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Growth in Well-Stocked Natural Oak Stands in Missouri

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This bulletin reports on School of Forestry
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Growth in Well-Stocked Natural Oak Stands in Missouri

ANDREW J. NASH

INTRODUCTION

In 1951 the School of Forestry initiated a study intended to determine the rate of growth on well-stocked oak forests. That year a number of circular one-fifth acre plots were established under a variety of ownership and site conditions.

This study does not attempt to portray growth on all forest lands in the state, but only on those stands which had some sawtimber volume. The stands for which these plots are representative are above average when compared to the statewide average volume on forest land. According to King, Roberts and Winters (1949) the average board foot volume for all oak forests in Missouri was, in 1946, 789 board feet per acre. Growth was estimated at that time to be 45 board feet per acre per year.

Remeasurement of these plots is scheduled at five year intervals, the first of which took place in 1956. This report presents the findings of the first remeasurements; subsequent remeasurements will strengthen the information given in this report.

The location of the plots, by county, is given in Figure 1.

PROCEDURE AND CONDITIONS

The plot information obtained at the first, and subsequent measurements includes:

a. Location
b. Ownership
c. Description of the ground cover
d. Tally of trees by species and diameter class
   1. Trees in the 2 to 6-inch diameter class were tallied by 2-inch diameter classes
   2. Trees 7 inches and over were tallied and listed separately
e. Notes on form, defect and crown class were taken for each tree 7 inches dbh[1] and over.

[1] *Diameter at breast height.*

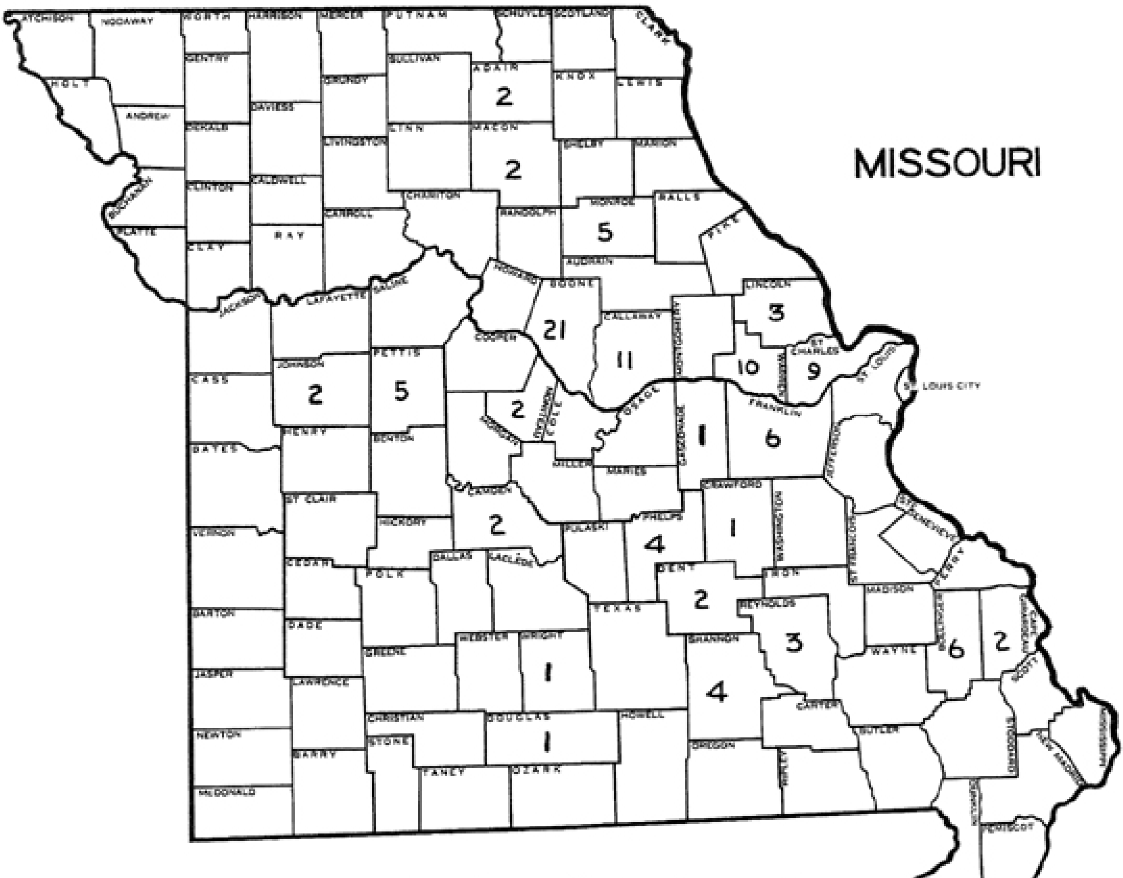

Fig. 1—Number of growth plots by county.

In the original calculations, basal area per acre was determined for each diameter group, and board-foot volume was computed for trees 10 inches dbh and over. The board-foot volume was calculated by the International ¼-inch Rule for a Form Class of 76. The same standards of basal area and volume were used in the first remeasurement and will be followed in later remeasurements, in order to make comparisons valid.

In addition to the information taken in the original survey, the 1956 data included a summary of ingrowth, or trees which were formerly below the 7-inch dbh class and which had since reached that diameter limit. The same procedure was followed for those trees reaching the board-foot volume class (10-inch dbh). Average diameters were calculated for the two diameter groups and the five-year growth in volume and basal area was determined.

In the 1951 survey, site index was not measured. A great number of independent variables affect growth of trees and some expression of site would increase the usefulness of the study, since it would enable volume increase to be designated by site. Auten (1945), Coile (1948) and Brown (1953) have worked on this problem and have reported on the effectiveness of a number of independent variables. Formulas have been developed to express growth in terms of slope, aspect, depth of soil, amount of clay particles in different horizons, etc. Lutz and Chandler (1946) and Wilde (1958) cover the subject of forest soil in relation to site quite thoroughly in their writings. Other workers, such as Austin and Baisinger (1950), Roth (1916) and Westveld (1952) have discussed the problem of forest site evaluation in relation to soil, topography and climate for different forest regions of the United States. In a study of this nature, a detailed soil analysis was not required, but "site" was to be based on some of the more important physiographic factors which affect tree growth. Topographic features such as aspect, slope, and position on the slope affect tree growth in a number of ways. The cooler, more moist north and east aspects increase the ability of the soil to retain moisture for longer periods of time; conversely, the south and west aspects are, relatively speaking, hot and dry, with more sun increasing evaporation and transpiration. In areas which have not been glaciated, different soil series profiles are exposed because of the action of decomposition of the original bedrock and soil parent material, coupled with erosion of the exposed soil. In glaciated regions, the soil mantle is usually thicker and less consolidated than in non-glaciated areas, with less topographic variation of soil series. For this study it was decided that the plots should be separated into aspect classes and geographic areas.

The aspect classes were necessarily quite broad, being divided into:

1. North aspect, which included all aspects from north-west through to east,
2. South aspect, which included all aspects from south-east through to west.

There is strong evidence that the area south of the Missouri River was not covered wih ice sheets during the glacial period. These soils, therefore, are a result of being formed in place by the process of soil development from geologic material. There is some degree of "slumping" or deposition of one soil type on another by gravity action, but, in general, the soil types south of the Missouri River are not complicated by the deposition of glacial till, as they are north of the river. Loess, (wind-blown silty deposits from major stream beds), covers a large area in the northern portion of the state. This differs markedly from the loess caps found in the southern and southwestern areas where the original deposits came from the Great Plains region, not from river outwashes. Relatively few of the plots used in this study are located on either the "fresh" loess north of the river or on loess caps south of the river.

For these reasons, the plots were separated into two geographic areas for comparison:

1. Plots located north of the Missouri River.
2. Plots located south of the Missouri River.

There are nine possible comparisons which can be made on the basis of the aspect and regional break-downs:

1. All plots regardless of aspect or geographical region
2. All north aspect plots throughout the state
3. All south aspect plots throughout the state
4. North of the Missouri River
   5. North aspect plots
   6. South aspect plots
7. South of the Missouri River
   8. North aspect plots
   9. South aspect plots.

A comparison between geographical areas and aspect classes is made later in this bulletin.

Examples of predominantly oak stands on different sites are given in Figures 2 and 3.

Number of Plots

In 1956, a total of 92 plots was remeasured. Included in the 92 plots measured in 1956 were 17 plots which had received some degree of cutting during the five-year interval.

A tabulation of the number of plots in each of the categories listed above is given below:

Fig. 2—White oak stand on east slope north of the Missouri River.

Fig. 3—White oak stand on a rocky west slope north of the Missouri River.

NUMBER OF PLOTS BY AREA AND ASPECT CLASS

Condition	Number
All plots regardless of area, aspect or condition	92
North aspect, state-wide	52
North aspect, North of the Missouri River	26
North aspect, South of the Missouri River	26
South aspect, state-wide	23
South aspect, North of the Missouri River	14
South aspect, South of the Missouri River	9
Plots on private land which have been logged	17

Ownership Classes

The plots had been established on a number of ownership classes in an attempt to cover as wide a range of conditions as possible. Of the 75 plots which were used in this study, 41 were on forest lands which are under state control, such as state parks, state forests or land administered by the School of Forestry, University of Missouri. On these lands, it was expected that there would be a minimum of disturbance for a sufficient number of years to allow valid conclusions to be drawn for growth rate. The remaining plots, 34 in number, were on privately owned forest land over which no control could be exercised. It is quite possible that some of these 34 plots on private land will be cut between the remeasurement in 1956 and the next remeasurement in 1961. The 75 plots are considered to be natural stands, on which some trees may have died by natural causes.

DISCUSSION OF GRAPHS

To portray the results given in Table 1, a series of graphs is shown in Figures 4-7 inclusive. Each graph combines the results for north and south slopes for easier comparison.

The relation between the two variables appears to be linear in all cases, and the least squares method of fitting a straight line was used to determine the position of the line. The formula for the straight line is also shown on each graph.

In each of the graphs (Figs. 4-7) the symbols are the same, being:

X = basal area in square feet per acre for all trees 10 inches dbh and over.

$\hat{Y}$ = board-foot volume, International ¼-inch Rule of trees 10 inches dbh and over.

State-wide Plots

Of the 92 board feet per acre per year growth on all plots throughout the state, ingrowth accounts for 37 board feet. This is growth on trees which were, in 1951, below the minimum sawtimber diameter but which had grown during the succeeding five years into merchantable size.

Although the growth rate, based on 1951 volume, was greater on south as-

TABLE 1--RESULTS OF GROWTH STUDIES FOR THE FIVE-YEAR PERIOD
(Board-foot volume and growth by geographic areas and aspect classes)

Location	Aspect	Board-foot Vol. Int. ¼" 1951	Board-foot Vol. Int. ¼" 1956	Growth in Bd. Ft. Vol.	Aver. Ann. Growth	Growth as % of 1951 Vol.
		Per Acre	Per Acre	5 Years	Per Acre	
State.wide	N & S	3230	3690	460	92	2.86
	N	3710	4220	510	102	2.75
	S	2440	2815	375	75	3.04
North of Mo. River	N & S	3120	3650	530	106	3.39
	N	3640	4220	580	116	3.20
	S	2315	2750	435	87	2.74
South of Mo. River	N & S	3340	3690	350	70	2.09
	N	3880	4295	415	83	2.14
	S	2820	3105	285	56	1.97

pect plots (3.04 percent) than on north plots (2.75 percent), the actual board-foot volume growth is 27 board feet per acre less. The initial level of growing stock supplies the answer to this apparent reversal of figures. The per acre volume on north plots in 1951 was 3710 board feet per acre and only 2440 board feet per acre on south plots, making the lower annual growth on south aspects a higher percentage when based on initial volume.

Plots North and South of the Missouri River

Differences in growth and rate attributable to geologic parent material and climate are shown in Figure 5.

Here the situation is the reverse of that given above. The annual increment and growth rate are both lower south of the river than north, although the initial volume per acre is higher, 3340 board feet per acre vs. 3120 board feet per acre. The geologic formations and development of the soils are widely different between the two areas.

North Aspect vs. South Aspect Plots

The average stocking on north aspects is greater than on south aspects both north and south of the Missouri River. A history of repeated fires and mis-use of timber lands supplies the answer. In the Ozarks, deliberate burning and uncontrolled fires were a common occurrence. The practice of heavy cutting in merchantable timber reduced the growing stock to a very low level. The results are evident in the differences in stocking between the two geographic areas.

All areas in the state which come under the Fire Prevention districts of the Missouri Conservation Commission and those areas managed by the U. S. Forest Service are benefiting to the extent that the occurrence of forest fires is less,

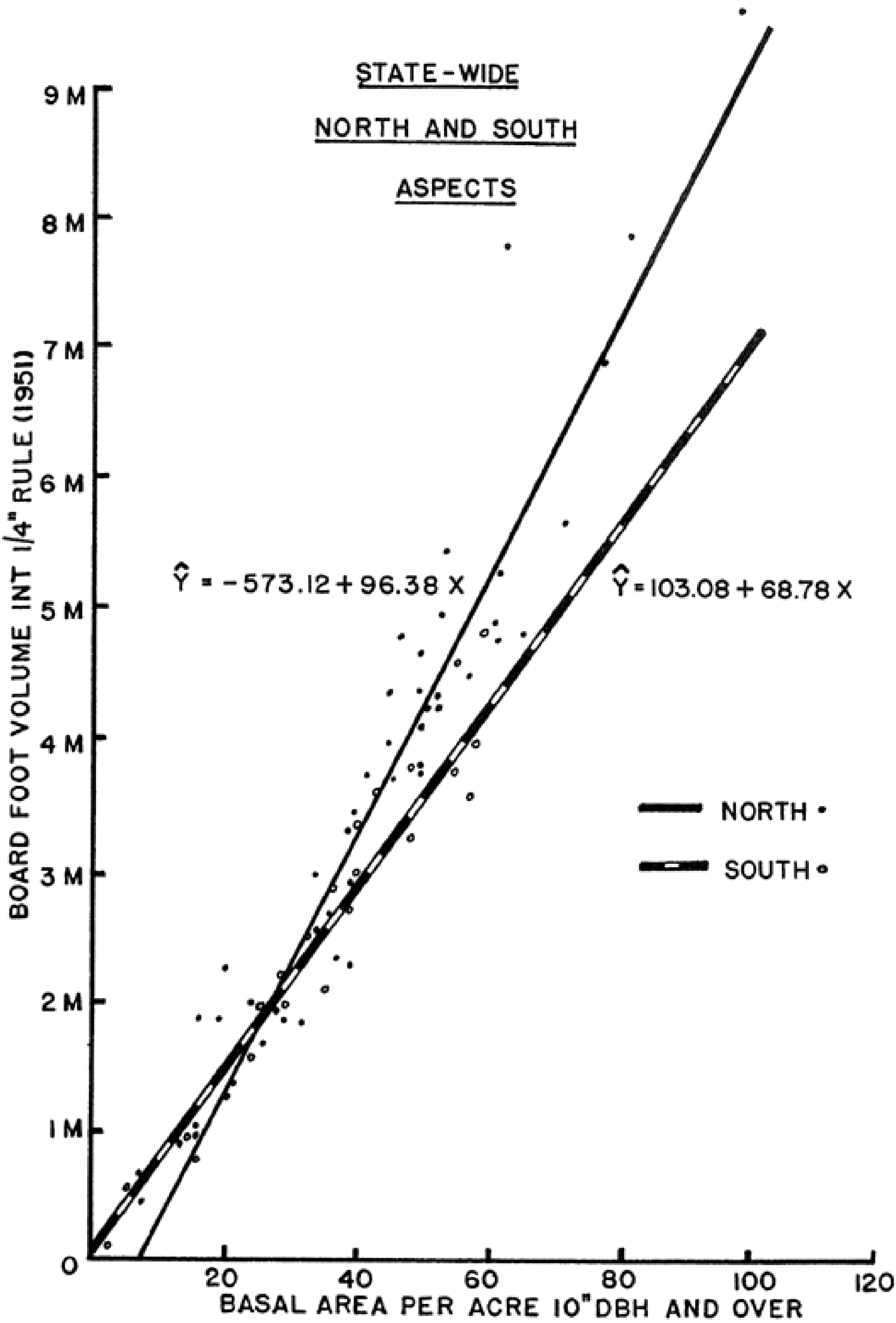
STATE-WIDE
NORTH AND SOUTH
ASPECTS
Ŷ = -573.12 + 96.38 X
Ŷ = 103.08 + 68.78 X
NORTH •
SOUTH ∘
BOARD FOOT VOLUME INT 1/4" RULE (1951)
9 M
8 M
7 M
6 M
5 M
4 M
3 M
2 M
1 M
0
20
40
60
80
100
120
BASAL AREA PER ACRE 10" DBH AND OVER

FIGURE 4

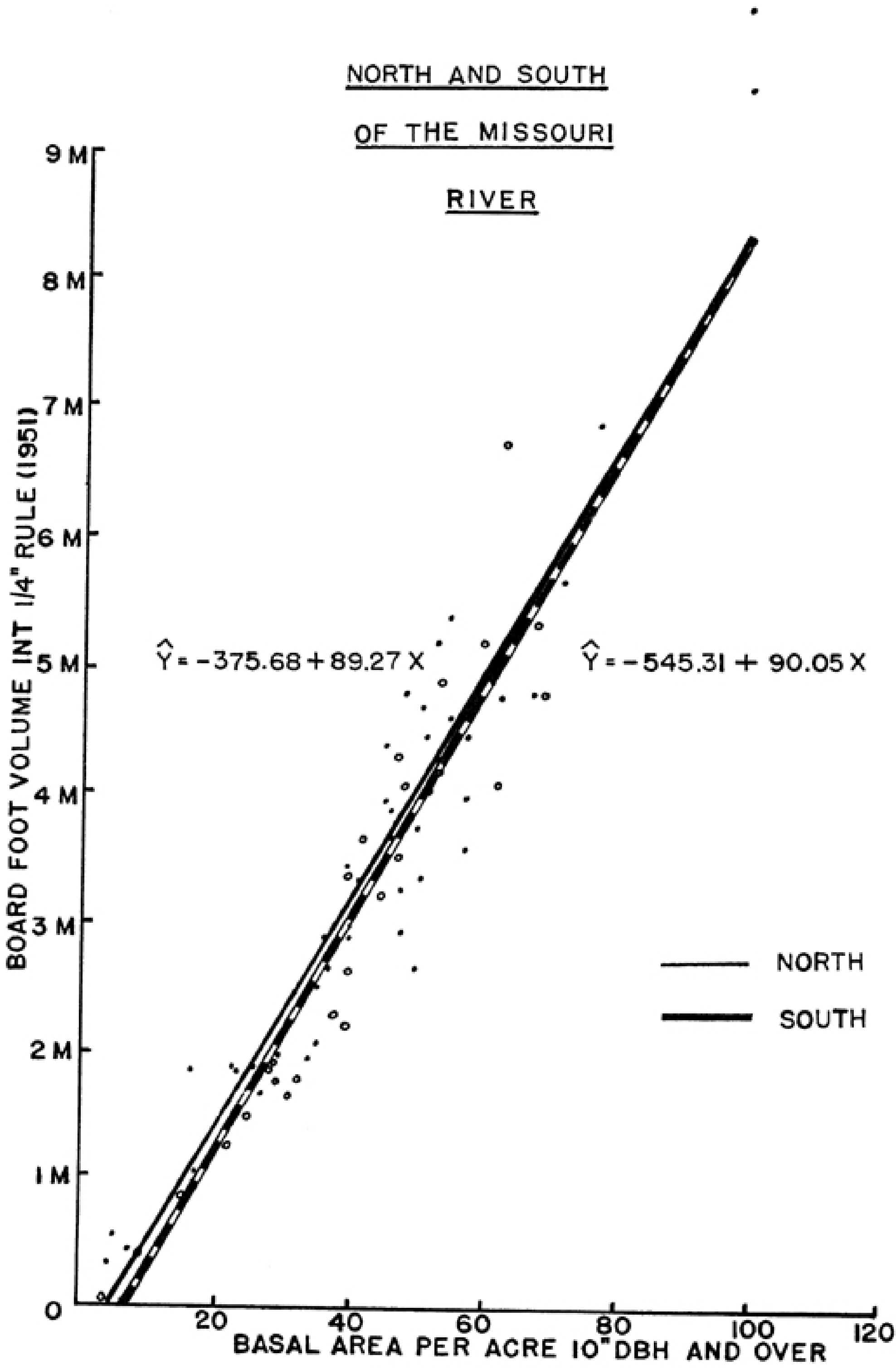
NORTH AND SOUTH
OF THE MISSOURI
RIVER
BOARD FOOT VOLUME INT 1/4" RULE (1951)
9 M
8 M
7 M
6 M
5 M
4 M
3 M
2 M
1 M
0
20
40
60
80
100
120
BASAL AREA PER ACRE 10" DBH AND OVER
Ŷ = -375.68 + 89.27 X
Ŷ = -545.31 + 90.05 X
NORTH
SOUTH

FIGURE 5

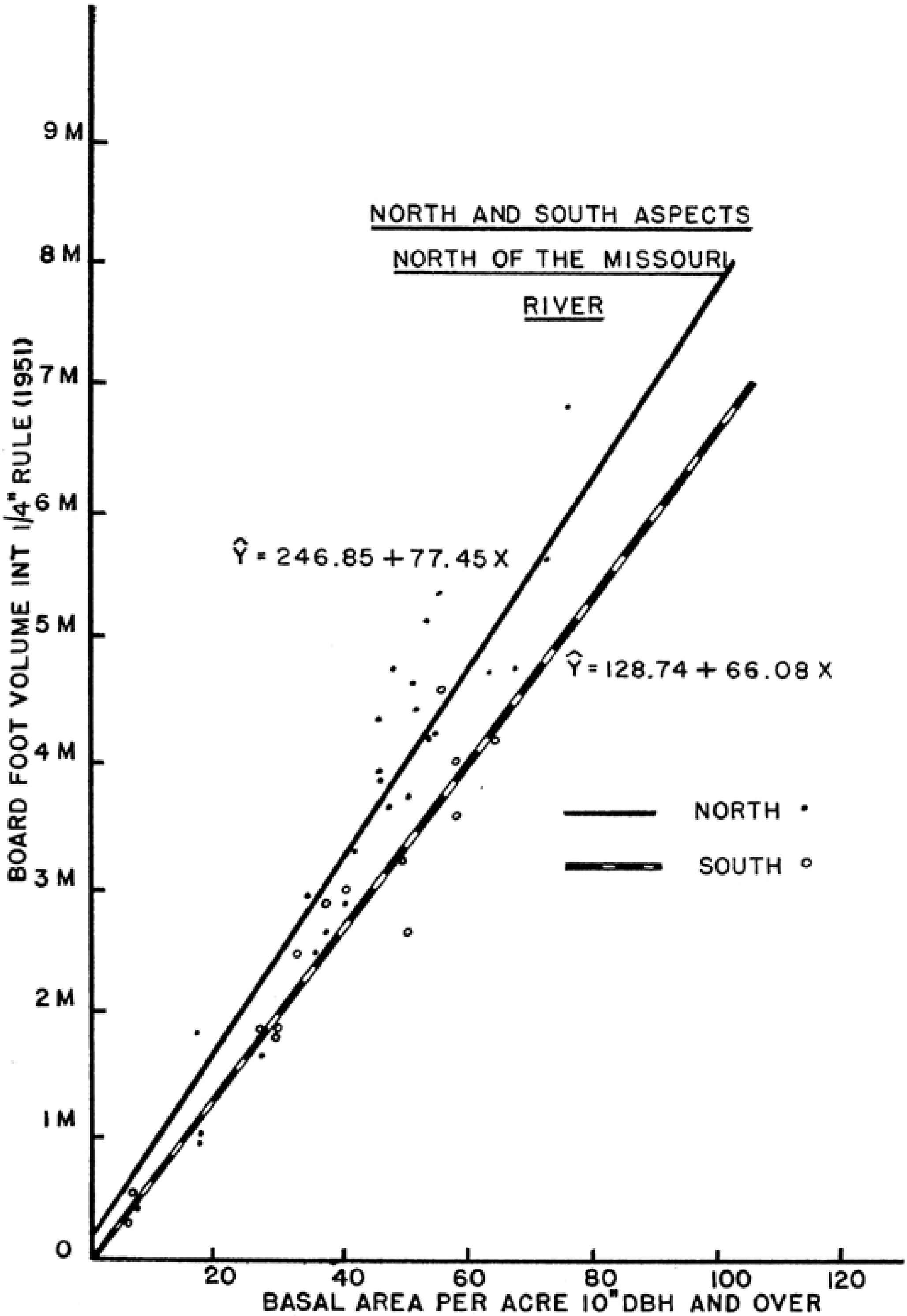
NORTH AND SOUTH ASPECTS
NORTH OF THE MISSOURI
RIVER
BOARD FOOT VOLUME INT 1/4" RULE (1951)
9 M
8 M
7 M
6 M
5 M
4 M
3 M
2 M
1 M
0
Ŷ = 246.85 + 77.45 X
Ŷ = 128.74 + 66.08 X
NORTH
SOUTH
20
40
60
80
100
120
BASAL AREA PER ACRE 10" DBH AND OVER

FIGURE 6

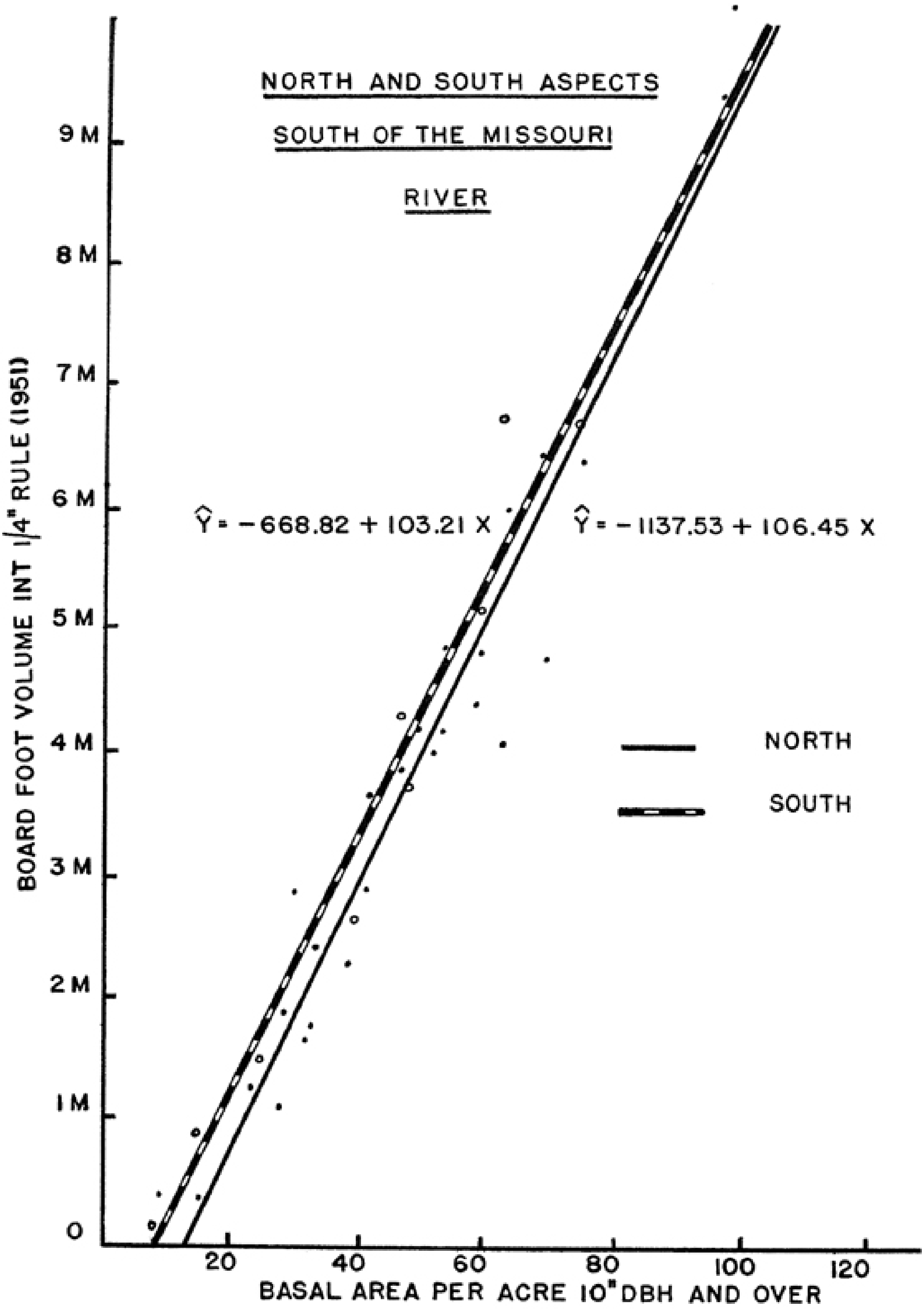
NORTH AND SOUTH ASPECTS
SOUTH OF THE MISSOURI
RIVER
Ŷ = −668.82 + 103.21 X
Ŷ = −1137.53 + 106.45 X
NORTH
SOUTH
BOARD FOOT VOLUME INT 1/4" RULE (1951)
0
1M
2M
3M
4M
5M
6M
7M
8M
9M
20
40
60
80
100
120
BASAL AREA PER ACRE 10" DBH AND OVER

FIGURE 7

even though some years do produce a large number of serious fires in certain areas. Protection from fire is one of the most important factors in increasing the level of growing stock and ensuring that the quality of the sawtimber is improved. Fire scars, according to Burns (1955) are a large factor in reducing quality of existing sawtimber stands. Future years will see a continuation of the trend of increasing volume and quality.

One of the graphs is not in line with the explanation given above. It is the case of the north and south aspect plots south of the Missouri River. For a given basal area, the south aspect plots result in a higher estimated board-foot volume than those on a north aspect. There were only nine plots occurring on a south aspect, while 26 were on a north aspect. The small number of plots makes the regression line of questionable value, as one or two plots with unusually high or low volumes can change the slope of the regression line a great deal. A larger sample *should* result in a lowering of the line, bringing it more in step with the state-wide data.

PRACTICAL APPLICATION OF THE RESULTS

The preceding graphs have more than academic value. In order to estimate the amount of saw-timber volume in a given area or on a particular aspect, the basal area of trees 10 inches dbh and over can be measured and a volume in board feet read directly from the graph. The basal area per acre may be obtained by actually measuring all trees above the minimum diameter or may be estimated by using a wedge prism or other device for subtending a given angle according to the Bitterlich method of cruising as discussed by Afanasiev (1957).

Another way of obtaining present volume is to make use of the straight line formula given for each condition class. For example, if the board-foot volume in a well-stocked oak stand located on a north slope in Macon County (north of the Missouri River) is desired, the basal area per acre contained in trees 10 inches dbh and over can be measured and applied to the formula directly. If the basal area were 76 square feet per acre, the board foot volume in the stand would be:

$$\hat{Y} = 128.74 + 66.08\ (76)$$
$$= 128.74 + 5922.08$$
$$= 6050 \text{ board feet per acre.}$$

Two features are outstanding in Table 1 and the graphs. One is the relatively low level of growing stock on all plots, and the other is the low annual increment per acre for the growing stock carried.

The reasons for this have been given. The objective of forest management, however intensive or extensive, is to accomplish two ideals. The first is to raise the volume of growing stock to an optimum level considering species and site. The second is to increase growth rate by judicious silvicultural practices. The oak forests in Missouri are at the beginning of the first stage in realizing these objectives. Adequate and continued protection from fire, insects and disease is the most important factor in continuing the progress made in the past 20 years.

Missouri's forest stands should be allowed to double their present board-foot volume.

Volume Prediction

The graphs showing volume per acre plotted on basal area per acre are sufficient for estimating present volume, but they cannot be used for predicting future volume unless future basal area per acre can also be estimated.

Figure 8 illustrates one method of predicting volume growth for the next five-year period based on performance during the preceding period. This is a common way of predicting growth. Plotting 1956 board-foot volume on 1951 volume results in a linear relationship, and if the plots have made any growth during the period, the line will slope at an angle greater than 45 degrees. For instance, Figure 8 shows that if the volume on a certain plot in 1951 had been 3300 board feet per acre, the expected volume in 1956 would have been 3850 board feet per acre. Taking this latter volume as "present" volume, and reading the graph, the estimated volume per acre in 1961 would be 4450 board feet per acre. It is simply a matter of shifting the entry on the abscissa to the right by an amount which depends on past performance. Volume prediction assumes that the trees on the plot will continue to grow at the same rate and that mortality will be no greater than in the preceding five years.

SPECIES GROWTH CURVES

Discussion of Growth Curves

Growth by species was not shown in Table 1. During the remeasurement in 1956, increment borings were made on a number of individual trees on representative plots in each aspect class in order to determine growth rate by species. The period for growth analysis was increased from the five-year remeasurement time to 10- and 15-year periods in order to smooth out climatic variations. A severe drought from 1951 to 1954 inclusive occurred throughout the state. This period coincided with the first few years growth of the plots, and it was considered advisable to increase the number of years when determining radial and diameter growth on individual trees.

Three main species of oaks were included in the growth information from the increment borings—white oak *(Q. alba* L.) black oak *(Q. velutina,* Lam.) and post oak *(Q. stellata* Wang.).[2]

The growth curves follow the classic pattern, showing a fast-rising curve for the smaller diameter classes, followed by a gradual decline in growth rate as the diameter increases.

Figures 9 through 14 show the growth curves for the three species for two aspect conditions, north slope and south slope.

[2] *The nomenclature has been taken from* Textbook of Dendrology *by Harlow and Harrar, 2nd Edition, 1941.*

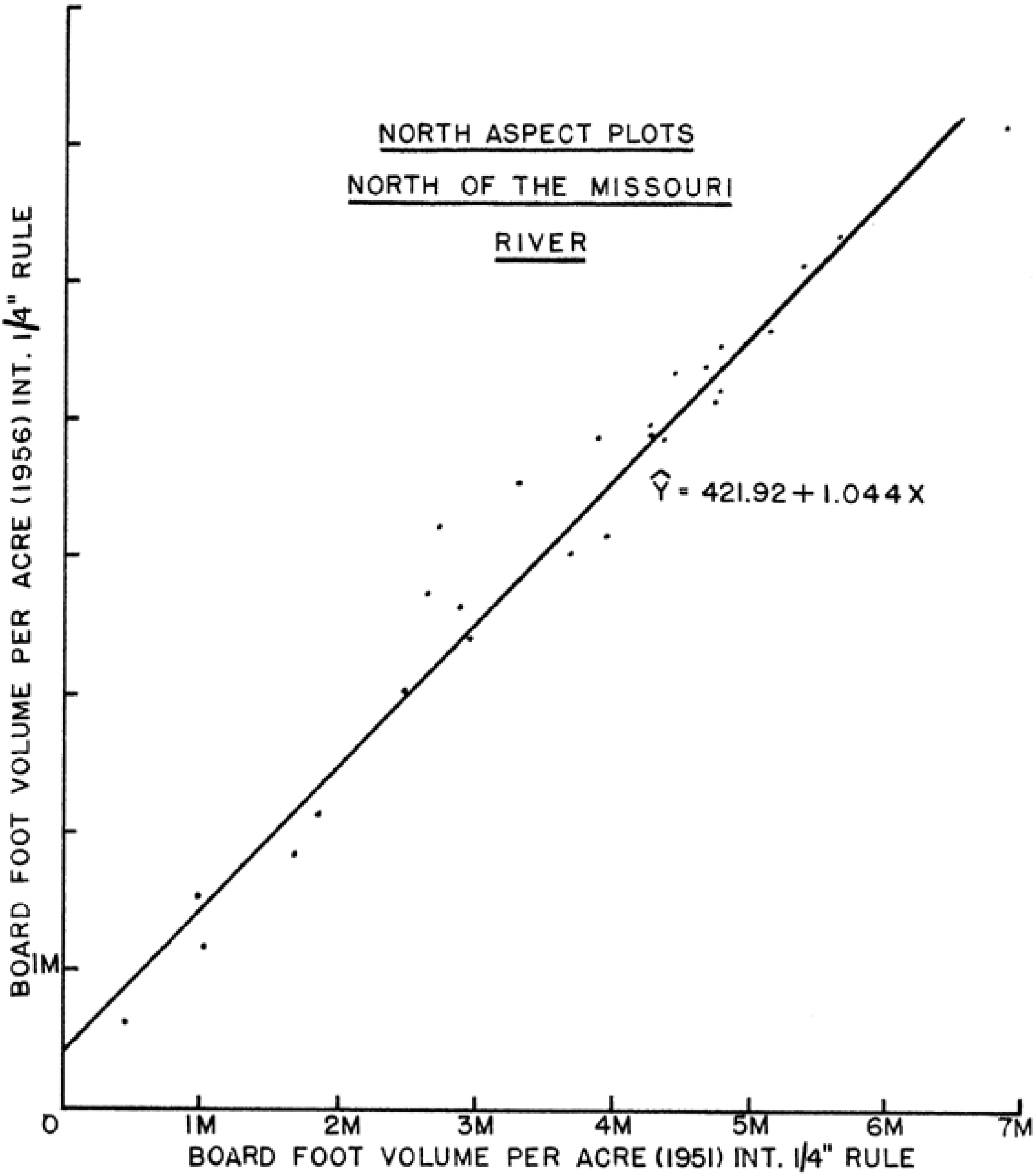

FIGURE 8

The curves for white oak illustrate the effect of aspect, which in turn, is an indication of site quality. The peak of the curves on north slopes occurs at approximately 16 inches dbh, while the peak for white oak on south slopes occurs at approximately 11 inches dbh. Even at 20 inches dbh, the growth rate is three times as much during the same period on north slopes as it is on south slopes.

As might be expected, the growth rate for post oak is considerably less than for the other species. Practically all the post oak in the sample occurred on areas south of the Missouri River where the soil on ridges and hill tops is of very low fertility and becomes cemented with a clay pan at varying depths. There is considerable improvement in growth rate on the cooler north slopes over the south slopes.

Black oak exhibits a remarkable growth rate on north slopes with the peak growth rate coming at approximately 12 inches dbh. During the previous 15-year period, the diameter increase was 4.5 inches at dbh. However, black oak shows a much faster decline in growth rate than white oak.

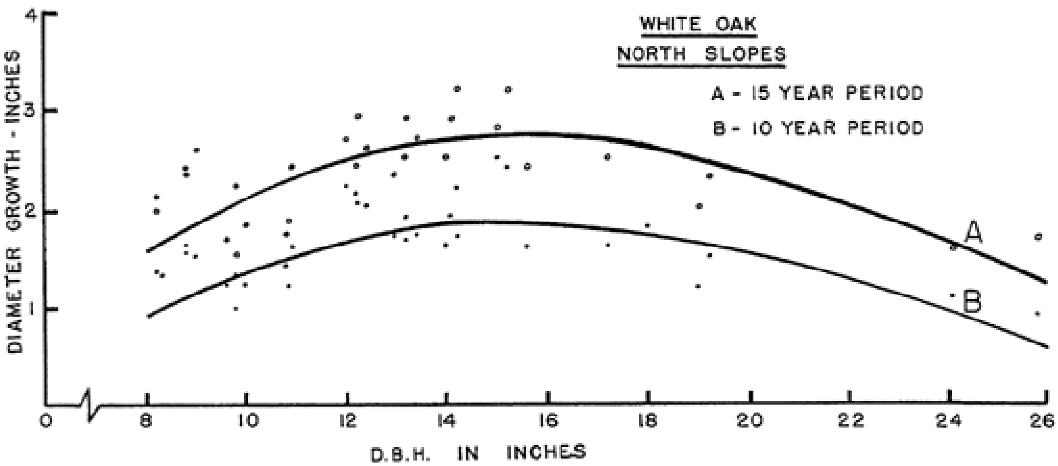

Fig. 9—Relation between diameter growth and dbh for white oak on north slopes.

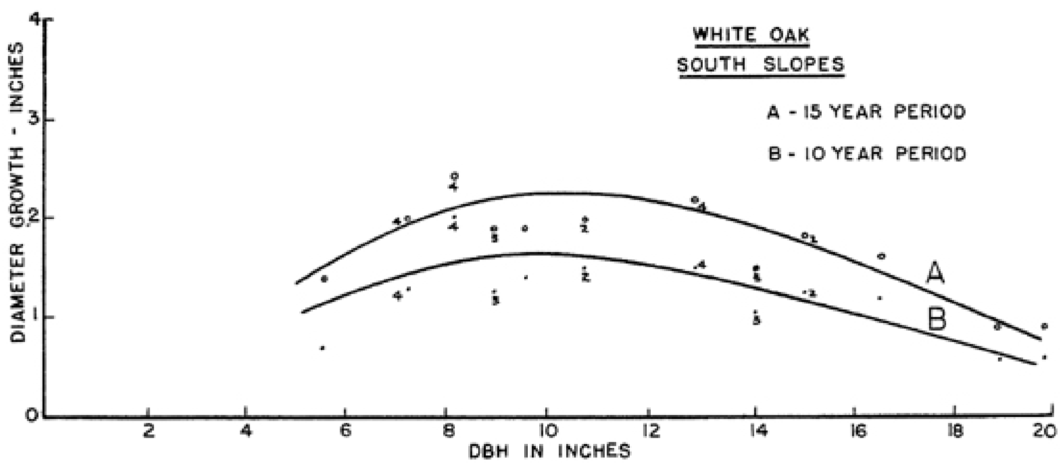

Fig. 10—Relation between diameter growth and dbh for white oak on south slopes.

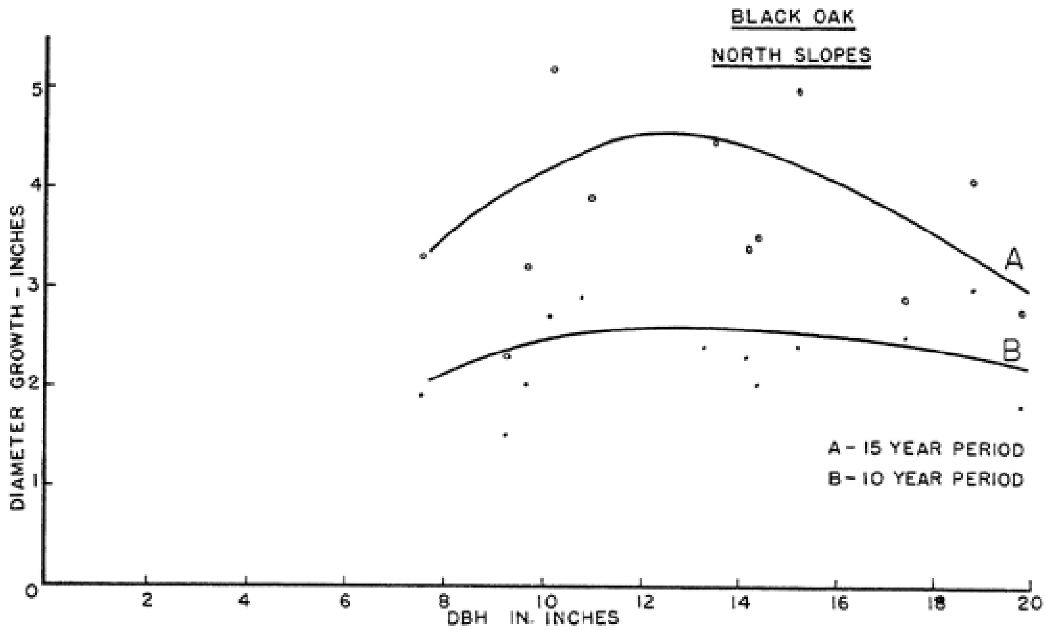

Fig. 11—Relation between diameter growth and dbh for black oak on north slopes.

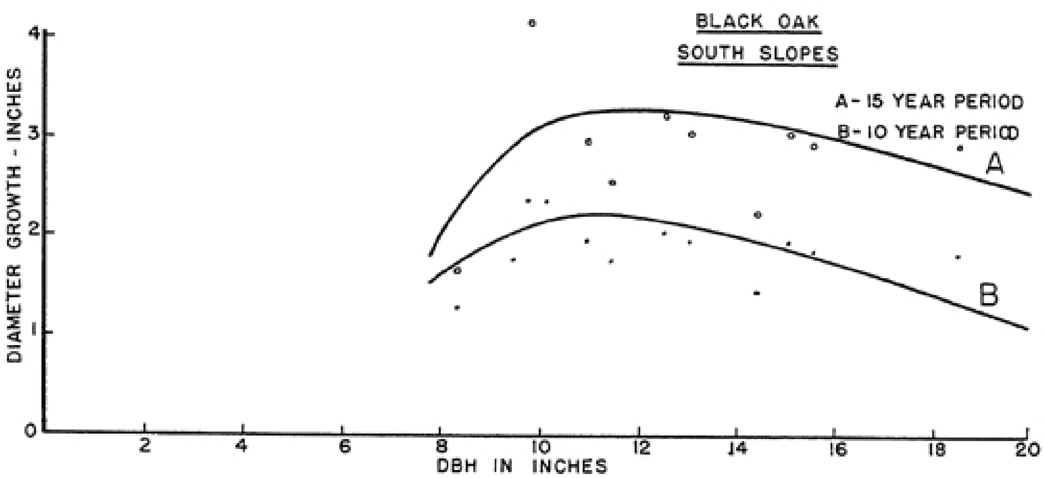

Fig. 12—Relation between diameter growth and dbh for black oak on south slopes.

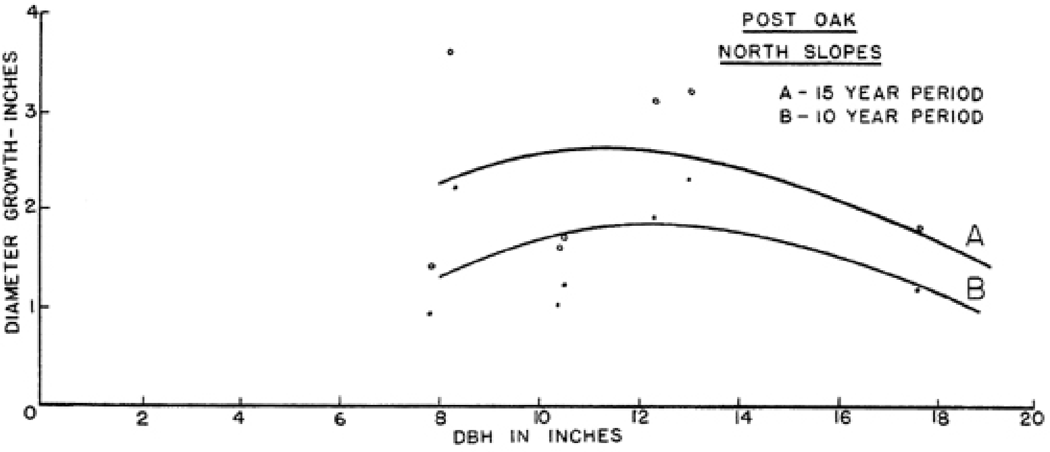

Fig. 13—Relation between diameter growth and dbh for post oak on north slopes.

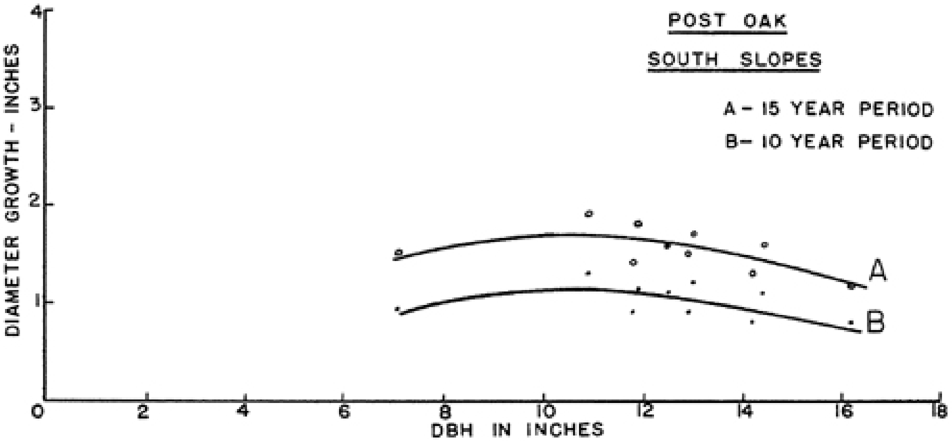

Fig. 14—Relation between diameter growth and dbh for post oak on south slopes.

SUMMARY

In 1951, a number of growth plots were established in well-stocked upland oak stands throughout Missouri. The range of "site" conditions varied from well-drained glacial till on north aspects in northern Missouri to exposed, dry post-oak ridges in the southern part of the state. The first five-year remeasurement was made in 1956, and this report deals with 75 plots which had not received any disturbance from fire or cutting since the plot was established. The average volume on all plots was 3230 board feet per acre, International ¼-inch Rule; this volume is considerably above the state-wide average for all oak stands which is, according to the Forest Survey conducted by the U. S. Forest Service in 1946, 789 board feet per acre.

Graphs are given showing board-foot volume as a function of basal area per acre in trees 10 inches dbh and over, for different areas in the state, together with a comparison between volumes on north and south aspects. All relations are linear, as might be expected from the two mutually dependent variables. Board-foot volume in well-stocked oak stands can be estimated from the graphs, provided the basal area per acre of sawtimber trees is known. The Bitterlich method of obtaining basal area can be used in the field and applied to the appropriate graph.

Plots located on cool, moist slopes north of the Missouri River showed the greatest board-foot volume increase during the five-year remeasurement period. Plots on south slopes south of the Missouri River exhibited the smallest increase. This is partly due to slope and aspect and partly to the geological material from which the various soils were derived.

A graphic method of predicting future volume is given and is based on past performance. Assumptions such as similar climate, constant growth rate and average mortality as in the previous five-year period must be accepted to predict future volume.

Increment borings were taken on the three major species encountered on each aspect class and graphs showing the variation in diameter growth with diameter are presented. The results indicate that black oak on north slopes showed the highest growth rate, followed by white oak and post oak. White oak, however, maintained a better growth rate for the larger diameter trees than either of the other two species.

The average growth rate for all stands sampled was 2.86 percent. The highest rate encountered was for plots north of the Missouri River (3.39 percent) and the lowest was on south aspects south of the Missouri River (1.97 percent). While the growth rates are not excessively high nor low, the reserve growing stock to which they are applied is, with very few exceptions, low. The main objective of forest management is, at present, to protect the stands and allow the growing stock to build up to approximately double its present volume.

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