BIO-ECONOMIC ANALYSIS OF EVENAGED SHORTLEAF PINE STANDS IN SOUTHEASTERN OKLAHOMA

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Bachelor of Science

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Stillwater, Oklahoma

1969

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1971

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SHORTLEAF PINE STANDS IN
SOUTHEASTERN OKLAHOMA

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ACKNOWLEDGEMENTS

The author would like to express his appreciation to Dr. Nathaniel Walker, for his help and guidance in carrying out this study. Additional thanks is due to Mr. T. H. Silker, for his personal interest, guidance, and encouragement. The assistance of the other members of my graduate committee, Dr. Edward Strugeon and Dr. B. C. Hamm, was also greatly appreciated and acknowledged.

To the Oklahoma State University Forestry Department, the author wishes to express his thanks for the use of their equipment and facilities. To Bob Cheek and Toby Goodale, the author wishes to express thanks for their technical assistance in gathering field data.

The author wishes to express appreciation to the Weyer-haeuser Company and to the Wildlife Department of Oklahoma for the use of their land and timber.

Special thanks are due to the author's parents, Mr. and Mrs. Melvin F. Endicott, whose constant encouragement and assistance throughout the author's life made his education possible. To his wife, Cathy, the author wishes to express his gratitude for her assistance and constant encouragement.

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CHAPTER I

INTRODUCTION

An ever-increasing demand in our Nation for products from the forest requires that our forest lands be made more productive. Increased production can be facilitated through an increased knowledge of the basic natural resources.

Even with the trend toward high-yield forest management, which is now being manifested to a high degree, much of the forest land in southeastern Oklahoma has remained in an unmanaged, or poorly managed, condition. A large part of this land area in the southeastern forested counties (about 4.8 million acres) is known to have considerable potential for the growing of shortleaf pine (Pinus echinata Mill.). However, much of the area has been cutover and is now poorly stocked in young pine timber. Poor quality upland hardwoods have invaded a large percentage of the cutover forest and now present serious problems in the management for high-yield pine production.

The need for increased production has re-emphasized the importance of site classification for pine production. Much of the acreage involved in this area is on the fringe of the southern pine belt and is in an environmental tension zone. Frequent droughts and high stress conditions indicate that much of the land in this fringe area is marginal and sub-marginal for pine production. As a result, most management practices and conversion techniques may be economically questionable.

This study is a bio-economic evaluation and analysis of timber management potentials in Pushmataha County, south of Clayton, Oklahoma, along the western edge of the commercial pine-hardwood timber zone. The objective is to determine the validity of using a specific group of plant indicators to forecast and strengthen the economic methods of delineating pine site management classes. This economic evaluation will be based on the use of a discount (soil rent) procedure.

CHAPTER II

LITERATURE REVIEW

The forest environment is divided naturally into ecological divisions or habitats, known to the forester as "sites." Spurr (1965) defines site as "the sum total of the atmospheric and soil conditions surrounding and available to the plant." This definition is very similar to Tamsely's (1926) definition of habitat, which is stated "the sum of the effective environmental conditions under which the association exists." Site is not a static system, but a dynamic system in which many variables interact. The resultant is not necessarily made up of any one variable or all the variables; site is considered the sum total of the "effective" factors among which usually one or more are dominant. With this type of interaction among variables and the lack of knowledge of the effects of these interactions, accurate determination of site quality becomes very complicated. How-ever, many attempts have been made at estimating forest site quality.

Heiberg and White (1956) give three approaches to evaluate the quality of a site:

1. The direct approach deals with the quality and magnitude of the various site factors that influence the

vegetation on the site. Soil moisture is one such site factor.

2. The indirect approach works with some measurable index, such as soil or vegetation types, that reflects the quality or magnitude of the site factors.

3. The growth or production approach considers the vegetation actually in question. Site indexes[1] and growth analysis are examples of this approach.

Each of these methods has drawbacks; however, the indirect approach seems to be the most applicable to practical, everyday forestry, and more promising than the direct approach (Heiberg and White, 1956).

Importance of Site Potential Classification

Productivity of timberlands varies tremendously by site quality. The practical importance of this fact is not often given adequate attention in forest management or in the buying and selling of forest lands. Davis (1966) states that management practices should be related to site. Site quality has a profound effect upon the volume and value, and upon species of timber that can be best grown on an area. It affects regeneration and cultural practices such as cleanings, thinnings, hardwood control, and improvement cuttings.

[1]Site index here refers to the average height attained by dominant and co-dominant trees at age 50.

The role of site quality in silvicultural theory has long been established; however, in actual forest management the concept is not often given the emphasis that it deserves. For example, it is a common practice to select planting sites on a cost basis alone rather than on a cost-benefit analysis. The result of using this procedure is often one of choosing a poor site over a good site, due to the lower cost of planting, in spite of the fact that higher yields from the good site make the good site the preferable investment alternative (Lundgren, 1961).

Wambach and Lundgren (1965) give a striking example of the effect of site quality on tree size and total volume production in red pine (Pinus resinosa Ait.). Comparing two site indexes of 40 and 75, the site index 75 land produces trees twice as large in DBH and height with three times the volume as trees on site index 40 land at stand age 100 (Figure 1). While advantages are not as obvious in comparisons with a narrower range of site indexes, this example shows the significance of site quality on timber management.

Soil-Vegetation-Site Methods ("Total Site")

"Total site" is considered as the "cumulative effect of surface soil texture; surface soil depth; sub-soil texture; sub-stratum position; texture and continuity; geologic origin of soil; aspect, topographic position; drainage position; climate; and plant and animal association" (Silker, 1961).

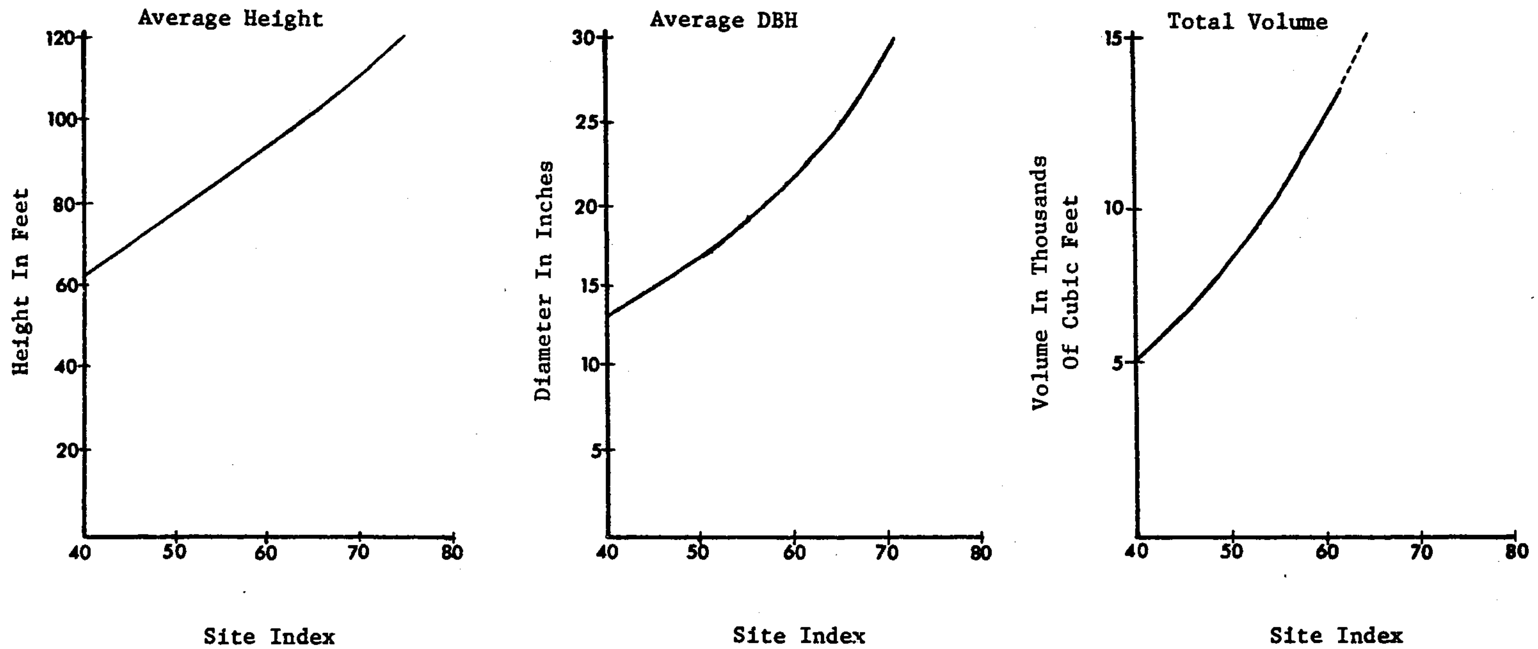

Figure 1. Tree Size and Cubic-Foot Yields of Managed Red Pine are Shown in Relation to Site Index, at age 100. The diameter and volume curves assume 800 trees per acre at age 35, and thinning at age 35 and every 10 years thereafter to 90 square feet of basal area. Total volume equals thinnings plus final volume. Site index equals height at age 50. (Wambach and Lundgren, 1965).

Evaluation of "total site" attempts to consider all factors that affect the site and its vegetation. Silker (1965) states that there are three main factors that should be considered in the evaluation of forest sites: (a) regeneration class for desirable, potential species, (b) associate species competition with the desired tree crop, and (c) growth or site index of preferred species. When all three factors are considered, "total site classification" can be effectively determined.

While it is widely recognized that the plant community as a whole will faithfully reflect the total effect of the habitat, past efforts in site quality classification have mainly been limited to tree-measurement (site index) and soil-site evaluation techniques. Cajander (1926) has been credited with being probably the first advocate of the use of plant indicators for classifying and evaluating forest sites and forest management chances. However, the site indicator concept has not gained practical acceptance in America until recently. As a result of the considerable attention given by Hills and Pierpont (1960) and Sisam (1938) to the utility of site indicator groups for classifying forest site quality, plant indicators are now commonly used in Europe and Canada.

Spurr (1952), one of the early American leaders in the use of site indicators, set up an "indicator plant spectrum" to aid in the problem of accurate classification in northeastern spruce and fir stands (Table I). The indicator spectrum is simply a list of indicator plants including

TABLE I

INDICATOR PLANT SPECTRUM, NORTHEASTERN SPRUCE AND FIR*

Genus or Species	Present	Common	Abundant
Site A			
Myrica			
Vaccinium			
Gaultheria			
Hylocomium			
Hypnum			
Chiogenes			
Pteridium			
Site B			
Coptis			
Bazzania			
Corylus			
Maianthemum	X		
Cornus	X		
Site C			
Aralia		X	
Clintonia			
Oxalis			
Dryopteris			X
Acer saccharum		X	
Site D			
Asplenium			
Smilacina			
Mitchella			
Viola			
Oakesia			

*Relative frequency of key species as tallied on specific forest sites. (Spurr, 1952) trees shrubs, herbs, and other vegetation, classified according to the sites they occupy. Plants indicating dry and infertile sites are placed at the top of Table I, and those denoting moist or fertile sites are placed at the bottom. Plant indicator species are recorded according to predominance, and then the checks are weighted. Site quality is measured at the center of the distribution curve produced by the checks (Spurr, 1965).

Attempting to establish a method of forest site quality mapping, Westveld (1954) used soil, forest cover types, and indicator plants as a guide to determining site quality. Assuming that climax forest vegetation types are in complete harmony with soil and the plant and animal life they support, Westveld thought that examples which were to serve as method guidelines could be found in the climax forest type. Theoretically, the concept is based on the idea that nature establishes the tree species or combination of tree species best adapted to the site in the form of the climax forest. However, he did not imply that management should necessarily proceed in the direction of the climax forest. Actually, he proposed that the compositional characteristics of the climax association should be used as guides for setting up silvicultural and managerial goals.

In the southeastern United States, forest plant species tend to have wider ecological tolerances than species studied in plant indicator systems in the northeast and Canada. As a result, a plant species occasionally occupies sites on which it normally does not occur. Hodgkins (1960) stressed that the use of precise plant indicators should be limited to sites in extreme stress conditions. In a later publication, Hodgkins (1960) developed a method for estimating site index of longleaf pine (Pinus palústris Mill.) by using a quantitative evaluation of indicator plants. A number rating system was assigned to the indicator plants to reflect their frequency and the site index, based on a soil moisture regime, was coded. Then for any one plot, the mean coded site index was determined as follows:

$$\text{Mean S.I.} = \frac{\text{(coded site index) X (dominance for each species)}}{\text{(all dominance values)}}$$

This method of calculation attempts to allow for the occasional off-site species and gives a more accurate estimation of the site quality.

In the Oregon Pumice Region, Dyrness and Youngberg (1958) set up a system of 5 brush associations to estimate site quality for ponderosa pine (Pinus ponderosa Laws.). They found that several distinct plant communities may occupy different topographic positions, be indicative of distinct changes in the total environment, and yet be situated on the same soil series. Therefore, insofar as understory vegetation groupings are concerned, changes in species composition of understory vegetation on the site are not always accompanied by important differences in morphological soil characteristics. Rather, changes in species composition often indicate less obvious changes in soil properties such as soil moisture availability and soil fertility. These authors found that understory vegetation types serve as a much more sensitive indicator of site quality than changes in soil characteristics. Changes in understory vegetation were definitely correlated with changes in advanced timber regeneration, timber stand density, supplies of forage available to livestock, and other important forest and range management characteristics.

To minimize the question of how understory vegetation is affected by management practices, fire, and other physical disturbances, Silker (1963) developed an ecological guide using understory and overstory hardwood species for evaluating pine sites. The use of indicator overstory hardwoods rather than understory vegetation was recommended, based upon the following premises:

1. Groups of hardwoods are practical, natural, and statistical expressions of total site factors affecting physiological minimums and maximums. Species frequency, commercial bole length, and form, act as mirror images of total environment.

2. Common hardwoods that occur throughout broad geologic, physiographic, and climatic ranges, should be used to assay site classification.

3. Hardwoods should be reliable indicators because: (a) many are climax plants; (b) they are less subject to change than ground flora that are readily affected by fire, cutting, and grazing; (c) they usually reflect the quality

of the site during the last 50 to 150+ years; and (d) they are conspicuous and readily identified.

This ecological guide was designed for use in the Coastal Plain soils of southeastern Oklahoma and east Texas and took the form of a wedge chart (Figure 2). Figure 2 shows the relationship between soil depth and indicator species sequence according to the moisture availability and apparent minimum moisture needs of each species.

Evaluation of Forest Land and Timber (Soil Rent)

Historically, timberland values have been based almost entirely on the conversion value of the timber stand currently existing on the land with little thought of the possibilities of continued production of forest crops. Today, land and timber represent large and relatively permanent capital investments. With the development of sustained yield programs, a greater economic importance for long range planning has emerged.

The value of forest land comes from the crops that it produces. An estimate of this value depends on the following four controlling factors: (a) the kind and intensity of management practiced, including its cost, (b) site quality, (c) the market value of the product, and (d) the importance of the time interval involved as measured by the rate of interest used (Davis, 1966).

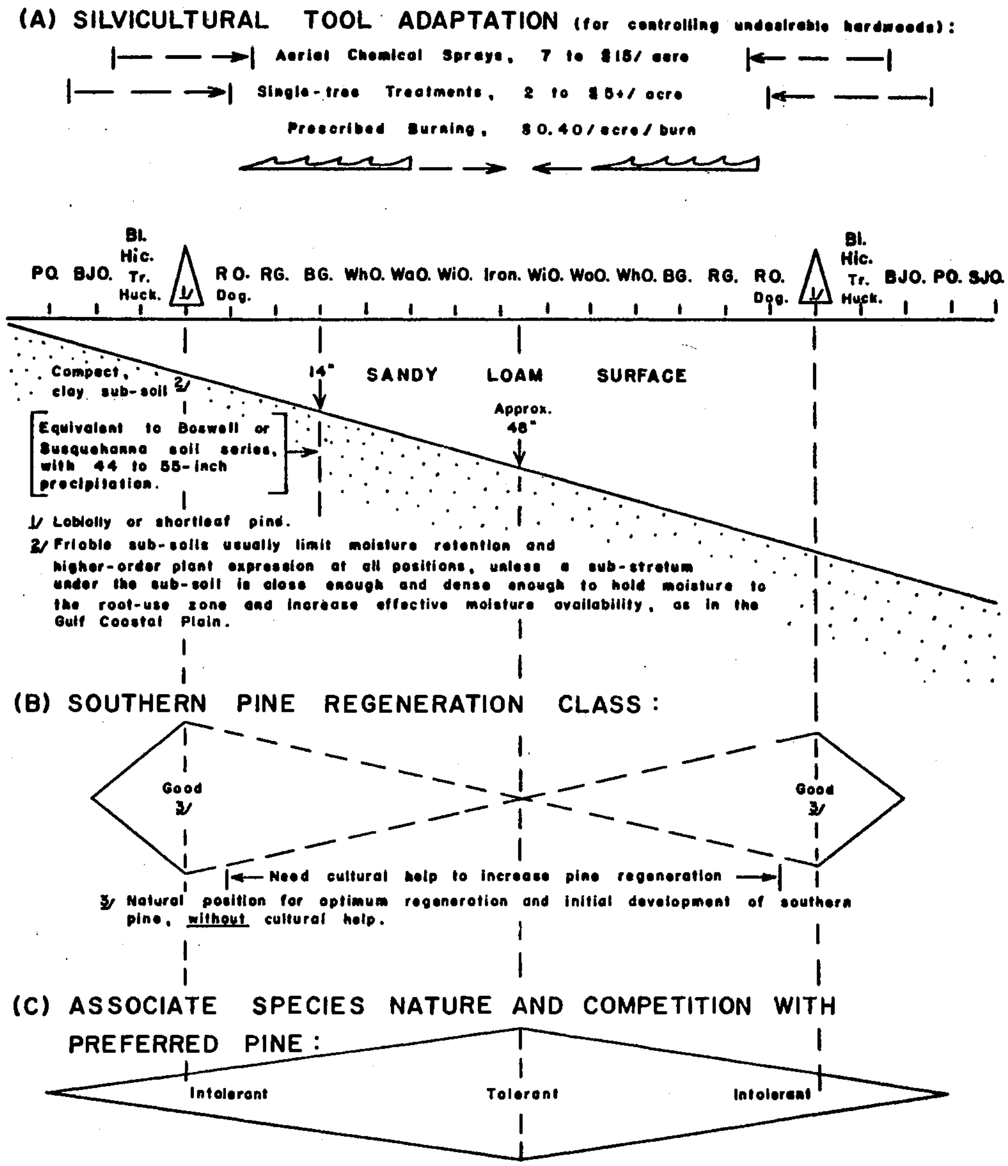

Figure 2. "Total Site Classification" by the Use of Plant Indicator Sequence. Tentative rating and relative position of predominant and common hardwoods in reflecting soil moisture availability. (Silker, 1963)(See Table II).

TABLE II

AN EXPLANATION OF SPECIES ABBREVIATIONS USED IN SILKER'S WEDGE CHART (FIGURE 2) (SILKER, 1963)

Wedge Chart Abbreviation	Common Name	Generic Name
P.O.	Post Oak	Quercus stellata (Wang.)
B.J.O.	Blackjack Oak	Quercus marilandica (Muench.)
Bl. Hic.	Hickory	Carya spp.
Tr. Huch.	Tree Huckleberry or Farkleberry	Vaccinium arboreum (Marsh.)
	Pine	Pinus echinata (Mill.) or Pinus taeda (L.)
R.O.*	Red Oaks	Quercus falcata (Michx.) or Quercus velutina (Lam.)
Dog.	Flowering Dogwood	Cornus florida (L.)
R.G.	Red or Sweetgum	Liquidambar styraciflua (L.)
B.G.	Black Gum or Black Tupelo	Nyssa sylvatica (Marsh.)
Wh.O.	White Oak	Quercus alba (L.)
Wa.O.	Water Oak	Quercus nigra (L.)
Wi.O.	Willow Oak	Quercus phellos (L.)
Iron.	Ironwood or American Hornbeam	Ostrya virginiana (K. Koch.)
S.J.O.	Sandjack Oak	Quercus cinerea (Michx.)

*Red oaks include black oak (Quercus velutina) and southern red oak (Quercus falcata). However, all indications tend to point out that black oak will express on sites drier than those that will accommodate southern red oak.

The importance of interest in the forest industry cannot be emphasized enough. Interest is often thought of as a screen by which the financial desirability is determined. Growing of timber involves relatively long periods of time. During such time, large amounts of capital are tied up in the land and timber. More often than not, the principal is borrowed and the interest on the principal is compounded over the period of the rotation. Even if the principal is not borrowed, it is necessary to consider the opportunity cost of having the capital tied up. The rate of interest used in the valuation techniques must be chosen carefully. This one factor exerts a very large and often overbearing influence on the estimated value of forested lands.

The Faustmann theory or soil rent concept considers each of these factors in the evaluation of the forest land and timber. The method takes a "businessman's" approach with its consideration of interest. It gives a monetary valuation of forested lands in terms of their timber producing capacities. This monetary value or net present worth is an estimation of the future net incomes from the use of the land for growing timber, discounted to the present. The net present worth, when shown at the beginning year of a rotation, is the capital value of the soil for growing timber.

When dealing with evenaged timber management, the soil rent concept is used to determine the net present worth at the beginning of a rotation. This estimate is made by starting with bare land and visualizing the establishment of a new stand. After establishment, the new stand increases in value until it becomes economically mature. At this point, the timber should be harvested. Normally, the estimate of the net present worth is obtained by discounting a perpetual or continuing series of net periodic yields. The periodic interval in this case is the rotation length (Davis, 1966).

The capital value or net present worth of a perpetual series of periodic net returns is obtained by using the periodic perpetual annuity formula (Walker, 1962):

$$V_o = \frac{R}{(1 + p)^r - 1}$$

where V_o = present capital value of a series of periodic returns obtained from the land

R = net returns received at rotation age

p = interest rate used

r = rotation length

Assuming that there were no production costs and all incomes were received at the end of the rotation, this formula would capitalize all future incomes and express their value at a time when the land is bare. However, costs and returns normally are incurred throughout the rotation. All costs and returns must be capitalized at a common point in time, usually at the beginning of the rotation. The items must also be capitalized in such a way as to include all future rotations. In this way, all returns will be net values and can be summed to give the total financial situation at one point in time.

Walker (1962) states that there are five basic elements that are present and exert influence on the financial aspects of growing timber. These five basic aspects are: (a) regeneration cost, (b) periodic costs occurring normally in the early part of the rotation, (c) periodic returns occurring mainly in the latter part of the rotation, (d) annual expenses, and (e) the final harvest.

Each of these factors will be reviewed and discussed. The following symbols will be used:

V_o = present capital value of an infinite series of estimated periodic net returns obtained from the land

Y_r = final harvest net income received at rotation age

r = rotation length

p = interest rate used

C = regeneration cost

T = thinning net return

W = weeding or cleaning cost

e = annual expenses

E = capitalized annual expenses

Regeneration or establishment costs occur only once during the rotation. Assuming that this cost will occur in the first year after the final harvest and at the beginning of each succeeding rotation, the total capitalized value must then be the sum of the present cost plus all future costs, and is given by the formula (Chapman and Meyer, 1947):

$$V_o = C + \frac{C}{(1 + p)^r - 1}$$

The formula may also be expressed as:

$$V_o = \frac{C \cdot (1 + p)^{r-c}}{(1 + p)^r - 1}$$

This cost has a definite bearing upon choice of rotation length and upon the capitalized value of the stand. With reproduction costs, it is desirable to minimize the cost by lengthening the rotation. The capital values of regeneration costs decline as rotation lengths are increased.

Periodic costs such as weeding and stand improvement cuttings may occur several times during a rotation. Such costs are usually incurred during the earlier parts of a rotation and must be carried to the end of the rotation before they are discounted. The capitalized value is obtained with the equation:

$$V_o = \frac{W \cdot (1 + p)^{r-w}}{(1 + p)^r - 1}$$

Periodic returns received from thinnings normally take place in the latter parts of the rotation. In the case of periodic returns, it is desirable to maximize by taking thinnings as early in the rotation as possible. Periodic returns are treated in a manner similar to periodic costs:

$$V_o = \frac{T \cdot (1 + p)^{r-t}}{(1 + p)^r -1}$$

Annual expenses consist of taxes, protection costs, insurance, and administrative costs. Since these items presumably will be continued indefinitely, they can simply be represented by a capital sum, E. This sum must be sufficient to pay the annual expenses with the interest flow from the capital sum. The capitalized sum is subtracted directly from the discounted value of net returns. Rotation length has no effect on the capital value of annual costs. The capitalized value is obtained with:

$$E = \frac{e}{p}$$

Walker (1962) states that annual expenses "constitute the greatest negative value against land." This fact indicates that such expenses should be held to a minimum consistent with full production.

Final harvests occur once each rotation; the first is due one rotation in the future. The capital value of the infinite series of final harvests is expressed by:

$$V_o = \frac{Y_r}{(1 + p)^r - 1}$$

After treating each of these factors separately, a general equation that considers all items can be written as (Davis, 1966):

$$S_o = \frac{Y_r + T\ (1 + p)^{r-t} \ldots -W\ (1 + p)^{r-w} \ldots -C}{(1 + p)^r - 1} - (C + E)$$

In the above, S_o may be defined as the expectation value of bare land, or as the net discounted present worth of the enterprise. The long numerator of the general expanded formula is an itemization of net periodic incomes and costs necessitated by the fact that there are various returns and costs coming at different times during the rotation. These incomes must uniformly be brought to rotation age with interest so that net income at rotation time can be calculated and capitalized by the discount procedure.

With evenaged management, the initial value is in the land. After the establishment of the stand, the forest crop increases in value until it is financially mature. It should then be cut. Land is again the only residual value at the end of a rotation. The S_o or soil expectation value represents the amount that can be invested in the land, with the expectation of receiving a net return rate equal to the capitalization rate. If the actual investment in the land is larger than the computed S_o value, it does not necessarily mean that there is a net loss on the operation. Usually, it simply means that the return rate will be less than the capitalization rate.

The actual soil rent is an annual opportunity cost per acre. It is obtained as the product of the rate times the capitalized value, hence:

$$\text{Annual Soil Rent} = S_o \cdot p$$

If the land is owned outright, the soil rent figure represents an imputed annual cost of ownership. However, if the capital for the operation is borrowed, the rent represents an actual return to the lender, and an actual cost to the borrower (Walker, 1962).

While the determination of soil value or rent may be important, another factor, determination of optimum rotation, is usually more important. Net present worth values represent external rates of return. They are called external because they are interpreted as being economic surplus or rent from all future rotations above all costs of production (Bentley and Teeguarden, 1965). Assuming that capital is held fixed, the total profit of operations will be maximized at the point where the rate of return is maximized. This point occurs where a stand's anticipated future value growth will not increase the present net worth or the soil rent. Thus, the timber becomes financially mature at the rotation length showing the maximum net present worth or maximum soil rent. Even though older stands may still yield positive net worth values, any extension beyond the rotation showing the maximum net present worth will cause a decrease in the net total profit.

In applying a significance to rotation length or derived soil values, it must be recognized that this value is a calculated figure controlled by the data and assumptions used in its determination. Faustmann's formula assumes complete certainty in respect to future costs and returns, and also that the goal is profit maximization. For these reasons S_o values should never be considered as fixed, but always should be considered in relationship to the assumptions used in the calculations. Even though the Faustmann method of soil rent determination does have some shortcomings, it represents the best basic economic investment concept available to foresters (Watt, 1967).

CHAPTER III

METHODS AND PROCEDURES

The Study Area

The study area is located in Pushmataha County between Clayton and Nashoba, in southeastern Oklahoma. Seven of the eighteen research plots were located on Weyerhaeuser Company lands near Nashoba, and the eleven other plots were located on the Pushmataha Wildlife Refuge managed by the Oklahoma Wildlife Conservation Department. Sites were chosen as close to the western edge of the commercial pine-hardwood type as possible in order to provide the maximum environmental tension.

As a whole, the climate is humid and warm. Although the average annual precipitation of 46 inches is normally evenly distributed, very severe summer droughts are common, due to the high summer temperatures and this area's high evapotranspiration, rated at about 36. The frostfree period for the study area varies from 215 to 235 days per year (Gray and Galloway, 1969).

Topography of the area is rugged and includes narrow valleys and mountain ridges. Elevations range from 700 to 1400 feet above sea level. Level areas are limited, and found only adjacent to or bordering streams and drainage systems. Only two of the research plots, 1 and 18, are located on what could be designated as level land. The remainder of the plots are located on ridges with slopes of eight percent or more. As a whole, the topography and climatic conditions are similar for the plots studied.

Plot Classification

Three land management, or site classes, were chosen for study according to the plant groups listed on Silker's (1963) wedge chart (Figure 2). These three pine-hardwood plant associations chosen for study were: (a) southern red oak, (b) hickory-tree huckleberry, and (c) hickory. There were two criteria used for locating plots. First, plot centers were picked only after it was decided that pine frequency was at or near full stocking. Second, the highest order, or most demanding hardwood had to have a "common"[1] or greater frequency on the plot. Six field plots for each of the three plant associations were examined. The pine age groups of twenty plus and thirty plus years were studied in each of the three plant associations. Thus, each age group and each plant association were replicated three times.

Soil series, slope position, aspect, and past management practices were not considered when the plots were set up. However, plots were chosen to give the necessary dominant or

[1] A frequency rating "common" was applied if at least one plant was recorded on each of the three quadrants in a one-tenth acre plot.

co-dominant pine sample trees, adequate associate species tally, and estimated age groups. One-tenth acre plots were used in order to minimize the effect of changes in site quality and soil characteristics.

Plants were classified according to their frequency of occurrence. Species with several plants occurring in each of the four quadrants of a one-tenth acre plot were classified "predominant." Those occurring at least once on each of three of the four quadrants were classified "common." Species occurring less frequently were classified as "scattered" (Wilson, 1968).

Soil Data

The study area lies in the physiographic province of the Ouachita Highlands. Acid red-yellow podzolic soils known as the Hector-Pottsville association are considered to have developed from the gray and brown shales and sandstones laid down during the Mississippian and Pennsylvanian periods. These soils are strongly leached and are generally light colored. The sub-soils are mottled. The predominant soils have been mapped as a Hector-Pottsville complex. Normally, the Hector is a shallow, light brown sandy soil over sandstone. The Pottsville is a shallow, light colored loam over clay-shales. The two soils commonly occur together on hillsides underlain with alternating sandstones and shales (Gray and Galloway, 1969).

One soil profile was examined and sampled for each one-tenth acre plot studied. Where possible, the profile was dug to a depth of four feet, near the plot center. The depth, color, texture, and fragment position and textural class of the A_1, A_2, B_1, B_2, and C horizons were described, where possible. Soil samples (500 grams) of each horizon were taken for future reference.

Physical Plot Data

All plants over one foot in height were tallied by species and diameter at breast height in two-inch DBH classes.[2] The minimum height used in the study was lowered from the 4.5 foot level used in Wilson's (1968) study on plant associations in order to pick up a greater number of the associated species. This first tally was made to determine only the associated species frequency on the plots. If there were multiple stems per plant, only the largest stem was recorded. Additional tallies were made to give more specific data on merchantable hardwood and pine stocking.

On the pine stocking tally, all pines taller than 4.5 feet were recorded. The following information was collected for each pine: (a) diameter to the nearest 0.1 inch at breast height and at stump height, (b) height to the nearest foot to a three- and four-inch top, and (c) the total height to the nearest 0.5 foot. Due to previous post and pulpwood

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[2]DBH refers to diameter at breast height.

cuttings on many of the plots, all cut pine stump diameters outside bark, to the nearest 0.1 inch, were recorded. This type of recording was made so that the original stands, before cutting, could be reconstructed, and so that the volumes of the thinnings might be estimated. Merchantable hardwoods were tallied by species, diameter at breast height to the nearest 0.1 inch, and height to the nearest foot of the merchantable stem. The minimum merchantable stem for hardwood was set at a 5-inch DBH with the requirement of at least two 4-foot cuts to a 4-inch top.

A regeneration tally on both pine and hardwood seedlings between six inches and one foot in height was made by species on eight .001 acre sub-plots. These eight sub-plots were located twenty feet from plot center, at forty-five degree intervals clockwise from north. The six inch minimum height was set because it was felt that a seedling must reach six inches before it is considered as established. The regeneration tally was not included in the species frequency ratings due to its questionable reliability and possible variability following fire, browsing, and management practices.

Additional general physical information was tallied for each plot. These data included slope percent, aspect, distance to the top and bottom of the slope, rock outcrops, stoniness, fire history, grazing history, timber stand improvement history, and general topographical information.

Site Index and Stem Analysis

Three dominant or co-dominant shortleaf pines per plot were felled and measured for age and total height, and were then subjected to a stem analysis. The actual dominant tree height and age readings were plotted on site index curves, thus giving the estimated site indexes at age fifty. Annual ring count was taken at stump height, six inches or less above the ground, and one year was added to the ring count as an allowance for the average time required to bring the seedling to average stump height. The total age of the tree could then be determined.

Each felled tree was cut into four-foot sections in order to make stem analyses, to provide data for local volume table construction, to reconstruct past stand volumes, and to determine periodic and mean annual growth. At the top of each section, the height above ground, diameter inside bark, diameter outside bark, number of rings in section, and the distance on an average radius from the center to each fifth ring, were recorded. Also, the height to a 3-inch and 4-inch top, to the nearest foot, and the total height to the nearest 0.5 foot were recorded. Each tree was numbered, and classified according to plot and according to plant association.

Volume Tables

The stem analysis made on the three sample pine trees per plot was used to develop a local volume table. Stem analysis served as a base to construct the taper curves on each of the sample trees. Using these taper curves, and by using the planimeter method described by Meyer (1953), the cubic foot volume inside and outside bark to a 3-inch top, to a 4-inch top, and total stem volume, were calculated. These volumes to a 3-inch and 4-inch inside bark were correlated with their corresponding diameters at breast height outside bark and subjected to a least squares regression analysis as illustrated in Meyer (1953). This procedure was based on a logarithmic volume equation:

$$\text{Log } Y = \text{Log } a + b \cdot \text{Log } D = \text{Log } a \cdot D^b$$
$$Y = a \cdot D^b$$

Tables III and IV give the cubic foot volumes of pine trees from 4 inches to 16 inches DBHOB.[3] These figures are inside-bark volumes to a 4-inch top and 3-inch top, respectively, and were arrived at by using the following regression equations:

1. To a 3-inch top: $\text{Log } Y = .0317011 + 2.5084192 \text{ Log } D$
2. To a 4-inch top: $\text{Log } Y = .0282045 + 2.5518238 \text{ Log } D$

The cubit foot volumes were determined by substituting the values for the coefficients, a and b, into the logarithmic volume equations and solving for given values of D. These volumes, (Y), and corresponding diameters at breast height, (D), were then plotted on log paper so that intermediate

[3]DBHOB refers to diameter at breast height outside bark.

TABLE III

LOCAL VOLUME TABLE IN CUBIC FEET TO A MINIMUM 4-INCH TOP FOR TREES 4-16 INCHES IN DIAMETER* (Shortleaf Pine, near Clayton, Oklahoma)

DBHOB	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Inches				- - C u b i c		F e e t - -				
4	0.969	1.032	1.098	1.166	1.237	1.309	1.384	1.463	1.543	1.627
5	1.713	1.801	1.893	1.987	2.084	2.185	1.287	2.394	2.501	2.612
6	2.728	2.844	2.966	3.089	3.216	3.346	3.478	3.616	3.754	3.898
7	4.041	4.192	4.343	4.501	4.659	4.820	4.986	5.156	5.328	5.504
8	5.685	5.866	6.053	6.242	6.438	6.636	6.833	7.040	7.249	7.460
9	7.674	7.897	8.119	8.347	8.577	8.809	9.052	9.291	9.542	9.790
10	10.044	10.304	10.566	10.834	11.098	11.374	11.657	11.940	12.225	12.515
11	12.813	13.111	13.416	13.721	14.033	14.345	14.671	14.996	15.321	15.653
12	15.992	16.338	16.683	17.036	17.386	17.753	18.119	18.483	18.853	19.232
13	19.617	20.011	20.402	20.800	21.195	21.597	22.008	22.426	22.852	23.273
14	23.703	24.141	24.573	25.027	25.476	25.919	26.383	26.842	27.309	27.784
15	28.268	28.744	29.245	29.738	30.223	30.733	31.235	31.762	32.281	32.791
16	33.326									

*Computed with the equation $\hat{Y} = a + D^b$

TABLE IV

LOCAL VOLUME TABLE IN CUBIC FEET TO MINIMUM 3-INCH TOP FOR TREES 4-16 INCHES IN DIAMETER* (Shortleaf Pine, near Clayton, Oklahoma)

DBHOB	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Inches				- - C u b i c		F e e t - -				
4	1.025	1.091	1.159	1.230	1.303	1.378	1.456	1.538	1.620	1.707
5	1.796	1.887	1.981	2.078	2.177	2.280	2.386	2.495	2.605	2.718
6	2.837	2.956	3.080	3.206	3.335	3.468	3.602	3.742	3.883	4.029
7	4.174	4.327	4.481	4.640	4.800	4.963	5.132	5.304	5.478	5.655
8	5.838	6.021	6.210	6.401	6.598	6.797	6.996	7.203	7.414	7.626
9	7.841	8.065	8.288	8.517	8.747	8.979	9.223	9.463	9.714	9.961
10	10.215	10.476	10.737	11.005	11.268	11.544	11.826	12.109	12.392	12.682
11	12.978	13.275	13.578	13.882	14.192	14.501	14.825	15.149	15.471	15.800
12	16.137	16.480	16.822	17.172	17.519	17.883	18.245	18.604	18.971	19.345
13	19.727	20.115	20.501	20.895	21.285	21.682	22.087	22.499	22.919	23.335
14	23.758	24.189	24.616	25.062	25.504	25.940	26.397	26.848	27.307	27.774
15	28.249	28.717	29.208	29.692	30.169	30.669	31.161	31.678	32.186	32.686
16	33.211									

*Computed with the equation $\hat{Y} = a + D^b$

values could be determined. The estimate could be made accurately because of the straight-line relationship of volume to DBHOB when plotted on log paper (Figures 3 and 4).

Another regression equation was developed to determine the cubic foot volumes inside bark of pine trees 4 inches DBHOB and less by using total volume data. This information, given in Table V, was plotted from the equation:

$$\text{Log } Y = .0384453 + 2.4265255 \ \text{Log } D$$

The local volume tables were developed in order that plot volumes could be estimated and the mean annual growth and periodic annual growth of the sample trees could be calculated.

Table VI was used to determine the cubic foot volumes of merchantable hardwoods. This table is a standard form class 70 cubic foot volume table developed by Mesavage (1947), and it gives volumes inside bark for lengths of merchantable stems based on measurements of DBHOB. The table was enlarged to include 8-foot and 12-foot merchantable lengths in the diameters larger than 10 inches. These extrapolated values were obtained by assuming the volume of a half log to be 60 percent of the volume of one log for a tree of equivalent DBHOB. While this method may not give absolutely correct values, it is based on the ratios in the original volume table and gives values proportional to the original table values.

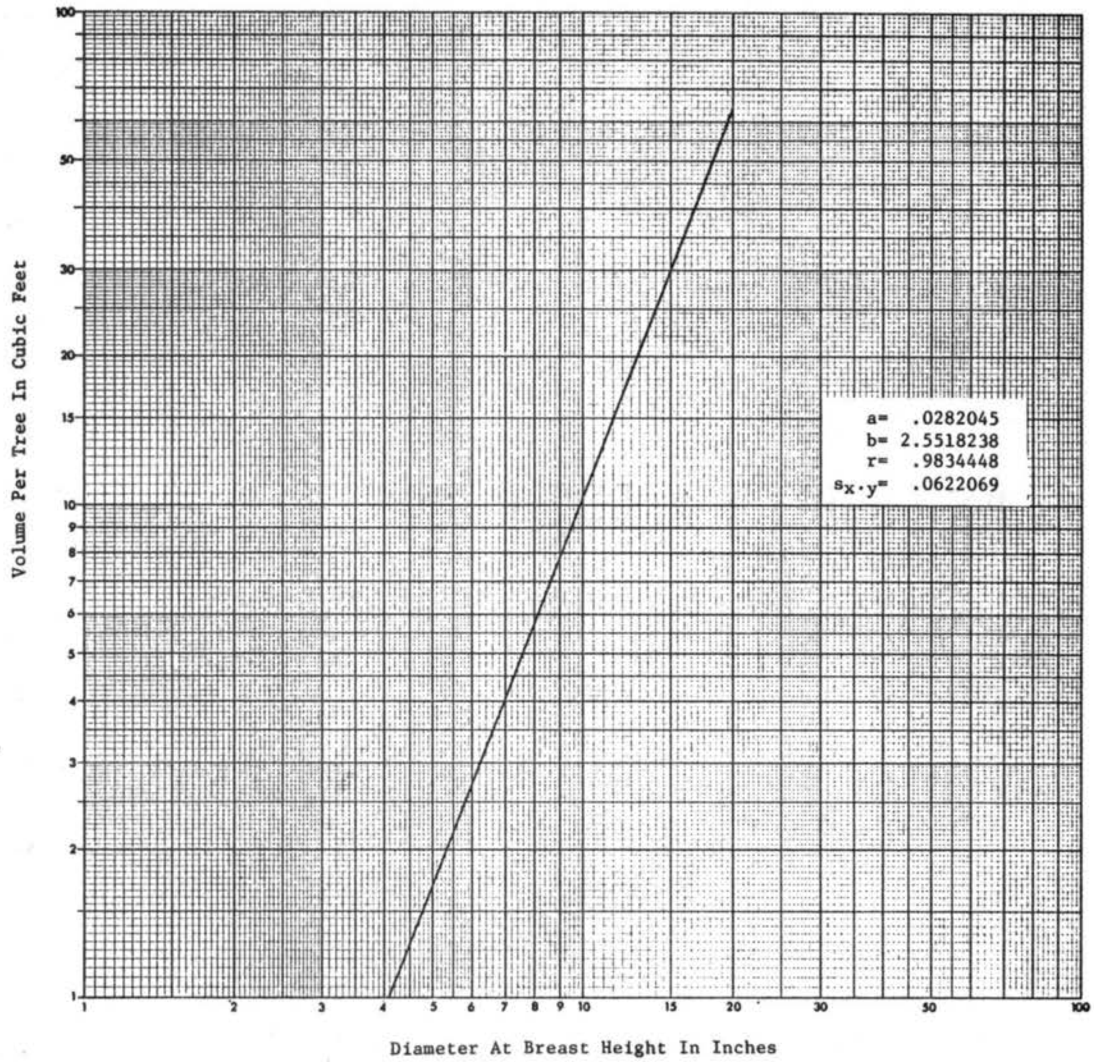


Figure 3. Logarithmic Straight-Line Relationship of Volume to DBHOB in the local volume table for shortleaf pine, minimum 4-inch top, for trees 4-16 inches in diameter.

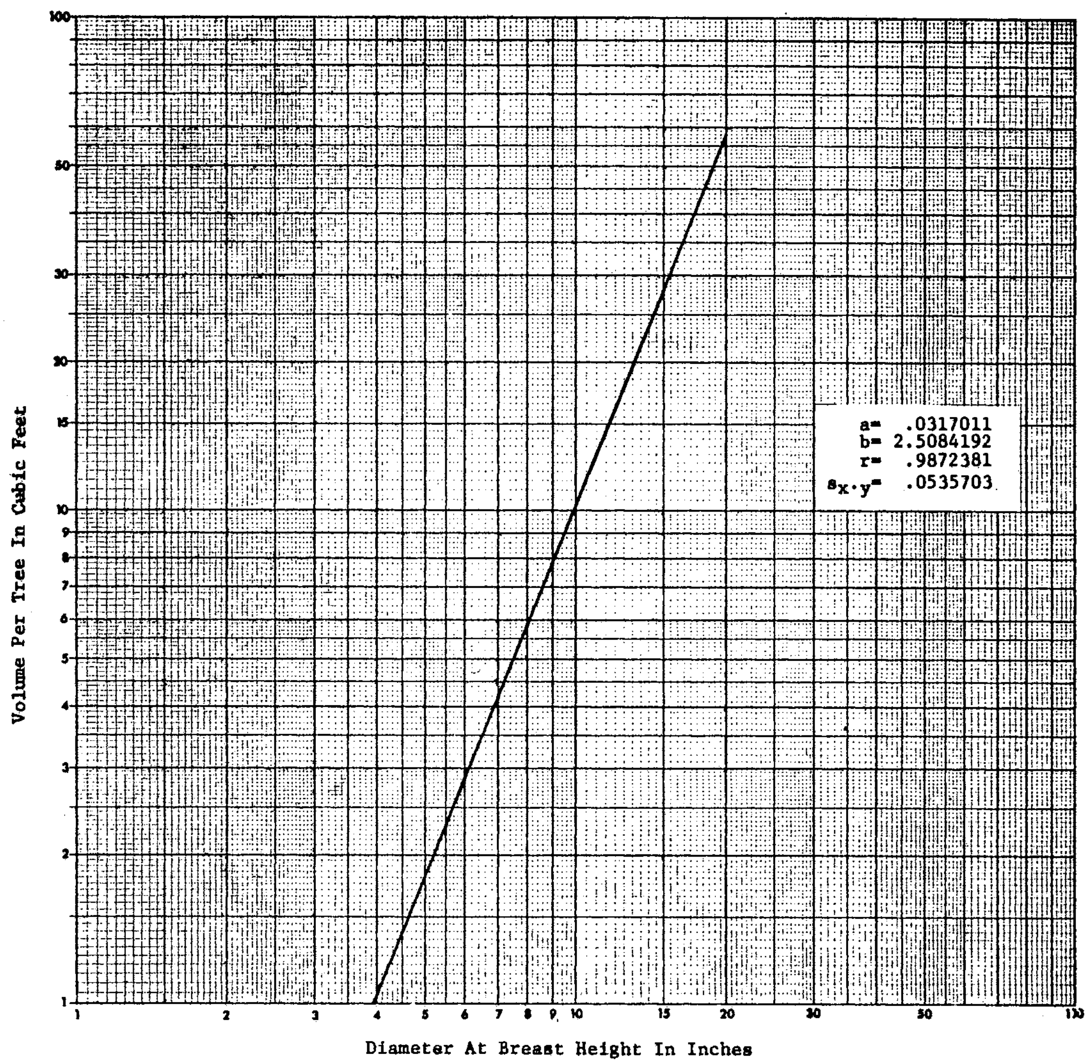


Figure 4. Logarithmic Straingt-Line Relationship of Volume to DBHOB in the local volume table for shortleaf pine to a minimum 3-inch top, for trees 4-16 inches in diameter.

TABLE V

LOCAL VOLUME TABLE IN CUBIC FEET FOR SHORTLEAF PINE LESS THAN 4 INCHES DBHOB

DBH OB	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Inches				-- Cubic		Feet --				
0	.000	.000	.001	.002	.004	.007	.011	.016	.022	.030
1	.038	.048	.060	.073	.087	.103	.120	.139	.160	.182
2	.206	.233	.260	.290	.322	.355	.391	.428	.467	.509
3	.552	.598	.646	.696	.748	.803	.860	.919	.980	1.045
4	1.111									

TABLE VI

STANDARD FORM CLASS 70 VOLUME TABLE FOR HARDWOODS*

DBHOB	Cubic Foot Volumes Inside Bark by Merchantable Stem Length 8 ft.	12 ft.	16 ft.	20 ft.	24 ft.
Inches		-- Cubic	Feet --		
5	.8	1.1	1.4	1.6	1.9
6	1.1	1.5	1.9	2.2	2.5
7	1.6	2.1	2.6	3.0	3.4
8	2.0	2.6	3.4	3.9	4.4
9	2.5	3.2	4.2	4.8	5.4
10	3.0	4.0	5.0	5.7	6.4
11	3.7	5.1	6.1	7.2	8.2
12	4.3	6.0	7.2	8.5	9.8
13	5.1	7.1	8.5	10.1	11.6
14	5.9	8.2	9.8	12.1	13.4
15	6.8	9.8	11.1	13.6	15.4
16	7.7	10.8	12.8	15.1	17.4

*(Mesavage, 1947)

Double Bark-Thickness

Double bark-thickness was obtained by relating diameters inside bark to diameters outside bark on each 4 foot section on all 54 sample trees. The plotted measurements indicated a very strong relationship between the corresponding diameter outside bark and diameter inside bark. The measurements were subjected to a least squares regression analysis. The analysis was calculated from the straight line equation:

$$Y = a + b \cdot X$$

where Y = Diameter inside bard
X = Diameter outside bark

The relationship was arrived at by using the regression equation (Figure 5):

$$Y = -.0566 + .8951 \cdot X$$

The equation is used to compute the diameter inside bark for the corresponding diameter outside bark. In order to determine the double bark-thickness at any given diameter outside bark, the diameter inside bark was subtracted from the corresponding diameter outside bark measurement. The calculated double bark-thickness values are shown in Table VII.

Plot Timber Volumes

Standing timber was classified as merchantable, premerchantable, and unmerchantable. Merchantability was set at a minimum required to provide two 4-foot cuts to the desired

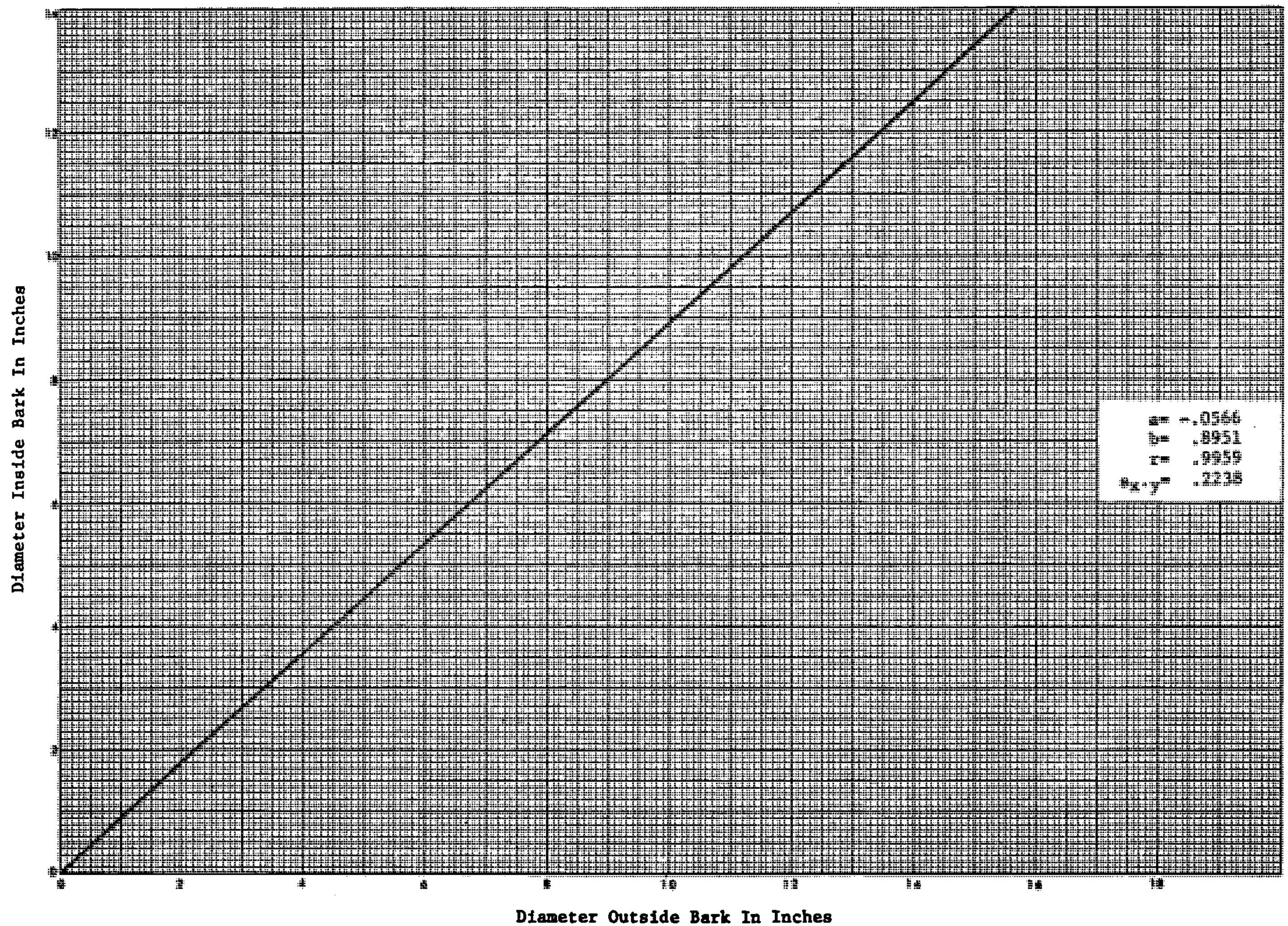


Figure 5. Linear Relationship of the Diameter Inside Bark to Diameter Outside Bark (Shortleaf Pine, near Clayton, Oklahoma).

TABLE VII

DOUBLE-BARK THICKNESS IN INCHES FOR DIAMETERS OUTSIDE BARK IN INCHES* (Shortleaf Pine near Clayton, Oklahoma)

DBHOB	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Inches				--	Inches	--				
0.	0.0	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
1.0	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.24	0.25	0.26
2.0	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.36
3.0	0.37	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.46	0.47
4.0	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57
5.0	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.65	0.67	0.68
6.0	0.69	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.77	0.78
7.0	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.89
8.0	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
9.0	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.10
10.0	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20
11.0	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.31
12.0	1.32									

*Values for double-bark thickness between diameters 0.1 and 4.0 inches were obtained by extrapolation.

minimum top diameter. Merchantable trees, both pine and hardwood, were assigned cubic foot volumes, as given in the local volume tables and standard volume table respectively. The volumes were then totaled for each DBH class and summed for the plot (Table VIII). Older residual trees were listed as "residual tree" basal area, and were not assigned volumes. Both premerchantable and unmerchantable stems were assigned basal areas, but were not given cubic foot volumes (Table IX). Merchantable stems were also given basal area figures in order to get total plot basal area.

A study of the stem taper from the stump to DBH had to be made before thinned pine volumes could be determined, the reason being that only the stump diameters could be obtained for thinned pine stems. The relationship of stump diameter to DBH was plotted on regular graph paper and subjected to a least squares regression analysis. The straight-line relationship was expressed by the equation:

$$Y = a + b \cdot X$$

where Y = DBHOB

X = Stump diameter outside bark

The estimated DBHOB values for given stump diameters are shown in Table X. These values are outside bark measurements and were arrived at by using the regression equation (Figure 6):

$$Y = -.167588 + .8032343 \cdot X$$

After preparing the conversion table, all stump diameters

TABLE VIII

MERCHANTABLE PINE AND HARDWOOD CUBIC FOOT VOLUMES ON PLOTS STUDIED

Plot	Site Index	Plant Association	Merchantable Pine Volume		Thinned Pine Volume	Merchantable Hardwood Volume
			3" Top	4" Top	4" Top	4" Top
			- - Cubic		Feet	- -
3	48	Hickory	110.83	108.87	21.226	5.4
4	48		105.82	103.19	3.426	7.9
11	58		93.45	91.61	8.413	6.2
12	47		68.54	52.52	44.005	
14	51		64.69	50.80	10.278	35.1
15	52		50.07	35.90	7.398	15.2
7	60	Hickory-Tree Huckleberry	139.65	136.12		18.4
8	57		114.29	111.06		16.8
9	49		40.05	29.37	16.432	11.0
10	47		30.83	27.41	11.293	31.6
13	52		75.07	63.86	23.449	25.0
16	60		154.07	147.11		14.2
1	62	Southern Red Oak	272.33	270.47	41.718	
2	61		149.13	142.36		5.6
5	62		108.85	100.63		9.1
6	63		96.42	92.98		17.5
17	59		106.17	100.28		9.6
18	57		213.70	210.83		10.0

TABLE IX

PREMERCHANTABLE AND UNERMCHANTABLE PINE AND HARDWOOD STOCKING ON PLOTS STUDIED

Plot	Site Index	Plant Association	Premerchantable Pine Basal Area 3" Top (Cubic Feet)	Premerchantable Pine Basal Area 4" Top (Cubic Feet)	Residual Pine Basal Area (Sq. Ft.)	Hardwood Basal Area Premerchantable (Sq. Ft.)	Hardwood Basal Area Unmerchantable (Sq. Ft.)
3	48	Hickory	.301	.301	1.069	.235	3.135
4	48		.279	.279		.490	2.414
11	58		.005	.005		.843	2.330
12	47		2.945	4.076	.927		2.066
14	51		4.820	5.777	.616	.074	1.557
15	52		2.817	3.841	1.984	.239	.981
7	60	Hickory-Tree Huckleberry	.272	.272		.503	2.075
8	57		.270	.270		.556	2.631
9	49		4.209	4.992	.922	.181	.664
10	47		.904	1.078		.164	2.062
13	52		1.556	2.252		.180	2.873
16	60		.333	.594		.322	2.092
1	62	Southern Red Oak				.392	1.227
2	61		.066	.027		.671	2.137
5	62		2.065	2.413	1.729	.809	1.996
6	61		1.189	1.189	1.090	.571	1.553
17	59		1.882	2.056		.327	1.481

TABLE X

RELATIONSHIP OF DBHOB TO STUMP DIAMETER OUTSIDE BARK*
(Shortleaf Pine, near Clayton, Oklahoma)

Stump Diameter O.B.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Inches					-- D B H O B, Inches --					
4	3.045	3.126	3.206	3.286	3.367	3.447	3.527	3.608	3.688	3.768
5	3.849	3.929	4.009	4.090	4.170	4.250	4.331	4.411	4.491	4.571
6	4.652	4.732	4.812	4.893	4.973	5.053	5.134	5.214	5.294	5.375
7	5.455	5.535	5.616	5.696	5.776	5.857	5.937	6.017	6.098	6.178
8	6.258	6.338	6.419	6.500	6.580	6.660	6.740	6.821	6.901	6.981
9	7.062	7.142	7.222	7.302	7.383	7.463	7.543	7.624	7.704	7.784
10	7.865	7.945	8.025	8.106	8.186	8.266	8.347	8.427	8.507	8.588
11	8.668	8.748	8.829	8.909	8.989	9.070	9.150	9.230	9.311	9.391
12	9.471	9.552	9.632	9.712	9.793	9.873	9.953	10.033	10.114	10.194
13	10.274	10.355	10.435	10.515	10.596	10.676	10.756	10.837	10.917	10.997
14	11.078	11.158	11.238	11.319	11.399	11.479	11.560	11.640	11.720	11.801
15	11.881	11.961	12.042	12.122	12.202	12.283	12.363	12.442	12.524	12.604
16	12.684									

*Calculated with the equation $\hat{Y} = a + bX$

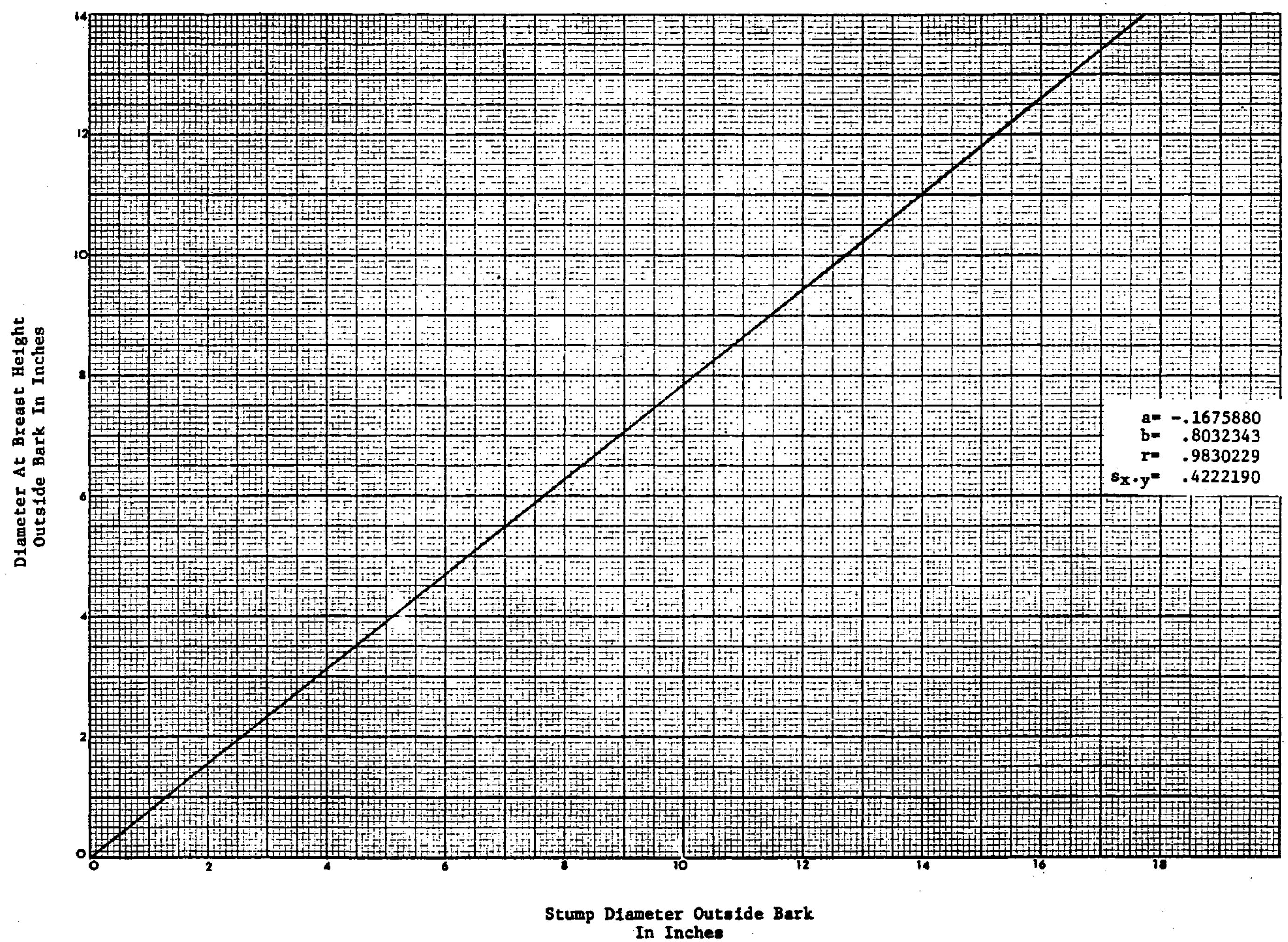


Figure 6. Linear Relationship of Stump Diameter Outside Bark to Diameter at Breast Height Outside Bark (Shortleaf Pine, near Clayton, Oklahoma).

were converted to DBH measurements. The thinned pine volume (Table VIII) was then determined in the same manner as the standing merchantable timber.

Growth Analysis

Meyer (1953) defines mean annual growth in evenaged stands as the volume of the stand divided by the age of the stand, and periodic annual growth to be the amount by which the volume of a stand increases annually or in a short period of years.

Through the use of both the stem analysis and the local volume tables, an estimate of the mean annual growth and periodic annual growth by 5-year intervals was made. Double bark thickness was added to the diameter inside bark at the top of each 4 foot section. Diameters outside bark for each section of the 54 sample trees were then converted to cubic foot inside bark volumes. Volumes were summed for the plot. The total plot volumes were subjected to the mean annual growth and periodic annual growth calculations using the formulas:

$$PAG = \frac{\text{Volume at } n_2 \text{ years} - \text{Volume at } n_1 \text{ years}}{n_2 - n_1 \text{ years}}$$

$$MAG = \frac{\text{Volume at } n \text{ years}}{n \text{ years}}$$

These results were further reduced to growth figures for the average sample tree.

Past stand volumes were obtained by reconstructing the stand from the stem analysis on the sample trees. Ratios between the volume levels at 5-year periods on the 3 sample trees per plot were then used as multipliers for the volume levels in the previous 5-year age period, starting with the present stand volume. Volumes removed in thinnings were added back to the stand volume levels in the appropriate 5-year periods, thus reconstructing the past stand volumes for each 5-year period from the present stand volume.

The above-described procedure, developed in Germany, once played a very important part in volume and growth determination in practical forestry. The method does have some obvious weaknesses. First, it assumes that the average diameter dimensions of the sample trees are identical with the average diameter dimensions of all trees on the plot at any given time during the rotation. This assumption does not always hold true for the past or future. Second, the method assumes that an accurate determination of volumes or growth rates of a site can be taken from a few sample trees (Meyer, 1953). Today, more precise data can be taken through the use of continuous inventory systems using C.F.I. plots. However, in the absence of data taken at periods during the life of the stand, the reconstruction of stand volumes through sample tree growth provides the only method for estimating the past stand volume levels.

Value Schedules and Plot Values

Two value schedules were used for pine stumpage (Table XI). Schedule #1 was based on a fixed price of $5 per cord, regardless of tree size. The cord volume for each DBH class was calculated assuming that 4-inch trees would yield 70 cubic feet, and 14-inch trees 100 cubic feet, of solid wood per cord. By multiplying the percentage of a cord made up of a given DBH times the value per cord, the dollar value per tree could be determined. Schedule #2 was based on a sliding value scale in order to account for corresponding increases in the volume of solid wood per cord and the higher specific gravity accompanying increases in age and diameter. The schedule assumed a value of $2 per cord and $7 per cord for 4-inch DBH and 14-inch DBH stems respectively, with intermediate values obtained by a linear increase between $2 and $7. After a dollar value per cubic foot for each DBH class was determined, the value was multiplied by the cubic foot volume per tree to obtain the value per tree. The same volume table was used with both value schedules.

Two value schedules were also calculated for hardwood stumpage (Tables XII and XIII). These tables were prepared in the same manner as the pine value schedules. They were, however, based upon the standard form class 70 cubic foot volume table developed by Mesavage (1947). Use of this table brought into consideration the factor of merchantable height. Fixed prices of $3 per cord and a sliding scale value of

TABLE XI

SHORTLEAF PINE STUMPAGE VALUE SCHEDULES

DBHOB	Schedule 1* Dollars 4" Top	Schedule 1* Dollars 3" Top	Schedule 2** Dollars 4" Top	Schedule 2** Dollars 3" Top
	- - D o l l a r s - -			
4	.069	.074	.028	.029
5	.118	.123	.059	.061
6	.180	.187	.108	.112
7	.256	.264	.179	.185
8	.347	.356	.277	.285
9	.452	.461	.406	.415
10	.571	.581	.570	.580
11	.704	.713	.774	.784
12	.851	.859	1.020	1.030
13	1.011	1.017	1.314	1.322
14	1.185	1.188	1.659	1.663
15	1.372	1.372	2.058	2.057
16	1.572	1.567	2.516	2.507

*Value per tree based on constant value per cubic foot, regardless of tree size.

**Value per tree based on a sliding scale of values per cubic foot, from $.029 for 4" trees to $.076 for 17" trees.

TABLE XII

HARDWOOD STUMPAGE VALUE SCHEDULE BASED
ON A SLIDING SCALE

	Cubic Foot Volumes Inside Bark by Merchantable Stem Length				
DBHOB	8 ft.	12 ft.	16 ft.	20 ft.	24 ft.
Inches	- - Cubic Feet - -				
5	.016	.023	.029	.033	.039
6	.027	.036	.046	.053	.061
7	.044	.058	.072	.083	.094
8	.061	.079	.104	.119	.134
9	.084	.107	.141	.161	.181
10	.133	.144	.180	.205	.230
11	.142	.196	.235	.277	.316
12	.176	.246	.295	.349	.402
13	.219	.305	.366	.434	.499
14	.266	.369	.441	.545	.603
15	.320	.462	.556	.614	.725
16	.376	.527	.625	.737	.849

TABLE XIII

HARDWOOD STUMPAGE VALUE SCHEDULE BASED
ON A FIXED SCALE

	Cubic Foot Volumes Inside Bark by Merchantable Stem Length				
DBHOB	8 ft.	12 ft.	16 ft.	20 ft.	24 ft.
Inches	- - Cubic Feet - -				
5	.033	.045	.058	.066	.078
6	.044	.059	.075	.087	.099
7	.061	.080	.099	.114	.129
8	.073	.095	.125	.143	.161
9	.088	.113	.148	.170	.194
10	.102	.137	.170	.194	.218
11	.122	.168	.201	.237	.270
12	.137	.191	.230	.271	.313
13	.158	.220	.263	.312	.359
14	.177	.246	.294	.363	.402
15	.198	.285	.344	.396	.449
16	.218	.306	.362	.428	.493

from \$1.50 to \$4.50 per cord, for 4-inch and 14-inch DBH stems, respectively, were set on the hardwood stumpage.

The current values of standing pine stumpage to a 3-inch and 4-inch top (Tables XIV and XV) were calculated by applying a dollar value from the pine stumpage value schedules (Table XI) to the appropriate number of trees in the DBH class on the plot. The total pine stumpage value per plot was then determined by summing these values for each DBH class. Hardwood stumpage values to a 4-inch top were determined in a similar manner, using Tables XII and XIII. The gross plot value was then calculated by adding the standing pine plot value to the hardwood plot value. The value of the thinned pine was determined in the same manner as the standing pine stumpage value. The value of the thinned material was not included in the present gross plot value since it was to be kept separate in the discounting procedure.

Discount Procedure (Soil Rent)

Net present worth values were derived for each plot on both a fixed price scale and sliding scale for five percent and eight percent capitalization rates (Table XVI). These S_O values were calculated by considering final harvest yields and thinnings (Table XIV). All costs were omitted at this point in analysis. The capital values were expressed by:

$$V_o = \frac{Y_r + T\ (1 + p)^{r-t}}{(1 + p)^r - 1}$$

TABLE XIV

CURRENT DOLLAR VALUE PER ACRE OF MERCHANTABLE PINE AND HARDWOOD STOCKING TO A 4-INCH TOP ON PLOTS STUDIED

Plot	Site Index	Plant Association	Merchantable Pine Value		Thinned Pine Value		Merchantable Hardwood Value	
			Fixed Price	Sliding Scale	Fixed Price	Sliding Scale	Fixed Price	Sliding Scale
			- - D o	l l a r s	- -			
3	48	Hickory	62.08	61.49	13.33	9.68	1.81	2.03
4	48		62.04	52.15	2.36	1.18	2.43	3.43
11	58		53.21	49.86	5.27	3.85	2.53	1.34
12	47		36.41	17.38	29.55	16.53		
14	51		35.23	16.79	7.08	3.54	11.59	13.43
15	52		24.90	11.82	4.65	3.36	4.93	4.62
7	60	Hickory Tree Huckleberry	82.24	68.03			6.26	6.95
8	57		68.54	52.74			5.61	6.31
9	49		19.83	10.02	11.24	5.80	3.78	4.15
10	47		18.89	9.27	7.70	4.03	10.21	12.86
13	52		43.57	22.53	15.39	9.45	8.16	9.80
16	60		89.21	72.88			4.48	5.92
1	62	Southern Red Oak	168.15	178.81	26.03	19.05		
2	61		73.44	63.57			2.03	1.64
5	62		66.42	39.66			3.23	3.03
6	63		60.02	39.19			5.68	6.97
17	59		65.23	41.25			3.25	3.51
18	57		116.25	126.63			4.05	2.22

TABLE XV

CURRENT DOLLAR VALUE PER ACRE OF MERCHANTABLE PINE TO A 3-INCH TOP AND HARDWOOD STOCKING TO A 4-INCH TOP ON PLOTS STUDIED

Plot	Site Index	Plant Association	Merchantable Pine Value		Thinned Pine Value		Merchantable Hardwood Value	
			Fixed Price	Sliding Scale	Fixed Price	Sliding Scale	Fixed Price	Sliding Scale
				- - D o	l l a	r s - -		
3	48	Hickory	63.24	62.58	13.73	9.95	1.81	2.03
4	48		63.66	53.35	2.46	1.22	2.43	3.43
11	58		54.27	50.86	5.43	3.97	2.53	1.34
12	47		47.99	21.76	30.72	17.09		
14	51		45.28	20.57	7.38	3.66	11.59	13.43
15	52		35.19	19.72	4.74	3.46	4.93	.62
7	60	Hickory-Tree	84.39	69.69			6.26	6.95
8	57	Huckle-berry	70.43	54.20			5.61	6.31
9	49		27.88	12.98	11.71	6.00	3.78	4.15
10	47		21.38	10.18	8.02	4.17	10.21	12.86
13	52		51.54	25.64	15.96	9.77	8.16	9.80
16	60		93.74	75.61			4.48	5.92
1	62	Southern Red Oak	169.21	179.88	26.03	19.85		
2	61		77.36	65.90			2.03	1.64
5	62		72.13	42.15			3.23	3.03
6	63		62.29	40.42			5.68	6.97
17	59		69.30	53.99			3.25	3.51
18	57		117.92	128.25			31.05	2.22

TABLE XVI

CAPITALIZED INCOME VALUES PER ACRE AT FIVE AND EIGHT PERCENT DISCOUNT (NO COSTS CONSIDERED)

Plot	Site Index	Plant Association	Fixed Price Scale 5%	Fixed Price Scale 8%	Sliding Price Scale 5%	Sliding Price Scale 8%
			- - Dollars - -			
3	48	Hickory	10.35	2.81	9.64	2.59
4	48		8.49	2.22	7.17	1.86
11	58		17.66	6.43	15.86	5.76
12	43		27.12	11.42	14.08	5.96
14	51		20.28	8.08	12.63	5.03
15	52		13.08	5.25	7.58	3.06
7	60	Hickory-Tree Huckleberry	23.51	8.24	19.92	6.98
8	57		18.52	6.35	14.75	5.06
9	49		15.13	6.48	8.59	3.65
10	47		20.48	9.31	14.30	6.43
13	52		30.32	13.02	18.86	8.09
16	60		32.08	12.28	26.99	10.33
1	62	Southern Red Oak	22.61	5.70	22.81	5.71
2	61		16.71	5.48	14.44	4.73
5	62		22.35	8.37	13.70	5.13
6	63		24.04	9.40	16.89	6.61
17	59		21.98	8.23	14.36	5.38
18	57		18.82	5.36	20.16	5.74

After the net present worth values for the plots were derived, they were subjected to four different analyses. First, annual expenses of $0.75 per acre were capitalized and subtracted from the capitalized income values for each plot. The residual capital was then evaluated to determine the maximum amount that could be used for regeneration costs. The evaluation is obtained with:

$$C = \frac{V_o \left[(1 + p)^r - 1\right]}{(1 + p)^r}$$

A zero rent was assumed in this analysis.

In the second analysis, both the capitalized value of annual expenses of $0.75 per acre and a capitalized value for the minimum regeneration cost were subtracted from the capitalized income values per plot. Minimum regeneration costs were set at $4, $5, and $6 for hickory sites, hickory tree-huckleberry sites, and southern red oak sites, respectively. The residual remaining after these calculations is termed S_o (soil expectation value). Soil rent is obtained from the S_o value as follows:

$$\text{Annual Soil Rent} = S_o \cdot p$$

The third analysis considered annual costs, minimum regeneration costs, and an assumed investment in land. Annual costs and minimum regeneration costs were assumed to be identical with values used in the second analysis. The investment in land was placed at $5 per acre. The rental on this arbitrary land investment ($5 x .05 = $0.25) was treated as an annual cost per acre and capitalized for all future rotations. The residual capital value, remaining after the above deductions were made, represents a capital available for distribution to timber stand improvement work.

The fourth analysis used the residual capital value remaining after the costs shown in the second and third analyses had been deducted. The residual capital value was used to compute a final harvest (Y_r) flow equivalent. The flow value represents the additional amount of final harvest net income per acre needed to break even on operations. The flow values were obtained with:

$$Y_r = V_o \left[(1 + p)^r - 1 \right]$$

Reconstructed Plot Values

In the selection of study plots for this project, the attempt was made to obtain representation from two age classes, 15 to 25 years and 30 to 40 years. As it turned out, there was much more variability in the age classes sampled than was originally intended. Stands varied in age all the way from 22 to 47 years. Average diameters, volumes, and basal areas are stand attributes dependent upon age as well as site index, hence these stand attributes are not strictly comparable if an age variation exists. Furthermore, the application of the soil value procedure to these plot data is sensitive to age variation, particularly after stand age 30 is passed. A need for reducing plot information to a common age was evident, so that meaningful comparisons between the site qualities, as reflected by the plant associations, could be made. Five plots having age classes well beyond the 30-year point were reconstructed with the above in mind.

The principle used in reconstructing these plots is that diameter increment over a relatively short period of years appears to be proportional to the diameters of the trees at the beginning of the period. In cottonwood, for example, Walker (1967) has shown that the rate of diameter increase over a 10-year period averages approximately 2 inches for a 5-inch tree, and approximately 4 inches for a 10-inch tree, and that the regression of diameter increase over DBH is linear over the 10-year period. Although comparable information for shortleaf pine could not be found, it seems reasonable to assume that the proportionality in diameter increment should hold over a range of species in even-aged stands.

Using the concept of diameter increment proportional to size, and using the development of the sample trees from age 30 to their present age, the present growing stock on the plots supporting the older age classes could be reconstructed at age 30, and the volumes and values estimated at that period of time. The following ratio was used:

$$\text{Ratio of past to to present DBH} = \frac{\text{Average sample tree DBH, age 30}}{\text{Present average sample tree DBH}}$$

The average stand DBH at age 30 could then be estimated with:

$$\text{Present average stand DBH} \times \frac{\text{Average DBH, age 30}}{\text{Present average DBH}}$$

The numbers of trees in various DBH classes at age 30 were estimated with the use of Tables XVII and XVIII. Values from the value schedules prepared for this project were then used to convert the reconstructed stand tables to plot values. Having obtained the estimate of value per plot and per acre, the soil value could then be estimated for rotation age 30. The stated procedure made it possible to compare the plots with more certainty, and it also permitted some estimate of optimum rotation length to be made.

Basically, the reconstruction procedure is sound, but it is not without weaknesses. The main weakness is that the reconstruction of the average stand is based on a stand table for fully stocked pure pine stands. While the studied stands are progressively moving toward full stocking, actually, none of them is stocked as heavily as is indicated in various yield tables for the species. The number of hardwood stems on the plots furnished some evidence of this light degree of pine stocking. Since present stands appear to be understocked, it is logical to assume that at younger ages they were understocked to a greater degree. This weakness has been compensated for somewhat by estimating the actual average number of trees per acre in the stand at age 30 and the lower mortality rate characteristic of understocked stands. However, the method probably overestimates the number of trees per acre at age 30.

The optimum rotation age was found by using the reconstruction procedure as described above for each 5-year period

TABLE XVII

NUMBER OF TREES PER ACRE IN SHORTLEAF PINE*

Age (Years)	Site Index in Feet at Age 50			
	40	50	60	70
	Trees per Acre			
15	11,300	7,700	3,600	2,730
20	6,000	3,425	2,520	1,965
25	3,405	2,495	1,905	1,480
30	2,565	1,855	1,370	1,060
35	1,955	1,400	1,030	780
40	1,525	1,085	815	625
45	1,260	890	670	515
50	1,055	760	570	440

*Misc. Pub. #50 (1929), Table #100.

TABLE XVIII

STAND TABLE FOR FULLY STOCKED SHORTLEAF PINE ON ALL SITES*

DBHOB of Average Tree in Stand	Percentage of All Trees in and Above A Given DBHOB Class							
- - Inches - -	- - Inches - -							
	2	4	6	8	10	12	14	16
3.0	100	15	2					
3.5	100	35	5					
4.0	100	55	11					
4.5	100	67	24	3				
5.0	100	74	32	7				
5.5	100	80	43	13	2			
6.0	100	85	53	20	4			
6.5	100	88	60	29	8	1		
7.0	100	90	67	35	12	2		
7.5	100	93	73	44	17	5		
8.0	100	94	78	51	23	7	1	
8.5	100	95	83	58	27	11	3	
9.0	100	96	86	64	36	14	4	1
9.5	100	97	90	70	41	19	6	1
10.0	100	98	91	75	50	25	9	2

*Misc. Pub. #50 (1929), Table #161.

to age 20 and by applying the 5 percent discount procedure to the estimated incomes and costs. The optimum rotation is the one which maximizes the present net worth and the soil rent.

Site Index Confidence Intervals

A calculated estimate of the mean ($\overline{X}$), standard deviation(s) and a tabulated t-distribution value at the .05 level were used to make the site index confidence statements. The confidence statements were developed from the form, $\overline{X} - t_{.05}\, s_{\overline{X}} \leq \mu \leq \overline{X} + t_{.05} s_{\overline{X}}$ (Snedecor and Cochran, 1967).

The value, $\overline{X}$, is obtained from a limited population and represents an arithmetic average which is an estimate of the true mean (μ). The statistic $\overline{X}$ is calculated by the formula (Meyer, 1953):

$$\overline{X} = \frac{\Sigma X_i}{N}$$

where ΣX_i = summation of the values
N = number of observations

The standard deviation(s) measures the dispersion or degree of scatter of the X_i observations around the estimated mean ($\overline{X}$). Standard deviation is defined as the square root of the mean of the squares of deviations from the mean (Meyer, 1953). Mathematically, the standard deviation equation is expressed (Snedecor and Cochran, 1967):

$$s_{\overline{X}} = \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{N - 1}}$$

Variance $s_{\overline{X}}^2$ is the square of the standard deviation and is given by the formula (Snedecor and Cochran, 1967):

$$s_{\overline{X}}^2 = \frac{\Sigma(X_i - \overline{X})^2}{N - 1}$$

CHAPTER IV

RESULTS AND DISCUSSION

The measured site indexes at age 50 for three sample trees on each plot are averaged, arranged by plant associations, and given in Tables XIX, XX, and XXI.

Variation in the average site indexes for the southern red oak plant association plots ranged from 57 to 63, with a mean site index of 60.7. The confidence interval for the southern red oak association with 5 degrees freedom is stated as $P(56.3 \leq \mu \leq 65.1) = 0.95$ (Table XIX). This statement means that there is a 95 to 5 chance that the mean site index will fall between 56.3 and 65.1.

The mean site index for the hickory-tree huckleberry plant association plots is 54.2. Actual site indexes ranged from 47 to 60 and resulted in the largest site index range of the three plant associations (Table XX). The confidence statement, using the same method as described in Chapter III stated $P(41.0 \leq \mu \leq 67.4) = 0.95$ with 5 degrees freedom.

Variation for the hickory plant association site indexes ranges from 47 to 58, with a mean of 50.7 (Table XXI). The confidence interval statement is given as $P(41.1 \leq \mu \leq 60.3) = 0.95$, with 5 degrees freedom.

TABLE XIX

CONFIDENCE INTERVAL STATEMENTS FOR THE MEAN POPULATION SHORTLEAF PINE SITE INDEX FOR THE SOUTHERN RED OAK PLANT ASSOCIATION

Plot Number	Average Age (Years)	Average Height (Feet)	Site Index (x)
1	47.3	60.2	62
2	35.0	50.5	61
5	28.7	47.0	62
6	26.7	45.2	63
17	28.7	43.8	59
18	41.3	51.8	57

ΣX	364.0
$\bar{X}$	60.7
ΣX^2	22,108.0
$s^2_{\bar{X}}$	2.873
$s_{\bar{X}}$	1.695
$P(56.3 \leq \mu \leq 65.1) =$	0.95

TABLE XX

CONFIDENCE INTERVAL STATEMENTS FOR THE MEAN POPULATION SHORTLEAF PINE SITE INDEX FOR THE HICKORY-TREE HUCKLEBERRY PLANT ASSOCIATION

Plot Number	Average Age (Years)	Average Height (Feet)	Site Index (X)
7	32.3	47.7	60
8	33.0	45.5	57
9	27.7	44.8	49
10	26.0	35.0	47
13	22.0	30.7	52
16	25.0	36.7	60

ΣX	325.0
$\overline{X}$	54.2
ΣX^2	17,763.0
$s_{\overline{X}}^2$	26.473
$s_{\overline{X}}$	5.145
$P(41.0 \leq \mu \leq 67.4) =$	0.95

TABLE XXI

CONFIDENCE INTERVAL STATEMENTS FOR THE MEAN POPULATION SHORTLEAF PINE SITE INDEX FOR THE HICKORY PLANT ASSOCIATION

Plot Number	Average Age (Years)	Average Height (Feet)	Site Index (X)
3	45.3	46.3	48
4	45.3	46.3	48
11	30.7	44.3	58
12	27.3	34.8	47
14	27.3	37.7	51
15	27.0	38.2	52

ΣX	304.0
$\overline{X}$	50.7
ΣX^2	15,486.0
$s_{\overline{X}}^2$	13.89
$s_{\overline{X}}$	3.726
$P(41.1 \leq \mu \leq 60.3) =$	0.95

The relationship between shortleaf pine site indexes and the plant association can be illustrated by the site index curves shown in Figures 7, 8, and 9. Each of these figures represents the average height and average age for the three shortleaf pine sample trees on each of the six plots studied for the association. Figure 10 illustrates the mean age and mean heights for each of the three plant associations. Mean site indexes for the southern red oak, hickory-tree huckleberry, and hickory associations are shown as 60.7, 54.2, and 50.7, respectively. While site index ranges overlap, the mean site indexes do show a definite increasing trend. The increasing site indexes are associated with increasingly demanding plant associations. The mean site indexes tend to be lower, and grouped closer together than in Wilson's (1966) study; however, this fact is thought to be a result of the much higher stress conditions of the study area.

Individual species occurrence and frequency are illustrated in relation to shortleaf pine site index and plant association in Tables XXII and XXIII. The hardwood indicator species are listed in accordance with Silker's wedge chart (Figure 2) relating apparent moisture demand regime. The vertical dash lines in Table XXII indicate the upper levels of the plant associations.

Average merchantable plot volumes (Table XXV) and average plot basal areas (Table XXVI) illustrate the trends of higher productivity with the more demanding plant

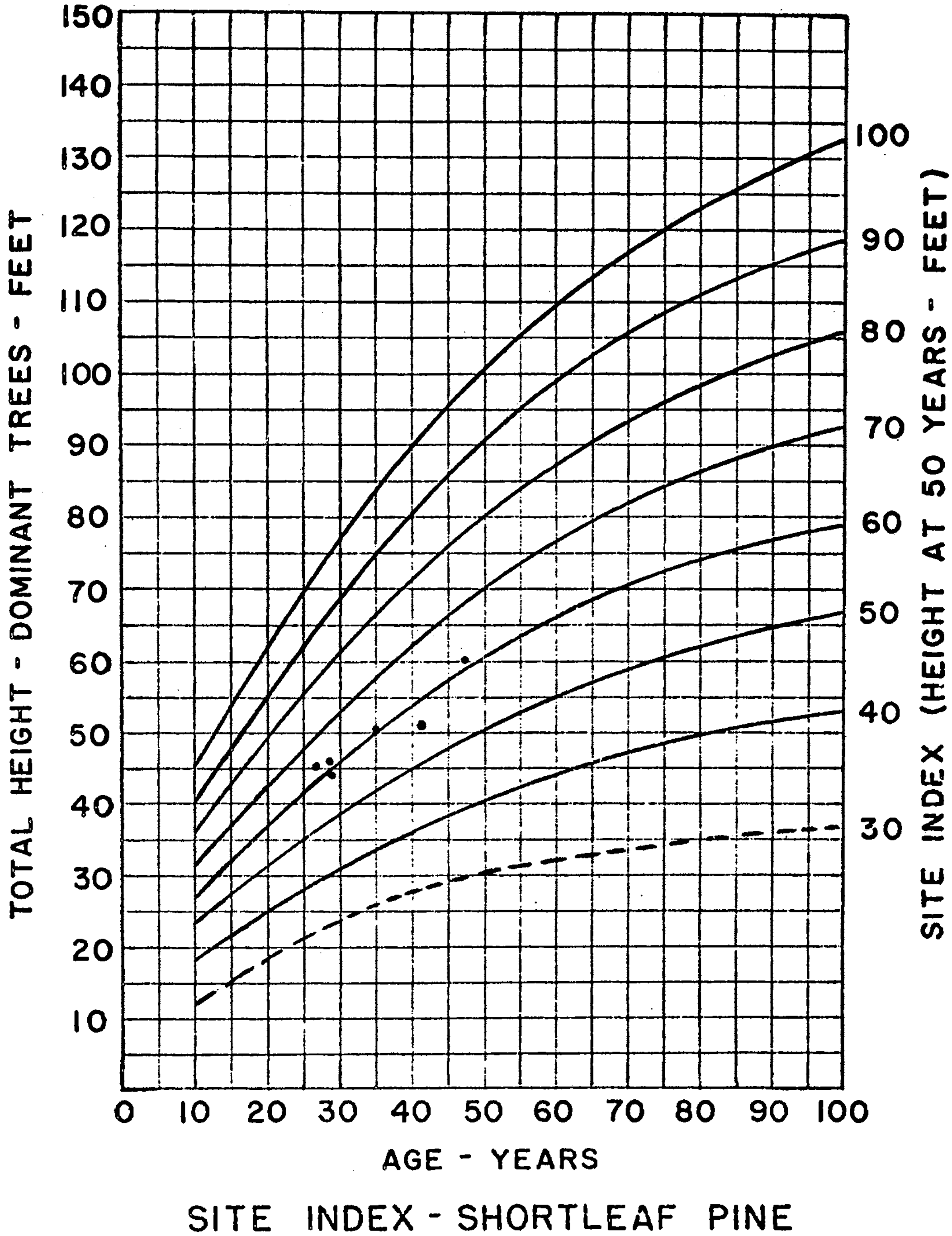


Figure 7. Southern Red Oak Plant Association Plot Site Indexes.

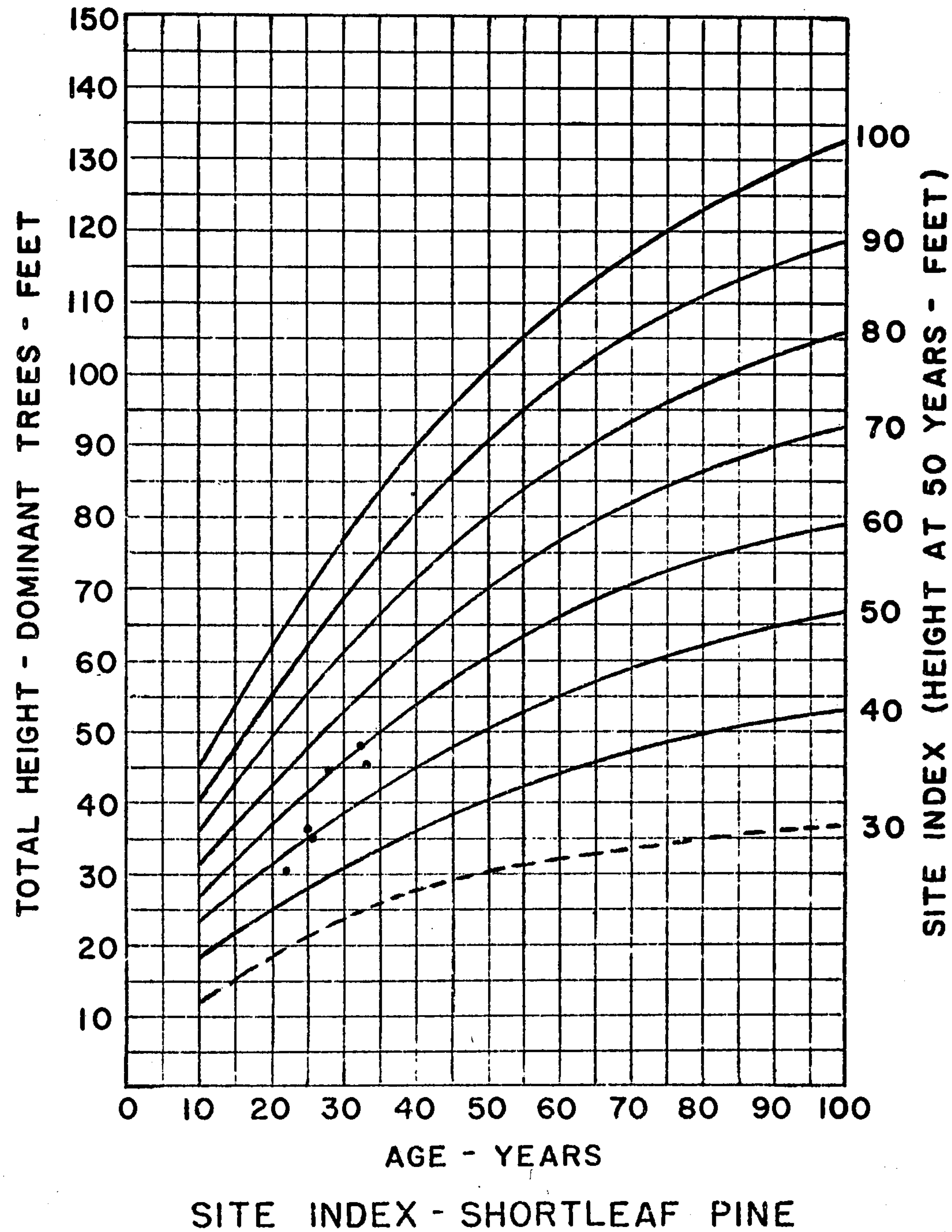


Figure 8. Hickory-Tree Huckleberry Plant Association Plot Site Indexes.

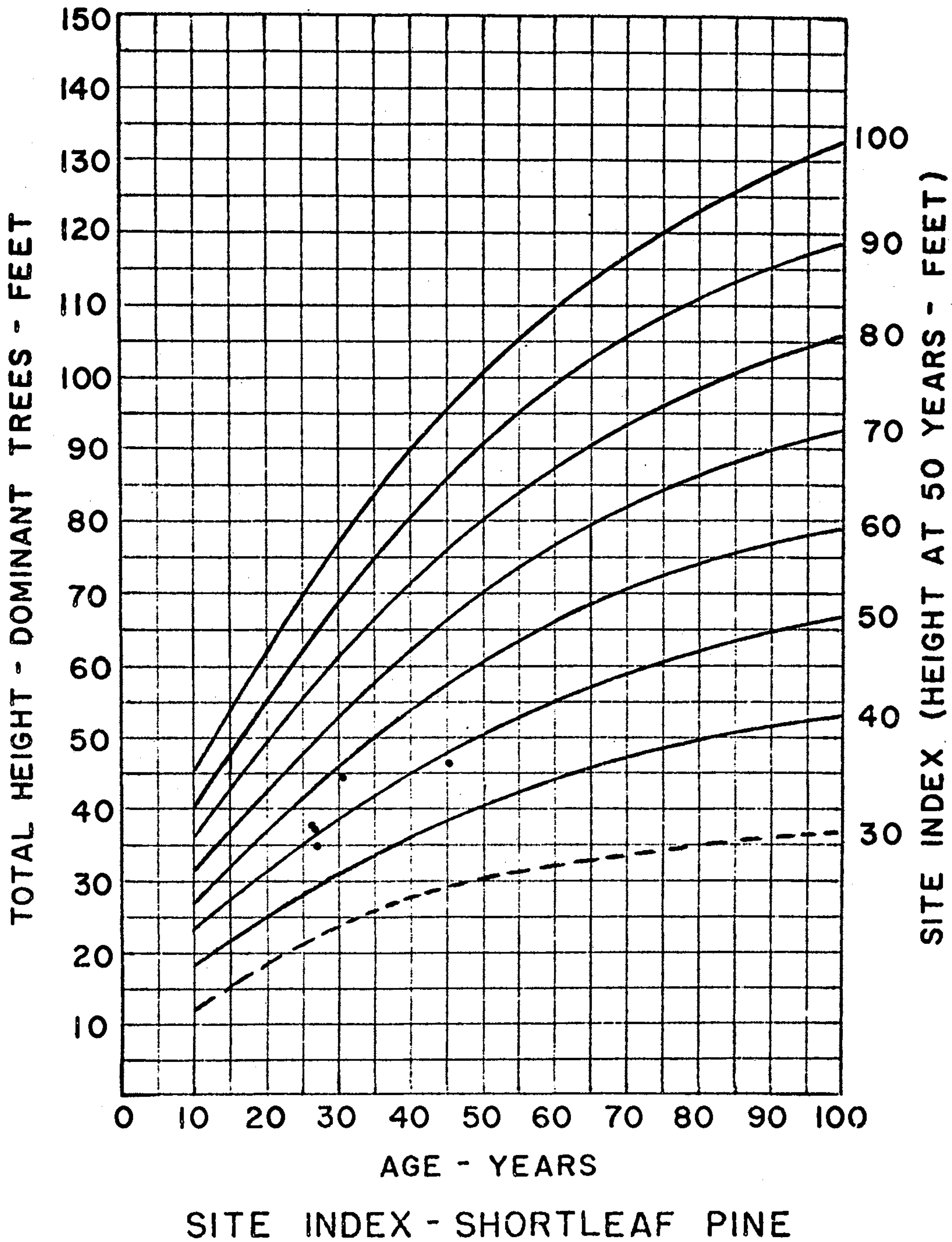
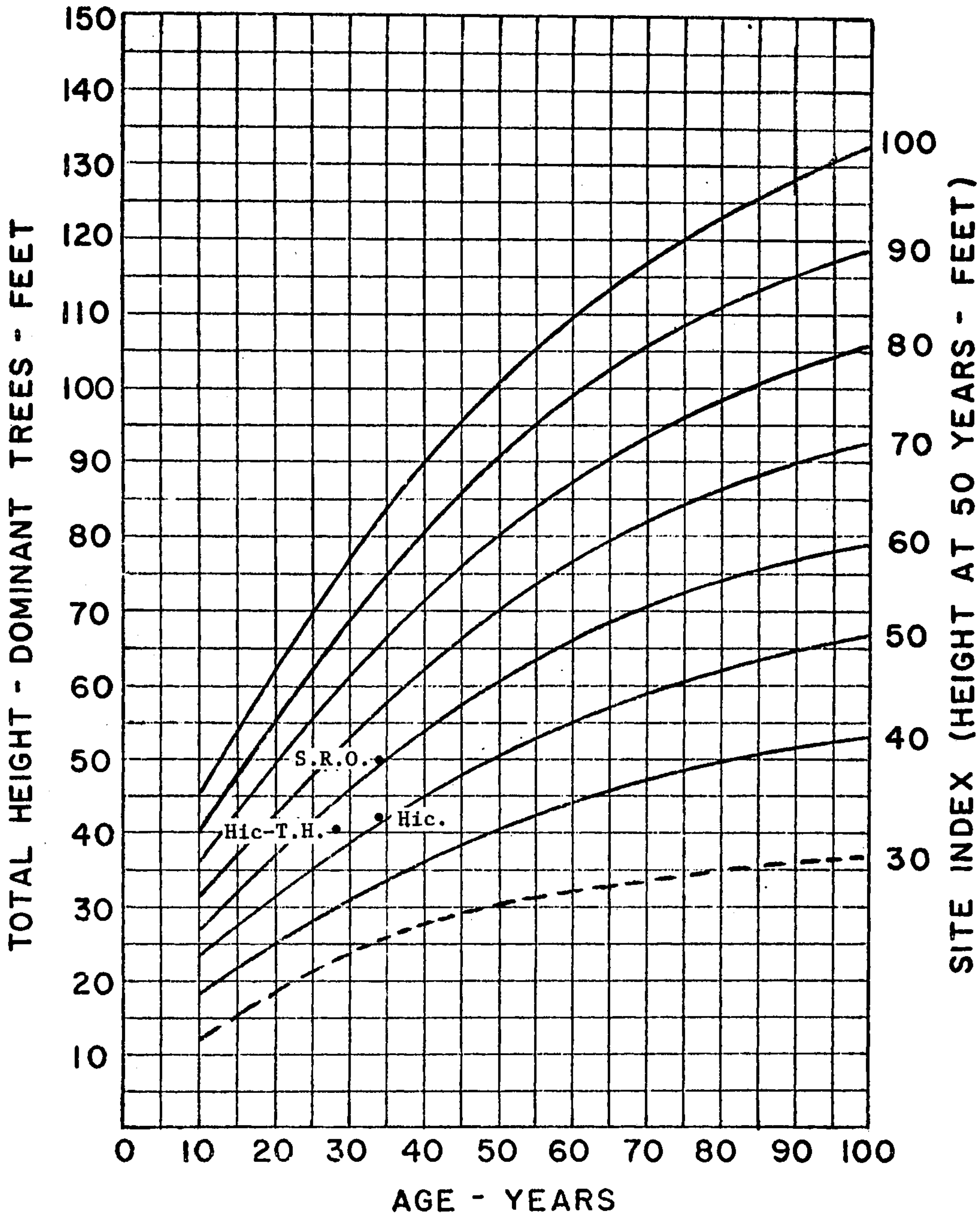


Figure 9. Hickory Plant Association Plot Site Indexes.



SITE INDEX - SHORTLEAF PINE

Figure 10. The Mean Site Indexes for the Plant Associations.

TABLE XXII

SPECIES FREQUENCY OF INDICATOR SPECIES FOR PLOTS STUDIED

Plot Number	Pine Site Index	Plant Association	P.	P. O.	B. J. O.	Hic.	T. H.	B. O.	Dog	S. R. O.	B. G.	Wh. O.	Wa. O.	W. O.
3	48	Hickory	28	42	2	17				1				
4	48		30	75	6	9							2	
11	58		13	39	19	5	3	1						
12	47		174	60	9	9		2						
14	51		258	58	9	9		3		1				
15	52		166	38	21	21	2	3		2				
7	60	Hickory Tree Huckle-berry	37	81	81	19	3	2						
8	57		57	46	46	53	15	2						
9	49		132	27	27	12	15	2						
10	47		52	51	51	23	5	2						
13	52		108	43	43	6	6							
16	60		43	34	34		19							
1	62	Southern Red Oak	17	62.	62	6	31	8		7			12	
2	61		34	44	44	14	11	3		12	1	2	4	1
5	62		116	37	37	41	18	20		5	6	4		
6	63		101	28	28	18	3	11	1	3				
17	59		107	40	40	27	1	2		5	2	3	3	2
18	57		23	74	74	11				6		2		

TABLE XXIII

ASSOCIATED SPECIES FREQUENCY CLASSIFICATION*

Plot Number	Plant Frequency: Predominant	Common	Scattered
3	PO, Hic, WE	C	BJO
4	PO, Hic, WE	BJO	Pl, C, WaO, HT
11	PO, BJO, Hic		BO, TH
12	PO, BJO, Hic	WE	BO
14	PO, BJO, Hic		BO, SRO
15	PO, BJO, Hic	BO, WE	TH, SRO
7	PO, Hic, TH	BJO	BO, C
8	PO, Hic, TH	BJO	WE, HT, C
9	PO, Hic, TH	BJO	WE
10	PO, Hic	TH	BO
13	PO, BJO, Hic, TH	BO	SRO
16	PO, BJO, TH		WE
1	SRO, BO, PO, Hic, TH, WO	A, HT, Pl	C
2	SRO, PO, Hic, TH	BO, Pl	WhO, WO, A, BG
5	SRO, BO, PO, Hic, TH	Pl	BG, WhO
6	SRO, BO, PO, Hic, WE	TH, Pl, BJO	HT, FM, A
17	BO, Hic, PO	SRO, FM	BG, HT, WhO
18	SRO, Hic, PO, WE		WhO, HT, FM

*See Table XXIV.

TABLE XXIV

AN EXPLANATION OF SPECIES ABBREVIATIONS USED IN ASSOCIATED SPECIES FREQUENCY TABLE AND ASSOCIATED SPECIES FREQUENCY CLASSIFICATION TABLE

Table Abbreviation	Common Name	Generic Name
P.	Shortleaf Pine	Pinus echinata (Mill.)
P.O.	Post Oak	Quercus stellata (Wang.)
B.J.O.	Blackjack Oak	Quescus marilandica (Muench.)
Hic.	Hickory	Carya spp.
T.H.	Tree Huckleberry	Vaccinium arboreum (Marsh.)
B.O.	Black Oak	Quercus velutina (Lam.)
Dog.	Flowering Dogwood	Cornus florida (L.)
S.R.O.	Southern Red Oak	Quercus falcata (Michx.)
B.G.	Black Gum	Nyssa Sylvatica (Marsh.)
Wh.O.	White Oak	Quercus alba (L.)
Wa.O.	Water Oak	Quercus nigra (L.)
W.O.	Willow Oak	Quercus phellos (L.)
A.	Ash	Fraxiunus spp.
N.R.O.	Northern Red Oak	Quercus rubra (L.)
H.T.	Red Haw	Crataegus spp.
Pl.	Wild Plum	Prunus spp.
W.E.	Winged Elm	Ulmus alata (Michx.)
C.	Eastern Redcedar	Juniperius virginiana (L.)
F.M.	American Beautyberry	Callicarpa Americana (L.)

TABLE XXV

AVERAGE MERCHANTABLE PLOT VOLUMES

Plant Association	Average Site Index	Age Group	Average Volume per Plot (Cubic Feet)	Plot Number	Merchantable Plot Volume (Cubic Feet)
				12	96.525
Hickory	50.0	15+	83.734	14	96.178
				15	58.498
				9	56.802
Hickory-Tree Huckleberry	49.3	15+	79.805	10	70.303
				13	112.309
				5	109.730
Southern Red Oak	61.3	15+	110.03	6	110.480
				17	109.880
				3	135.496
Hickory	51.3	30+	118.745	4	114.516
				11	106.223
				7	154.520
Hickory-Tree Huckleberry	59.0	30+	147.897	8	127.860
				16	161.310
				1	312.188
Southern Red Oak	60.0	30+	226.993	2	147.960
				18	220.830

TABLE XXVI

AVERAGE PLOT BASAL AREAS

Plant Association	Average Site Index	Age Group	Average Basal Area per Plot (Sq. Feet)	Plot Number	Total Plot Basal Area (Sq. Feet)
				12	14.697
Hickory	50.0	15+	14.479	14	16.204
				15	12.537
				9	10.558
Hickory-Tree Huckleberry	49.3	15+	11.864	10	10.598
				13	14.442
				5	15.807
Southern Red Oak	61.3	15+	13.713	6	12.945
				17	12.388
				3	14.290
Hickory	51.3	30+	11.787	4	11.091
				11	9.980
				7	13.736
Hickory-Tree Huckleberry	59.0	30+	12.620	8	11.274
				16	12.849
				1	17.369
Southern Red Oak	60.0	30+	15.109	2	11.140
				18	16.819

associations. Plots are grouped by both age class and plant association, and average site indexes are listed for comparison in the tables.

A reversal of the higher productivity trend in the hickory and hickory-tree huckleberry associations in both average plot volume and average basal area is shown in the 15 years plus age group. The cause of the deviation from the order given in Silker's wedge chart (Figure 2) can basically be attributed to the high variation of the stocking levels in the younger age stands and site indexes of the two associations. The hickory 15 years plus age group averages 920 more pine stems per acre than does the hickory-tree huckleberry 15 years plus age group (Table XXVII).

In the productivity comparison, the site index is higher for the average 15 years plus hickory association than for the average 15 years plus hickory-tree huckleberry association. The three hickory-tree huckleberry sites fall into the lower site index range of the association and overlap into the hickory association site index range. Normally, lower site index sites will support more juvenile stems per acre than will sites with high site indexes. However, the higher sites usually have the higher plot volumes and basal areas due to the larger average DBH. It is evident that the 15 years plus hickory-tree huckleberry site is understocked, since it has fewer trees per acre, in spite of a lower site index, than is the case in the hickory association (Table XXVII).

TABLE XXVII

AVERAGE NUMBER OF PINE STEMS PER ACRE

Plant Association	Average Site Index	Age Group	Average Pine Stems per Acre	Plot Number	Average Age of Stand	Pine Stems per Acre
				12	27.3	2100
Hickory	50.0	15+	2083	14	27.3	2400
				15	27.3	1700
				9	25.0	1670
Hickory-Tree Huckleberry	49.3	15+	1163	10	26.0	640
				13	22.0	1180
				5	28.7	1160
Southern Red Oak	61.3	15+	1050	6	26.7	940
				17	28.7	1050
				3	45.3	330
Hickory	51.3	30+	277	4	45.3	350
				11	30.7	150
				7	32.3	370
Hickory-Tree Huckleberry	59.0	30+	407	8	33.0	420
				16	27.7	430
				1	47.3	290
Southern Red Oak	60.0	30+	290	2	35.0	340
				18	41.3	240

The understocking in the hickory-tree huckleberry association gives additional evidence as to why a reverse in association order has occurred. Walker (1967) states that total production at the end of the rotation is positively correlated with the density of stocking at some given time during the rotation. In other words, in stands with equal site indexes, those with higher stocking would show higher total production. This fact shows up in the comparison between the two plots. From these arguments, it can be concluded that if the two associations had shown equal stocking and site index, the hickory-tree huckleberry association should have shown the greater total production. The reason for the expectation of greater production on the hickory-tree huckleberry sites is the higher soil moisture availability.

It is well known that stocking levels in the older age classes tend to level off and normally become stable, as does basal area. The 30 years plus age group (Tables XXV and XXVI) indicates that stocking follows this relationship, and that normal plant association order is found in both the volume and the basal area analyses.

The moderately large site index interval between hickory-tree huckleberry and southern red oak can be interpreted as showing that another plant association could be placed between these two levels. This plant association would be black oak, with the species black oak exhibiting common frequency. Both general field observation and plot data indicate the fact that black oak tends to express itself at a lower site index than does southern red oak. The large volume difference between associations cannot, however, be attributed entirely to the differences in plant association. The average age for the 30 years plus hickory-tree huckleberry type is 10 years less than the average 30 years plus southern red oak group. Thus, age variation is partly responsible for the large volume difference between the two associations.

Tables XXVIII, XXIX, XXX, and XXXI give the net present worth values of the plots after they have been subjected to the discount procedure as described in preceding material. The four analyses allow the plots to be compared as to actual net worth at the present time. However, it can be seen that the variability in the average age of pine trees on these plots has had an effect on the present net worth and dollar values per acre of merchantable pine and hardwood (Tables XIV and XV). The effect of the rotation length on the cost of interest is evident. Many plots with much higher values per acre at rotation, due to larger product sizes, actually have lower present net worth values due to the adverse effect of the carrying costs. In particular, plots 13 and 16 in the hickory-tree huckleberry association show higher present net worth values than any southern red oak plot. It becomes evident that valid comparison cannot be made unless the age variation is accounted for in some way.

TABLE XXVIII

ANALYSIS 1: RESIDUAL CAPITAL VALUE AVAILABLE FOR REGENERATION COSTS

Plot Number	Average Age of Stand	Fixed Scale Value Schedule 5%	Fixed Scale Value Schedule 8%	Sliding Scale Value Schedule 5%	Sliding Scale Value Schedule 8%
	Years	-- Dollars --			
3	45	(4.13)*	(6.36)	(4.76)	(6.58)
4	45	(5.79)	(6.84)	(6.96)	(7.28)
11	31	2.07	(2.68)	.67	(3.29)
12	27	12.12	1.78	(.67)	(2.99)
14	27	3.87	(1.14)	(1.74)	(3.81)
15	27	(1.41)	(3.61)	(.543)	(5.53)
7	32	6.72	(1.04)	3.89	(2.20)
8	33	2.82	(2.79)	(.20)	(3.98)
9	26	(.09)	(2.51)	(4.61)	(4.96)
10	22	3.61	(.06)	(.46)	(2.41)
13	25	10.80	3.11	2.72	(1.10)
16	28	12.72	2.56	8.93	.84
1	47	6.84	(3.58)	7.02	3.58
2	35	1.40	(3.64)	(.44)	(4.34)
5	29	5.56	(.90)	(.98)	(3.79)
6	27	6.62	.02	1.38	(2.42)
17	29	5.28	(1.03)	(.48)	(3.57)
18	41	3.30	(3.85	(4.46)	(3.48)

*Parentheses indicate a negative value.

TABLE XXIX

ANALYSIS 2: RESIDUAL SOIL RENT VALUES

Plot Number	Average Age of Stand	Fixed Scale Value Schedule 5%	Fixed Scale Value Schedule 8%	Sliding Scale Value Schedule 5%	Sliding Scale Value Schedule 8%
	Years	- - D o l l a r s - -			
3	45	(.46)*	(.86)	(.49)	(.87)
4	45	(.55)	(.90)	(.62)	(.58)
11	31	(.12)	(.59)	(.21)	(.64)
12	27	.33	(.20)	(.32)	(.64)
14	27	(.01)	(.47)	(.39)	(.71)
15	27	(.37)	(.70)	(.64)	(.87)
7	32	.11	(.53)	(.07)	(.63)
8	33	(.14)	(.68)	(.33)	(.78)
9	26	(.35)	(.69)	(.67)	(.92)
10	22	(.11)	(.50)	(.42)	(.73)
13	25	.37	(.18)	(.20)	(.57)
16	28	.52	(.22)	.26	(.38)
1	47	.05	(.79)	.06	(.79)
2	35	(.28)	(.83)	(.39)	(.89)
5	29	(.03)	(.62)	(.46)	(.88)
6	27	.04	(.55)	(.32)	(.77)
17	29	(.05)	(.63)	(.43)	(.86)
18	41	(.16)	(.82)	(.09)	(.79)

*Parentheses indicate a negative value.

TABLE XXX

ANALYSIS 3: RESIDUAL CAPITAL VALUE AVAILABLE FOR TIMBER STAND IMPROVEMENT WORK

Plot Number	Average Age of Stand	Fixed Scale Value Schedule 5%	Fixed Scale Value Schedule 8%	Sliding Scale Value Schedule 5%	Sliding Scale Value Schedule 8%
	Years	- - Dollars - -			
3	45	(14.15)*	(13.82)	(14.86)	(14.04)
4	45	(16.01)	(14.41)	(17.33)	(14.77)
11	31	(7.47)	(10.48)	(9.27)	(11.15)
12	27	1.66	(5.65)	(11.38)	(11.11)
14	27	(5.18)	(8.99)	(12.83)	(12.04)
15	27	(12.38)	(11.82)	(17.88)	(13.91)
7	32	(2.82)	(9.73)	(6.41)	(10.99)
8	33	(7.73)	(11.58)	(11.50)	(12.87)
9	26	(12.09)	(11.80)	(18.37)	(14.63)
10	22	(7.12)	(9.32)	(13.30)	(12.20)
13	25	2.39	(5.33)	(9.07)	(10.26)
16	28	5.37	(5.88)	.28	(7.83)
1	47	(4.06)	(12.97)	(3.86)	(12.96)
2	35	(10.62)	(13.46)	(12.89)	(14.21)
5	29	(5.58)	(10.85)	(14.23)	(14.09)
6	27	(4.16)	(9.96)	(11.31)	(12.75)
17	29	(5.95)	(10.99)	(13.57)	(13.85)
18	41	(8.12)	(13.41)	(6.78)	(13.03)

*Parentheses indicate a negative value.

TABLE XXXI

ANALYSIS 4: ADDITIONAL FINAL HARVEST INCOME PER ACRE NEEDED TO BREAK EVEN AFTER COSTS

Plot Number	Average Age of Stand	Fixed Scale Value Schedule		Sliding Scale Value Schedule	
		5%	8%	5%	8%
	Years	- - Dollars - -			
3	45	112.99	427.32	118.66	434.12
4	45	127.84	445.56	138.38	456.69
11	31	26.43	103.41	32.80	110.02
12	27		39.48	3.77	77.64
14	27	14.16	62.82	35.07	84.14
15	27	33.84	82.60	48.87	104.19
7	32		104.47	24.13	118.00
8	33	30.95	135.21	46.04	150.27
9	26	30.90	75.48	46.95	93.58
10	22	13.71	41.35	25.61	54.13
13	25		31.17	21.64	60.01
16	28		44.85		59.72
1	47		469.93		469.57
2	35	47.96	185.55	58.21	195.89
5	29	17.39	90.24	44.34	117.19
6	27	11.37	69.60	30.92	89.10
17	29	18.54	91.41	42.29	115.19
18	41	51.90	301.22	43.34	292.69

In order that a more uniform age comparison could be made, the five older age classes were reduced to common age 30 and subjected to the assumptions for the four analyses given in Tables XXVIII, XXIX, XXX, and XXXI. The procedure used in the reduction to common age 30 is described in Chapter III. The figures on the average reconstructed plot at age 30 are given in Tables XXXII and XXXIII. In a comparison of the reconstructed figures (Tables XXXII and XXXIII) and the present figures for the plots (Tables XXVIII, XXIX, XXX, and XXXI), it can be seen that the reconstructed present net worth figures are increased substantially at the younger age. It should be noted that these reconstructed figures are based entirely on the value of the pine stems with no hardwood considered; thus the actual values of the reconstructed stands are underestimated. The comparison between the reconstructed older stands and the younger stands still brings out the trend of increasing present net worth with increasing plant association levels.

In the growth analysis, the periodic annual growth and mean annual growth figures were graphed to determine at what age the technical rotation occurs and to compare the growth rates of the different indicator associations. The graphs indicate that none of the plots have reached the technical rotation age. However, the point of technical maturity could be estimated reasonably well due to the steep downward trend of the periodic annual growth curve in the latter part

TABLE XXXII

RECONSTRUCTION OF THE PRESENT NET WORTH VALUES ON THE AVERAGE PLOT FOR PLOT 1, 2, AND 18, OF THE SOUTHERN RED OAK PLANT ASSOCIATION, AT AGE 30

Value Schedule Scale	Capital-ization Rate	Analysis I	Analysis II	Analysis III	Analysis IV
			- - Dollars - -		
Fixed	5%	13.07	.46	4.19	
Fixed	8%	2.12	(.22)*	(7.43)	67.34
Sliding	5%	8.46	.16	(1.80)	5.98
Sliding	8%	.14	(.33)	(9.63)	87.27

*Parentheses indicate a negative value.

TABLE XXXIII

RECONSTRUCTION OF THE PRESENT NET WORTH FIGURES ON THE AVERAGE PLOT FOR PLOTS 3 AND 4, OF THE HICKORY PLANT ASSOCIATION, AT AGE 30

Value schedule Scale	Capital-ization Rate	Analysis I	Analysis II	Analysis III	Analysis IV
			- - Dollars - -		
Fixed	5%	(1.43)*	(.35)	(12.06)	52.12
Fixed	8%	(4.11)	(.45)	(12.12)	109.84
Sliding	5%	(5.56)	(.62)	(17.43)	75.33
Sliding	8%	(5.88)	(.55)	(14.09)	127.69

*Parentheses indicate a negative value.

of the rotation. This point appears to fall between 45 and 50 years in all associations.

While the technical rotation falls between 45 and 50 years, the financial rotation occurs at a much earlier age. The financial rotation was determined by the maximum soil rent method. This approximate point of financial maturity occurs at 25 years for the sliding scale value schedule and at 20 years for the fixed scale value schedule. Tables XXXIV and XXXV give the data to support this statement for the southern red oak and hickory-tree huckleberry plant associations. The financial rotation in the hickory plant association occurred at 20 years for both the fixed and sliding scale value schedules.

The financial rotation length is dependent on the price schedules chosen to evaluate the plots. Both the fixed and sliding scales were set up with a pulpwood operation in mind and tend to favor the smaller tree sizes. Due to this fact, it is felt that the financial rotation length is possibly shorter than it would be if higher value products were considered. However, it should be noted that, due to the low growth rate in the Ouachita Highlands, saw timber and pole production is economically questionable even in the southern red oak indicator associations.

With optimum rotation lengths established for each association, it is now possible to set up a minimum income per acre necessary to cancel out the cost of growing the timber in the different associations. The break-even incomes are

TABLE XXXIV

SOIL RENT VALUES ON RECONSTRUCTED
SOUTHERN RED OAK PLOTS

Value Schedule Scale	Capitalization Rate	Soil Rent Values 20 Yrs.	25 Yrs.	30 Yrs.	35 Yrs.
		-- Dollars --			
Fixed	5%	.58	.36	.02	(.29)
Sliding	5%	(.34)*	(.26)	(.32)	(.44)

*Parentheses indicate a negative value.

TABLE XXXV

SOIL RENT VALUES ON RECONSTRUCTED
HICKORY-TREE HUCKLEBERRY PLOTS

Value Schedule Scale	Capitalization Rate	Soil Rent Values 20 Yrs.	25 Yrs.	30 Yrs.
		-- Dollars --		
Fixed	5%	(.16)*	(.21)	(.35)
Sliding	5%	(.85)	(.63)	(.65)

*Parentheses indicate a negative value.

given in Table XXXVI by assuming a cost of $.75 per acre for administrative costs, $.25 per acre return on investment in the form of rent, and regeneration costs of $6, $5, and $4 per acre for the southern red oak, hickory-tree huckleberry, and hickory associations, respectively.

In trying to establish the minimum plant association or site index needed to provide a break-even point for planting or regenerating shortleaf pine, the rotation length and value schedule must be stated first. It is felt that with a sliding scale value schedule and at any rotation length, the break-even point should be established at a minimum site index of 60. This minimum site index 60 would establish southern red oak as the lowest plant association acceptable for management of shortleaf pine. It should be stressed, that while the southern red oak and hickory-tree huckleberry associations optimum sliding scale value schedule rotation falls at 25 years, these associations do not break even with the costs assumed in the analysis (Tables XXXIV and XXXV). With a fixed value schedule and a rotation length of 20 years, the minimum site index could be lowered to about 55.

Sites with a hickory-tree huckleberry association and pine site index as low as 55 could be considered as economically manageable for pine, but only under the condition that the rotation length is set at 20 years and the fixed scale value schedule is used. However, since sliding scale value schedules are apt to be more prevalent than fixed scale

TABLE XXXVI

MINIMUM FINAL HARVEST INCOME PER ACRE NECESSARY TO BREAK EVEN ON OPERATIONS

Plant Associations	Rotation Length (Years)	Value Schedule	Capitalized Cost per Acre	Minimum Final Harvest Net Income Necessary per Acre
			- - Dollars - -	
S. R. O.	20	Fixed	29.63	48.99
	25	Sliding	28.51	68.03
Hic.-T.H.	20	Fixed	28.02	46.32
	25	Sliding	27.10	64.67
Hic.	20	Both	25.68	42.46

value schedules in the future, it is thought that a minimum site index of 60 and a 25 year rotation are more realistic.

It cannot be stated, however, that a stand on a site index lower than 60 will not be profitable to manage. The site index 60 figure is arbitrary and is set for the average stands located in the study area. For example, on plots 13 and 16, stocking and average DBH have caused the present net worth of these plots to be higher than most southern red oak plots at the same rotation length. Thus some stands, due to certain combinations of factors may have higher present net worth figures even though they are located on a less favorable site. With all factors held equal, stands normally will reflect increasing present net worth figures in relation to the increasingly demanding plant associations and the attendant increasing index. This statement can be made with some confidence since in stands of equal stocking, the stand on the higher site will normally produce a given average diameter in less time than will a stand on a lower site.

CHAPTER V

SUMMARY AND CONCLUSIONS

The findings of this study indicate that there is a definite correlation between shortleaf pine site index and associated plant groups. The mean shortleaf pine site indexes for the southern red oak, hickory-tree huckleberry, and hickory associations, based on age fifty years, are 60.7, 54.2, and 50.7, respectively. Although the site index ranges did overlap, the mean site indexes showed a definite increasing trend associated with increasingly demanding plant associations.

In the economic analysis, the technical rotation was observed to occur at about 45 years. However, financial maturity, obtained by the maximum soil rent method, occurred at a much earlier age. In the southern red oak and hickory-tree huckleberry associations, financial maturity occurred at 25 years when the sliding value schedule was used and at 20 years when the fixed value schedule was employed. Financial maturity occurred at 20 years for the hickory association regardless of the value schedule used. The large difference between the technical and financial rotations is a result of the type of value schedules used on the evaluation of the plots. The value schedules were set up for a pulpwood operation and tend to favor smaller sized trees.

The minimum break-even point for shortleaf pine management was set at a minimum site index of 60, assuming that a sliding value schedule and optimum rotation length of 25 years are to be used. This site index establishes the southern red oak plant association as the minimum plant association for pine management in the study area. In none of these plant associations can management be profitable using a sliding scale value schedule at the 5 percent level with the costs assumed in these analyses. When evaluated by a fixed scale value schedule, some stands with site indexes of 60 and lower can be managed profitably for shortleaf pine. If a fixed value schedule and rotation length of 20 years are used, the minimum break-even point can be lowered to site index 55, and the hickory-tree huckleberry association can be included.

The higher degree of variations in stocking levels in the understocked stands of this area result in some stands below the minimum site index being economically manageable. However, a definite correlation exists between the plant association (site index) and the productivity and present net worth on the plots.

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