of coppice rotations. Similarly, some forests are in immediate proximity to dense centres of population—as, e.g., the Wienerwald just outside the gates of Vienna—permitting almost perfect utilization because of a voracious market; some forests, on the other hand, are still virgin and as yet out of profitable reach of the lumberman's axe. Gradually, though, the increasing prices of timber are making accessible at a profit even the stands most remote from centres of population, and soon there will be no virgin forests in Austria.†

Again, the task of forest management is, sometimes, as in Salzburg, burdened by servitudes; elsewhere no such restrictions exist. As a result the market varies greatly, but in general it is developing rapidly, especially in the export trade to Germany and Italy and other European or Oriental countries.

Eighty-five per cent of the Austrian timberlands are managed as high forest, of which one-third is selection forest mostly in the "high" protection zone of the Alps; 12 per

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* See "Methods of Natural Regeneration in Austria" and "Methods of Artificial Regeneration in Austria," Articles VIII and IX, respectively, in the series: "Some Aspects of European Forestry," F. Q., Vol. XI, No. 4, pp. 470–498, reprinted in 1913.

† The Austrian government now constructs its own logging devices, sawmills, railroads, chutes, flumes, etc.; these are used by the purchaser of the stumpage for which use he pays a proportionately higher stumpage price. Formerly stumpage was sold as in America, and the purchaser put in his own improvements; as rapidly as possible these improvements were then bought up by the government and paid for in cash or in timber.

cent are managed as coppice; 3 per cent as coppice with standards.

Forest organization in Austria has reached a remarkable state of perfection despite the exceedingly irregular conditions as portrayed. The Austrian Kameraltaxe (Austrian formula—see method No. 5) dates from 1788; in the Tyrol a volume period method was in use in the sixteenth century. From these early beginnings a systematic forest organization has been built up and extended even to the most remote regions,* comprising not only the state forests but also the large tracts privately owned. Practically half of the forested area of Austria is under working plans.

The salient features of Austrian working plans as contained in the government code of 1901 † are as follows:

Division of Area begins with the setting aside of protection forest wherever necessary; it is usually divided from the lower

* For example, the remote Bukowina, lying between Russia and Rumania on the extreme eastern border of Austria, shows 73 per cent of its 1,113,970 acres of forest covered by detailed working plans in perfect operation. When this province was acquired by Austria in 1775 from Turkey it was largely—nearly 50 per cent of the total area—in trackless virgin forest. The first work of forest organization, that of making provisional working plans, was completed in 1818. About 1850 the preparation of final working plans was begun on the basis of period area method; failing of systematic revisions these soon became mere waste paper, the more so since it was impossible, for lack of markets and of logging facilities, to carry out the cuttings as planned. In 1875 a thorough reorganization of the forest administration in the Bukowina was begun looking to the opening up of the hitherto inaccessible timber resources. A section of forest organization (Einrichtungsabteilung) was created in the Bukowina district similar to that already existing in all the other district offices of the empire. A thorough reconnaissance (Durchforschung) was made and on this basis new provisional working plans prepared, beginning, of course, with the more accessible forests. As the data and utilization warranted it, these were transformed into regular plans with frequent revisions, on the model of those prescribed for the rest of Austria. For the development of working plans practice in the provinces of Bosnia and Herzegovina, see "Die forstlichen Verhältnisse und Einrichtung Bosniens und der Herzegovina," L. Dimitz, Vienna, 1905, briefed For. Quart., Vol. III, No. 2, pp. 143–150.

† "Instruktion für die Begrenzung, Vermessung und Betriebseinrichtung der Oesterreichischen Staats und Fondsforste," 3d edition, 1901.

slopes by a trail following the appropriate contour. This protection belt is always managed as strictest selection forest. The management for the rest of the working unit is then decided upon and the area divided into "Betriebsklassen" (working groups), cutting series, compartments, and subcompartments.

An area with a uniform silvicultural method and rotation, uniform market and constituting a single logging unit is called a *Betriebsklasse;* it is further divided into cutting series, whose formation depends on the topography, the species, and the method of reproduction. A single cutting series does not usually comprise more than three compartments. The boundaries of the cutting series are topographical or artificial—roads, compartment lines, etc. These boundaries are to be cleared of timber to a width of from 16 to 26 feet, in order that a wind-resisting mantle may form along the edges of the stands. Cutting series are shown on the maps by arrows.

The compartments (Abteilungen) are units of convenience; their shape is quadrangular, 2600 to 3300 feet long and about two-thirds as wide. The boundary lines are topographic, cultural (roads, railroads, etc.), or else artificial. The last are either "Schneisen" and are usually made 6½ feet wide (2 metres), or are "Wirtschafts Streifen," with the regular width of 16 to 26 feet (5–8 metres).

The division into subcompartments (Unterabteilungen) is based (1) on differences in required treatment of which the following are distinguished: High forest with clear cutting; high forest with shelterwood cutting; high forest with selection cutting; simple coppice; coppice with standards; forest burdened with servitudes; protection forest, voluntary or enforced by law: or (2) on differences in species if the stands are pure: or (3) on substantial differences in percentage of mixture if the stands are mixed: or (4) on differences in average age, exceeding ten years in young, twenty years in old high forest, five years in coppice forest: or (5) on marked differences in site quality or stand quality as shown by substantial differences in the height growth of equal-aged stands: or (6) on marked differences in the density of stocking: or (7) on need of artificial reproduction.

The minimum size of a subcompartment is $1\frac{1}{2}$ acres. The boundaries are marked with stenciled numbers painted in oil color on the corner trees or else by means of symbols made with a tree scribe; in young stands narrow alleys are cleared.

Estimates and Forest Description.—As a general rule yield tables are constructed for the various silvicultural methods of management, species, and site classes, based on sample areas measured during the progress of the field-work. The following form is used:

Column 1. Age.
2. Number of stems per hectare.
3. Basal area at 1.3 M. above ground, in square metres.
4. Average diameter at 1.3 M. above ground, in centimetres.
5. Average height in metres.
6. Average annual height increment in metres.
7. Volume by timber classes, in cubic metres.
8. Increment—current annual, in cubic metres.
9. Increment—mean annual, in cubic metres.
10. Increment per cent—mean annual.

These yield tables are compared with the published yield tables of the International Association of Forest Experiment Stations.

The description of the individual stand covers the following phases:

(1) Soil and site.

(2) Species, percentage of mixture and general form of the stand. The percentage of mixture is expressed in tenths according to the area occupied by each species. Shelterwood cuttings are considered as preparatory if .8 of the original volume remains; as seed cuttings if .5 to .8 remains; as removal cuttings if less than .5 remains.

(3) Both the average age and the age limits are given.

The table of age-class distribution takes the following form:

Column 1.	Compartment number.	
2.	Subcompartment letter.	
3.	Site and stand quality.	
4.	Barrens and blanks.	
5.	I stands 1–20 years old — partly stocked	in hectares.
6.	I stands 1–20 years old — fully stocked	in hectares.
7.	II stands 21–40 years old	in hectares.
8.	III stands 41–60 years old	in hectares.
9.	IV stands 61–80 years old	in hectares.
10.	V stands 81–100 years old	in hectares.
11.	VI stands 101–120 years old	in hectares.
12.	VII stands over 120 years old	in hectares.
13.	Total area.	in hectares.
14.	Area in hectares of the areas under reproduction.	
15.	Area in hectares of the areas under selection forest.	
16.	Remarks.	

A separate age-class table is prepared for each "Betriebsklasse" (working group).

Areas in process of reproduction are entered in full in Column 14. But, if the cutting is shelterwood, the proper proportions of the areas appear also in the age class (Columns 4–12) so as to show the existing proportion of old timber, young growth, and blanks.

Below the actual area of each age class, the normal area thereof is entered for the purposes of comparison.

(4) As index to the yield the following factors are entered:

(*a*) The average height of the stand.

(*b*) The sum of the basal areas.

(*c*) The site quality and species occupying it.

(*d*) The present density in tenths of 1.0 = fully stocked. Stands are to be considered fully stocked if the actual volume per hectare corresponds to the volume given in the yield table for the same age, site quality, species, and silvicultural method.

(5) The volume of those stands which are to be cut in the next two decades.

(6) The mean annual increment prorated to the end of the rotation.

The data on volume and increment of the younger stands is taken from yield tables; in stands approaching maturity exact measurements in the field are required. Stands of varying density and all under 5 acres in size are to be calipered completely. In very irregular stands (e.g., mixed species, uneven-aged, etc.), sample plots are measured to cover from 5 to 10 per cent of the total area. The volume is calculated from the calipered diameters by measuring average trees, so chosen that in height and diameter they represent the stand in miniature.

These data are combined in a tabular forest description which takes the following form (general stand table):

Column 1. Locality.
2. Compartment—number.
3. Subcompartment—letter.
4. Soil and slope.
5. Species, per cent of mixture and general form of stand.
6. Age of stand—years.
7. Average height of stand—metres.
8. Total basal area—square metres.
9. Site quality.
10. Density of stand in decimals of 1.0.
11. Area in hectares.
12. } Volume in cubic metres { per hectare.
13. } { for total area.
14. } Mean annual increment prorated { per hectare
15. } to rotation age, in cubic metres { for total area.
16. Volume increment per cent.
17. Quality increment per cent.
18. Index per cent.
19. Remarks.

This is supplemented by a general forest description for the entire area, covering all of the forest conditions—natural, legal, political, economic, commercial, financial, and administrative, including personnel.

Determination of the Cut is for a decade in advance. The allowed cut is divided into final cuttings, thinnings, and accidental cuttings. The basis of regulation is the normal periodic cutting area. If the conditions are regular this is adhered to as strictly as possible. Often there are large amounts of overmature timber, as, e.g., in the virgin forests of the Bukowina mentioned in foot-note preceding, where with a 120-year rotation the stands over 100 years old aggregate 116,592 hectares instead of the normal (based on age-class relation) of 33,221 hectares; an excess of 83,371 hectares.* In these overmature stands the increment merely offsets the decay and their interest yield on the investment is nil. To substitute for them young, thriftily growing stands was axiomatic, but required cutting in excess of the normally allowed area. The amount of excess permissible was fixed on the following three considerations: (1) Not so great that reproduction, natural or artificial, cannot keep pace with the cutting, and so imperil the continuity of the forest; (2) not so great as to depress prices by glutting the market and thus losing all the financial advantage gained by stimulated increment; (3) not so great as to cause too serious disturbances of the sustained yield. These considerations were met by a sliding scale of gradually approaching the normal as follows: In the I period of twenty years 1.5 the normal area can be cut (sometimes 1.6 in the first decade, 1.4 in the second decade); in the II period of twenty years 1.3 of the normal area can be cut; in the III period of twenty years 1.2 of the normal can be cut, and thenceforth approximately the normal amount only is to be cut. During the decade ending 1910 the average annual cutting area in the Bukowina

* "Die Forstwirtschaft und ihre Industrien . . . im Herzogthume Bukowina," by E. Guzman, Vienna, 1901.

was 3008 hectares, or approximately 1.5 the normal of 2031 hectares.

The rotation age is determined on the basis of highest net annual income (forest rent) unless there are cogent reasons, such as legal constraints, logging or market conditions, for keeping a higher rotation. Stands are usually considered mature, i.e., of proper cutting age, whose index per cent has sunk below the adopted interest per cent on the investment and whose cutting will not interfere with the proper development of the cutting series.

In addition to the stands thus mature, the cuttings of the ensuing working period are to include all very open stands and stands with unsatisfactory increment whose reproduction is obviously desirable; and also such stands as must be sacrificed to the proper progress of the cutting series.

The aim is, obviously, to approach a normal distribution of the age classes. The length of time required in this approach to normal is fixed tentatively. To aid in this and in the fixation of the decade cutting area the results of past cuttings are reviewed, especially in their effect on the development of the proper age-class distribution; this last is shown graphically for decades past.

Based on these considerations the decade cutting area is finally fixed and the volume thereon, increased by adding the increment to the middle of the decade, constitutes the allowed cut for the decade.

In the selection forest of the protective belt, everything is subordinated to the protective function and hence no sustained annual cut is determined, but the allowed cut merely approximated from experience.

Control and revision of the working plan which is documented in bound form and called an "Operat."—The following current records are kept:

(1) The memoranda book ("Gedenkbuch") wherein all changes other than those changes which result from the cuttings prescribed in the working plan are entered. Changes in sur-

veys; in logging methods; substantial injuries to the forest by man, climate, fire, etc.; the progress of the hunt and of fishing; personnel; statistics of volume yield and money returns; forest experiments, etc. It corresponds closely to the general part of the Prussian "Hauptmerkbuch."

(2) The management book corresponds to the Prussian control book, together with the specific part of the Prussian "Hauptmerkbuch." It is divided in two parts: The first gives for each subcompartment (figure of control—"Kontrollfigur") the yield of cuttings by classes of material and area, the completed seeding and planting, and the early care of the stand. The second part contains the total annual cut of the whole forest (working unit, "Wirtschaftsbezirk") compared with the estimate.

(3) Index of changes in status, comparison of the total annual actual with the allowed cut in volume and area; summary of accidental—i.e., unforeseen—cuttings, of plantings, of receipts and expenditures, of net income, etc.

Regular revisions are made in the last year of the ten-year working period; revisions may be necessary between times if unforeseen contingencies occur, such as large windfall, insect damage, change of area, etc. The most important tasks of the revision are: First, the determination of whether the provisions of the working plan just terminating were observed in every detail; whether and to what extent the departures therefrom were justified; and whether the prescriptions of the working plan proved correct, singly and collectively. Second, the correction of the existing maps and estimates which may necessitate the collection of additional field data. Third, the preparation of the working plan for the next ten years.

SECTION FOUR

RÉSUMÉ

A review of the practice of working plans in Europe shows that forest organization developed very differently in the various countries. The differences consist in the form of the working-plan document; in the length of the working period; in the methods of estimating, forest description, mapping; in the principles and nomenclature of the divisions of area. These differences arose primarily out of differences in the forest conditions to which the methods of forest organization were adapted; in part also because the various practices developed independently of one another. Many of the rules and regulations for working plans remained practically unknown outside of their immediate sphere of application.

Despite these differences, the various existing methods of forest organization are very similar in the essentials of working plans. For all, the most important task is recognized to be the designation of the areas which are to be reproduced. For this the character and composition of the individual stands is scrutinized. The more unfavorable the condition of the stands is in regard to growth, density, etc., the more is their early cutting indicated. At the same time, however, all the existing methods demand that the stands are not to be considered by themselves alone, but in conjunction with the whole area of which they form a part and their treatment decided upon accordingly. In general agreement are, furthermore, the methods of determining the allowed cut. At first, regulation was by volume alone, as fitted the irregular conditions encountered; as management progressed, area came to play a more and more important part in regulation. Area and volume combined are now the basis of regulation in all intensively managed forests. In Prussia, Austria, Saxony, and other countries, the criterion of yield is the normal periodic cutting area wherever the conditions are sufficiently regular. This area is increased or diminished according to the distribution of the age classes. The volume on the periodic cutting area constitutes the allowed periodic cut and affords, by volume regulation, a check on the sustained character of the yield.

The consequent progress of forest organization is also very similar. In the formula $\frac{a}{r}$ or $a\frac{20}{r}$, which represents the annual or the periodic cutting area, respectively, r, the rotation, is set as a definite figure, as indeed is necessary for the execution of a working plan during a definite working period. As a matter of fact, however, the rotation age is not a fixed quantity, when considered for a longer period of time, but a varying quantity influenced by the changing conditions of management. To recognize these conditions and to set forth clearly their influence is the common task of all methods of forest organization, a task more important than the form of the working-plan document and the method of determining the cut. The rotation age, i.e., the age of technical, economic, financial, or other maturity, whichever may be chosen, is dependent on all the conditions of site, silviculture, utilization, and economics, which influence the increment of the stands and the value of the timber.

CHAPTER II

IN AMERICA

SECTION ONE

EARLY BEGINNINGS *

Working plans are almost coincident with the beginnings of American forestry. Before the control of the national forests passed over to the Forest Service of the Department of Agriculture in 1905, the then Bureau of Forestry, through its offer of coöperation with private owners, prepared many working plans for timber tracts in the Eastern and Southern States. Since these plans were for very irregular, extensive conditions and were generally intended for execution by laymen who had little or no conception of the purposes of forest management, it was inevitable that they exceeded the confines of mere forest organization and often consisted chiefly of elaborate forest descriptions and estimates, emphasizing the silvical characteristics of the more important species, of logging methods and rules to prevent waste. Actual calculation of the cut was confined to a rather crude diameter-limit method which emphasized the possible periods of return for an equal or approximately equal cut. Little or no attempt was made to distribute the cut according to the needs of the individual stands: the regulation was by volume alone.

As working plans these were, probably, with rare exceptions, failures; for no plan can hope to live that is made from the

* See "Working Plans: Past History, Present Situation, and Future Development," by Barrington Moore, Proc. Soc. Am. Fsters., Vol. X, No. 3, pp. 217–258, especially pp. 220 to 224.

outside without an adequate understanding of the silvicultural and economic conditions. It was a precocious attempt to make a plan on European models without the basis of exact knowledge which is the fruit of decades of European experience.

The plans, as such, were valuable chiefly for the estimates, maps, and other field data which they furnished to the owner, and for the volume, growth, and other silvical data which they furnished to the Bureau, together with a splendid field training for the men concerned in the work.

It is doubtful if any of the plans were ever maintained; for no adequate provisions were made for their control and revision and, though drawn up for decades in advance, they soon lapsed into desuetude.

Some were published as bulletins of the Bureau, and are now chiefly valuable for the volume and growth tables, and other silvical data which they contain, and as landmarks of the progress toward an American forest management.

SECTION TWO

RECONNAISSANCE

On February 1, 1905, the Forest Service of the Department of Agriculture took over the charge of the then forest reserves. The tremendous task of organizing the administrative machinery over an area of over 100 million acres absorbed all the energies of the forest service, and although the need of working plans was repeatedly recognized by those in authority and a few sporadic plans were actually made,* nothing systematic was

* For the details of this development see article "The New Reconnaissance, Working Plans that Work," in Proceedings Soc. Am. Foresters, Vol. IV. No. 1. Reprinted Yale Publishing Association, 1909. See also "Working Plans: Past History, Present Situation, and Future Development," by Barrington Moore, Proc. Soc. Am. Foresters, Vol. X, No. 3, pp. 217–258, especially pp. 224–232.

done until the winter of 1907–08, when for the first time rough estimates of the timber standing on the various national forests were compiled.

The section of reconnaissance in the office of forest management was reorganized and its activities diverted from a study of the distribution, existing volume, utilization, and management of the more important commercial species (so called "Commercial Tree Studies") to the far more pressing task of systematizing and controlling the estimates, allowed annual cut, marking rules, stumpage rates, and sale policy of the national forests which then aggregated about 175 million acres.

The compilation of estimates from the various national forests was so glaringly inadequate that steps were immediately taken to secure reliable estimates of all the forests, beginning with those where the cutting was heaviest and threatened to exceed the proper allowance. By the placing of several parties in the field each season good progress has been made towards securing fairly reliable estimates and forest descriptions and usually excellent maps.

Based on these field data, insufficient though they are, simple working plans have been prepared in accordance with standard outlines. The outline of 1912 which is still in effect is as follows:

I. General Description

(General data which relates to two or more sections of the plan, or which can be treated more logically here than under other sections. Under most headings the discussion will be a summary of important points treated in detail in other sections of the plan.)

Creation. Area, past and present. Totals of alienated lands by classes. (Tabulated form.)

Physical features. (Concise. Include the information which has a distinct bearing upon or forms the basis for the provisions of the plan.)

- Climate. (Data not of direct application may be placed in the Appendix.)
- Topography. (For use in the division of the forest into working circles, as well as its bearing upon use, development, and administration of the forest.)
- Geology. (As it affects soils, etc.)
- Soils. (In such form that statement made may be applied directly in silvicultural practice, settlement, policy, etc.)
- Land classification. Forest, agriculture, grazing, barren, etc. (Tabulated. Brief discussion, if necessary.)

Transportation. (Railroads, water, etc., only as it affects the administration or the development of the forest.)
Settlement. Present and probable future. (As it affects the forest and the plan.)
Industries. Mining, grazing, ranching, lumbering, etc. (Only as they have a bearing on the plan.)

II. Silviculture

Timber:

- Estimates and detailed descriptions of timber. Estimates by species, separately by divisions, blocks, and other natural or artificial subdivisions. Quality and condition of timber, age classes if stand is even-aged, accessibility, information on logging, etc., as necessary, cut-over areas. (Tabulation.)
- Forest Types. Composition, occurrence, distribution of age classes, and condition of timber. (Concise general descriptions, and the fundamental silvicultural requirements and principles which form the basis for the choice and application of silvicultural systems.)
    - Species. (Concise. Treat, from the standpoint of the type and the stand rather than the individual tree, the characteristics and requirements upon which will be based conclusions regarding the species to be favored and the relation in the management of each species to the others in the stand or type.)
        - Climatic, soil, moisture, and light requirements.
        - Growth, form, volume, etc. (Tables to be included in the plan if they will be used frequently, otherwise in the Appendix.)
        - Reproduction. Advance reproduction present. Conditions necessary to secure it.
    - Value of wood. (Properties. Comparative values.)
    - Causes of injury. Fire, insects, fungi, mistletoe, smelter fumes, weather, animals, etc. (Control under protection.)
- Increment. Yield tables or other data, or the method used to determine increment. Effect of thinnings on growth, etc.

Timber operations.

- Markets.
    - Consumption and demand, local and general, past, present, and future. Relation to surrounding forests if any. Cut, by years, sales, and free use. (For use in the determination of working circle boundaries and in regulation.)
    - Prices. (To aid in stumpage appraisals.)
- Methods and utilization. (Methods in relation to preservation of proper silvicultural conditions, also as a basis for costs. Reasonable possibilities in utilization.)
- Costs. (As a basis for stumpage appraisals.)

Objects of Management. Watershed protection, species of timber and classes of material, sustained annual or periodic yield, etc. (State specifically in order of importance the objects which materially affect the provisions of the plan.)

Silvicultural Systems and their application. For each type. (Concise descriptions of the systems adopted and provisions for their specific application. Include brush disposal.)

Regulation of yield:

- Rotation, cutting cycles, etc. (Rotation of maximum volume production. Cutting cycles as short as practical considerations will allow.)
- Division of the forest into necessary divisions (working circles), areas within which sustained yield, annual or periodic, is now or will ultimately be desirable, based upon markets, transportation, and to-

pography. (This may be done elsewhere in cases where such action will simplify treatment.)

Blocks and chances only when they are actually needed to assist in regulation. (Blocks—main logging units or groups of logging units. Chances—single logging units or the subdivision of blocks necessary to carry out the management.)

Annual or periodic cut. The limitation of cut including sales and free use. Accurately for ten years, and approximately for the periods of the rotation. (Include in the plan only the essential features of the method used, and cover necessary details in the Appendix. Blank table for tabulation of limitation and amounts actually cut. Sales and free use.)

Sales. (By divisions, if advisable.)

Policy. Restriction and encouragement and location. (The plan of cutting and specific application to actual conditions of the preceding conclusions and of the service policy and regulations. Past management to be treated only as it will help in an understanding of that proposed.)

Stumpage appraisals. Maximum and minimum rates.

Administration and other features. Special force needed. Costs. (Summary for use in obtaining total forest expenditures in Section VII.)

Free Use. (Principles applying specifically the general free use policy, especially where it is more or less vague and general. By divisions, if advisable.)

Present and prospective annual demand by classes of users and of forest products.

Policy, restriction, or encouragement by districts and classes of products.

Administration. Free use areas. Blanket or year long permits. Other measures to promote economy. Special force needed. Costs. (Summary for use in obtaining total forest expenditures in Section VII.)

Map or maps showing topography, types, classification of timber, boundaries of divisions, blocks, etc., free use areas, cut-over areas, etc.

Forestation:

General relation to ultimate timber management.

Areas requiring forestation. By types. (Brief description. Tabulated.)

Methods and species. (Concise. Base upon results of past work. In addition to sowing, planting, etc., include seed collection, poisoning rodents, etc.)

Detailed plan. (Five years, or if impracticable, omit and provide for annually.)

Areas, methods, and costs. (Tabulated.)

Administrative features. Special force needed. (Regular and special work such as seed collecting, etc.)

Nursery.

Ultimate production, species, and numbers.

Methods. (Essential features.)

Detailed plan. (Five years.)

Species, numbers, and costs. (Tabulated form.)

Administrative features. Special force needed.

Map showing areas to be reforested, classified as above, etc.

Investigations: (Which can be conducted inexpensively in connection with the regular administration of the forest and which should result in practical information needed in the administration. Brief.)

III. Grazing

Range Management:

Types. (Concise descriptions of each.)

Names of important and characteristic forage plants.

Accurate data on seasons of growth.

Accurate data on forage value.

Acreage. With forage. Waste. (Tabulated.)

Carrying capacity. Present. Possible. Brief descriptions. By allotments or divisions. (Tabulated.)

Demand and other local conditions in the live-stock industry which affect grazing on the forest. Relation to silviculture.

Allotments.

Arrangement. (Division of the range between cattle and sheep, grazing districts, and individual allotments to be shown on map. Guiding principles, or necessary comment in the discussion.) To secure

Best division between cattle and sheep.

Full and equal utilization.

Best division of types and early and late ranges.

Best division of watering places.

Proper silvicultural and watershed protection.

Number and kind of stock grazed. By allotments or divisions. Number of permits by classes.

Seasons. (To secure full utilization of the forage without seriously interfering with the natural requirements of plant growth, each portion of the range should occasionally, every few years, be grazed only during the last half of the natural growing period in order to keep the plant constitutions strong and allow some actual reseeding. So far as is consistent with this principle, the green tender feed should be available for the stock during as much of the season as is practicable. This is essential, especially for sheep. This plan may be considered a variation of seasons or a division of allotment.)

Fees. By classes of stock and season. (Tabulated.)

Methods of handling stock.

Cattle. (Salting and necessary riding by permittees to secure equal utilization of range and prevent congregation along streams and water holes, with resulting destruction of plant growth and poor development of stock.)

Sheep.

Size of bands.

Herding. (Develop open quiet herding and avoid driving back to camp.)

Salting. (Encourage abundant use of salt, it means easier herding, less danger from poison and disease, and less damage to the range.)

Other stock. (When special provisions are required.)

Range improvements:

(Permanent improvements in the improvement section.)

Reseeding either with cultivated plants or by restricting grazing for natural reseeding, posting poisonous areas, changes or improvement in stock driveways, extermination of predatory animals, prevention of erosion by proper handling of stock.

Policy and administration.

General principles of policy not already covered. Protective and maximum limits, new owners, advisory boards, etc.

Administration. Extermination of predatory animals, counting stock, or other special phases of the work. Special force required. Costs. (Summary for use in obtaining total of forest expenditures in Section VII.)

Investigations:

Proper seasons, carrying capacity, poisonous plants, artificial reseeding, demonstration tests of proper utilization, effect of grazing upon reproduction, and most efficient systems of grazing management to eliminate damage. Herbarium with necessary notes.

Map or maps, showing types, water, fences, corrals, topography, grazing districts, allotments, reserved areas, driveways, or other factors or features which influence or illustrate the handling of the stock.

IV. Lands

Settlement:

Soils. (Classification with brief description and a statement of comparative agricultural and forest value of each class based upon land values, forest expectation values, etc.)

Demand for agricultural lands. Past, present, and future.

Policy. (In 1, 2, and 3 order, application of policy based upon the preceding classification, results of past policy, service policy, and any other principles as a guide to examiners. Practicability of detailed classification of certain districts in advance of application.)

Map, showing soil classification, if data is available.

Uses and Easements:

Resources.

Demand. Past, present, and future.

Policy. (Special features which are important by kinds of uses or easements. Include charges compared with value to users.)

Water-power:

Resources. Streams, sites, power. Cost and market data and stream measurements. (Tabulate.)

Demand. Past, present, and future.

Policy. (Special features.)

Administrative sites:

Sites, rights of way, etc., withdrawn, or still needed and to be withdrawn. Include comprehensive plan of rights of way needed for future sales and other uses as well as sites and rights of way required in administration. (Tabulate or show on map.)

Administration:

Special force needed. Other administrative questions.

Costs. (Summary for use in obtaining total forest expenditures in Section VII.)

Investigation:

Map or maps showing status, location of uses, easements, water-power projects, administrative sites, etc.

V. Protection

Fire: (By divisions or geographical subdivisions, if advisable.)

Liability. Statement of value of destructible resources by classes, and for districts or regions.

Timber, expectation value of young growth, forage.

Arbitrary value per acre of watershed protection. (Possible money damage. Tabulate.)

Hazard or risk. Statement by types or regions based upon character of stand, danger of fires starting, and difficulty and cost of suppression. (Should be based in part upon a study of past experience.)

Protection required. (Principles which sum up on the basis of liability and hazard the relative amount of protection needed in specified parts of the forest.)

Control.
- Improvements available. By districts. (Brief description, tabulate if map is not sufficient.)
  - Communication. Telephone, etc.
  - Transportation. Railroads, roads, trails, pack trains, etc.
  - Fire lines.
  - Look-out stations.
- Supplies and tools. (Distribution or how they are to be purchased. etc. Tabulate.)
- Coöperation.
  - Adjoining forests, between ranger districts, State associations, corporations, individuals, etc.
- Organization and administration.
  - For look-out stations and patrol. Numbers of men and duties by districts. (Tabulate so far as possible.)
  - For fighting fires. (Tabulate if possible.)
    - Regular and temporary force.
    - Coöperation, labor, including users.
    - Outside labor.
  - Costs. (Summary for use in obtaining total of forest expenditures in Section VII.)
- Specific and detailed instructions to rangers based on the above, and resulting in its direct application should be issued to all forest officers engaged in fire protection.
- Map showing types, topography, improvements, and as much of above information as is possible and advisable. Copies to accompany letters of instruction.

Insects:
- Extent of infestation and damage.
- Control, administrative measures, methods. Special force needed. Costs. (Summary for use in obtaining total of forest expenditures in Section VII.)

Other damages:
- Extent. Amount of damages.
- Control, administrative measures. (As under Insects.)

Game:
- Policy and administrative measures.

Investigations:

VI. Improvements

Improvements. Comprehensive plan of the improvements needed. Location, brief description, estimated costs, indicate those which should be undertaken within the next five years. (Tabulated form.)
- Roads, trails, telephone lines; fire lines, administrative fences, stock fences, including the fencing of poisonous areas and bog holes, bridges, corrals, dwellings, other buildings, water development, steam improvement, dams to prevent erosion, other projects.

Maintenance, as above.

Policy and administration.
- Improvement policy of the forest. (Concisely by lines of work such as silviculture, grazing, protection, general administration, etc.)
- Administrative provisions. Special force needed. Costs, exclusive of the costs of individual projects.

Map showing all improvements constructed and planned, with a sufficient amount of other data to make intelligible.

VII. Administration

Administrative districts. Number, area, and relative importance or amount of work. (Tabulate.)

Force. Office and field and assignment. Salaries.
Also a brief forecast of future requirements. (Tabulate.)
Permanent, statutory.
Semi-permanent and temporary.

General administrative policy of forest. (General relation of important lines of work. Include also points not already covered; fully and briefly in 1, 2, and 3 order.)

Receipts and expenditures and results. By lines of work for fiscal years, past and estimated future.
Administrative provisions for increasing receipts or reducing expenditures.

Map, boundaries of administrative, or other districts.

Appendix

Material which should be preserved in connection with the plan, but which will be used infrequently in actual forest administration.

List of species.

Details of methods used in the collection of data, costs, and areas covered. (Reconnaissance.)

Tables, growth, volume, etc., when it is reasonably certain that they will be used infrequently.

Details of method for regulating yield.

Detailed silvical discussions upon which conclusions and principles outlined in the plan are based, if preservation seems necessary or advisable.

General notes upon which the conclusions in the plan were based.

Inventory of existing improvements, if desired. (Tabulate.)

The first attempts to determine the allowed annual cut for each national forest, necessarily in advance, often, of any regular working plan, were very crude. Nevertheless, though based on insufficient data, the attempt recognized the fundamental principle of a sustained yield.

For each national forest the annual cut has been fixed since 1908. At first this was taken, roughly, as equal to the current annual increment, a crude calculation based on often faulty estimates and insufficient growth data, but giving at least a working basis.

The allowed cut so calculated was not distributed on the ground, since this would have been a useless play, but instead a definite sale policy was drawn up for each forest by dividing the forest into areas where ordinary sales, i.e., of large size, are desirable, areas where small sales (for local industries) only are desirable, areas for free use of inhabitants only, and areas reserved as protection forest.

This rough division of area, indicated on forest and district maps, was further supplemented by general notes on areas requiring cutting because of overmaturity, insect damage, disease, fire, and the like.

Minimum stumpage rates for each species and class of material were also fixed for each national forest so as to prevent the wide variation in prices obtained.

It had been the custom to draw up special marking rules for each timber sale of larger size. To avoid constant repetition these began to be combined into a set of marking rules for all the various forest types contained within a certain national forest and these rules made standard for all sales within that forest.

The rules by forests were then combined into general marking rules for the various silvical regions of the West. This work was completed in November, 1908, and the mimeographed marking rules as sent out to all forest officers represented the best information then available on the very important question of marking trees for cutting in timber sales. They have been revised from time to time and have been aptly supplemented by actual examples of properly marked areas as an ocular demonstration of how to do it.

Although the section of reconnaissance had brought together all the data stored in the files of the service and built thereon the first crude beginnings of a systematic forest organization, further progress would have been impossible except for the active coöperation of the men in the field. Realizing the inadequacy of the existing estimates and the time which must elapse before each forest could be covered by detailed reconnaissance, a circular letter was sent to all the supervisors in the spring of 1908 requesting them to make every effort to correct and amend existing estimates during the approaching field season and to segregate the estimates by blocks (i.e., by watersheds), by species, and by classes of material.

A similar letter was sent asking the supervisors to draw up, each for his forest, a plan of sale policy, indicating those areas on which cutting should be restricted or encouraged according to economic and silvicultural conditions, etc.

The first crude regulations of the cut, sale policy, and minimum stumpage rates were also sent to each of the six inspection districts and the chief inspector requested to revise and amplify them according to his local information.

In the Southwestern district (No. 3), Acting Chief Inspector Woolsey availed himself of this splendid opportunity to draw up a complete, far-sighted limitation of cut and sale policy for each forest and for the district and also minimum stumpage rates by forests, species, and classes of material. His sale policy was by far the most complete of any prepared, the more so as he proceeded to determine the allowed annual cut for each forest, separately for saw timber and cord-wood, by Von Mantel's method (see method No. 2). Crude as this method is, it was a marked step in advance in the regulation of cut on the national forests.

When the six Western administrative districts were created in December, 1908, the office of management, and with it the section of reconnaissance, ceased to exist. So enormous had been the undertaken task of systematizing and controlling the estimates, allowed annual cut, marking rules, stumpage rates, and sale policy that only the foundations of a correct forest organization were turned over to the districts whereon to build.

The office of silviculture in each of the districts took over the task and the manual of procedure in the district offices provided for annual revisions of the estimates, sale policy, allowed annual cut, minimum (later standard) stumpage rates, and marking rules, to be submitted by the supervisors, combined by the district forester and in the case of the allowed annual cut, forwarded by him to Washington for review by the forester and approval by the secretary. The limitation of annual cut as fixed by the secretary—based, of course, on reasons of sale policy—could not be exceeded without his consent. However, this was seldom required; for inaccessibility and competition with private timber restricted the bare possibility of national forest sales to a point far below what the forests would support. Thus in 1911 the annual cut which the national forests were estimated to be able to sustain permanently, totalled 3,274,-000,000 board feet. The actual cut under both timber sales and free use permits was, in 1916, 665,000 M., but little over 20 per cent of the actual yield of the forests.

SECTION THREE

PRESENT PROCEDURE *

The decentralization of working plans control resulted in a most unequal progress in forest organization. Starting with the same foundations in December, 1908, there were, in matters of working plans, much confusion and wasted effort. This unfortunate condition was relieved by the issuance, late in 1911, of the forest plans section of " The National Forest Manual " † which restores system and purpose to the work of forest organization and is a big step in advance towards unifying the working-plan procedure of the various districts.‡

This has not been superseded by the National Forest Manual of November, 1914. " When the National Forest Manual of 1914 was issued it was decided to omit from it discussions of technical practice. It was felt that these subjects could

* See " Working Plans: Past History, Present Situation, and Future Development " by Barrington Moore, Proc. Soc. Am. Foresters, Vol. X, No. 3, pp. 217–258, especially pp. 233 to 251.

† " The National Forest Manual: Instructions to forest officers, relating to forest plans, forest extension, forest investigations, libraries, coöperation, and dendrology. Issued by the Secretary of Agriculture to take effect November 1, 1911." Washington, Government Printing Office, 1911.

‡ This has been aided by the issuance of " Instructions for Reconnaissance Surveys and Maps," June 9, 1913, amended and incorporated in the " Topographic Survey Manual " of 1916, and of " Instructions for Intensive Timber Reconnaissance," April 3, 1914, amended and reissued as the " Timber Survey Manual " on June 3, 1916.

best be treated in separate manuals. This accounts for so little space being given to the subject of working plans in that Manual. The reference to the 'Working Plan Manual' was to a proposed manual on working plans more complete than any previously attempted. It has not been practicable to undertake the preparation of this manual up to the present time, so that the latest word on instructions and procedures is really that contained in the manual of 1911." *

There follows, in somewhat condensed form, the Forest plans portion of The National Forest Manual of 1911:

FOREST PLANS

The object of the forest plan is to systematize and control the management of each forest upon a definite basis which shall represent the cumulative experience and information which the service has acquired.

Three different kinds of plans, differing only in scope and intensity, will be used in developing the management of the respective forests, namely, preliminary plans, working plans, and annual plans.

A preliminary plan is simply a systematic statement, prepared from the best information now available, of the resources of the forest, the conditions governing their use and development, and the administrative measures to be followed in their management.

A working plan is a similar statement, more complete and final in character, based upon thorough investigation and accurate data, and including a definite scheme of management devised for a period of years.

The annual plan is covered by the various periodic estimates and reports. It constitutes a periodic revision of the preliminary or working plan, together with the specific application of these plans to the business of the forest for the ensuing year.

* The author is indebted for this statement to Mr. R. Y. Stuart of the Forest Service, in a personal letter dated April 17, 1916.

The subjects to be covered in all forest plans are:

1. General administration.
2. Silvicultural management.
3. Grazing management.
4. Permanent improvements.
5. Forest protection.
6. Uses of forest land.

Each forest plan will provide for the management of a whole administrative unit or forest. No plan should include more than one forest. Where conditions in adjacent forests are similar, or the forests supply the same markets, these facts will be considered, particularly in the location of cutting area and limitation of the annual cut. Such considerations will also be necessary in grazing and protection.

Where necessary, because of important market or topographic considerations, the forest may be divided into areas, each of which will be managed with the idea of sustained yield. If necessary to assist in regulating the cut, a subdivision of the above areas may be made; this should be on the basis of logging units or groups of logging units, the boundaries depending entirely upon topography. Unnecessary divisions will not be made, since they complicate administration. Where possible the lines of administrative subdivisions and those for the technical management of the forest will be coördinated.

Final responsibility in the preparation of all forest plans rests with the supervisor. He should, in submitting the plan for approval, transmit any recommendations of the officer in direct charge of its preparation which differ materially from the plan as submitted.

Since the completion of any plan is but the beginning of systematic management, every effort should be made to improve plans which have been prepared and to obtain the additional data needed for more efficient administration.

PRELIMINARY PLANS

A preliminary plan should be prepared as soon as practicable on each forest from the data now available. The compilation of such data in the form of a definite plan of management will systematize and strengthen the administration of the forest and furnish a basis for further extension and improvement. The following points should be covered:

Under "*General Administration*" should be given:

1. The forest force, based upon the men required to transact economically the business of the forest and furnish adequate protection during the fire season.

2. Division of the forest into administrative and patrol districts to be shown on a map.

3. A record by classes of past receipts and expenditures and an estimate of future receipts and expenditures.

Under "*Silvicultural management*" should be given:

1. Divisions and subdivisions, if any, with reasons.

2. Approximate estimates of timber by convenient, technical, administrative, or legal subdivisions.

3. The silvicultural systems which should be used, by types, and by divisions if modification of the system on different divisions is necessary. Principles to govern marking drawn from the best silvical data available. The object of management for the forest, as far as available information makes it possible, or for divisions, classes of material to be produced, species to be favored, and rotation desirable.

4. A rough classification of the timber on the forest, or parts of the forest, in accordance with its age and condition, showing the bodies of mature timber, of thrifty timber not yet in need of cutting, and of young growth; together with a plan of cutting, showing the order in which the various areas should be logged. Areas of protection forest where no cutting is recommended should be indicated. The approximate periods in which immature stands will reach merchantable size should be shown.

5. Recommended limitations on the annual cut * for the ensuing four or five years.

6. Data on methods of logging, accessibility of merchantable bodies of timber, costs of logging and manufacture, markets and market conditions, demand, prices, etc.

7. The policy for the whole forest, or divisions if advisable, which should be followed as to sales, reservations for local industries, and free use, together with the opportunities for desirable sales.

8. Tentative stumpage rates for the entire forest, or divisions.

9. Improvements needed to facilitate the sale or protection of timber. (To be incorporated in the permanent improvement plan.)

10. The approximate areas on which artificial reforestation will be necessary in whole or in part, together with the species. to be used, and, broadly, the plan to be followed during the ensuing four or five years, plans for nurseries, outline of desirable experiments, etc.

11. The order in which the various parts of the forest should be covered by complete reconnaissance,† desirable silvical studies leading toward better management, etc.

This part of the plan should be accompanied by a map showing topography in as much detail as data available will allow, roads, trails, forest types, age classes, if necessary, nursery sites, and areas proposed for artificial regeneration. Much of the other data called for may be shown either on the map or in concise tabulation with explanatory notes.

Under "*Grazing*" the essential point is to compile all available information on the range conditions in the forest as a basis for systematic range protection, development, and improvement. The following outline is intended only as a guide:

1. Classification of grazing lands and estimates of carrying capacity, including:

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* I.e., determination of the cut.

† I.e., forest surveys.

(1) Determination of characteristic ecological types or groups of forage plants, each of which includes certain combinations of grasses, weeds, and browse. The types should be mapped on a base map of the forest. Groups containing poisonous plants may demand particular attention.

(2) Concise descriptions of each group or type including notes on individual species, the seasons when the plants may be used, the relative grazing value of the types, and the class of stock for which they are best suited.

(3) A record in tabulated form of the kind and amount of stock at present grazed on the land, with an estimate of its present grazing capacity, and if overgrazed or poorly stocked with forage plants the capacity to which it may be brought by proper treatment.

2. Range improvements: Map record of present and needed watering facilities, including wells, streams, springs, natural and artificial ponds and tanks, drift fences, and other improvements necessary for the best use of the range. (To be incorporated in the permanent improvement plan.)

3. The plan of management should include, with necessary maps, notes, and explanatory data, provision for:

(1) The control and eradication of poisonous plants.

(2) Improvement of overgrazed or poorly stocked areas, including reseeding, the use of a rotation scheme of excluding stock from areas for a part of the year to allow seeding of native plants, etc.

(3) Fuller use of the range by the class of stock for which it is best suited, including areas not now used.

(4) Exclusion or reduction of stock or the change of grazing seasons when necessary for silvical reasons or the protection of watersheds for irrigation or municipal water-supply. Reduction to prevent overgrazing, or erosion caused by grazing.

(5) The better handling of stock, including salting, bedding, the prevention of concentration to the injury of the range, improved herding methods, etc.

(6) Improvement in range districts, range allotments, etc.

(7) The extermination of predatory animals, based upon the kind and amount of damage done.

(8) The extermination of prairie dogs, based upon the area occupied and the damage done.

A systematic plan for the "*Permanent Improvements*" on the forest should be steadily developed, extended, and improved.

The improvement plan will take the form of a map, and such additional notes as may be necessary for its proper understanding. Rough estimates of cost should be included wherever obtainable. The following kinds of work will be considered: Roads, trails, bridges, telephone lines, signal systems, permanent and temporary headquarters, pastures, look-out towers, fire lines, tool boxes, improvements necessary for range development or making timber accessible, and areas in which the blazing and posting of trails is urgent.

Under "*Forest protection*" provision will be made for protection against fire and insects, and the protection of nurseries and plantations against rodents.

A plan for fire protection, as complete as is now practicable, should be formulated and put into effect on each forest.

The fire plan will consist of a map showing detailed topography, forest types, all permanent improvements which will be of any value in fire protection, look-out points, lines of fire patrol, camping sites, places where assistance in fighting fire may be obtained, areas of particular menace and areas in particular need of protection, and detailed directions to rangers concerning fire patrol, and coöperation with other districts and forests.

Under "*Uses of Forest Lands*" data should be collected showing:

1. Sale prices of agricultural lands within or near the forest, including stump lands, unimproved non-timbered lands, and improved ranches.

2. Cost of clearing and stumping timbered lands.

3. Comparative value of timbered land for agricultural and forest purposes.

The location of all uses which have been granted should be recorded on a base map of the forest. Any information secured as to tracts desirable for particular uses should be similarly recorded, especially reservoir and dam sites, as part of the inventory of the resources of the forest.

The water-power possibilities of the forest, including stream measurements and the collection of cost and market data.

All administrative sites should be shown on the improvement map of the forest. Sufficient additional data will be recorded to show in concrete form the system of administrative sites devised for the forest, including patrol and look-out stations, nurseries, and sites required for logging facilities, and other uses in connection with the sale of timber.

WORKING PLANS

A working plan is simply an extension and development of the preliminary plan, based upon more exact data. Such a plan should ultimately be prepared for every forest as the need for a more systematic basis of management becomes urgent. Reconnaissance work should, except in unusual cases, result in working plans.

Working plans will be prepared first on forest where the demand for timber is great as compared with the supply, and where large quantities of timber are evidently mature and it is reasonably certain that sales can be made if the proper data are secured. It may be advisable to prepare special working plans for forests on which large areas are in need of reforestation. Special grazing working plans may be prepared for forests where the use of forage resources is of importance. Special problems in any other phase of service work demanding careful study may require the preparation of working plans. Where conditions on a forest differ widely, it may be advisable to cover only the part of a forest to which the special administrative urgency applies.

Each working plan will outline the general management of the forest for a long period, usually a rotation in the recommendations on timber cuttings, and the management in detail for some such period as ten or fifteen years.

The amount of detail in the working plan will depend upon the value of the forest products concerned, the need for intensive methods, and the certainty or possibility of large returns within the probable life of the plan. On forests or parts of forests where the demand for timber equals or exceeds the amount which can be cut with safety, the plan for silvicultural management must be in much greater detail than where the demand is comparatively small. The requirements of detail in the different parts of the plan and in different working units must be adjusted to the administrative needs of the forest in all lines of work.

When it has been decided to make a working plan, its essential features and the field-work necessary should be outlined at a conference between the officer who will have charge of the field-work, the supervisor of the forest, the assistant district foresters concerned, and the district forester at his discretion. It is particularly necessary that the general system or systems of management be determined, and the methods for determining the yield of each unit be decided upon. Plans may then be made to secure the exact data needed and unnecessary work eliminated. The preliminary plan for the forest and working plans already prepared will form the basis for this discussion.

Field data will in general be obtained by special parties, which as far as possible should consist of experienced men. As far as possible, the data for all parts of the plan will be collected at the same time, if necessary by specialists temporarily assigned to the party. The data for planting or grazing features may be collected independently when the need justifies it. The work will be done under the direction of the supervisor.

As far as possible all data in the working-plan report will be tabulated with brief notes of necessary explanation. While working plans must be complete, every possible effort will be made to eliminate unnecessary discussion and to put them in concise form. All detailed data relating to climate, geology, soil, growth studies, silvical notes, etc., should be placed in the appendix of the working plan, and everything in the plan subordinated to the actual scheme of management for the forest.

Working plans will be approved by the forester.

The general ground to be covered by working plans is as follows:

Under "*General Administration*" the topics listed for preliminary plans should be discussed with such further detail as more intensive study makes possible.

Under "*Silvicultural management*" the topics listed for preliminary plans shou'd be developed with much greater accuracy and in much greater detail.

To secure uniform data from the national forests in each district, the district forester will decide upon standard field methods. Standardization will include:

1. Methods of making estimates under specified conditions to secure results of uniform accuracy.

2. The unit for recording estimates in both surveyed and unsurveyed ground.

3. The minimum sizes to which timber will be estimated and a method of classifying reproduction and young timber below this minimum.

4. A scale for field and base maps and the conditions under which contour or hachure maps will be made.

5. The form and character of notes on silvicultural questions, forest descriptions, etc.

6. The principles upon which the silvicultural system, the rotation, the period for which management will be planned in detail, etc.

In each district, also, to insure reasonable uniformity under similar conditions, a careful study will be made of the methods of determining the limitation of annual cut under each silvicultural system which will be used, and standard methods established.

In the completed plan the data secured under each topic will be summarized and the conclusions stated. The following points are of special importance:

1. Silvicultural systems based on the most reliable silvical data available, and upon careful observations on the part of the working-plans officer (i.e., the forest organizer).

2. A carefully drawn set of marking principles (marking rules) designed to put into effect the silvicultural systems recommended.

3. The maximum annual cut to be allowed during the ensuing ten or fifteen years, and the approximate cuts for each period of the rotation.

4. The order in which the important bodies of merchantable timber should be sold.

5. The order in which areas needing artificial restocking should be sowed or planted, and the acreage to be covered during each year of the period for which detailed recommendations are made.

Under "*Grazing*," technical reconnaissance and special studies should be conducted, following the general ground covered under preliminary plans, but with more detail and greater exactness; it should be directed as far as practicable by grazing experts.

The *permanent improvement plan*, *protection plan*, *and plan for uses of forest land* for the forest should be considered and developed as far as may be practicable in connection with the intensive timber estimates and other investigations conducted by working-plan parties.

ANNUAL PLANS

The annual reports, estimates, and recommendations submitted on the various lines of forest work should be based upon the preliminary or working plan for the forest and should refer specifically to the portions of the plan dealing with the subject in question. They should show how far it is feasible to apply the plan to the work of the forest during the current or ensuing year, the specific action proposed to put its provisions into effect, and the changes which appear advisable.

Annual recommendations on maximum and minimum stumpage prices and limitation of yearly cut should be submitted to the district forester. These and the planting and nursery reports should refer to the portion of the plan dealing with *silvicultural management* and indicate any necessary changes in its application. Revisions of the cutting methods advocated in the plan and of other features of its silvicultural management should be submitted whenever they appear advisable, together with any additional data secured on estimates, logging costs, market conditions, etc.

The annual *grazing* report and recommendations constitute a concise restatement of the preliminary or working plan and its application to the business of the ensuing year. Additional data should be reported and necessary changes from the plan noted.

In submitting the annual *improvement* estimates a copy of the improvement map of the forest, showing the plan as revised and extended to date and indicating the work of greatest urgency, should be furnished.

In connection with the annual fire report, the *fire plan for* the forest should be checked over and necessary modifications noted. The annual planting and nursery reports should include a current revision and application of the portions of the protection plan dealing with rodents. Special reports and revisions of the forest plan as regards protection from insects and diseases will be submitted from time to time on forests where this work is of importance.

In connection with the current business and periodical reports relating to *uses of forest land*, the preliminary or working plan should be steadily revised and extended.

The application of the foregoing instructions has been

[To face page 248]

A Burned Area Forming a Subcompartment, Arizona.

Courtesy of the Forest Service, United States Department of Agriculture

worked out by each of the districts. The outline for the plan of silvicultural management, as worked out in the Southwestern district, follows: *

The Method.—The forest management, sales regulations, and systematic silviculture will be carried on by means of:

1. Card or sheet records by supervisors.
2. Annual plan by supervisor.
3. Maps by specialists.
4. An appendix file by local force.
5. Preliminary plan by specialists.
6. Final plans. (Not to be attempted at present.)

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* See "A Proposed Method of Preparing Working Plans for National Forests," J. C. Kircher, For. Quart., Vol. XII, No. 2, pp. 145–157. Also "Development of Silvicultural Working Plans on National Forests in the Southwest," J. C. Kircher, Proc. Soc. Am. Fsters., Vol. X, No. 3, pp. 259–262. Also "Forest Service Silviculture Plans," T. S. Woolsey, Jr., Proc. Soc. Am. Fsters., Vol. XI, No. 1, pp. 1–16.

OUTLINE AND INDEX

SILVICULTURAL CHAPTER—SUPERVISOR'S ANNUAL PLAN, 19...

..................NATIONAL FOREST................19...

(1) General conditions:

(a) General conditions of the Forest—areas where insect or fungus attacks have been noticed; damage from live stock and areas from which grazing should be restricted (discuss in detail); from mistletoe or other causes; discuss extent of damage and preventative measures adopted or planned; problems presented by fire..

(2) Cost of handling sales (for past fiscal year)..........................

(a) Summary of costs for each advertised sale during past field season.

(b) How have costs of sales administration been reduced during past year? Suggestions for further reductions..................

(3) Limitation of cut:

(a) Estimate of cut in timber sales, free use, settlement and trespass during present fiscal year, separately for green and dead saw timber and cord-wood.................................

(b) Estimate for coming fiscal year..............................

(c) Reasons for increase or decrease in annual cut.................

(d) Recommended limitation of cut for saw timber and cord-wood for ensuing fiscal year for sales and free use separately..........

(4) Maximum and minimum stumpage prices:

(a) Maximum and minimum prices recommended for ensuing year. (If same as for present year, simply say so.) Explain any changes fully...

(5) Silviculture Manual:

(a) Recommendations for specific changes in the current Manual....

(6) Silvical report:

(a) Subject reported upon last year by forest assistant.............

(b) Subject recommended for assignment during coming field season; name of officer to whom it should be assigned...............

(7) Sowing and planting (omit until forestation is past experimental stage unless reports desired by Director Fort Valley Experiment Station):
(a) Reports to be submitted for all investigative or other projects....
(b) Proposed sowing and planting projects—give location, acreage, method of forestation, etc. If investigative projects follow outline prescribed under investigative projects...............

(8) Timber sale policy:
Suggested modifications of existing policy in
(a) Marking—rules and system of cutting.........................
(b) Brush disposal..
(c) Contract requirements....................................
(d) Utilization...
(e) Miscellaneous...

(9) Seed collecting (to be submitted August 1 of each year on special sheet):
(a) Amount and kind of seed needed...........................
(b) Amount and kind of seed which is abundant...................
(c) Recommendations for seed collecting.........................

(10) Working plan modifications:
(a) Where a preliminary plan has been approved, recommend necessary modifications, so that it may be corrected and amended to conform with the requirements of the next fiscal year. (This should be in shape to fit into the loose lead plan)...........

(11) Converting factors:
(a) Any necessary changes in current converting factors..........

(12) Free use:
(a) Policy and specific plans..................................
(b) Demand..
(c) Complications which have arisen in free use administration during past year with recommended changes and methods......
(d) Areas closed against free use; need for additional areas with complete report on each................................

(13) Current timber sales:
(a) List of newspapers in which timber sale advertisements should be inserted during next fiscal year........................

(14) Timber trespass:
(a) Brief report on all unclosed cases of record giving action necessary to complete settlement.............................

(15) Common and technical names of tree species discovered on forest during past year and not already catalogued......................

(16) Timber reconnaissance:
(a) Required; reasons why..................................
(b) Costs estimated..

(17) New sales:
  (*a*) Areas which should be sold and why........................
  (*b*) Possible purchasers...
  (*c*) Action necessary to promote sales..........................

(18) Protection of timber resources:
  (*a*) Necessary road withdrawals which were omitted when land was recommended under the Act of June 11, 1906.............
  (*b*) Mill sites which should be withdrawn from entry under the Act of June 11; give location and area, and necessity for withdrawal

(19) Stock excluded areas:
  (*a*) Recommendations with full explanation for timber sale areas from which stock of specified classes should be excluded to prevent unusual damage to reproduction. (See paragraph 6, Form 771*a*)..

(20) For each sale submit estimate of unburned slash; acres which must be burned (reduce fire lines to acreage basis); cost of burning per acre; percentage which can be disposed of by regular force; additional allotment required (to be submitted on September 1st of each year).

(21) Investigative projects (to be submitted November 1st of each year): Special studies recommended for consideration by the District Investigative Committee; give details of new studies recommended, i.e., purpose and need, showing relative importance, general scope and method, and probable cost ....

(22) Correction of watershed or logging unit estimates on Form S 15 which follows ....

FORM S 15 (FOREST AND DISTRICT)

CUMULATIVE REPORT OF STAND (BY LOGGING UNITS) IN M.B.M.

Watershed...................... District........................
Logging Unit................... Forest..........................
Forest plan division..............

Stand 19.... 19....

	Cut.	Loss.	Net Stand.	Cut.	Loss.	Net Stand.
Yellow pine..........						
Douglas fir..........						
White fir............						
Engelmann spruce....						
Miscellaneous........						
Total.........						

To be cut.............per cent
To be left.............per cent
No. of cords=
Per cent of error in estimates.

....

19.... 19....

	Cut.	Loss.	Net Stand.	Cut.	Loss.	Net Stand.
Yellow pine..........						
Douglas fir..........						
White fir............						
Engelmann spruce....						
Miscellaneous........						
Total.........						

To be cut.............per cent
To be left.............per cent
No. of cords=
Per cent of error in estimates.

INDEX

BOOKS

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By John Arden Ferguson, A.M., M.F., Professor of Forestry at The Pennsylvania State College. viii+241 pages. 5¼ by 8. Illustrated. Cloth ....net, **$2.00**

This book brings together in available form ideas and principles relating to the care and management of the farm woodlot and the utilization of the products of the woodlot.

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