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THE FIVE-YEAR INTERCEPT METHOD OF SITE
INDEX DETERMINATION IN RED PINE

Thesis for the Degree of M. S.
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Calvin F. Bey

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SITE INDEX DETERMINATION IN RED PINE

By

CALVIN F. BEY

AN ABSTRACT

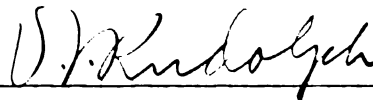
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CALVIN F. BEY

ABSTRACT

The quality of a given forest site is determined by a complex of soil and climatic factors. No single factor has been found to correlate sufficiently with growth to serve as a measure of site quality. The use of plant indicators as a measure of site quality is recognized as a valuable method of forest site quality determination in some instances. The most commonly used index for red pine is that based on total height attained at a given age. In order to reduce the amount of work involved in obtaining the site index values and to permit the evaluation of site index in younger stands, a new technique has been proposed. This method permits greater utilization of the information we presently have on site index.

The internodal distance method, here known as the 5-year intercept method, is based on two assumptions. We assume that height growth made by each tree for five years beginning with the attainment of breast height can be measured correctly. We also assume that once trees of a given species have reached breast height on comparable sites, they will grow at essentially comparable rates for the next five or more years, whereas on contrasting sites they will grow at consistently contrasting rates.

The greatest value of the 5-year intercept method would be obtained with a complete study of growth and soil site evaluation from permanent sample plots. The unavailability of proper stands does not permit the establishment of such a study at the present time. The purpose of this study is to determine the relationship of the values

obtained by the conventional site index method of total height over total age with that of the 5-year internodal distance beginning with the first node above breast height. Such a study is held to be necessary to permit greater utilization of the information we presently have based on site index.

An analysis of the data collected revealed two major results. An analysis of variance test showed that the average time required for sample trees of each plot to reach breast height was not significantly correlated with the 5-year height growth values. This indicates that special factors exert an influence on the establishment time.

An analysis of variance test showed that the correlation between average site index for each plot and average 5-year intercept was highly significant. This implies that the site index values can be explained by, or estimated from, the concomitant variations in the 5-year internodal length values.

The 5-year intercept method of site index determination enables us to obtain site index values on younger stands, and to obtain the site index values on all sites with less effort.

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INTRODUCTION

Red pine (Pinus resinosa Ait.), also called Norway pine, is one of the most valuable coniferous species for reforesting old burned and abandoned fields or pastures in the Lake States. Red pine is long lived, makes fairly rapid growth, prunes itself well, and produces straight, sound, high-grade timber. It grows fairly well on sandy and gravelly soils, of which there are many in the Lake States.

At the present time red pine stands occupy slightly less than one million acres in the Lake States. The plantable area in the Lake States exceeds eight million acres and much of this is suitable for red pine (3). The reforested area and importance of red pine is therefore likely to increase.

Seed source studies of red pine in the Lake States and Northeast have indicated some distinct differences during the first 20 years in survival and growth related to origin (13). According to Hough (8) variations, or ecotypes, exist between the Lake States and Northeast regions but not within the individual regions. For this study, the red pine examined will be considered as a closely knit genetic entity.

Site quality refers to the productive capacity of a given site under certain conditions. A site may be evaluated in three ways: (7)

(1) Directly in terms of quality and magnitude of the various site factors such as light and temperature.

(2) Indirectly in terms of some measurable index which reflects the magnitude of the site factor or vegetation itself, such as physical properties, nutrients, topography, and vegetation. The use of plant

indicators as a measure of site quality is recognized as a valuable method of forest site quality determination in some instances.

(3) In terms of actual production such as volume or height growth. In respect to forest site quality, the actual production method is the most practical and easiest to use. The indirect method is often used on plantable areas which are devoid of trees.

Site index, as applied to Eastern forests, is the height in feet attainable by the average dominant and codominant trees in relatively pure, even aged, and well stocked stands at the age of 50 years. It reflects the combined effect of different environmental factors and is used as a measure of stand productivity.

Planters are interested in site index primarily as a guide to which of several areas to buy or plant, and as a means of predicting the yield of whatever species may be planted on the area chosen. Forest managers are frequently interested in what a stand is most likely to produce in the next ten or twenty years rather than throughout its entire life.

Site index curves are simply growth curves for a given genetic entity under a given set of environmental conditions. Of necessity, American site index curves have been derived from temporary sample plot data; that is, from the measurements taken in the stand for the first time. This method involves determining total ages and heights of a large number of stands, fitting of a single average regression of age on height, and drawing of higher and lower harmonized curves. The disadvantages of this method are many.

This method assumes that the curves of the poorest sites have the same growth pattern as those of the best sites. According to Bull (2), this is not the case. Proper growth curves can be attained only by plotting individual growth curves for a given site.

The process of harmonizing site index curves assumes that site differences are apparent at an early age. If a site produces a higher tree at age 50, it assumes it will be higher at all preceeding and all subsequent ages. This assumption is in contrast to the fact that many plantations and even-aged natural stands on marginal sites may grow normally in youth and only in middle age exhibit sharply decreased growth. Stands on other sites may grow slowly in youth and in middle age exhibit sharply increased growth.

The total height over total age relationship cannot be properly used in stands where dominant and codominant trees have been affected by past suppression, nor in stands where high grading has been practiced. These conditions would undoubtedly produce site index values which are somewhat low for the given site. Although height is generally considered to be independent of density, extremely dense or very open stands are likely to have some effect on the actual site index values. The above conditions are exemplified in various parts of the Lake States where red pine occurs sparingly, often with only a few of the dominant trees remaining. In most of these areas, the secondary growth of red pine is usually also very scanty.

In young stands, a misconception or error in total age seriously affects the site determination. An error of two years in a 20-year-old

stand means an error of ten percent in the site index value. In contrast, an error of two years in a 50-year-old stand means an error of only four percent.

The large variability in the establishment period is a major source of error when the conventional method is applied to young stands. The large variability is apparently a result of many factors which do not influence the latter growth of the tree. A further reason for omitting the portion of the tree below breast height is the difficulty in determining the total age when the planting date is not known. The number of annual nodes below breast height cannot be counted accurately, and the estimate of age by counts on increments cores is scarcely better.

Many red pine plantations in the Lake States today are growing on sites which are more productive than those on which red pine occurs naturally. The site index values of many of the stands exceed that of those found by Gevorkiantz (6). Had not red pine been planted on these better sites, it is very likely that hardwoods would be present there today. This condition means an increase in average site quality for red pine, and demonstrates a need for additional study on red pine site index.

The use of the red pine site index curves (6) is limited to stands which are at least 20 years old. Below this age, the curves are subject to error and cannot be considered to give reliable results. A method of determining site index which is independent of age would then be more useful for young stands.

A considerable amount of literature and tables in use today refer to site index values. Because of the difficulty in measuring total heights, especially in stands 25 - 35 feet or more in height, site index values are often not obtained, or not obtained accurately, and the information in the tables is not used to a great extent. An attempt should therefore be made to decrease the work required to obtain these values.

It is apparent that some other method of site index curve determination should be used. The best method would be to obtain data from permanent sample plots. This method, capable of producing polymorphic curves, is not used because permanent sample plots, which are at least 50 years old are not available. The stem analysis method is generally considered better than the temporary plot technique, but requires a considerably greater amount of work. Until curves by another method are developed, we will have to use the temporary plot, height-over-age information. A new technique will permit greater utilization of the site index information we presently have, as well as permit site index determination in stands less than 20 years old. The internodal distance method is a new technique.

The purpose of this study is to determine the relationship of the values obtained by the conventional site index method of total height over total age with that of the 5-year internodal distance beginning with the first node above breast height. This method, here known as the 5-year intercept method, is based on two assumptions: (1) Height growth made by each tree each year for five years beginning with the attainment of breast height can be measured correctly. (2) Once trees

of a given genotype and at a wide range of plantation spacings have reached breast height on comparable sites, they will grow at essentially comparable rates for the next five years or more, whereas on contrasting sites they will grow at consistently contrasting rates.

REVIEW OF LITERATURE

In 1931, Bull (2) tested a method which is analogous to the 5-year intercept method. He recorded the number of years that were required for a tree to grow from 3 feet to 9 feet above ground, as well as intervals of 3 to 13, 4 to 10, and 4 to 14 feet above ground. He was attempting to eliminate the initial establishment period by starting at 3- and 4-foot heights. Although he gives no statistics nor account of information collected, Bull reports that the method gave very erratic and unsatisfactory results.

Wakeley and Marrero (16) are the actual pioneers in the 5-year intercept method. As early as 1937 Wakeley proposed such a plan, as an alternative method of site index determination for young coniferous stands. Later Marrero tested such a 5-year intercept in southern pine plantations on four species. Marrero concludes that generally, 5-year intercept lengths were significantly correlated with total height, the coefficient of variation of intercept was generally greater than that of total height, and that as shown by t-tests, the intercepts usually indicated the same significance or non-significance of site differences between paired plantations as were shown by total heights. Marrero found on a number of sites that intercept lengths of trees already established naturally at time of planting coincided closely with intercept lengths of trees planted later. Despite the multinodal growth habit of the southern pines, Marrero reports that successive annual increases in height can readily be distinguished on trees up to 15 and 20 years old.

In 1955, Warrack and Fraser (17) conducted a study on juvenile Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) in an attempt to determine the relationship between the site index and a 3-year and 5-year intercept length beginning with the first node above breast height. Separate relationships between the 4- and 6-node span distances and site index were derived in the form of a linear regression by the method of least squares. Both regressions were highly significant. From these relationships, the site index values can be read from the graph for a given cumulative internodal distance or can be determined by the regression equations. Statistically, determinations by the 4-node span are not significantly less precise than by the 6-node span.

Also in 1955, Ferree, Shearer, and Stone (5) conducted a study in young red pine plantations which demonstrated that height growth of dominant and codominant trees for the 5-year period above breast height can be a reliable indicator of growth in the next 15 to 20 years. No attempt was made to correlate the site index as determined by the conventional method with that of the 5-year growth intercept.

DESCRIPTION OF STUDY AREA

Data for the experiment were collected from Upper and Lower Michigan and Ontario, Canada. The Upper Michigan plots were confined to the eastern part of the state and the Lower Michigan plots were concentrated in the Lansing and Tawas City areas. The general location is indicated in Figure 1 and in the table showing the range of 5-year intercepts sampled (Table 3). The data were collected from four experimental forests, four public forests, and two private forests.

The climate of Michigan varies considerably and is probably quite typical of the variation for most of the Lake States range of the species. The average January temperature varies from 14°F. in the northern part to 24°F. in the southern part of Michigan. The average July temperature varies from 62°F. to 72°F. The annual precipitation averages from 30 to 34 inches over the area studied. The average frost-free season ranges from 140 days in the north to 160 days in the southern part of Michigan.

The majority of the stands investigated are the result of CCC planting in the 1930's. The land has had a variety of past uses. The Canadian land history reveals that the land was cleared of all timber in the 1880's and turned into agriculture use. After intensive cultivation for 30 years the soil became depleted. Grazing use followed. After 10 to 15 years the grazing became very poor and in 1928 forest planting started. Many of the Michigan plantations also originated in this way. A portion of the plantations are also the result of plantings on abandoned farm land and burned over forest land.

The soils of the stands examined range from very fine to coarse sand and sandy loams. A complete field analysis of the soil was not run in any case, but where possible soil types were obtained from soil classification maps. Several plots examined which were on a Bohemian very fine sandy loam type, yielded the highest growth rate and site index of any plots examined.

In all cases the soil was covered with thick layers of needles. The needle depth varied from 2 - 3 inches in the northern stands to somewhat less in the southern stands.

The lesser vegetation in all stands was very sparse. Grasses and other herbaceous plants were found in the majority of the stands, but only to a limited extent. In no stand was there any red pine reproduction found. A few of the red pine stands, which were adjacent to hardwood stands, contained a small amount of hardwood reproduction.

FIELD PROCEDURE

The general distribution of red pine plantations was obtained by personal contacts with District Foresters and other forest research personnel located throughout Michigan. The stand and plot selection was determined upon investigation within the plantations. The plots were all located in pure red pine stands. The main emphasis in plot selection centered on finding an area where uniform site conditions appeared to exist. Areas which contained small pot-holes or knolls were avoided. After the above requirements were met, ten dominant and codominant trees were selected at random within a 1/4 acre area. Since most plantations examined were relatively young, the distinction between dominant and codominant trees was very small. No attempt was made to take a certain number of trees from each crown class. All trees which were obviously deformed or injured were rejected. No measurements were taken in any stands in which the age was less than 20 years. The distribution of ages of plots taken is shown in Table 4.

A total of 56 plots were taken in 40 different red pine stands over the wide range of site conditions found to exist in Michigan. Actually, a much larger number of red pine plantations were examined during the study. In order to keep the sampling balanced, to avoid having many samples in one site condition and only a few in others, special effort was made to limit the sampling to two or three plots in stands which were obviously similar in regard to site and age. The chief difficulty encountered in plot selection was locating plots where extremes in site quality existed. In the majority of the stands

examined an average or near average site quality could be found. Only by extensive search in many stands was it possible to find plots which were very high and very low in site quality.

DATA COLLECTED

An attempt was made to sample as many of the phases of the site as possible, which could be recognized in the field, that might affect tree growth. No emphasis was placed on any specific site factor but rather the main emphasis centered on obtaining measurements from the greatest possible site variations.

The measurements and information which were recorded in the field are shown in Figure 2 and include the following items:

1. Location - For approximately one-half of the plots, the location was recorded to the nearest forty acres using the Public Land Survey method. This information was later used for checking on planting data, age of planting stock, and soil type. In other cases, it was only possible to name the Forest or District and the relative position within it. Since it was not necessary to check the trees or plots at a later date, the relative position was generally sufficient. Table 3 shows the distribution of plots by location and intercept class.

Figure 1 shows the general stand locations.

2. Age - Where possible, the age of the stand was obtained from planting records. In other cases, the age was obtained by taking an increment boring at the base of the tree or by counting the total number of branch whorls present. The counting of branch whorls was used in the younger and shorter plantations. In both the boring and counting method, several to many trees were examined in order that the age estimate be more reliable. The total age is considered to be the age since planting. From planting records examined, most trees planted

were of 2-0 stock. The distribution of the ages of plots sampled and ages of planting stock are shown in Table 4 and Table 5 respectively.

3. Age at Breast Height - The age at breast height was determined by counting the number of whorls above breast height and subtracting these from the total age. No difficulty existed in differentiating the secondary from the primary whorls. In dense and tall stands it was sometimes difficult to distinguish and determine the exact number of whorls at the tops of the trees. The distribution of the ages of plots at breast height is shown in Table 6.

4. Total Height - The Haga hypsometer was used to determine the total height of each tree. The height was recorded to the nearest foot. The distribution of the total heights of plots is shown in Table 7.

5. Diameter Breast Height - The diameter breast height was measured with a diameter tape and recorded to the nearest tenth of inch.

6. Five-year Internodal Distances - The internodal distances for a five-year period beginning with the first node above breast height was recorded. A calibrated bamboo pole was tied to the tree. The observer then stood approximately 20 feet from each tree and recorded the values as seen on the pole at the six specified nodes. Later office work revealed the individual and total intercept distances. Table 3 shows the distribution of plots by location and intercept class.

7. Supplemental Information - The approximate spacing and general conditions of the stand were recorded. Other comments for each plot included items on past treatment, general soil characteristics, slope, and exposure.

ANALYSIS OF DATA AND RESULTS

Influence of the Establishment Period

The average time required for sample trees of each plot to reach breast height was plotted against the height growth for the 5-year period beginning with the first node above breast height. Figure 3 shows the relationship.

From 6.0 to 13.8 years after planting were required to reach the breast height level. A straight line regression fitted by the least squares method results in a very slight negative slope to the curve. ($b_{yx} = -.1755$). Further examination of the data revealed a very weak correlation coefficient. ($r_{yx} = -.2448$). An analysis of variance test showed the above data to be not significantly different from zero. This indicates that the site factors which determine and influence the establishment time are not significantly correlated with the growth for the 5-year period above breast height. In other words, there are special factors which exert an influence upon the establishment time. Presumably these consist of such factors as planting stock quality, planting technique, initial competition, surface soil characteristics, degree of natural or artificial protection, and degree of frost or animal injury. It is therefore evident that the inclusion of height-age data from below breast height would inject a large and unrelated error into site index calculations.

Relationship of Site Index and Five-Year Intercept

The average site index for each plot was determined by the conventional method of height over age using the site index curves for red pine in the Lake States (6). In each plot, the individual 5-year internodal lengths were averaged. The average site index for each plot was plotted over the average 5-year internodal growth. The relationship is shown in Figure 4.

The range of site indices extended from 33 to 88. (See Table 8). To obtain these from the source listed above, required the formation of lower and higher site index curves and interpolation between the curves. The additional curves were based on the assumption that the higher and lower curves would follow the same form as the existing curves. Over this range of site indices, the average 5-year internodal lengths per plot extended from 2.51 to 11.79 feet.

A straight line linear regression fitted by the least squares method revealed a curve with a slope of $b_{yx} = 5.168$. This means that for each unit of internodal length, in this case one foot, the site index will be affected by 5.168 site index units. For example, if the difference in average internodal distance between two stands is three feet, the difference in site index will be approximately 15.5 units. The value of "a" was determined to be 23.12. The site index values may be read directly from the graph, or may be computed from the formula, $y = 23.12 + 5.17 x$, where "y" equals site index values and "x" the 5-year intercept in feet. The standard error of the estimate, a measure of the dispersion of the individual values from the mean, was

calculated to be 6.39 expressed in site index units. A correlation analysis test showed the correlation coefficient equal to .8939. ($r_{yx} = .8939$). The correlation coefficient is simply a measure of the degree of association of the estimated site index values with that of the five-year intercept values. The correlation coefficient squared (r_{yx}^2), here equal to .6991, means that approximately 70 percent of the site index units can be explained by, or estimated from, the concomitant variation in the 5-year internodal length values. An analysis of variance test shows the slope of the curve and the correlation coefficient to be highly significant.

A test for the linearity of regression shows the data to be not significantly different from a straight line relationship (See Table 12). In spite of this, a curvilinear regression was run. The formula for the curve is, $y = a + bx + cx^2$, where "a" equals -.0002, "b" equals 12.5290, and "c" equals -.5166; "y" stands for the site index and "x" the 5-year intercept values. The standard error of the estimate equaled 5.66 expressed in site index units.

The entire data showing differences in actual and estimated site index values is presented in Table 9, and is summarized in Table 1.

Table 1. Dispersion of Height-Over-Age Site Index Values from Site Index Values Estimated by the Curvilinear Regression (Figure 5).

	No. of Plots	Per- cent	Cumula- tive Percent
Within $\pm$ 2 units of estimated site index	24	42.9	42.9
Within $\pm$ 4 units of estimated site index	12	21.4	64.2
Within $\pm$ 6 units of estimated site index	12	21.4	85.6
Within $\pm$ 11 units of estimated site index	6	10.7	96.3
Within $\pm$ 16 units of estimated site index	2	3.6	100.0
	56	100.0	

The correlation index, analogous to the correlation coefficient is a measure of the degree of association of the estimated site index values with that of the five-year intercept values. The correlation index value for this curve is .9180. The correlation index squared, equal to .8427, means that approximately 84 percent of the factors influencing site index are directly associated or can be measured by the 5-year internodal lengths of the tree, and that 16 percent are associated with other factors. Since the total height is the variable factor in site index, this correlation means that 85 percent of the factors which influence total height also influence the length of the 5-year intercept. Sixteen percent of the factors which influence total height but not the 5-year intercept may include the factors which influence the initial establishment period. An analysis of variance test of the correlation index revealed it to be highly significant.

The site index values can be conveniently read from the curve for any given intercept or computed using the curvilinear formula. From the graph (Figure 5) the following information is obtained.

Table 2. Estimated Site Index Values Based on Intercept Length.

Five-Year Intercept Length in Feet	Estimated Site Index
3.0	33
4.0	42
5.0	50
6.0	57
7.0	62
8.0	67
9.0	71
10.0	74
11.0	75
12.0	76

Fractional intercept lengths can now be determined by simple interpolation between the estimated site index values.

DISCUSSION

This study has been an attempt to bridge a gap between the 5-year intercept method and the conventional height-over-age method of site index determination. The correlation connects the site index values estimated by the 5-year intercept with the vast amount of knowledge already present, which is based on the conventional height-over-age index values.

Although the results of analysis indicates a high significance for the 5-year intercept method, this report is not intended to proclaim it as a final prescription. This study is actually only a basic step in what may be done with the 5-year intercept. A more complete study would involve obtaining growth information from permanent sample plots correlated with soil site indices. The time and effort involved in conducting such a study would undoubtedly be very great. When the polymorphic curves have been derived from permanent sample plots, the 5-year intercept will become a more useful tool for management and silvicultural purposes.

It is apparent that many of the weaknesses which are inherent in the conventional height-over-age site index method are also incorporated into the 5-year intercept estimated site index values. This is an unfortunate but inevitable circumstance. As long as we are converting our 5-year intercept measurements into conventional site index values, we are not free from the disadvantages detailed in connection with indices based on total height. The value of the 5-year intercept method, as presented in this report, centers on the ease and convenience

of determining site index values, and the ability to evaluate younger stands. The only measurement required for site index determination is that of the 5-year height growth period. With this method, the site index of any stand which has grown for a 5-year period beyond breast height can be evaluated.

SUMMARY

The most frequently used forest site index for a given species is that based on total height attained at a given age. The height-over-age site index curves derived by this method have many disadvantages. A new technique will reduce the amount of work required in obtaining site index values as well as permit site index determinations in any stand which has grown for a 5-year period beyond breast height.

The 5-year intercept method is a new technique. The purpose of this study has been to determine the relationship of the values obtained by the conventional site index method of total height over total age with that of the 5-year internodal distance beginning with the first node above breast height.

The data were collected from 56 plots in 40 different red pine stands over the wide range of site conditions found to exist in Michigan and nearby Ontario. The measurements and information which were recorded in the field included the location, total age, age at breast height, total height, diameter breast height, 5-year internodal distances, and other general stand characteristics. Ten dominant and co-dominant trees were selected at random within an area not to exceed 1/4 acre. A special effort was made to obtain a uniform number of plots from each of the site qualities occurring in the study area.

The average time required for sample trees of each plot to reach breast height varied from 6.0 to 13.8 years. An analysis of variance of the regression line showed that the time required to reach breast height was not significantly correlated with the 5-year intercept.

This indicates that there are special factors other than site quality factors which exert an influence upon the establishment time.

The range of site indices, determined by the conventional total height over total age method, extended from 33 to 88. Over this range of site indices, the average 5-year internodal lengths per plot extended from 2.51 to 11.79 feet. A straight line regression fitted by the least squares method revealed a curve with a slope of $b_{yx} = 5.168$. A correlation analysis test showed the correlation coefficient equal to .8939. An analysis of variance test shows the slope of the curve and the correlation coefficient to be highly significant.

Although the data could not be shown to be significantly different from a straight line relationship, a new curve was drawn using the curvilinear method of regression. For this curve the standard error of the estimate equaled 5.66 and the correlation index .9180. The correlation index squared, equal to .8427, means that approximately 84 percent of the factors which influence total height also influence the length of the 5-year intercept. An analysis of variance test showed the correlation index to be highly significant.

The 5-year intercept method of site index determination permits values to be obtained with greater ease, and permits evaluation in young stands.

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APPENDIX

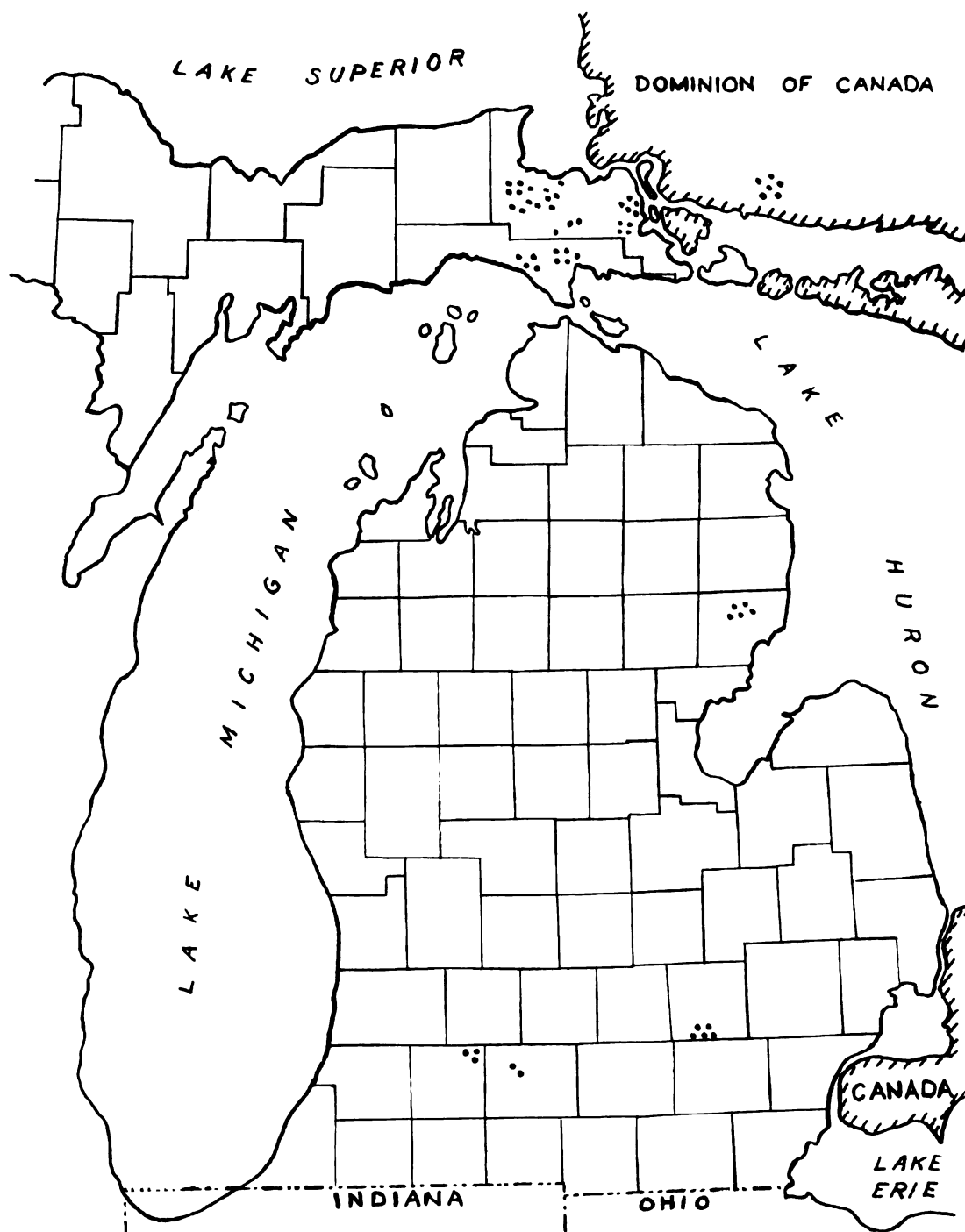


Figure 1. The approximate location of stands in which sample plots were taken. Each dot represents one plot.

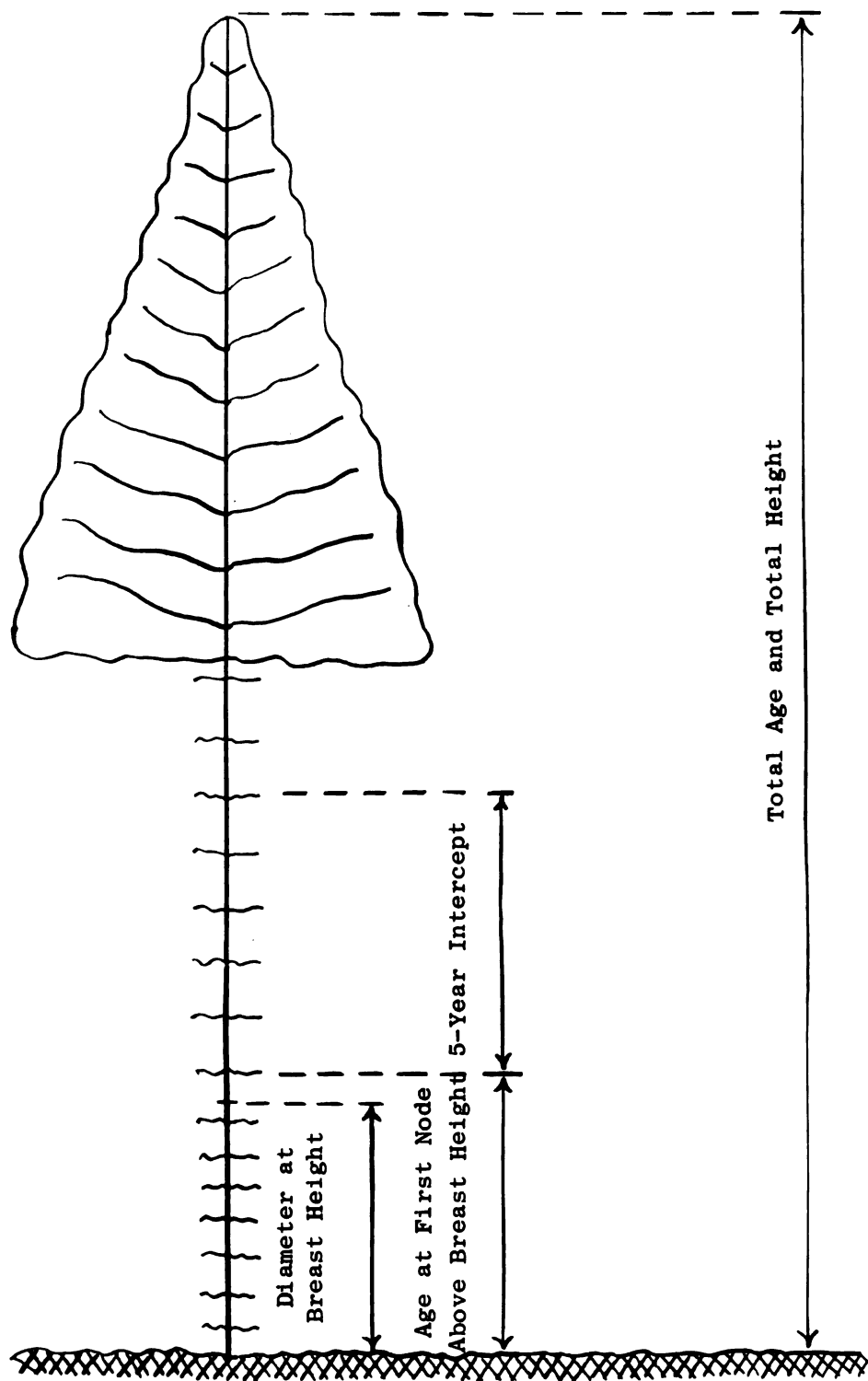


Figure 2. Diagram showing measurements taken on each tree in the field.

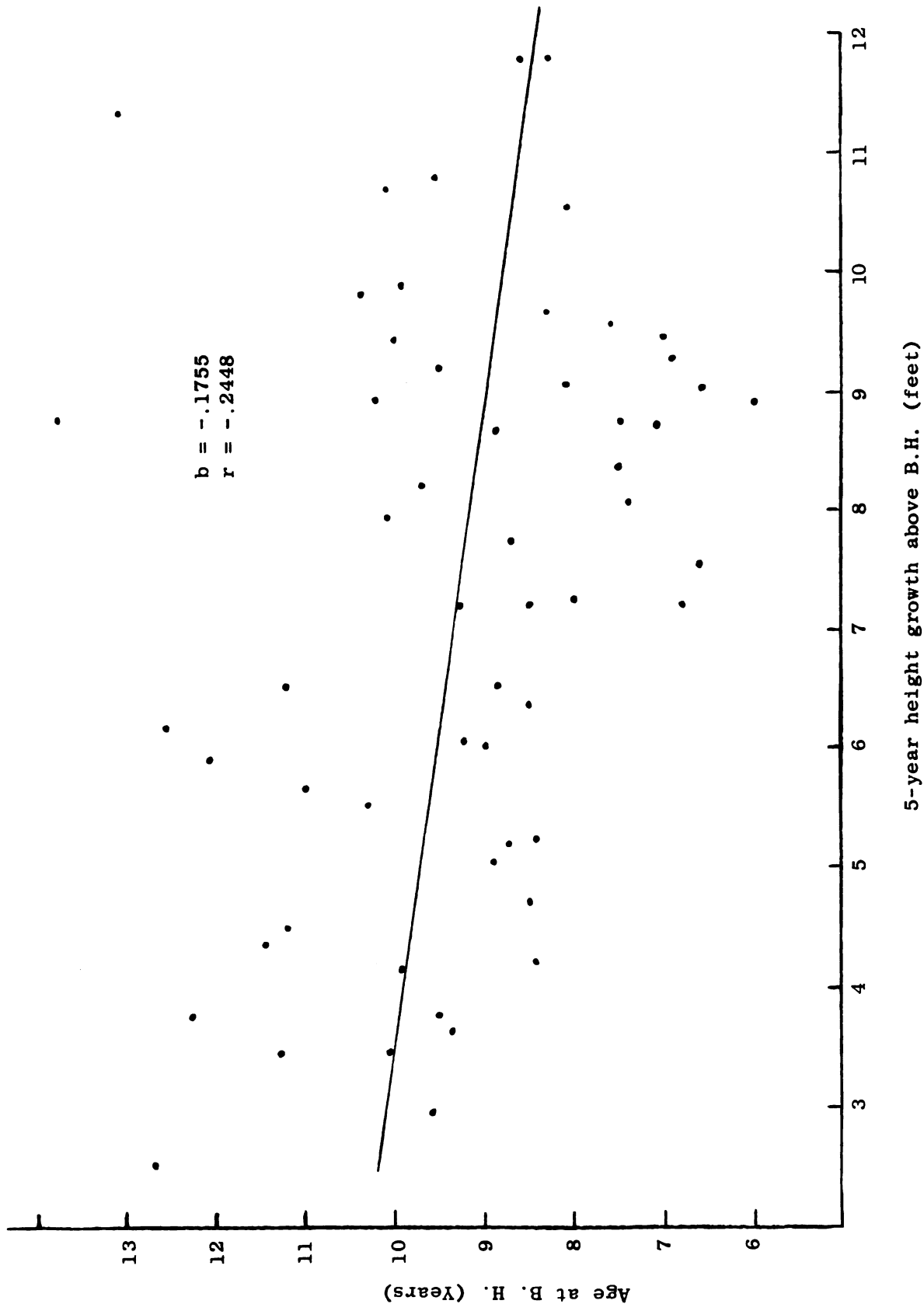


Figure 3. Relationship of age at breast height and 5-year height growth above breast height.

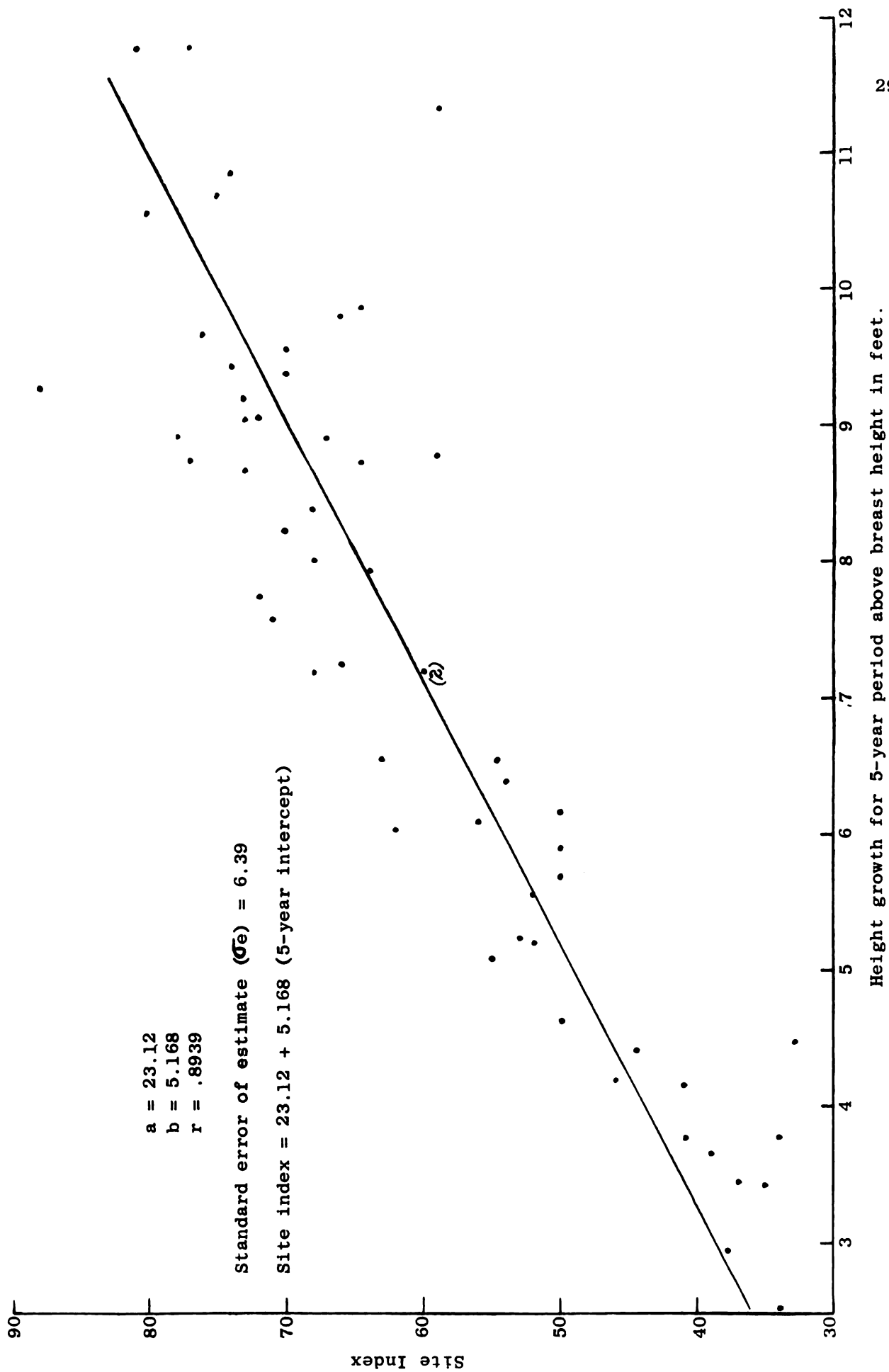


Figure 4. Relationship of internodal distance and site index.

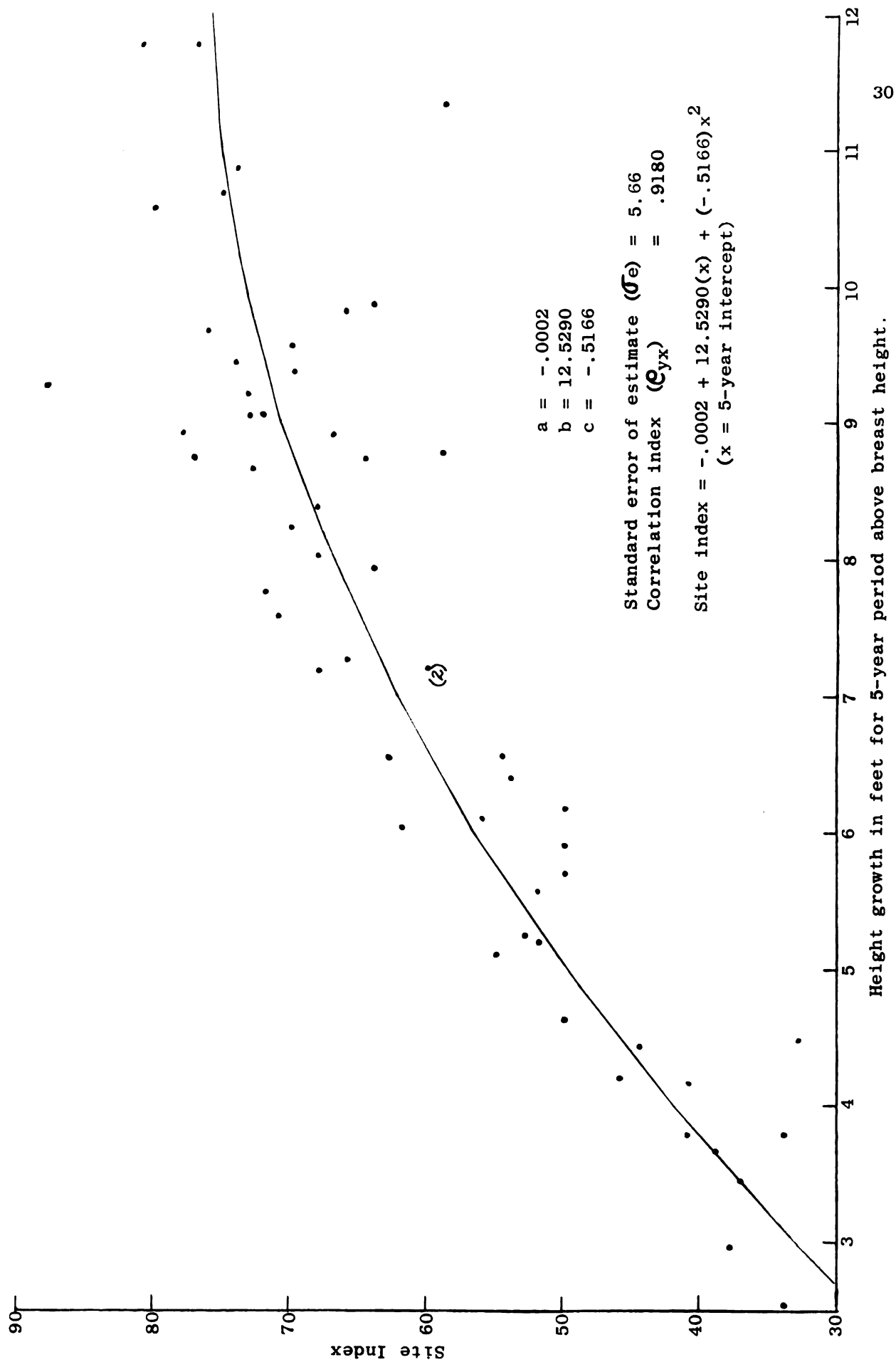


Figure 5. Relationship of site index and internodal distance.

Table 3. Distribution of Plots by Location and Intercept Class.

Forest Name and Location	Intercept Class in Feet											Total
	2.50	3.50	4.50	5.50	6.50	7.50	8.50	9.50	10.50	11.50		
	3.49	4.49	5.49	6.49	7.49	8.49	9.49	10.49	11.49	12.49		
Dunbar Forest						3	2				5	
Sault Ste. Marie, Mich.												
Stinchfield Woods							2	2	1		5	
Pinckney, Mich.												
Kirkwood Forest				2	1	2	1				6	
Thessalon, Ontario												
Kellogg Forest							1			2	3	
Augusta, Mich.												
Lake Superior State Forest		1									1	
Newberry, Mich.												
Huron National Forest	1	2	1		1						5	
East Tawas, Mich.												
Marquette National Forest	3	4	3		2		4				16	
Raco, Mich.												
Marquette National Forest				2	1	1	1				5	
St. Ignace, Mich.												
Mackinac State Forest				3	1						4	
Rexton, Mich.												
Kimball Forest							1		1		2	
Battle Creek, Mich.												
Kiwanis Forest								2	2		4	
Dafter, Mich.												
TOTAL	4	7	4	7	6	6	12	4	4	2	56	
											31	

Table 4. Distribution of Ages by Plots.

Age	Number of Plots
21	1
22	10
23	8
24	2
25	3
26	3
27	6
28	4
29	4
30	1
31	2
32	8
34	1
38	3
Total	56

Table 5. Age of Planting Stock by Forest and Plots.

Forest Name	Plot Numbers	Age
Dunbar	1-5	2-0
Kirkwood	6-11	2-0
Marquette	12-32	2-0
Mackinac	38-41	2-0
Huron	42-46	2-0
Kellogg	47-48	3-0
Kellogg	49	2-0
Stinchfield	52-53	2-0
Stinchfield	54-55	2-2

The age of the planting stock of the plots omitted was not available.

Table 6. Distribution of Ages at Breast Height by Plots.

Age at Breast Height in Years	Number of Plots
6	5
7	6
8	16
9	11
10	7
11	5
12	4
13	2
Total	56

Table 7. Distribution of Total Heights by Plots.

Total Height in Feet	Number of Plots
12.5 - 17.4	4
17.5 - 22.4	6
22.5 - 27.4	8
27.5 - 32.4	9
32.5 - 37.4	10
37.5 - 42.4	7
42.5 - 47.4	7
47.5 - 52.4	4
52.5 - 57.4	1
Total	56

Table 8. Distribution of Site Indices by Plots.

Site Index	Number of Plots
25 - 34	3
35 - 44	7
45 - 54	9
55 - 64	10
65 - 74	19
75 - 84	7
85 - 94	1

Total	56

Table 9. Site Index Estimated from Intercept Index Curve (Figure 5)
Compared with Height-Over-Age Index.

Plot Number	5-Year Intercept	Site Index		Difference, Estimated- Actual	Difference as Percent of Actual Site Index
		Actual	Estimated		
1	9.21	73	71	-2	2.7
2	8.23	70	68	-2	2.8
3	7.94	64	67	3	4.7
4	8.67	73	70	-3	4.1
5	7.76	72	66	-6	8.3
6	9.07	72	71	-1	1.4
7	7.59	71	65	-6	8.4
8	8.02	69	66	-3	4.3
9	7.20	60	63	3	5.0
10	5.56	52	54	2	3.8
11	6.39	58	59	1	1.7
12	7.21	60	63	3	5.0
13	8.73	74	70	-4	5.4
14	7.18	68	63	-5	7.4
15	9.06	73	71	-2	2.7
16	9.44	74	72	-2	2.7
17	8.92	78	71	-7	9.0
18	5.24	53	52	-1	1.9
19	3.44	37	37	0	0.0
20	2.95	38	33	-5	13.2
21	3.77	41	40	-1	2.4
22	4.48	33	46	3	9.1
23	3.78	34	40	6	17.6
24	3.42	35	37	2	5.7
25	4.16	41	43	2	4.9
26	4.63	50	47	-3	6.0
27	5.20	52	51	-1	1.9
28	6.55	54	60	6	11.1
29	6.02	62	57	-5	8.1
30	5.69	50	55	5	10.0
31	8.75	77	70	-7	9.1
32	8.38	68	69	1	1.5
33	4.41	44	44	1	2.3
34	10.86	74	75	1	1.4
35	9.68	76	73	-3	3.9

Table 9. Site Index Estimated from Intercept Index Curve (Figure 5)
Compared with Height-Over-Age Site Index. (Continued)

Plot Number	5-Year Intercept	Site Index		Difference, Estimated- Actual	Difference as Percent of Actual Site Index
		Actual	Estimated		
36	10.56	80	75	-5	6.2
37	9.56	70	72	2	2.8
38	6.10	56	57	1	1.8
39	5.90	50	56	6	12.0
40	6.17	50	58	8	16.0
41	7.26	66	63	-3	4.5
42	6.56	63	64	1	1.6
43	5.09	55	51	-4	7.3
44	2.51	34	28	-6	17.6
45	3.66	39	39	0	0.0
46	4.20	46	44	-2	4.3
47	11.79	77	76	-1	1.3
48	11.79	81	76	-5	6.2
49	9.27	88	72	-16	18.2
50	8.92	67	71	4	6.0
51	10.69	75	75	0	0.0
52	9.39	70	72	2	2.8
53	9.82	66	73	7	10.6
54	9.86	64	73	9	14.1
55	8.78	59	70	11	18.6
56	11.33	59	75	16	27.1

Mean difference + 0.3 $\pm$ 5.66

Table 10. Analysis of Variance for Correlation Coefficient of Age at Breast Height and 5-Year Intercept Relationships.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F	Table F(5%)
Total	55	171.8			
Between	1	10.3	10.3	3.55	4.02
Within	54	161.5	2.9		

Table 11. Analysis of Variance for Correlation Coefficient of Site Index and 5-Year Intercept Relationship.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F	Table F(1%)
Total	55	11,190.9			
Between	1	8,942.6	8,942.6	214.0**	7.08
Within	54	2,248.2	41.6		

**Significant at 1 percent level.

Table 12. Analysis of Variance for Test of Linearity of Regression.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F	Table F(5%)
Total	54	2241.9			
About regression	3	289.9	96.6	2.52	2.80
Within groups	51	1952.0	38.3		

Table 13. Analysis of Variance of Correlation Index of Site Index and 5-Year Intercept Relationship.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Computed F	Table F(1%)
Total	55	11,190.8			
Between	2	9,472.0	4,736.0	151.6**	5.05
Within	53	1,718.8	31.2		

**Significant at 1 percent level.

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