SILVICULTURAL MANAGEMENT OF THE OAK-HICKORY FOREST TYPE IN SOUTHERN MICHIGAN

THESIS FOR THE DEGREE OF M. F.

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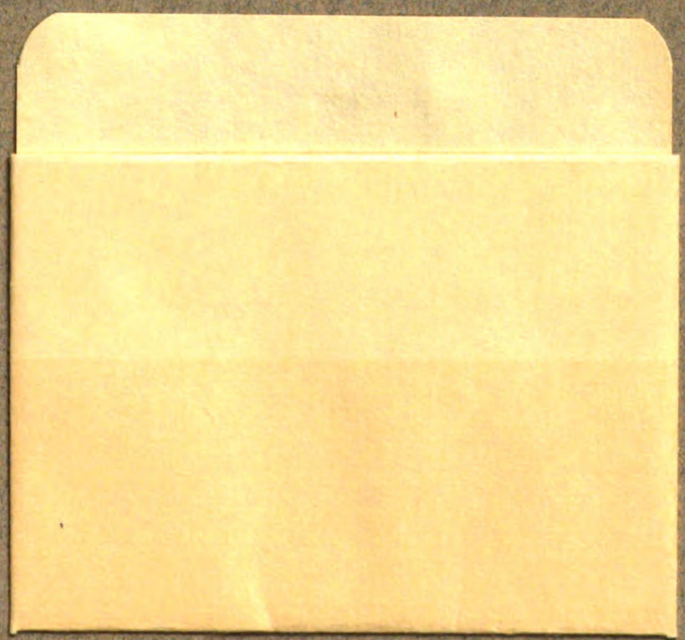

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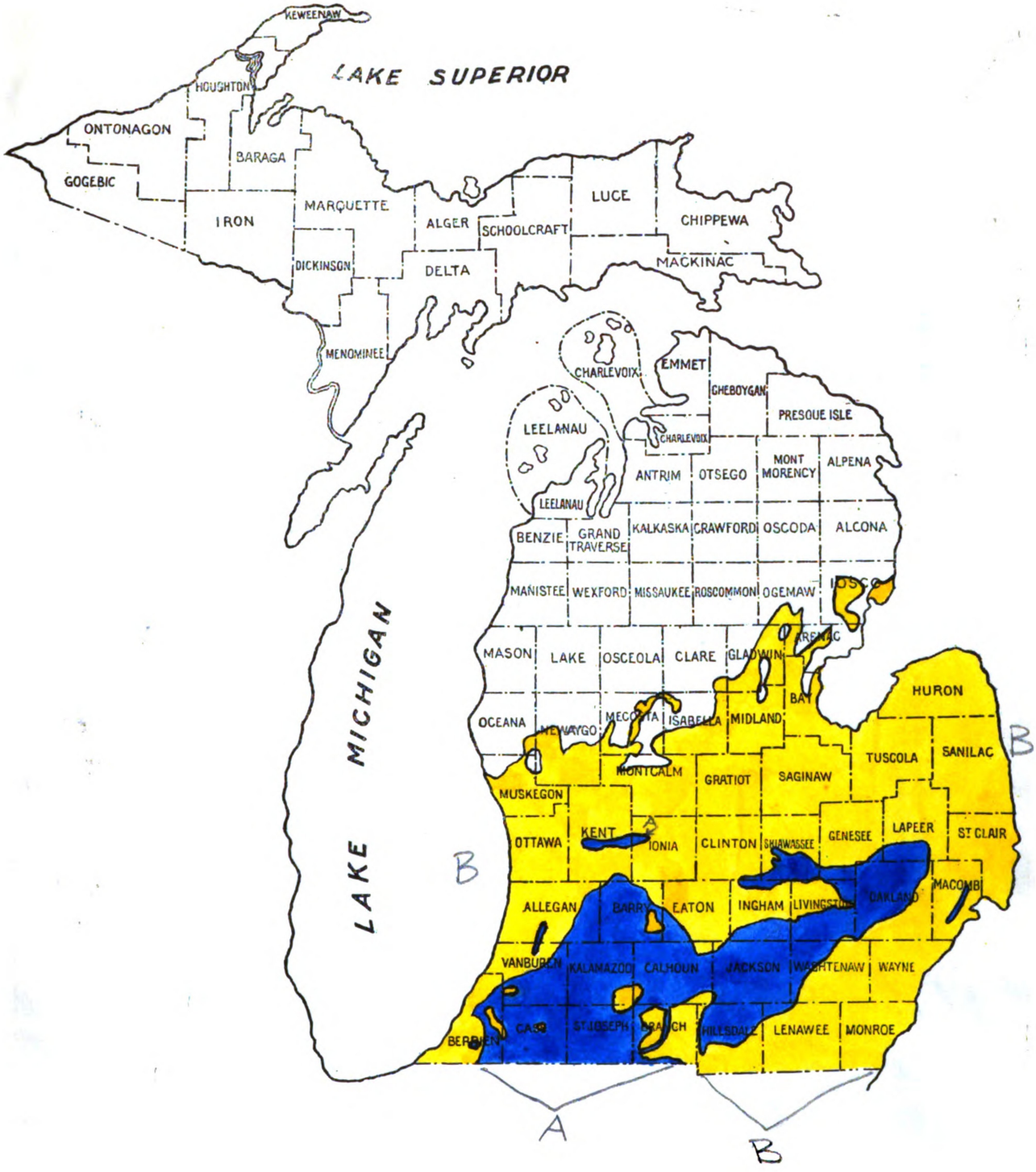


Figure 1

THE OAK-HICKORY TYPE

A Blue - Oak-Hickory dominant.

B Yellow - Not dominant, but plentiful.

CONTENTS

SILVICULTURAL MANAGEMENT OF THE OAK-HICKORY TYPE IN SOUTHERN MICHIGAN

THE TIMBER-GROWING SITUATION

Throughout the region in which the oak-hickory type is found there are many problems to be solved, both economic and silvicultural. Most of the problems concern farm woodlots, as they comprise much more area than larger tracts.

The farm woodland area east of the Great Plains is more than 152,000,000 acres, or over 44 per cent of the total area of timbered and brush land. Farmers own 40 per cent of all the timber in the eastern United States.

Most of the writings on forest problems have discussed conditions in farm woodlots. Larger tracts of timber have problems of cutting methods, reproduction, logging, and marketing, and there is room for much research.

The difficulty of finding a market for woodlot products sometimes impedes silvicultural practice. For instance, it may be necessary to make improvement cuttings, but if no market is available it is better to leave the trees standing. Trees may be left several years, however, without much deterioration. Silvicultural practice is largely dependent upon profitable marketing of woodlot products.

The method of taxing as followed under the general property tax is unfair to the timber owner, as the rates and assessed valuations are not reduced in proportion to the yield from timberlands.

A tax each year at the same rate as on cropped land results in accumulation of tax payments for possibly many years before the timber can be cut, and the returns are sometimes less than the total tax payments.

Many states are now passing laws to relieve the situation. Michigan has two laws to encourage private forestry. One is for woodlots up to 40 acres in area, and one is for larger wooded areas which are only valuable for growing timber. The chief accomplishment of each act, when applied, is to reduce the tax burden (112, 110).

Ohio (119), Indiana, and Wisconsin have similar tax laws for woodlots or for large areas in private ownership. These laws usually prohibit all grazing.

As a sidelight on a discussion of private woodlands, it is interesting to note the opinion of the president of the Federal Land Bank of Springfield, Massachusetts, (88). This bank loaned 42 million dollars, between 1917 and 1926, to farmers in New England. They were long-term first-mortgage loans, made up to about half the value of land and buildings and at a low rate of interest. This is the best form of loan for farmers. Mr. Thomson says, "Our experience has shown that there are many farm loans that could not be made if it were not for the woodlot on the farm being an important part of the security."

The present study recognizes the importance of marketing problems and other economic problems, but confines itself almost entirely to silvicultural needs of the oak-hickory type.

OBJECT OF STUDY

The oak-hickory forest type is a term used by foresters to designate those timber stands which characteristically are an association of oaks and hickories; that is, where oaks and hickories predominate. In ecological terms, oak-hickory is an association of the deciduous forest formation, and is commonly considered as a climax type.

The object of this study was to secure information regarding actual conditions in the oak-hickory forest type of southern Michigan, particularly in regard to regeneration and improvement of the present stands, and from that information endeavor to draw conclusions and make recommendations.

The study is local in scope as far as collection of field data is concerned, but it is felt that the results should be applicable to other stands where composition, former treatment, climate, soil and physiographic conditions are similar. Such may be found in northern Ohio, Indiana, Illinois, and probably in parts of southern Wisconsin and Minnesota. The oak-hickory type extends much farther south, but climatic conditions soon become different.

Not much research work has been done in this type, but the field is broad because of the wide range and importance of the type.

METHODS OF STUDY

Information was collected in different ways. By observation of conditions in the woods, notes were taken and are used in the thesis. The data on the individual trees of the stand were collected by means

of permanent sample plots, on which each tree was numbered with an aluminum tag. One plot was placed in each of the 5 woodlots on the W. K. Kellogg Farm in Kalamazoo County, Michigan. Four plots were one-half acre in area and 1 plot was 1 acre in area. The latter was placed in Woodlot No. 1, an open stand.

Regeneration was studied by means of strip transects, charted in $\frac{1}{1000}$ acre units (6.6 x 6.6 feet square). These units were placed in strips of 2 to 5, making study areas of $\frac{2}{1000}$ to $\frac{5}{1000}$ acre. Each small tree was located on a chart, in the spring. Each transect was again checked in the fall to determine what changes had taken place as well as the cause of those changes. Notes were made on the relation between the reproduction and the various site factors such as herbaceous vegetation, shade and root competition, soil class, and soil moisture.

Studies were made of the possibilities from sprouting of stumps. Diameter growth was studied by means of stump counts on trees recently felled. During marking for improvement cuttings, data were collected on diameter, species, and reason for removal of trees. Figures were later secured as to the volume cut.

An experiment in hog pasturing yielded good results, the object being to break the sod and improve conditions for germination and establishment of seedlings.

Considerable under-planting was done in the woods, and a few figures secured from that.

DESCRIPTION OF THE ORIGINAL OAK-HICKORY TYPE

Occurence and Composition

The distribution of this type can be given only roughly, in the stricter sense at least. It is less difficult when mixed forests with oak-hickory predominant are included.

In Michigan the type was prominent in varying degrees of predominance south of a line drawn east and west through Saginaw Day. Within that region were many areas of maple, beech, basswood, and associated species, found on the better soils. Many mixtures also occurred, between maple-beech and oak-hickory types. Practically all of this region was once covered with extensive forests of hardwoods. Toward the northern limit white pine and hemlock were often mixed with oaks, and basswood, elm, and red maple occurred on the lower lands. Less numerous, but sometimes found among the oaks, were white ash, black walnut, butternut, and (very sparingly in the south) yellow poplar. These are woods of high value today, but much less numerous.

Zon (107) describes the oak-hickory as becoming more pure toward the west, embracing western Ohio, Indiana, Missouri, and Oklahoma, and largely bordering on the prairies. The oaks and hickories, with some ash, black walnut, elm, and box elder are the species which push farthest into the prairie region. Hickory is especially predominant in the Mississippi Valley in western Tennessee, eastern Arkansas, and northwestern Mississippi. Zon's

distribution of oak-hickory also includes a large part of southern Wisconsin from Milwaukee north and west across the state and following up the Mississippi Valley; a strip in Minnesota extending for some distance up the Mississippi and then following along the edge of the prairie into the northern part of the state; a large area in eastern Texas extending almost to the Gulf and to the Rio Grande; and toward the west this type, mixed with cottonwood and other species, follows the water-courses across the short-grass plains almost to the foothills of the Rockies.

In Indiana (23), the original and present types consist sometimes of almost pure stands of white oak or black oak, the former on hard clay soils, the latter on clay grading into sand and gravel. Chestnut oak is found on ridges with shallow sand-stone soils, where all tree growth is more or less stunted.

Hickory does not seem to be prominent in Indiana, but is mentioned as a tree for planting in the better, deep and level, soils of the white oak type.

The oak types seem to be distributed more through the southern and northern portions of Indiana than through the central part.

In Illinois (10), on the bottomlands of the rivers, we find white oak, swamp white oak, hickory, and other equally important species in mixture. These soils are rich, mostly clays or silts. Other less important oaks are found also.

On sand plains and dunes, black-jack oak occurs on the poorer sites, black oak, hickory,and white oak on the better ones. This type is intermediate between bottomland and upland types.

In the upland types are found some rich soils, especially in the Ozark upland south of the limit of ice invasion and on loessial uplands bordering river flood-plains, where the best oaks, hickory, tulip poplar, ash, red gum and black gum, elm, wild black cherry, black walnut, and cucumber-tree occur.

In the glaciated region of Illinois are found some of the better species as well as poorer ones, on silt loams or poorer soils.

Oak and hickory occurred in southern Ontario, but no information was secured as to its character in original stands.

In general, the oak and hickory occurred throughout the region in mixture with other hardwoods and seldom in pure oak, hickory, or oak-hickory stands over a very large area.

Physiography of Southern Michigan

The oak and hickory in Michigan are on glaciated land, and therefore a great variety of soils and sudden changes occur between them. Soils range from very light sands and coarse gravels to heavy clays, and one extreme may break into the other extreme within a few feet.

Most of southern Michigan has a rolling topography. Drainage is not complete in many parts, and lakes and swamps are plentiful. The outwash plains are often very fertile and make the best farm lands in the oak-hickory areas. The soils in general are not as good as those where maple and beech occurred in the original forest.

Veatch (36) has reconstructed the original forests of Michigan, based on a study of soil types. This determination

is presumed to be accurate, at least on areas where the soils have been mapped. Figure 1 shows the area where oak and hickory were dominant or in nearly pure stands. The blue area was primarily oak-hickory. Yellow is the area where oak and hickory were usually not dominant but were found mixed in considerable quantities with other hardwoods.

Veatch has for several years been taking notes on the relations between forest cover and soils, and studying certain areas where soils are accurately mapped and where remnants of the original forest still remain.

From a study of one area of one and a half townships in Ingham County, some interesting correlations may be seen. The most fertile, loam soils bear maple, beech, and basswood, with other hardwoods, but very little oak and hickory. Fox loam, however, seems to bear oak and hickory as dominants, with some hard maple, beech, basswood and elm. But with increasing sand or gravel content, in sandy loams, gravelly loams, loamy sands, and sand, oak and hickory become more and more prominent. These species form the characteristic association of all the sandy loams and sands, with some variation in mixtures due to wetness or dryness of sites.

The settlers in the early days recognized a relation between soil and forest, and soon came to regard "hardwood land" the better soil for general farming, and "pine land" the poorer. Scientists have long known that correlations exist between soils and plant distribution and growth, and they have recorded such observations. That correlations do exist, then, can be accepted without question.

It is a modern concept that climate determines the regional character of soil (9C); "While, locally, differences in moisture and temperature which have been a cause of variations in native vegetation have also been the natural factors, in association with parent soil material which have caused local variations in soil. Since the plant derives its water and nutrients mainly from the soil, it follows that differences in these factors in the soil must effect corresponding differences in individual plants or in associations of plants."

Relationship is worked out by Veatch on the basis of soil type, the entire profile and all soil factors being considered. It is not generally true that a geological formation is the equivalent of a soil, and that assumption should be discarded.

Climate of Southern Michigan

The climate of southern Michigan may be represented well by a description of the climate of Kalamazoo County, which lies in the heart of the oak-hickory type, as given in the soil survey bulletin of that County (8C). "Kalamazoo County is characterized by short summers and long, cold winters, not always severe. In the winter the temperature may fall to 20° or more below zero. In the summer it may range from 100° F. to 34° F. The mean annual temperature as recorded at Kalamazoo is 47.9° F. The summer mean is 69.9° F. and the winter mean is 24.9° F. The highest temperature recorded is 104° F. in August and the lowest is -25° F. in February.

"The annual precipitation averages about 34 inches and is well distributed through the year, being heaviest in spring and

summer. The rainfall varies from year to year, but is seldom so deficient as to result in injury to the crops, except on the drier sandy soils. The precipitation for the driest year on record was 21.79 inches. In the wettest year (1877) the rainfall in the spring, summer, and fall seasons was from 4 to 6 inches more than the average. The snowfall averages about 41 inches annually.

"The average date of the last killing frost in the spring is May 10, and of the earliest in the fall October 10, which gives a normal growing season of 153 days. Crops are sometimes damaged by frost. The latest date of killing frost recorded in the spring is May 27, and the earliest date in the fall is September 14.

"The prevailing winds are from the southwest from June to January inclusive, and from the west during the rest of the year."

Recorded at Kalamazoo, elevation 955 feet.

Seeley (80) records the general elevations in Michigan, and it is interesting to note that the elevation of 800 to 1000 feet covers roughly the same area as the oak-hickory type as mapped by Veatch (96) in the southern portion of the Lower Peninsula; an area having a rougher topography, more distinct glaciation, and perhaps more conglomeration of soil types than lower elevations surrounding.

The northern limit of oak and hickory, subdominant, shows an annual precipitation of 30 inches to 32 inches, while the southern border of Michigan shows 36 inches. The greatest rainfall comes in May and June. Snowfall is quite uniform - 40 to 50 inches. Prevailing winds are southwest or west. Average dates

of last killing frost in spring and first killing frost in the fall show a difference of as much as 20 days between north and south in the general oak-hickory area. Length of growing season, therefore, varies from 140 days at the northern limit to 160 days in the extreme southwestern corner of the State.

THE EFFECT OF PAST AND PRESENT TREATMENT OF THE FORESTS

Description of Area Studied

The investigation was conducted on the W. K. Kellogg Farm, 4 miles in a direct line northwest of Augusta, in Kalamazoo County, Michigan. This farm is 14 miles northwest of Battle Creek and about an equal distance northeast of Kalamazoo. The description of location is as follows: Parts of Sections 5, 6, 7, 8, and 9, Township 1 south, Range 9 west. The location is 1 mile south of the Barry County line and 3½ miles west of the Calhoun County line. The area of the farm is about 750 acres, and there are 55 acres of woodland broken into 5 woodlots. These are called woodlots No. 1, 2, 3, 4 and 5.

The timber is of a distinct oak-hickory type, the oak predominating, with several other species in smaller amounts. They were formerly under at least three different ownerships, and differences in condition of the stands are very largely due to the ways in which they were handled.

The topography of the area including woodlots 2, 3, 4 and 5 is rolling and of glacial till, while woodlot 1 is on a level outwash plain. Differences in elevation over all woodlots do not exceed 30 feet. Elevation above sea level is about 950 feet. Drainage is good in all the woodlots.

Differences in soil are not great enough to cause much difference in the composition of the woodlots. They are all on sandy loam or loam soils. What slight differences that do exist

may be due partly to differences in drainage conditions or to cutting in the forest. Podsolization is often evident, with hard cemented layers below the podsol layer. Woodlot 1 is on Fox loam, rusty-brown in color. Woodlot 2 is on Bellefontaine loam and sandy loam. Woodlot 3 is on Bellefontaine sandy loam. Woodlots 4 and 5 are on Bellefontaine loam or grading into sand and muck at the edge of the marsh.

The Effects of Cutting

Reduction of the Area of the Type

The most prominent effect of cutting in the early stands was the reduction of area occupied by the type. The degree of reduction depended upon agricultural activity, degree of land utilization for agriculture, and density of settlement; until now the forest is entirely absent on a great many farms. Where settlement has not been so heavy or where there is poor or rough land, considerable areas may remain as remnants of the original forest. This applies to the oak-hickory type along with other types.

Ohio has 3,500,000 acres of woodland stands.

Barely 7 per cent of Indiana's former forest area remains now. Some cleared land is already being abandoned, due to poor soil and erosion (on steep slopes where farming is attempted). It is stated that at least 75 per cent of Indiana could be devoted indefinitely to agriculture (33).

Indiana had classified 20,311 acres under its tax exemption law for woodlands up to October 1, 1933. Grazing is

prohibited cl... T... forest land. ...,672 ... the state forest, ... productive and public, ... area of Indiana is ...,000 acres (11). ... 5,712,000 acres, and ... 10,000 acres (.7).

The composition of the forest

Species

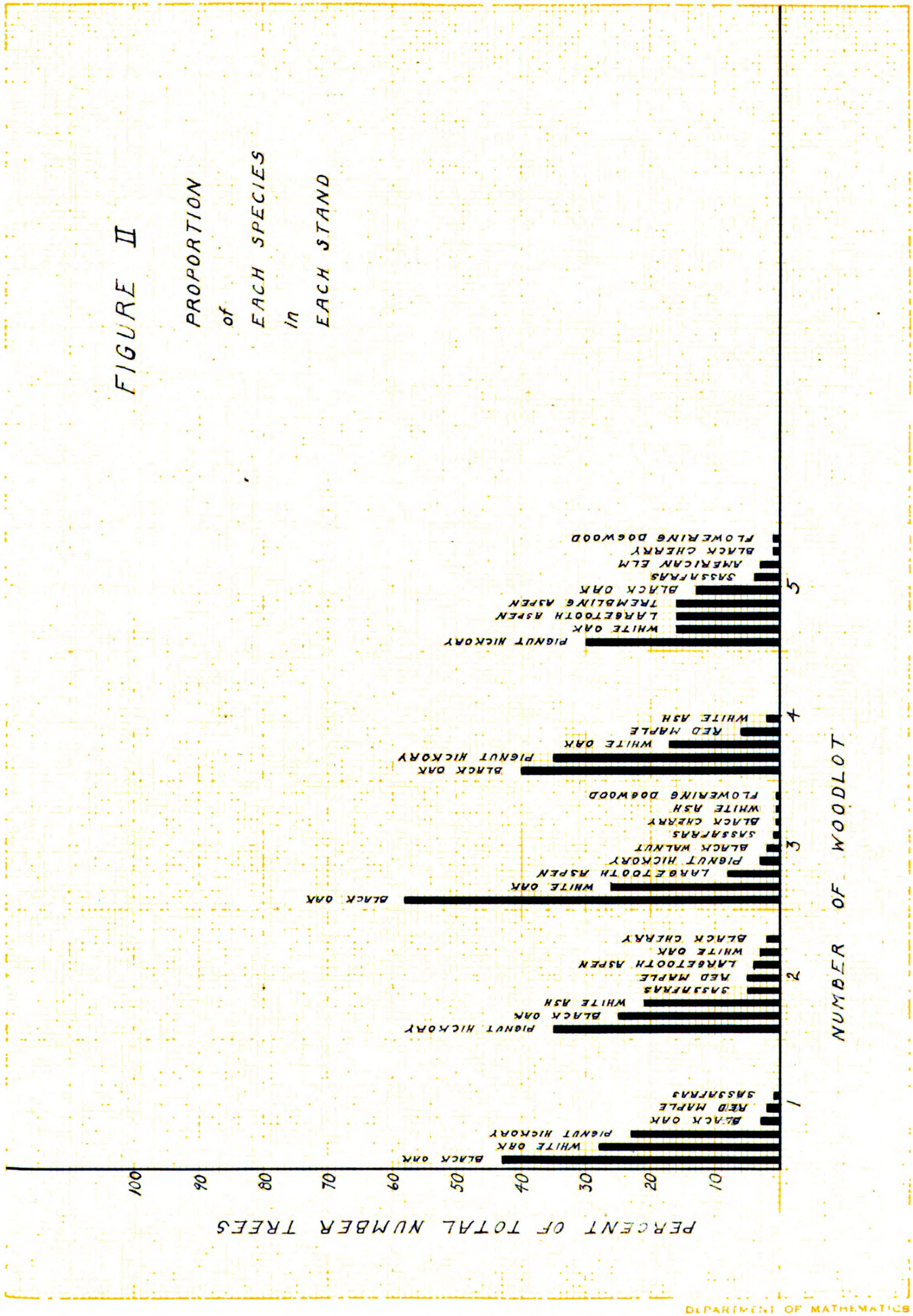
The composition of the oak-hickory type in the ... studied may be shown for each woodlot as in Table 3.

Table I. Composition of the Oak-Hickory Type (Based on ½ acre plots, except one 1-acre plot in Woodlot 1)

Species	WOODLOT 1		WOODLOT 2		WOODLOT 3		WOODLOT 4		WOODLOT 5	
	No. trees per acre	% of total	No. trees per acre	% of total	No. trees per acre	% of total	No. trees per acre	% of total	No. trees per acre	% of total
White oak	38	28	8	3	188	26	30	17	70	16
Black oak	57	43	66	25	426	58	70	40	56	13
Pignut hickory	30	23	94	35	24	3	60	35	136	30
Black cherry	4	3	4	2	4	0.6			6	1
Sassafras	1	1	14	5	8	1			18	4
Red Maple	2	2	14	5			10	6		
White ash			56	21	4	0.6	4	2		
Large-tooth aspen			10	4	56	8			72	16
Fl. Dog-wood					4	0.6			2	1
Bl. Walnut					18	2				
Tr. Aspen									74	16
Elm									14	3
Total No. per acre	132	100%	266	100%	732	100%	174	100%	448	100%

Black oak predominates in three of the woodlots, and pignut hickory exceeds all others in two of the woodlots. Second place falls to white oak thrice, black oak once, hickory once, and in one woodlot second place is held equally by white oak, largetooth aspen, and trembling aspen. The aspens in this case are all small, and the trembling aspen is found only in a dense clump on the edge of a marsh. White ash makes a very good showing of 21 per cent of the total number in woodlot 2, being exceeded only by hickory and black oak, and greatly outnumbering white oak which is only 5 per cent of the total. White ash is entirely or almost entirely absent in the other woodlots. Elm is found only at the border of marshes. Black walnut comprises 13 per cent of woodlot 5, which is a coppice stand of white and black oaks, growing on a hillside sloping west into bottomland a few hundred feet from Gull Lake, a body of water 4½ miles long. The soil is a mixed sand and gravel.

Figure II shows the proportion of each species in each woodlot in graphic form.



Thrift Classes

In order to understand better the number of trees in relation to their future status in the stand, it is important to study the condition of the trees of each species. Three classes were recognized - thrifty, fair, and poor.

1. Thrifty Condition - Healthy in appearance. Smooth, tight, even bark that is practically free from insect holes or of fungus, as examined carefully from the ground level upward. Foliage dense, dark, and lustrous, indicating an abundance of food material. Tree is straight and well-formed. No large dead branches.

2. Fair Condition - General appearance not as good. Tree is perhaps crooked, with small or poorly-shaped crown. Large dead branches indicate lack of nutrition. Foliage not so dense, dark, and lustrous. Perhaps one or two small decayed spots. Trees which can be improved with good management.

3. Poor Condition - General appearance unhealthy. Insect work (bark or wood borers) often evident. Decay may have become a serious menace to the lumber value of the tree. The tree is often crooked or very slender, with very small unsymmetrical crown. Large dead branches indicate over-maturity. Foliage is sparse and lacks luster, and leaves are small. A tree which will probably not live more than a comparatively few years. This is true of some over-mature and over-topped trees.

Table II shows for each woodlot and species the proportion in each condition class.

Table II. Proportion of thrifty, fair and poor trees of each species, expressed in percentage of total number of each species
(Basis: Number of trees per acre, shown in Table I)

Species	Woodlot 1			Woodlot 2			Woodlot 3			Woodlot 4			Woodlot 5		
	CONDITION CLASS*														
	T	F	P	T	F	P	T	F	P	T	F	P	T	F	P
	Per cent of Total Number in Each Species														
Black oak	60	35	5	76	18	6	76	21	3	77	17	6	57	39	4
White oak	53	37	10	0	75	25	62	34	4	53	33	14	40	37	23
Pignut hickory	37	40	23	43	28	29	42	50	8	73	23	4	41	40	19
Black cherry	100			100			0	0	100				67	33	
Sassafras	100			0	29	71	50	50					33	45	22
Red maple	100			43	43	14				100					
White ash				50	39	11	0	50	50	100					
Largetooth aspen				100			32	54	14				31	36	33
Flowering dogwood							100							100	
Black walnut							78	22							
Trembling aspen													87	5	8
Am. Elm													86	14	
Per cent of Total	55	35	10	52	29	19	67	28	5	73	21	6	50	33	17

*Thrifty, Fair, and Poor condition classes are represented by T, F, and P.

It is not always possible to determine accurately the true condition of a tree, or to accurately predict its future, from an ocular examination. One must allow for human error. The classification given above should be valuable, however, for purposes of comparison of the trees in these stands.

An outstanding point is the high percentage of thrifty black oak as compared to white oak and pignut hickory, the white oak being lowest in three of the woodlots and hickory lowest in two of the woodlots. In one stand there were no thrifty white oaks; the number was small and may give a false representation; such is no doubt true of other species that are few in number.

In most cases the proportion of thrifty trees runs well above the proportion of trees of fair condition. But taking fair and poor trees together, the percentage of defective trees is high. The range of percentages for the three main species (black oak, white oak and hickory) is as follows:

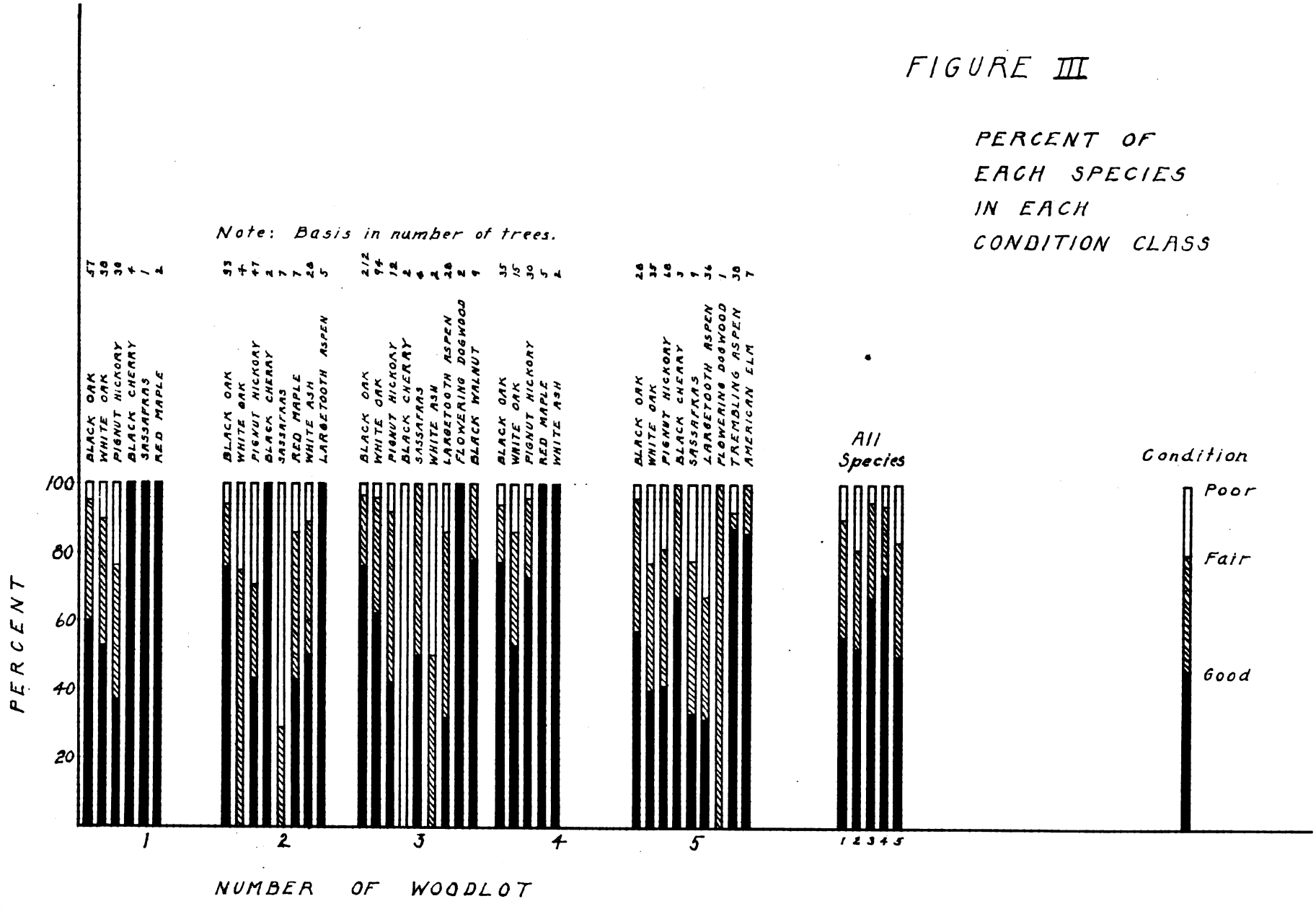
Thrifty condition - 0 to 77%
Fair condition 17 to 75%
Poor condition 5 to 29%

For each woodlot, the proportion in each class, all species combined, varies considerably. Woodlot 4 has the highest percentage of thrifty trees (73%), while Woodlot 5 has the lowest, with 50%. Fair trees vary from 81% to 35%, poor trees from 5% to 19%.

Figure III shows the percentage of thrifty, fair, and poor trees of each species in each woodlot, illustrating graphically the information in Table II.

FIGURE III

PERCENT OF EACH SPECIES IN EACH CONDITION CLASS



Crown classes

The trees on each plot were placed in three crown classes - dominant (including codominant trees), intermediate, and overtopped (oppressed or suppressed). In general, the black oaks are dominant in the larger [illegible], white oak is [illegible], and hickory is largely intermediate. Most of the cherry and red maple are dominant, but there are only a few specimens. Many of the white oaks are dominant. [illegible] equal to the oaks and often become dominant as individual trees or groups of trees. The [illegible] is small, only 10 to 15 feet high in most cases, and is called dominant when [illegible] of trees of about equal height are clumped at the edge of the stand. A single small tree standing in the open was called dominant.

It is a [illegible] that the condition of trees, their vigor or health in particular, is influenced by the position they hold in the stand. In the dominant trees is usually more vigorous than in intermediate or overtopped trees, and vigor is the factor of resistance to disease, [illegible]. Vigor indicates good health. In order to study this relationship, Table III was constructed, showing the number of thrifty, fair, and poor trees per acre in each of the three crown classes, for each locality.

Table III. Number of thrifty, fair, and poor trees per acre, for each crown class

Number of Woodlot	CROWN CLASS								
	Dominant			Intermediate			Overtopped		
	Condition Class								
	Thrifty	Fair	Poor	Thrifty	Fair	Poor	Thrifty	Fair	Poor
	Number of trees per acre								
1	52	19	1	20	56	11	0	1	2
2	110	10	4	24	56	20	4	30	33
3	332	52	10	140	100	0	10	52	12
4	88	6	2	58	30	6	0	2	2
5	126	26	20	82	74	22	14	46	30

The results are much as expected, although it is a little surprising that there are not more poor overtopped trees; in three woodlots there are more fair overtopped trees than poor overtopped trees. It would be expected that most intermediate trees are classed as fair, but that is true in only two of the woodlots. In the other three woodlots there are more thrifty trees than fair trees, and comparatively few poor trees. Dominant trees, however, fall overwhelmingly into the thrifty condition class, and in each woodlot there are many more fair than poor trees.

Relative Amounts of Seedling and Sprout Growth

The cuttings in the oak-hickory type have influenced the amount of sprout growth, which springs from the base of stumps. Old stumps do not sprout as vigorously as young stumps. Woodlot 3 is composed largely of trees propagated by stump sprouts. The former stand had been clear-cut at an age when the stumps were only 6 or 8

inches in diameter and evidently in vigorous condition, for a dense coppice growth resulted, equaling over 700 trees to the acre when at 3 to 5 inches D.B.H. The average D.B.H. for black oak is 3.9 inches, for white oak 2.6 inches, and for hickory 2.3 inches. Practically every tree of these species originated as a stump sprout. Other species, of which there are less than 100 to the acre, are, most of them, also from stump sprouts. Only 8 out of 221 trees appeared to be of seedling origin. There may have been a few more which could not be definitely determined. However, the evidence indicates that almost all the trees associated in oak-hickory stands will sprout, at least when cut at an early, vigorous age.

Some of the large trees in other stands are of sprout origin, but no study of them was attempted. The large, mature trees in the stands originated from seed. Most of the trees in the woodlots, aside from Woodlot 3, were of seedling origin.

A study was made of the amount of sprouting that can be expected from stumps remaining after cuttings. The stumps examined were left from a cutting made in the winter of 1928-29, and were studied in the fall of 1929.

A discussion will be made of each species according to information secured.

White Oak

Basis 16 stumps. Diameters ranged from 1 to 30 inches with only one stump (14 inches) between 6 and 21 inches. No sprouts on any stumps between 21 and 30 inches, those ages ranging from 150 to 250 years. The 14-inch stump was sound and alive but did not sprout. From 1 to 6 inches the sprouting was very prolific, all ages being under 30 years. The maximum number of sprouts was

35, for a 6-inch stump, and the heights were 1 to 3 feet. No sprouts were dead on the 6-inch stump. This stump was also about 3/4 rotten, the rot lying in the center. Some poor trees sprouted, others did not.

Black Oaks

Basis 30 stumps. Diameters ranged from 1 to 24 inches, and the largest stumps were less than 125 years old. The largest stump (24 inches) was only about 80 years old, in sound condition, and bore 9 sprouts from 2 - 4 feet tall, all living. A smaller stump, 20 inches, but older (110 years), was sound but bore no sprouts. This seems to show the vigorous sprouting ability of the faster-growing trees. The largest number of sprouts was 25, on a 5-inch stump; heights of sprouts were 1 to 4 feet, and only 1 sprout was dead. The age was less than 50 years. In general, the sprouting is more prolific when the stumps are small, as the younger stumps are more free from rot and insect work and the cambium is more active. Not all sound young trees sprout, however, at least in the first season after cutting. Survival is good in all cases. All survival is from 75% to 100%.

Pignut Hickory

Basis 7 stumps. Diameters ranged from 5 to 15 inches. At 7 inches and above, the stumps were over 30 years old, but less than 100 years. All were in good condition. The 15-inch stump bore no sprouts. The 11-inch stump bore 2 sprouts 15-20 inches high, both living. A 5-inch stump bore 7 sprouts 2 to 4½ feet high, and all living. All except the 15-inch stump were sprouting. Survival was complete in all but one case. The largest number of

sprouts is 21, on a 4-inch stump, and the heights were ½ to 3 feet. Only 3 were dead, out of the 21.

Largetooth Aspen

Basis 6 stumps. Diameters are divided into four 4-inch stumps, one 8-inch stump, and one 12-inch stump. All are under 50 years of age. Only 1 stump was sprouting. It was a 4-inch stump, in fair condition; there were 11 sprouts ½ - 3 feet in height, and 10 were living. The other stumps, sound and poor alike, were not sprouting. The 12-inch stump had one root sucker.

Sassafras

Basis 6 stumps. Diameters 3 to 11 inches. Ages usually under 50 years. Three stumps were sprouting. The largest number of sprouts on a single stump was 11. This was a 4-inch stump which was in fair condition. The heights were 2 - 6 feet. Eight sprouts survived. Age was under 50 years. The 11-inch stump had 3 inches of rot across the center. There were no sprouts, but numerous root suckers. This stump was over 50 years old. Two stumps were quite rotten and the bark was loose; therefore no sprouting was possible.

Black Cherry

Basis 2 stumps. Diameters 3 and 8 inches. Both were sprouting, the 3-inch stump bearing 8 sprouts which were all living; heights varied from 10 inches to 4 feet. The 8-inch stump bore 3 sprouts. The stumps were less than 50 years of age, and both sound.

Flowering Dogwood

This tree was found sprouting from the stump, but does not need consideration here because it is of little importance except as an under-story tree, for protection of the ground,

for beauty, for protection of birds, and for protection from winds near the forest floor.

The above species all sprout from the stump, and we have a possible source of new tree growth after cutting which will permit short rotations. The growth is more rapid and new trees are started quicker than seedlings are germinated.

The cambium is the active agent in production of sprouts, and should be protected as much as possible. Loosening of the bark, decay, etc., destroy the cambium.

It is not likely that much sprouting occurs in the second season after cutting, due to drying of the stump and cambium layer.

Sprouts of the black oak group seem to shoot up faster in the first season than white oak sprouts do. Hickory sprouts do well the first year. Sassafras sprouts reach the greatest height, 6 feet in the first season.

It should be emphasized that short rotations must be relied upon in coppice stands. Sprouting of trees originating as sprouts is probably no better, in terms of diameter, than sprouting from seedling trees. There are no data on that point. Sprout growth becomes poorer with successive cuttings, due to rot in the base of the trees and deterioration of the old root system, and it is necessary to renew the stand with seedling trees. This should be done usually after each two or three rotations. The young growth then has new root systems and healthy, sound stumps on which to build a new coppice stand. Long rotations may be alternated with short rotations.

The Density of the Stands

Heavy cutting of the forest results in open stands, where there are wide spaces between the crowns of the trees which in most cases will never be filled by an increase in the spread of surrounding trees. If young tree growth existed as advance reproduction at the time the large trees were cut, it is likely that they will in time fill the opening. But if the trees surrounding the opening are immature and growing vigorously, the increased light will cause wider branching on the side toward the opening, resulting in less clear and straight stems for lumber production. An opening which will close in 10 or 15 years will allow time for young trees to get well started and also prevent too much branching of surrounding trees. In a few more years one or two trees will mature, be cut, and leave more growing space and light for the young trees underneath.

Unfortunately, the large openings are not always stocked with reproduction. If the stand was previously dense, shade and root competition may have prevented establishment of advance reproduction. Increased sunlight, heat, and wind action result in a drying of the litter, humus, and top soil. Leaves become dry and loose and are often blown away. The increased light and growing space is an advantage, however, and usually considerable tree growth soon starts. The little trees may become established and occupy the area, but often the dry conditions and competition with grass, weeds and other herbaceous vegetation cause their death. Grazing accelerates and encourages grass at the expense of tree growth. The same is true of fire. Fire destroys young tree growth, leaves, twigs, and even the humus; after severe fires the mineral soil is often exposed. Weeds, grass, and other plants quickly seed in the burned area and are able to endure severe site conditions much

better than are tree seedlings. Fire also destroys young sprout growth, the bark of fresh-cut stumps is burned or loosened, and the cambium is destroyed so that there is no live wood at the root-collar. Sprouting is therefore impossible.

The five stands of timber at the Kellogg Farm vary considerably in density. Based on the sample plot data, the relation between the different woodlots is about as follows:

	Woodlot 1	Woodlot 2	Woodlot 3	Woodlot 4	Woodlot 5
No. trees per Acre	132	266	732	174	430
Range of D.B.H.	2-19"	1-16"	1-8"	3-19"	1-20"
Approximate Density	0.4	0.6	0.8	0.7	0.6

The figure for density is based upon 1.0 for full density or full crown cover. These figures bring out that Woodlot 1 is very open and density is poor; Woodlots 2 and 5 are of about the same density; Woodlot 4 is more dense; and Woodlot 3 (the coppice stand) is of the highest density. There is some correlation between density and number of trees per acre, but that is influenced by the size of trees. Large trees provide much greater crown space than small trees, of course, and fewer are required to equal the same density as a stand of smaller trees.

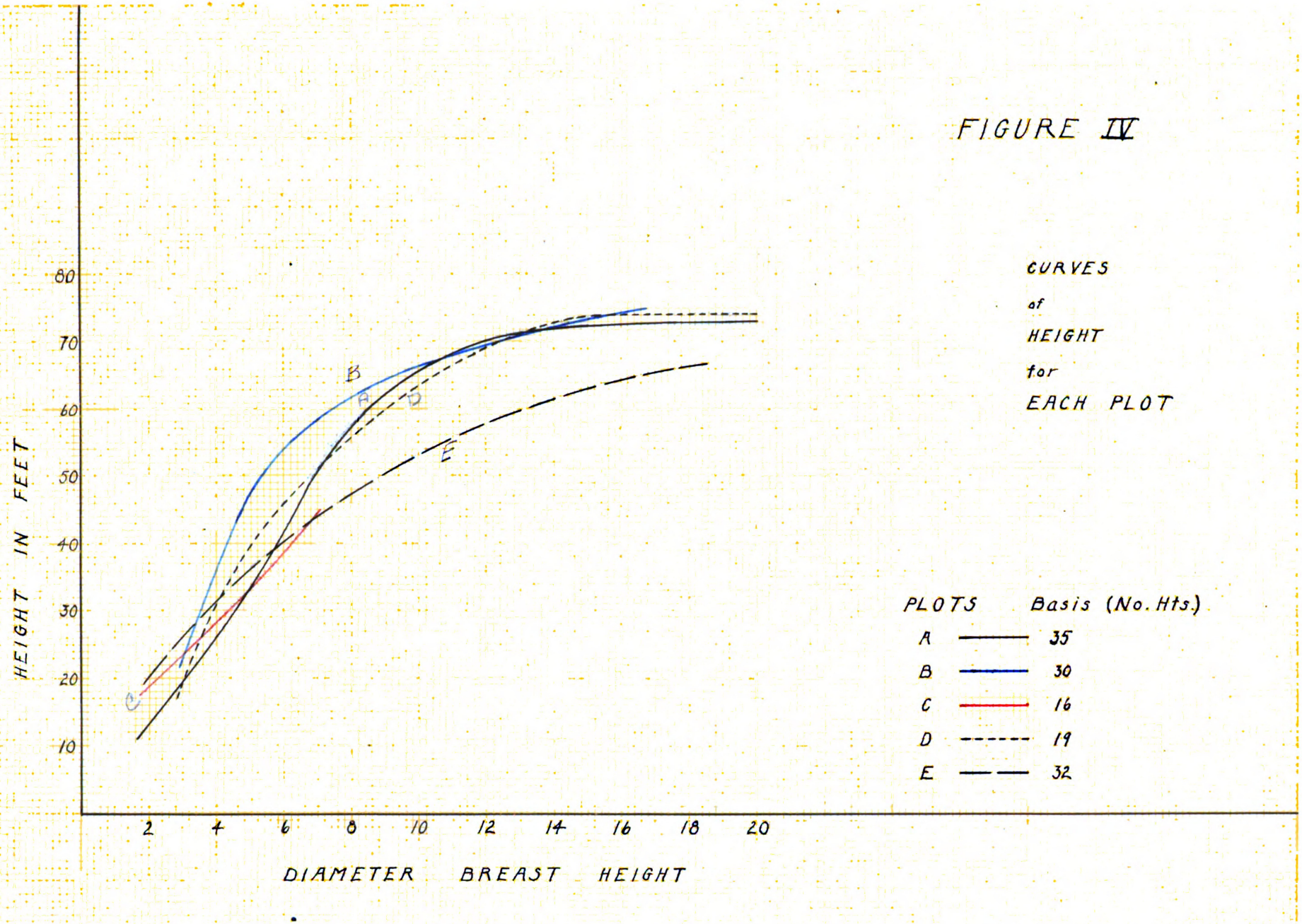
Volume of the Stands

The stands vary greatly in volume as well as in density. In order to get the most accurate figures possible for comparison, cubic foot volume was used on each plot. First, the basal area of each tree was secured, from the diameters and basal area tables.

A number of total heights were taken on each plot, including all species of trees and most of the diameter classes. The volume of a tree was computed by the formula for the volume of a paraboloid, Volume = Basal Area x Height ÷ 2 ($V = B \times \frac{H}{2}$).

A height curve was drawn for each plot. Figure IV illustrates the trend of height growth of five curves, one for each plot.

FIGURE IV



There is considerable variation in heights on the different plots. Curves are based on all species, as differences in height growth between species are not great enough to consider. Black oak is, of course, well up in both height and diameter growth; white oak is usually not quite so tall; black cherry, red maple, white ash, and largetooth aspen often grow very well in height; hickory grows very well in height but not large in diameter, and rarely reaches to the top of the oaks.

Total volumes per acre in cubic feet, for each species and for all species, is shown in Table IV. These volumes are based on the volumes on each plot, and are fairly representative of each woodlot, except perhaps in Woodlot 5 where the trees are larger in perhaps one-fourth of the stand than on the half-acre plot.

Table IV. Volume in cubic feet per acre

Species	Woodlot 1	Woodlot 2	Woodlot 3	Woodlot 4	Woodlot 5
	Cubic Feet per Acre				
Black oak	1726	1150	594	1056	1302
White oak	424	96	92	190	146
Pignut hickory	65	456	8	304	670
Black cherry	257	80	5		52
Red maple	72	162		354	
Sassafras	25	64	8		56
White ash		552	5	190	
Largetooth aspen		242	152		200
Trembling aspen					52
Black walnut			40		
Flowering dogwood			1		
American elm					6
Total	2547	2782	883	2954	2454

Table IV shows the importance of the black oaks in the stands, as they have much the largest volume in each woodlot. White oak, although usually second or third in number of trees, is second in volume in only one woodlot. Its place is often occupied in volume by hickory, ash, or largetooth aspen. Cherry comes in strongly in one woodlot. Red maples are few in number and therefore, produce

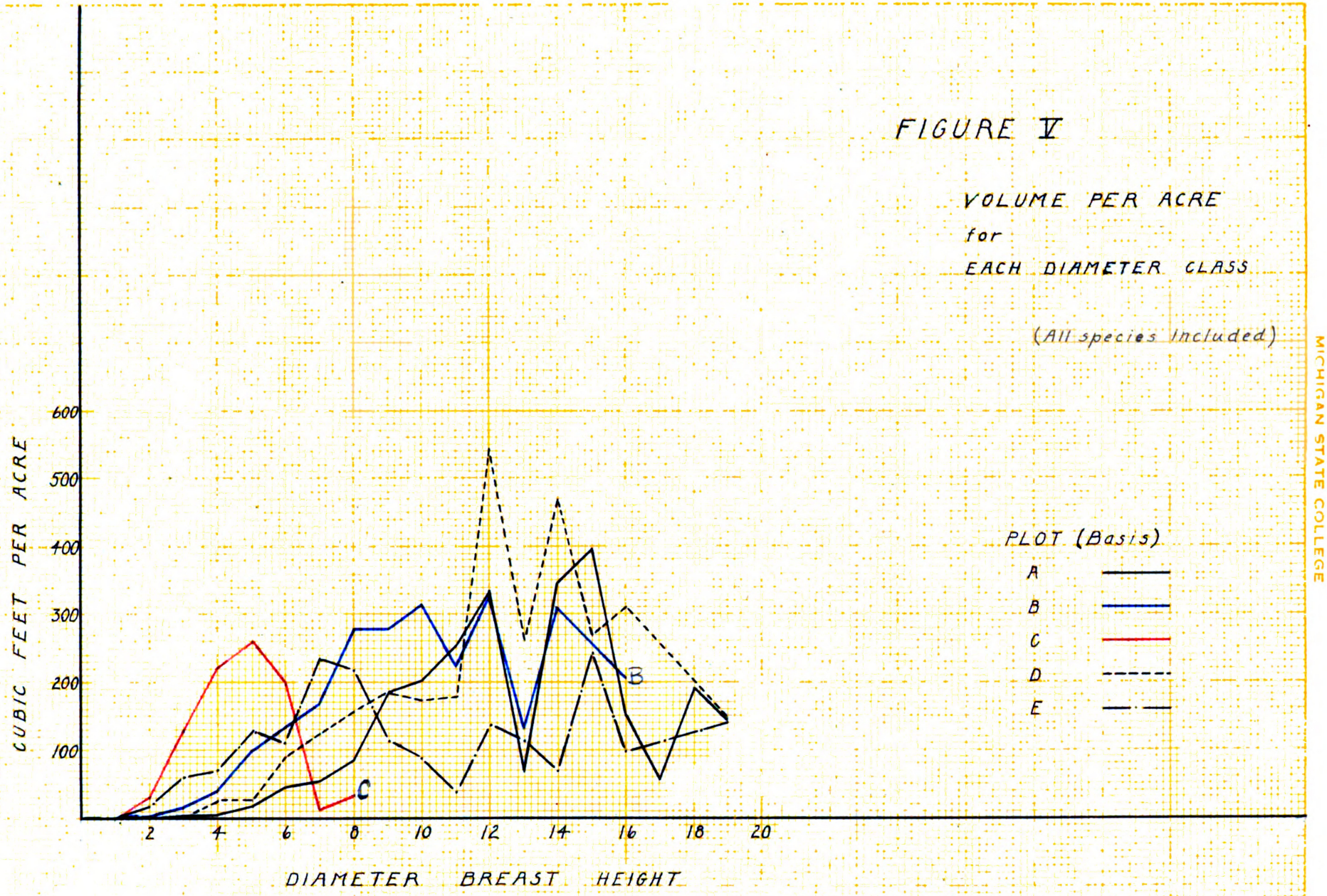
little volume. Black walnut is found in only one woodlot, and should be encouraged to produce more volume and to increase in number. Elm is found only at the edge of the marshes, and is of insignificant volume. Sassafras, trembling aspen, and flowering dogwood have little volume and are not important. They have very little effect on the other species, except that sassafras often seeds an opening quickly and may seriously interfere with the growth of better reproduction.

It is interesting to compare the stands in distribution of volume by diameter classes. The volumes of all species in each diameter class is added to make the total, which is plotted on the graph paper. The points are later connected to show the relation between volumes at different diameters for each plot, which diameters have the most volume, where volume begins and ends, the points of rapid volume increase and fall, etc. These are shown in Figure V.

FIGURE V

VOLUME PER ACRE
for
EACH DIAMETER CLASS

(All species Included)



Board foot volumes were estimated only in Woodlot 1, on the half-acre plot. The number of logs 10, 12, and 14 feet long were tallied, 8 inches and up in top diameter. The Scribner Decimal C log rule was then used in computing the volumes.

Table V. Number of logs and volume in board feet per acre, Woodlot 1. Based on tally of one-half acre plot

Top diameter (inside bark)	Length of Logs (feet)						Totals Per Acre	
	10		12		14			
	Number of logs	Volume (Bd.ft)	Number of logs	Volume (Bd.ft.)	Number of logs	Volume (Bd.ft.)	Number of logs	Volume (Bd.ft.)
8	12	240	2	40	20	400	34	680
9	4	120	2	60	10	300	16	480
10	2	60	4	120	16	640	22	820
11	4	100			4	200	8	300
12			2	120	10	700	12	820
13					6	480	6	480
14					4	400	4	400
Totals	22	520	10	340	70	3120	102	4040

The table shows 4040 board feet and 102 logs of three different lengths, per acre, in Woodlot 2. These 102 logs can be cut from 60 trees ranging from 10 to 16 inches in diameter.

A study of 13 stumps left from the cutting in the winter of 1928 - 29, in Woodlot 1, revealed several points:

1. The largest and oldest white oaks (the largest stump was 30 inches in diameter across the top) reach an age of 275 to 300 years.

2. White oak grows slower than the black oaks.

3. In all cases the growth in the last 10 years was the same or less than the growth from 20 to 10 years ago. This was due largely to maturity and decadence, suppression, or other causes which seemed to make removal necessary.

4. Sprouting of oak stumps occurred only when they were less than 80 or 90 years of age.

5. One 25-inch black oak grew 2 inches in diameter in the last 10 years. It was only 80 years old.

In Illinois yields of the mixed stands of oak and other species on the bottomlands and the better upland soils run from 3000 to 6000 board feet per acre, with a probable average of 5000 board feet per acre in original stands. The stands of black-jack oak and post oak have a very low yield and seldom is material produced other than fuel, posts, and mine props.

Illinois is called a prairie state, yet over 40% of it was originally forested.

In Minnesota, Cheyney and Brown (12) describe an oak type in the southeastern part of the state. Red oak comprises much the largest volume and also the largest number. White oak is much less important. Ironwood, although in diameter classes of less than 9 inches, makes up 11 per cent of the trees in the stand (probably a cutting and grazing effect). Aspen is nearly as prominent as ironwood. Maple, basswood, and elm are not common.

Red oak in southeastern Minnesota comprises 63 per cent of the total cubic foot volume. It makes the fastest growth, especially in the larger diameter classes.

Well stocked woodlots of the oak type have about the same volume per acre as those of the mixed hardwood type (in the same region). The saw-log material runs about 5000 board feet per acre. The annual growth is about 74 cubic feet per acre, and a growth of saw-log material of about 130 board feet.

Combined Effects of Cutting and Grazing

Reproduction

Careless methods of cutting used in the past resulted in opening up of the forest and the establishment of grass and other vegetation ahead of or along with young tree growth, unless there was advanced reproduction underneath the stands when cut; there would no doubt be some because of the unevenaged character of the stands. If undisturbed, the herbaceous vegetation and young trees would fill the openings and competition between them would probably be keen. In time, however, the trees would very likely win out. There would be no heavy grass sod formed.

When grazing follows cutting and the establishment of grass, the result is that the establishment of grass is favored over tree growth, for the little trees are browsed by the animals, are easily killed and are very slow to reestock the area. Grass, although browsed very closely, springs up again from the rhizomes and also seeds in very quickly. Heavy grazing therefore prevents all new tree growth. Nearly all the reproduction at the W. K. Kellogg Farm has started in the last 3 or 4 years, since grazing was stopped.

Following cutting, and also after grazing, undesirable species often grow in large numbers. In Ohio (7) and in southeastern Minnesota (15) it was found to be ironwood. Oaks were not abundant in the reproduction in an oak overstood. Ironwood made up 45 per cent of all the trees between 0.5 inch and 3.0 inches in diameter, (in [illegible]).

Sixteen reproduction transects, scattered through all the woodlots, were studied in the spring and again in the fall. Transects were located in spots where it was thought the results of certain environmental conditions could be illustrated, rather than placed haphazardly where no special conditions existed.

The first transect was charted on May 5, 1939, and the last (number 16) on June 11, 1939. They were examined again in the fall between October 16 and November 6.

The chart of each transect is made to show as accurately as possible the conditions on that small area and the immediate environmental conditions which influence the young tree growth on the transect. Attempts are made to show the effect, for instance, of heavy shade on the reproduction; also the effects of direct sunlight and resulting heat and dryness, of grass competition, of competition with roots of trees or herbaceous vegetation other than grass, and of drainage. It is not usually possible, however, to take one factor and say definitely what degree of influence it has, because the factors have a combined effect. Lack of reproduction on poorly-drained soil with a thick mat of grass and a heavy crown cover overhead is not due to poor drainage, grass competition, or shade alone; it is due to a combination of these three ecological factors and perhaps others which are not mentioned or perhaps not recognized.

The origin of each tree was noted, whether seedling or sprout. Each was charted in one of two age distinctions - current year (spring of 1939) and older. A current year seedling or sprout could be recognized by the soft, unlignified stem and immature leaf forms just emerged from the cotyledon. Stems were whitish and almost translucent, with no sign of bark on them. Also, there was no roughness, marking of the stem, and differences in lignification as in older seedlings where new growth shows softer and fresher than old growth.

Seedlings or sprouts of 6 inches or more in height were charted in 1-foot classes. When height growth passed from one class to another between spring and fall, that was noted in the re-examination.

There was some difficulty at times in determining the species of tree, but through practice they became easily recognized. A few were recognized when re-examined in the fall. A very few were not identified.

In some cases the trees that had died during the summer were not to be found, while many of them were still standing; some had dead leaves hanging to them.

Any other changes in the fall were noted, such as absence of herbs which were prominent in the spring.

Seasonal Influences

The summer of 1939 was a very severe one, due to lack of rainfall. Some farm crops were almost total failures, and yields were light. The effect is shown in mortality of seedlings where exposed to sunlight, wind and resultant drying.

The following data was compiled by A. B. Berrance,

of the U. S. Bureau of Plant Industry, at the W. K. Kellogg Farm. No records are available at the Farm over a period of years, but at Battle Creek (14 miles southeast) and at Kalamazoo (about the same distance southeast) records for 45 years are available. The altitude above sea level according to the U. S. Geological Survey is 938 feet, which is approximately the same as Battle Creek and about 90 feet higher than Kalamazoo.

Precipitation Records

	Average at Kalamazoo and Battle Creek (45 yrs.) - inches	At W.K.Kellogg Farm 1939 - inches	Per cent above or below normal equals 100
April	2.57	3.31	129
May	3.69	4.12	111
June	4.08	2.53	62
July	3.13	2.03	65
August	2.94	0.71	24
September	3.14	1.69	53
October	2.63	4.43	169

The precipitation from June to September (inclusive) was below normal, while for April, May, and October it was considerably above normal. The rainfall in September nearly all came at the end of the month. The four dry months show a total precipitation of only 7.56 inches, while the three wet months show 11.16 inches.

Temperature records show greater extremes of maximum and minimum than the normal for each month except October, which shows a slightly lower maximum than the normal. The latter is reach nearly 4°F. below the normal minimum and a little over 2°F. above

the normal maximum. The highest minimum at the Kellogg Farm in 1918 was 60.5°F. in July, and the lowest minimum was 38.6°F. for October. The highest maximum was 88.5°F. for July, and the lowest maximum was 53.3°F. for October. These maximums and minimums are based on average daily readings for each month.

The great amount of rainfall in April and May, when the little trees were starting growth, probably increased the succulence of the tissues and made them less able to resist the drought which began in June. The extremes of temperature no doubt had a bad effect on the seedlings. High temperatures increase evaporation from the soil and transpiration from the leaves, and dry winds have the same effect. Winds are strong at the Kellogg Farm, and seedlings have little protection because of lack of underbrush and lack of dense borders in the woodlots.

Sprouts, of course, grew much faster than seedlings.

On one or two transects there was a distinct difference between the amount of reproduction under the crowns of trees and in an opening between the crowns. This was probably due to root competition with large trees, degree of shade, and possibly other factors. Reproduction in the opening was not only denser but was taller. Proportionally, about as many trees died under the crowns as in the opening, during the summer. This is conflicting to what would be expected in a dry year. The small size and less resistance of the shaded trees, as well as root competition may account for the loss.

It is curious that some damage to small trees by small animals occurred during the summer. A few trees were bitten off at a foot or less above the ground, while a few others had bark

gnawed off, showing marks of small teeth. Presumably they were rabbits, but it is strange that they would attack trees in the summer time when there should be plenty of softer, green vegetation. Perhaps the dry summer destroyed too much of such food.

On a few of the transects there were one or two trees which had been planted during the previous fall. These were also charted, and found to be in good condition.

Survival by Transects

Table VI shows the number of trees of each species on each transect, considering each transect as $\frac{5}{1000}$ acre in area, and basing the figures on the data from 18 transects of $\frac{2}{1000}$ to $\frac{5}{1000}$ acre in area. This method is used for all the figures on reproduction. In each case the fall tally is used unless otherwise stated.

Table VI. Number of trees of each species, both seedlings and sprouts, in each transect

Species	Number of Transect															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Number of Trees															
Black cherry	5	108	64	68	5	54	6	2	18	6	10	7	10	87	29	117
White ash			3	73	43	17	4	5	55			50	1		2	
Sassafras				15		43		43	1	25	20		1	1	10	
Red maple				55	2	2			1	2		2			44	5
Flowering dogwood				5		10						117			1	
Black oak	1		2		2	5	1	5	25	6	5		2	7	5	2
Pignut hickory			2	1	11	1			1	4	7	5	1	1	4	
Juneberry					2					3	7	22				
White oak								7	2	5		17				
Largetooth aspen								2		2						
Black walnut				1												
American elm													1			
Total (Fall)	6	108	71	214	65	117	11	63	79	55	49	200	24	86	105	124
Total (Spring)	6	113	93	333	103	131	16	83	97	63	57	233	25	45	111	147
Per cent of Survival (Fall)	100	96	72	63	59	89	69	75	81	81	86	85	69	80	93	83

At the base of Table VI is the total number of trees on each transect, as charted in the fall. Below that is the total number of trees on each transect as charted in the spring. In comparing the number in spring and fall, the per cent of survival was computed; that is, the

proportion of the fall number to the spring number. Transect 1 gives a poor basis, there being only 3 trees in spring and fall. The others show larger numbers and give a better basis for survival percentages. Survival ranges from 89 per cent to 100 per cent with the majority over 90 per cent. Only 4 are below 70 per cent survival.

The transects vary a great deal in number of trees, which indicates a great variety of conditions influencing seeding or sprouting, germination, and survival. The minimum number is 0, the maximum is 214, per 1000 acre.

The number of species on the transects varies from 1 to 4.

It is evident that black cherry and white ash are very prominent in the reproduction.

Survival by Species

Table VII compares the species in spring and fall.

Table VII. Number of trees of each species in spring and fall, per cent of total number trees in each species (based on fall tally) and per cent of survival of each species (after fall tally). Totals of 10 transects, 5 / 1000 acre each.

Species	Number trees in Spring	Number trees in Fall	Per cent survival (after fall tally)	Per cent of total number trees (based on fall tally)
Black cherry	613	588	95.1	59.4
White ash	347	300	59.9	17.7
Sassafras	205	174	80.1	15.1
Flowering dogwood	171	153	91.1	10.9
Red maple	138	118	91.3	7.4
Black oak	85	80	70.5	5.0
Pignut hickory	43	39	91.0	1.9
Juneberry	40	34	85.0	1.3
White oak	31	31	100.0	1.1
Largetooth aspen	7	4	57.1	0.5
Black walnut	8	8	85.0	0.8
American elm	1	1	100.0	0.1

Black cherry is by far the most prolific in the reproduction. On 7 of the transects cherry leads all other species, and in one case it is the only species (Table VI). Cherry is also high in per cent of survival, even after the winter.

White ash is found in many numbers, but survival is poor. Red maple is also poor in survival. Flowering dogwood shows

a little poorer survival than maple, but there are only a few trees on which to base the percentage. Black walnut shows a loss of 1 out of 6 trees, or 83 per cent survival. The hop hornbeam there are only a few trees. The figure of 100 per cent survival for all is of course, unreliable.

From the data on hand it appears that the average per cent of survival would fall between 70 and 80. A more favorable year would without doubt, show better survival.

Origin.

Table VIII. Number of trees on each transect according to origin.

Number of transect	ORIGIN			
	Seedling		Sprout	
	Current year	Other than current year	Current year	Other than current year
	Number of Trees			
1		6		
2	19	66	1	
3	7	84		
4	13	200		
5	13	50		
6	17	33		10
7	9	2		
8	2	51	6	6
9	3	73	1	2
10	2	50	1	22
11		55		15
12		142	7	32
13	5	19		
14	3	55		
15	2	94	5	2
16		117	5	
Total		6		

By adding the totals of each origin class, dividing each total by this sum and multiplying by 100 it is found that 7.7 per cent of the reproduction are current year seedlings, 81.5 per cent are older seedlings, 2.0 per cent are current year sprouts, and 8.8 per cent are older sprouts. Also, a total of 89.2 per cent of the reproduction is of seedling origin, and 10.8 per cent is of sprout origin.

The loss of seedlings is much greater than the loss of sprouts. Current year seedlings show a loss of almost 50 per cent of the spring tally, while older seedlings show about 15 per cent loss. Current year and older sprouts each show about 10 per cent loss.

Sprouts are able to endure a very dry summer, due no doubt to the large root systems which feed them. Seedlings that have lived through one growing season are more hardy and there is little loss in an ordinary year. It appears evident that, with a moist summer, the loss of the current year seedlings would be much less than it was in 1929.

Table IX compares the different species as to origin.

Table IX. Number of trees of each species according to origin.
(Basis: Total number on 13 transects of $\frac{5}{1000}$ acre each)

Species	ORIGIN				Total Seedlings	Total sprouts
	Seedlings		Sprouts			
	Current Year	Older	Current Year	Older		
Black cherry	64	457	1		521	1
White ash	22	176		10	198	10
Sassafras	2	131	9	32	133	41
Red maple	4	103	5		107	5
Flowering dogwood	2	91		40	93	40
Black oak	5	56	2	3	61	5
Pignut hickory	4	24		11	28	11
Juneberry		32		2	32	2
White oak		6	7	18	6	25
Largetooth aspen		2	2		2	2
Black walnut		2			2	0
American elm		1			1	

Black cherry, white ash, sassafras, and red maple stand out prominently in numbers, especially in the older seedling group.

Influence of Site Factors

The following is a discussion of examples which illustrate the influence of the various factors on site conditions in the area studied.

Heights of the reproduction range from 1 or 2 inches up to 7 feet. The great majority of trees were less than $\frac{1}{2}$ foot high.

The height of the reproduction makes little difference in density. Height growth is not very noticeable in one season, although a few trees grew to the next higher foot class during the season.

On transect 10, where the reproduction of black cherry was dense and reached a height of 7 feet, a few trees were cut off at the ground and the ages studied. The growth rings show ages as follows: 1 foot, 3 years; 2 feet, 4 years; 3 feet, 4 years; 4 feet, 4 years; 5 feet, 4 years; 6 feet, 7 years; 7 feet, 8 years. The rings could not always be seen distinctly, so allowance must be made for error. But, as an estimate based on ring-counts on only 7 trees, the study indicates good height growth. These trees received only a little overhead light.

Competition of the reproduction with grass or sedge is very serious in some locations. Transect 1, $\frac{5}{1000}$ acre in area, had only 6 trees of natural growth in the fall; Transect 7 ($\frac{4}{1000}$ acre) had only 9 in the fall. In the latter case, however, the site was rather poorly drained and was well shaded. Survival was poor also, on the latter transect.

Transects 5 and 6 illustrate very well the effects of heating and drying on an exposed southwest slope and the contrasting effects of less intense sunlight and less drying on a more protected north slope. In both cases the slope is gentle.

Transect 5 has a thin covering of grass and sedge, evenly distributed and short. Some of the grass is Kentucky blue grass. Scattering individuals of purple violets, dandelions, and wood anemone occur. The site does not receive direct sunlight at all times. The leaf litter is thin and does not aid much in holding moisture. The opening is bordered by large trees of white ash, black oak, pignut hickory and red maple. None of the

reproduction is over 3 or 4 inches high. Losses occurred in all species except black oak (only one tree). Survival was only 71 per cent.

Transect 3 has a thin, scattered covering of sedge and grass, and a considerable amount of leaf litter which holds moisture, forms humus, and reduces evaporation from the surface. The potting poles lie across the transect. A few individuals of dandelion, purple violet, bracken fern, and Solomon's seal are found. Trees bordering the opening are black oak, red maple, pignut hickory and sassafras. There is some light directly from above and a little from the sides. The effects of a more moist slope, less direct insolation, and perhaps more shade are noticeable. (1) Less trees have died than on Transect 2. Per cent of survival is 89. (2). The trees are greener in the fall (Oct. 21, 1939), and the leaves do not drop off so soon as on Transect 2. (3). Growth is more vigorous.

In some locations the small trees are forced to compete with underbrush of red raspberry and common alder. These shrubs do not seriously hinder growth of seedlings, however, and it is thought that the trees will crowd them out.

Transect 4 has a survival of only 65 per cent. It is on a hillside with a southern exposure. In the spring the area was canopied with a luxuriant growth of mandrake which cast considerable shade. Grass or sedge occurred in small, scattered clumps. No other vegetation was prominent. There was a fair amount of litter and humus. The large trees were not yet fully leafed out (May 24, 1939), but their crowns were nearly closed. The species of large trees were black oak, white ash, black cherry, pignut hickory, and white oak. The reproduction was very dense, but

was less than 4 inches tall. Later, in June or July, the mandrake died, thus reducing the protection given the little trees. The heating and drying killed many seedlings. The weather was still very dry on October 19, and the last rain had been an inch or so at the end of September. The mandrake probably used considerable moisture in the soil also.

Sassafras shows ability to seed an opening very quickly and to grow rapidly. It is intolerant of shade, however, and better species can no doubt crowd it out. It is good management to remove the large sassafras and prevent seeding and competition with better trees. Sassafras sprouts readily also.

In general, there is more reproduction in sunlight than in shade. None of the species are very tolerant of shade.

It is sometimes difficult to explain the presence or absence of a species in certain locations. Transect 15 is located almost under the overhanging branches of a large white ash, yet there are only 2 ash trees on the area of 5/1000 acre. Red maple is most plentiful, and comes from several large trees near by. Cherry is also plentiful, but the nearest large tree is 175 feet north. How did the seed get here? The only explanation thought of was that birds carried the seed and dropped the pits.

Transect 16, with its dense cherry growth, is also a considerable distance from any large cherry trees. However, one stump close by appeared to be cherry. The leaf litter in this thicket is 2 to 3 inches deep - the most found on any of the transects.

The shrubby and herbaceous vegetation which is found on the transects is of some significance as a competitor with trees, as a protection to trees, or as an indicator of site conditions.

Some are only farm weeds, blown in from nearby fields, and often of no importance.

Shrubs and Herbs

The vegetation is as follows:

1. Red raspberry (Rubus idaeus)
2. Common elder (Sambucus canadensis)
3. Rose (Rosa sp.)
4. Purple violet (Viola cucullata)
5. Yellow violet (Viola sp.)
6. Catnip (Nepeta cataria)
7. Dandelion (Taraxacum officinale)
8. Cinquefoil (Potentilla sp.)
9. Canada thistle (Cirsium arvense)
10. Bull thistle (Cirsium lanceolatum)
11. Yarrow (Achillea millifolium)
12. Wood anemone (Anemone quinquefolia)
13. Kentucky blue grass (Poa pratensis) and other grasses
14. Sedges (Carex spp.)
15. Mosses
16. Common nettle
17. Meadow fescue (grass) (Festuca elation)
18. Mandrake (Podophyllum peltatum)
19. Strawberry (Fragaria sp.)
20. Small Solomon's seal (Polygonatum biflorum)
21. Brake fern (Pteris aquilina)
22. Wild lettuce (Lactuca canadensis)
23. Dewberry (Rubus villosus)
24. Wild cranesbill (Geranium maculatum)

25. Hepatica (Hepatica triloba)

26. Fleabane (Erigeron philadelphicus)

27. White clover (Trifolium repens)

28. Wild grape (Vitis sp.)

Others not found on transects but under similar conditions:

1. Goldenrod (Solidago sp.)

2. Burdock (Arctium minus)

3. Poke-berry (Phytolacca decandra)

4. Deadly nightshade (Solanum sp.)

5. Thornapple (Crataegus sp.)

6. Tick trefoil (Desmodium sp.)

The Effects of Poor Protective Measures

Site Deterioration

Some of these effects are illustrated at the Mallory Farm. Lack of soil protection due to heavy cutting was one of the first errors in management. There was no thought of the value of a dense border on the woodlots, for protection from winds, and now the drying effect of winds is great. This, along with dessication due to the heat of the sun and the growth of grass and weeds, causes deterioration of the site for forest growth.

Lack of protection from grazing animals has had a very evident effect in the absence of undergrowth of small trees. Woodlot No. 1 has been pastured for many years, with the result that an unobstructed view is obtained from end to end and to the other, which is one-fourth mile, except for the bare-trunks and

occasional clumps of oak seedlings or saplings. The reproduction that has come in since grazing is only a few inches high.

The other woodlots are in about as bad condition as far as reproduction is concerned, although the ground cover is heavier and not quite so much young growth is needed to protect the forest floor. The effect of pasturing is very evident in the woodlots also.

Ferns, sedge, and other herbs are undoubtedly much more prominent where grazing has been practiced, and that seems to be brought out in the woodlots although there is no ungrazed woodlot to compare with. When ungrazed after cutting some tree growth will start and prevent a heavy growth of other vegetation.

Where grazing follows cutting, it seems inevitable that tree seedlings are destroyed and grass is encouraged. Seedlings are easily killed by trampling and chewing of animals, but grass springs up again very quickly unless too closely grazed. Sheep are especially harmful to seedlings.

Secrest (71) states in 1910 that the agricultural sections of Ohio equal about 72 per cent of the land area of the state, and 70 per cent of all woodland in those sections is grazed.

The oak type in Ohio often degenerates from grazing effects, as reproduction is largely composed of tolerant and poor species like ironwood, blue beech, and black gum, which exclude seedlings of the oaks, hickories, and other intolerant species of the original oak type (the original also included some chestnut and sourwood). One example: A woods in which white oak predominated with associates of black, red and scarlet oaks. Sixty years ago the white oak was removed, and now the over-wood is of the red-oak group. Live stock had been excluded for 10 years before observation, and since then a dense growth of ironwood had become established.

oak did not comprise 1 per cent of this stand. Seeding was made by scattered mature ironwoods.

Litter and humus are very light in the woodlots. On transect 10 the leaf litter is 2 - 3 inches deep, the most found on any of the transects. The strong winds carry the leaves to the low spots where they accumulate. Some are blown entirely out of the woodlots. Sunlight and wind both dry the leaf litter and humus and prevent their accumulation in an even layer over the surface. There is not enough of this litter to smother the grass except in small hollows. In many places the litter and humus are barely thick enough to cover the mineral soil. A more quiet, moist air would prevent so much drying and blowing. Signs of fire are seen only in woodlot No. 3, the coppice stand. It was probably a light fire, as the base of the trees do not seem to be injured seriously. Where surface fires are severe, the bases of the trees are often partially burned and the cambium killed, thus weakening the trees and forming an entrance for insects and fungi. The litter and humus in the burned woodlot are very thin, however, and were evidently consumed rather thoroughly.

Insects and Disease

All the influences which bring about site deterioration are favorable to insects and disease. In general, insects are partial to sunlight rather than to shade, and to high temperatures rather than to low temperatures. The dessication of the soil and competition with grass often weaken the remaining trees and make them more susceptible to insect attack. Insects attack all parts of trees, often gaining entrance to the wood through openings in the bark.

Fungous diseases are attracted to trees that are in a weakened condition, and they gain entrance through any opening in the bark, often such openings as are made by boring insects.

In the oak-hickory type at the Kellogg Farm there is indication of poor vigor, especially in Woodlot No. 1, where cutting has been heavy, the ground is heavily sodded with grass, and grazing has been practiced until 3 or 4 years ago. The hickory bark borer (Scolytus quadrispinosus) occasionally kills trees by working in the cambium layer and girdling them. Black oak is also attacked occasionally by a cambium and wood borer. A few trees are killed. In trees which are weakened or dead are found flat-headed wood borers, probably the larvae of the flat-headed apple-tree borer (Chrysobothris femorata).

The June-beetle larvae, or white grubs, rear themselves in large numbers, presumably in grass sod and under the roots of field crops. A pasture field adjoining Woodlot No. 1 is believed to rear a great many, and this woodlot was seriously defoliated by the beetle adults in June, 1928. It is likely that many eggs are laid in the sod within the woodlot itself.

The oyster-shell scale (Lepidosaphes ulmi) attacks largetooth aspen and is killing some of them. It was not seen on any large ash trees, but one clump of sprouts was affected by oyster-shell scale.

Suggestions for Managing Oak-Hickory Stands

Improvement Cuttings

One of the first things to do with a forest which has been poorly handled is to make an improvement cutting. If the stand has been opened up considerably, it is nevertheless necessary to cut more trees, for usually the good trees have been removed and the poor ones left. Many of the poor ones must be removed, for they are decaying and overmature, damaged by insects which may spread to other trees, or broken and thus rather worthless. In some spots trees are crowded too closely and perhaps badly suppressed. They should be removed. Standing of trees on the border of a woods may be allowed because of its value in wind protection. A cutting was made in the winter of 1939-40. Trees to be removed were marked the fall before.

The following are the main reasons for removal of trees:

1. Poor form
2. Mechanical injury
3. Insects or disease
4. Undesirable species
5. Suppression
6. Competition
7. Maturity

Sassafras leads all other species in number of trees removed. This tree is almost worthless and considered a weed tree. Aspen is little better, and a number have been removed because of poor condition due to fungi or to the spider-skill rails insect. The white oak and black oak trees removed were in many cases large

over-mature trees. A large number of hickories were cut, most of them small, overtopped, suppressed, and crooked. A few hickories had been boxed.

The wood was cut for fuel and piled in short cords (12-inch lengths) except for 8 or 10 good logs and 6 or 7 piles of poles (which were to be cut into cordwood).

In woodlot No. 1 about 7 cords per acre were cut, on an area of 10 acres. The cutting was only 2 cords per acre in woodlot No. 2, on an area of 17 acres. A large pile of poles was cut and piled ready for sawing into cordwood. In woodlot No. 3 no cordwood was cut, but some poles were piled ready for sawing. The area of this woodlot is about 15½ acres. The marked trees were not all cut in No. 3. Woodlot No. 4, of 7 acres area, produced 4 cords. Woodlot No. 5, 14 acres in area, produced 4 cords per acre.

The vines of wild grape (Vitis sp.) were rather common in some parts of the woods. They grew far up into the trees, spreading over the crowns of some of them, their large leaves shading out the tree leaves, their stems twisting about and choking the tree branches, and their weight bending or breaking the trees. The vines were cut off at the ground - a very simple operation which removed further injury by stumbling or smothering.

The first cutting left many trees which should have come out because of their poor condition, but which were left to furnish protection to the ground. The protection is of value, in that the trees shade the ground, thus preventing erosion. In a stand which already has poor ground conditions, however, due

to heavy cutting and grazing, the necessity of utilizing over-mature trees may be greater than the benefit derived from protection of the ground. This is the case in Woodlot No. 1 especially. The market for fuelwood is poor at the present time, but trees in bad condition should be utilized as soon as possible. Parts of trees can be into lumber or ties, besides fuelwood. Trees should be cut when the market will allow it to be done most profitably. The advantage of tree crops is that the harvest can be postponed for several years without serious damage. The economic consideration seems more important than the silvicultural, when cuttings are to be made. If the two can be balanced so as to work for the good of each, the ideal is reached.

The removal of trees is not so harmful when grazing is prohibited because young trees have more chance in competition with other vegetation. This is assuming that the stand is already opened up.

In Woodlot No. 1, which is the most open, a second marking was made in the fall of 1941. All trees were marked that should be removed, regardless of their position in the stand. A number of over-mature white oaks that had been left before were thus to be removed. Sixty-four white oak were marked, many small trees among them. Diameters ranged from 7 to 17 inches. Black oak ranged from 8 to 22 inches, and 38 trees were marked. Hickory ranged mostly from 5 to 6 inches, and 14 were marked. Others were 6 red maple, 1 black cherry, and 10 sassafras.

Computing cubic foot volume of these trees by the method used on the sample plots, and converting to short cords by dividing by $\frac{30}{}$ (approximate number of cubic feet of solid wood in a short cord) there are as follows: White oak $\frac{73.2}{}$ cords,

black oak ~~6.1~~ 27.3 cords, sassafras ~~1.65~~ 5.67 cords, hickory ~~1.65~~ 5.07 cords, red maple ~~1.1~~ 3.3 cords, and black cherry ~~0.1~~ .45 cord.

The volume removed per acre was ~~6.15~~ 11.46 cords, or 344 cubic feet. Three hundred and forty-four is equal to 13.1 per cent of the total volume of Sample Plot A, of 1 acre, as it stood before the first cutting. The first cutting removed about 456 cubic feet, or 11 per cent, from Plot A. Adding 344 and 456, there is a total of 814 cubic feet, or 24.5 per cent, removed or to be removed from Plot A. This per cent is probably a little high, as the average volume per acre marked (for the woodlot) appears to be high for Plot A itself. Unfortunately there was no separate tally made of the second marking on Plot A.

Following the required amount of improvement cutting, which removes trees of all sizes, the aim should be to develop a selection cutting system. Trees cut should be restricted to those which are mature, except for now and then a smaller tree which is defective or too crowded. Perhaps a diameter limit can be selected which will fit a stand of this type. No recommendations can be made at present.

The volume removed in improvement or other selection cuttings varies with each stand, depending upon the kind of management in the past and the resulting condition of the trees. The cutting at the Holley Farm represents the volume removed according to the conditions found there. The figures will not apply to other stands unless they are similar to those studied.

Desired amount of sprouting

Sprouting from stumps is very prevalent in the oak-hickory type. Almost every species associated in this type will sprout to some extent. Thus there are possibilities for new growth aside from seedlings. Sprouts shoot up quickly the season after cutting, especially if the trees are felled in winter.

The black oaks and white oaks sprout very well, and should be especially encouraged. Where many trees are felled, and the stumps are not too old and rotten, the plentiful group of sprouts on each stump makes a good showing after one season. They should not be allowed to grow that way for more than a year or two, under good management, but should be thinned out, leaving perhaps 2 or 3 of the largest, straightest, and most vigorous on each stump. More thinning may be necessary a year or two later if they crowd each other too much.

Stumps from younger trees sprout best, and of course, many of the trees cut are very old. Sprouting can be only supplementary to seedling growth, then, when virgin stands are cut. Second-growth stands may be cut when still vigorous if coppice stands are desired. Coppice of oak-hickory should have a rotation of not more than 70 or 80 years. Under a selection system with most of the trees originating from seed, trees of sprout origin may be removed when feasible.

Grazing of course, destroys sprout growth and must be prevented.

Slash Disposal

Disposal of slash in the oak-hickory type as found in Michigan and some neighboring states is not a serious problem. Most of the timber is in small tracts which can easily be protected from fire. The larger tracts, if they have some fire protection, are probably not in great hazard from fire when slash from logging is left on the ground. In most cases, then, the pieces of the tops which are lopped off can be left where they fall.

In the cutting at the W. K. Kellogg Farm, the slash was burned as the operation proceeded. The object was to clean the forest floor and improve its appearance, in case the woods were used for recreational purposes. There is probably no other reason for such disposal.

Looking at slash disposal from a silvicultural point of view, there seems to be no reason for burning of slash in the ordinary selection cutting. The amount of slash is not great enough to pile up on the ground and smother seedlings underneath. The pieces of slash are usually not large, and if they are they can be quickly cut through and dropped in closer contact with the ground. The rotting of slash on the ground is very beneficial to surface conditions. As the wood breaks down and falls apart, it forms humus and thus increases the organic content of the soil. Dead wood, whether branches or twigs, collects moisture, and the closer it is to the ground the more moist is the under-side of the wood. This condition is favorable to rapid decomposition both in the wood and under it. Where the forest floor is sodded with grass or sedge, this decomposition aids in breaking it up and making better conditions for forest growth. It forms a richer

still not a light [illegible] seedlings. This effect is evident in woodlot No. 1 where this soil is very heavy in places.

The shade from a collection of this kind will cover all the ground and is not often a hindrance to planting or to the growth of trees.

Protection from Grazing

Protection from grazing of sheep, cattle, and horses is most important of all protective measures, for the future of the forest depends on it. Continuous grazing with no rest period for the animals destroys all young growth, and when the old trees die there is nothing left but a pasture field. If a pasture adjoins the woods and the animals have plenty to eat, they will use the woods only for protection from the sun or from storms. Damage may be done by trampling of seedlings and packing of the soil, but there is very little browsing. Animals will not feed upon tree leaves when they can get succulent grasses. If grass forage is not sufficient and overgrazing results, the stock will browse in the woods, feeding on the tenderest leaves or twigs of small trees or any herbaceous growth that is on the ground. It is better to set aside only a small portion of the woods to furnish shade. If this is not done, the number of stock must be reduced to the summer capacity of the pasture.

As mentioned earlier, many [illegible] trees at the expense of tree seedlings. This increasing growth of grass results finally in a heavy sod, unless over-grazed to the point where grass cannot thicken. Not only is grass forage in the woods usually not [illegible] in quantity than in open pasture, but the nutritive value is less.

ovid A. Allaman, in Ohio (35), estimated that it requires 5 acres of woods and 1 acre of common farm pasture to support a cow and a suckling calf during a five months' grazing season and that the cow if only fairly fat to begin with will gain 50 pounds and the calf 75 pounds. He also says that where fattening cows roam through a good woods adjacent to a good pasture they will take less than one-tenth of their food from the woods.

Hog Pasturing

After grazing is stopped, a serious problem may arise in the luxuriant growth of grass or sedge which springs up. At the Kellogg Farm in Woodlot No. 1 this situation occurs on a heavy sod. Tree seedlings find it very difficult to become established (see Transect 1), partly because seed cannot reach the humus or mineral soil where it can germinate, and partly because the grass competition is too great. Grass, sedge, and weeds grow one or two feet high, and in places are densely matted. Figures VI, VII and VIII show the growth, which is mostly sedge. Where brush or leaves lie heavy there is little vegetation. Conditions may possibly be better there for tree seedlings when they once get started.

One kind of animal may be pastured to advantage in an emergency such as this. The hog will root up and destroy a grass sod, thus exposing the mineral soil and providing a better seedbed and less competition for seedlings. The work of hogs cannot be permitted longer than for the time necessary to break up the sod fairly evenly over the area. If a good seed crop comes in the same year, the hogs should be removed by the time seed begins to fall. If they have not worked over the entire area, it may be

possible to fence off this area and place the hogs on it in the spring. If very little seed falls, the hogs may be left in until the ground freezes. In the spring they may again be placed on the area to finish breaking the sod.

Hogs show a tendency to work along the fence enclosing the area, and also near the place where they are watered or fed. The watering barrel or trough should be moved occasionally, and feeding should be done in different places. From experience in woodlot No. 1 at the Kellogg Farm it appears that hogs concentrate their rooting a good deal about the shelters in which they sleep. Every effort should be made to attract them to new parts. They finally do reach all parts, but are extremely erratic in their habits. One spot may be worked up thoroughly while another is only slightly disturbed, but given time they will cover the area.

Hogs will sometimes root to a depth of one foot. This is not desirable, however, as they are concentrating too much in one spot and may cause damage to trees by exposing roots. Ordinarily they root only 1 to 4 inches into the mineral soil, tearing the sod apart in doing so.

If any young trees are on the area, they are likely to be destroyed. A hog has a way to strip the leaves and bark from a small black cherry tree. Other seedlings may be uprooted. At the Kellogg Farm there had been almost no young trees on the area where the hogs were pastured.

The character of the season affects the amount of rooting which is done. Hogs were placed in a part of the woodlot early in July 1933, and from then until rainfall and cool weather came at the end of September very little rooting was done. The sod is

was not a big, and [illegible] so fat and lazy that the hens would not roost. It is likely that dust in their dwellings is beneficial also. When [illegible] on the [illegible] the [illegible] loitered on the roof-tree, [illegible] and [illegible]. The [illegible] would not roost until nearly [illegible] were so [illegible] the roost was [illegible].

The number of hens [illegible] was [illegible], of course, on the size of the area, the [illegible], the [illegible], and the length of the [illegible].

In pasture No. 1, 84 hens were fed all the [illegible] of [illegible]. The chief [illegible], weighing about 150 pounds each, and ninety-nine hens [illegible]. The fence was not secure and they escaped at numerous times, [illegible] for several days. They were fed with a [illegible] of [illegible] and [illegible] and each morning scattered about the [illegible], some of which were very evidently eaten or washed by [illegible]. The two hens were removed on December 10, as the ground was snow-covered and frozen a little. They had not made much impression on the [illegible].

Early in July 1914, two large Rhode-Island-China sows were placed on the [illegible]. On October 21, 8 young Rhode-Island-China sows (from the previous spring) were added. They were fed corn and potatoes, but not enough to fatten them. They did excellent well, although the old sows did more work and were shadier. About the middle of November, 3 of the young sows were removed; the 4 old ones and 5 young ones remained until November 17.

The ground had been cultivated, [illegible] by the time the hens were removed.

From the rather indefinite results of the experiment at the Rolla Farm, we may estimate that for a period of 7 months (May to September, inclusive) under these conditions, a half-[illegible] of

good size, simplex, probably Poland-China and with long snouts and lean bodies are sufficient to thoroughly root over an area of 5 acres. The ordinary swine is much softer and the ground is softer.

Hogs eat animal food in their diet, and by rooting about the grass roots they find earth-worms, grubs, etc., which shower this need. It is likely that they also eat tender roots.

The writer visited a woods of 10 acres in area at Holdcraft, Kalamazoo County, Michigan. In 1930 or 1931 a drove of hogs was placed in a woods which had been heavily cut-over and grazed, and was very open. The remaining trees were very large. That summer the hogs tore up the heavy sod very thoroughly. It was a good seed year, and as a result a very dense stand now exists, consisting of hard maple (greatly predominating), elm, basswood, white ash, black walnut, butternut, hackberry, blue ash, and papaw. This all resulted after the cessation of grazing, breaking of the sod by hogs, and one or more good seed crops. The species of trees found there would produce considerable seed in any year, however.

At the Kellogg Farm, seeding of oak and hickory would, of course, not be so dense because of the large seed, less number produced, and storage by squirrels.

Protection from Fire

Fire protection, as stated before, is not a big problem on small tracts of woods on farms. Surrounded in most cases by open fields, fire cannot spread far even if it does get started. Men are always near at hand. The causes for fire are few. A fire in oak and hickory is a surface fire, which does not move rapidly and

is not difficult to accomplish. Fires must be prevented because they burn the base of the trees and provide an entrance for rot fungi and insects, also destroying litter and duff layers, the organic matter on top of the mineral soil.

Fires in large brush are of the same character, but are more difficult to reach and are harder to fight. Detection is often not so quick. In such areas fire look-out stations should be established, using either high points or towers from which to view the country. Posters which caution visitors to be careful with fire are effective in fire prevention. Visitors should be cautioned about throwing burning tobacco, cigar butts, and cigaret butts along roads which pass through woods. They may also be requested to camp at selected spots which are cleared and from which fire cannot easily spread. It may be necessary to run fire patrols through the area during periods when the fire hazard is greatest. Patrol-men would travel by foot or by any other means of travel. Fire lines may be plowed through the area, depending upon the necessity for them.

Fire suppression may be accomplished by having crews available men to fight fires, and by having tools and equipment such as shovels, picks, axes, water-packs, hoses with pumps and hose, etc. Such tools and equipment should be placed where they are most easily reached when a fire starts.

Protection from Insects and Disease

The best protection which a forest of this type can have is a balanced natural condition similar to the virgin state. By proper management that condition can be approached, and insects

and disease will not be encouraged. The managed stand should be more healthy than a virgin stand because diseased and insect-infested trees are removed and each tree has the best opportunity for vigorous growth.

The managed stand is well-stocked, and the ground is protected from the drying action of sun and wind. Trees and weeds are kept down. Grazing is not permitted. Old trees are thinned and are made to resist disease and insects.

Livestock badly infested by the hickory bark borer should be cut in the fall or winter. The entire trunk, or at least the bark, should be burned before the beetle can escape in the spring. Well-managed trees are thought to resist the insect best. This insect occasionally becomes extremely abundant and kills thousands of hickories.

The borer in black oak should be controlled by cutting the trees in fall or winter and burning the wood and bark before the beetles emerge in the spring.

The flat-headed apple tree borer should be controlled by cutting and burning all infested trees. Unthrifty trees are most attacked. Good management promotes thriftiness.

June beetles may be kept down to some extent by not having sodded pasture near the woodlot, or the forest, or by plowing under, in the early fall, land which is in sod. This will prevent laying of eggs, in the first case, and in the second case will destroy many of the grubs. Beetles will not lay eggs in a plowed field left fallow through the summer. The well-managed forest has no grass sod such as in Woodlot No. 1, where the beetles can lay their eggs. It also will destroy June beetle larvae and at the same time make the forest floor less suitable for egg-laying by

[illegible]

[illegible]

Planting

Planting of small trees is often necessary to establish the stability of the forest. Large gaps in the canopy should be filled with seedlings, or the wind that has a full current will create conditions for windfall. Planted trees are larger than natural seedlings, have vigorous root systems, and can compete successfully with the vegetation. Planting distributes the trees more evenly than seeding.

Planting is necessary if it is desired to introduce a species, to hasten the reforestation of areas already partly, or to get full stocking.

In planting for the purpose of establishing a new stand, the number of trees planted per acre must be determined by the number of trees which will be removed.

Usually four planting holes are made per tree. There is no need for a hole to be very large, as natural soil will be present from a distance of a few feet would be used. A 2-foot spacing would result in planting 44 trees per acre, and if a 10-foot spacing were used, there would be only 4 trees per acre. Planting, if necessary, should be done in the early spring. The trees are larger and so planting can be done with 6-foot spacing, thus probably reducing cost to pay for the operation. It is not likely that replanting will be necessary

where planted trees are scattered among large trees and natural seedlings, at least if the no-load spacing is used. Distances could satisfactorily be used in most cases, as there is no need for accurate measurements.

At the U. S. Military Tract all the trees used for underplanting were hardwoods. Conifers such as white pine and red pine would very likely grow well on the lighter soils of the Military Tract and when not planted under shade. Both conifers are used in Indiana and Illinois.

The following are the species and number of trees which were planted per acre in each woodlot. This number was considered satisfactory for the areas covered. Spacing varied from 8 to 10 feet.

Woodlot No. 1 - planted at the rate of 217 per acre. White ash, red oak, basswood, silver maple, black cherry, elm, hard maple.

Woodlot No. 2 - planted at rate of 97 per acre. Species were silver maple, white ash, hard maple, red oak, basswood, black cherry, and elm.

Woodlot No. 3 - a few planted along edge of woods where rather open. White ash, red oak, silver maple, and white birch.

Woodlot No. 4 - planted at rate of 140 per acre. All were hard maple.

Woodlot No. 5 - planted at rate of 107 per acre. All were red oak.

The number of trees planted depended on not only the number of large standing trees but also on the number of seedlings of similar size to the trees being planted.

A few black walnut trees were planted along the edge of woodlot No. 2, where they would receive plenty of light and also aid in protection from winds.

The species planted at the Hillory Farm are not necessarily of the best, e.g., the silver maple (*Acer saccharinum*). But maple had been ordered, the nursery had substituted its stock, and the fast-growing, poorer tree was substituted. The growth will probably be as successful as that of other maples, however. A few white birch were planted to beautify a knoll near a road. Ash, red oak, and black cherry are native to the habitat of these seeds and should grow well.

Outside the woods, an area of about 3 acres has been cut clean. There may have been a little grazing since then, but none at least in the last 3 or 4 years. The area is now grown to trees (mostly up to 3 or 3 feet high, mixed with raspberry bushes, shrubs, grass, and weeds. Two hundred black walnut trees and 200 tulip trees were planted on the area, but filled in only one-half or less. The present young tree growth looks promising in some places, but sod is very heavy over parts of the area. It is located on the east side and adjoining Woodlot No. 2, and has probably received some seed blown in from the woods. The north consists of white ash, hickory, white oak, black oak, sassafras, etc. The area is not well-stocked, but with a little planting and more natural reproduction of seedlings or sprouts, the competing vegetation will be overcome and a complete cover established.

A little further south there are other species which are successful in planting. In Indiana (37) the species most suitable for the better soils are black walnut, white ash, hickory, white oak, and tulip poplar. On the poorer soils, from hard clay to sands or gravels, species recommended are shortnut, ash, black oak, pin oak, red cedar (on ridges with shallow soil), scrub eagle, white pine, jack pine, and Norway spruce. The latter does better, preferring a foot in diameter.

SUMMARY

The forests of the oak-hickory type are prevalent throughout much of southern Michigan, and outside of Michigan extending south and west over an immense area. The original nature of the forest woodlots in most regions. There are no very large tracts in Michigan.

The type covers the rolling, glaciated lands of Michigan and on poorer soils than the beech-maple type.

The most prominent species are white oak, red oak, black oak, and hickory, with other valuable species such as white ash and black cherry. Iron-wood, ash and sassafras are the poorest species but are not found in large volume.

The red and black oaks (scarlet) are the healthiest trees in the stands. They also produce the largest volume and have the fastest growth, and therefore should be conserved.

Many of the stands have been very poorly cut and are in bad condition. The cuttings were heavy and the trees severely opened. Grazing and competition with undesirable species have kept down the young tree growth.

These stands may be put into better condition by removal of grazing animals, by cutting to improve the stand in health and composition, and by planting and encouragement of sprouting to establish new tree growth in open places. Many acres in woodlots can be reforested by allowing them to grow up.

Insects and disease may be resisted by developing healthy, closed stands and by removing diseased and insect-infested trees.

The species of forest trees which follow in order of preference, in order of predominance in the full fully: black cherry, white ash, sassafras, flowering dogwood, red maple, black (and red) oak, giant hickory, American elm, slippery elm, bur white oak, black walnut, American elm. Survival of elm and maple is low. Cherry, ash, maple, black and red oaks, white oak, hickory, and walnut should be encouraged as much as possible.

Slash disposal is not a problem. Tops should be lopped so as to lie close to the ground, where they will quickly, thus aiding in destruction of insect and fungus, in addition of organic matter to the soil, and in improvement of conditions for establishment of new tree growth.

The fire hazard is not great, but serious injury to the trees results when fires do occur. Litter and trees are burned from the soil. Deterioration of site is a result.

Growth of sub-climax shade is slow, but the production of wood value is only one of the reasons why forests of this type should be grown. Other reasons are:

(1) Preservation of soil cover on lands subject to erosion.

(2) Protection of watersheds.

(3) Utilization of land too rough or too poor for farming.

(4) Reforestation of farms, other private lands, and public lands.

(5) To increase value of farm and other property.

(6) To provide security for farm loans.

(7) To serve as a livelihood for building and filling

(.) To serve as protection for [illegible] birds, and other animals or wildlife which are beneficial to farm or promote enjoyment of scenery life by their use.

TREES OF THE CAMPGROUND WILDLIFEFOOD PLOT

	Common Name	Scientific Name
1.	Black oak	Quercus velutina
2.	Red oak	Quercus borealis
3.	White oak	Quercus alba
4.	Pignut hickory	Hicoria glabra
5.	White ash	Fraxinus americana
6.	Black cherry	Prunus serotina
7.	Red maple	Acer rubrum
8.	Sassafras	Sassafras officinale
9.	Black walnut	Juglans nigra
10.	Largetooth aspen	Populus grandidentata
11.	Trembling aspen	Populus tremuloides
12.	Juneberry	Amelanchier canadensis
13.	American elm	Ulmus americana
14.	Flowering dogwood	Cornus florida

FIGURE VI

Southeast corner of Woodlot No. 1, looking southeast from clover and timothy field, June 19, 1939. Shows nature of woods, including some poorly-formed trees and a lack of undergrowth due to grazing. June beetle adults have partially defoliated a few of these trees in the picture. The sod underneath the trees, and the field in the foreground are believed to be breeding-places for June-beetles

FIGURE VII

Reproduction Transect No. 1, Plot A, Woodlot No. 1, on June 19, 1929. Shows dense and tall growth of grass and sedge, with scattered growth of catnip, Canada thistle, red raspberry, violet, dandelion, cinquefoil, yarrow, and wood anemone. A result of full overhead light and pasturing of animals. Pasturing ceased 1 or 2 years previously. Leaf litter is scattering. Only 6 trees of natural growth on the transect

FIGURE VIII

Looking north from southwest corner of Plot A, Woodlot No. 1, on June 19, 1939. Note heavy growth of grass and sedge and lack of reproduction. Grazing ceased 1 or 2 years before. Some trees show partial defoliation by June beetles.

FIGURE IX

Another view of Woodlot No. 1, June 19, 1928. Sassafras and white oak in foreground, with large black cherry in rear. Dense grass and sedge on ground. Small pile of rotting slash in lower left-hand corner. Slash in cages was for insect study

FIGURE X

Looking northeast across Plot B, Woodlot No. 2, June 19, 1939. Note denser stand and better ground conditions, although grazing occurred here to some extent in the past. Mandrake is prominent on ground, with some grass. No sod is formed. Not much young tree growth.

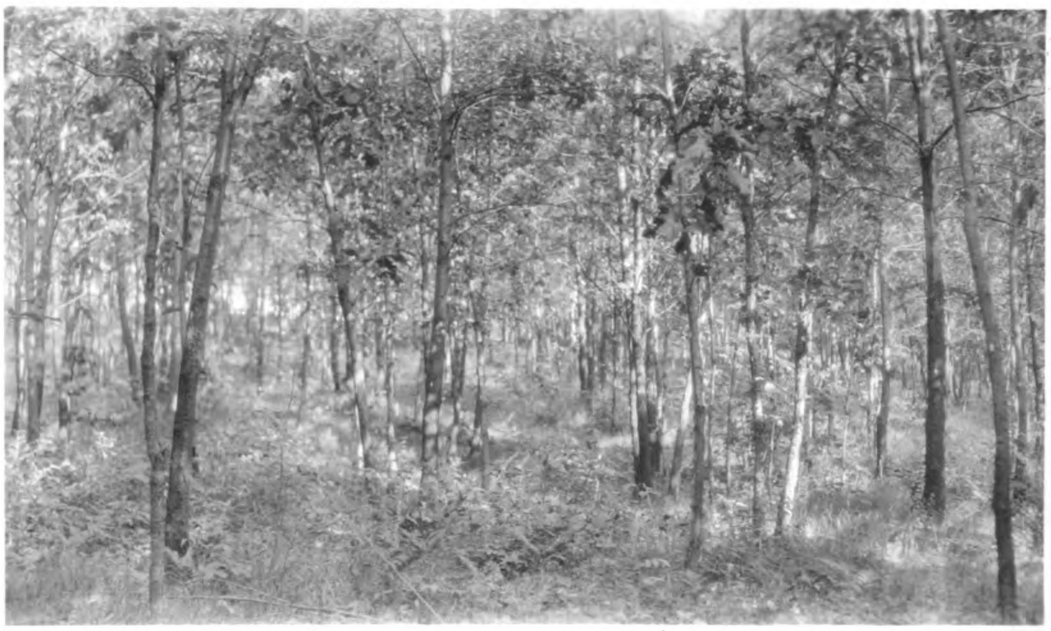


FIGURE XI.

Looking southeast across Plot C, Woodlot No. 3, on June 19, 1929. Practically all trees are of sprout origin, and nearly all are oak. Note ferns and grass on ground, which is fairly well shaded. No sod formed there, however. Trees are mostly 3 or 4 inches D. B. H.

FIGURE XII

View of clear-cut area, showing oak, hickory, and other young tree growth, also grass and weeds. Many trees are of sprout origin. Oak in foreground is 8 or 9 feet high. March 18, 1930.

FIGURE XIII

Looking northeast across Plot N, Woodlot No. 5. Sloping into marsh at right. Large-tooth aspen and sassafras in foreground, with oak and hickory in background. Woodlot No. 4 across marsh. March 19, 1950.

FIGURE XIV

Woodlot No. 5, looking north across March. March 19, 1930.

FIGURE XV

Looking northeast across Plot D, Woodlot No. 4. Dense cherry reproduction in back-ground, in which Transect 16 was placed. March 16, 1950.

FIGURE XVI

Work of hogs in Woodlot No. 1. This was formerly a heavy sod. March 19, 1930.

FIGURE XVII.

Work of hogs shown at right. Heavy sod on left of fence. March 19, 1920.

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