# AN ECONOMIC EVALUATION OF FOREST STANDS

# IN EASTERN OKLAHOMA, 1960


By

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AN ECONOMIC EVALUATION OF FOREST STANDS IN

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# CHAPTER I

## PROBLEM SETTING

Problems of forest management can be classified into two interdependent categories; physical and economic. Management decisions are subject to these restraints for any set and ordering of managerial goals. Disagreement over the optimum solution of a given problem of forest management stems not only from differing objectives, but also from lack of knowledge of the physical and economic restraints.

Timber production is a natural process which can be modified by management. The physical complexities of a naturally growing but artificially managed stand of timber are matched by economic difficulties. The most important and costly factor of production in the production process, as viewed by an economist, is time. The multiplicity of possible joint products is another determinant of economic difficulties.

From among the infinite variety of possible economic problems this study will attempt to answer only one general question, namely; what is the net dollar value of Oklahoma stands of commercial pine in 1960?

The joint product problem will alone be considered. There will be no attempt to optimize some arbitrary set of values such as present profit present value of the annual profit flow, stability of the local economy, estate to be left to posterity or other such possible target functions. On the other hand, one complex array of facts concerning the net dollar values of Oklahoma timber stands will be analyzed so that local forest managers will at least have improved knowledge of one dimension of the economic restraints that influence decision-making in the area.

## General Objectives

It is the general objective of this study to evaluate the pine forest stands of Eastern Oklahoma in terms of their capacity to yield revenue over and above the expenses incurred in processing standing timber up to the point of manufacture or sale. The physical characteristics of the local forest stands will need to be investigated for variation in tree distributions and logging costs. Tree distributions are referred to as forest structures and these structures affect the amounts and types of products that can be cut from an acre stand of uneven aged timber. Growth habits also influence yields of timber, so account will need be taken of their local variation. Prices of the local products will be needed to estimate revenues. Lastly the net revenues calculated must take into account variation due to alternative possibilities of product complexes that can be cut from a given tree in a stand. The complex that maximizes the net value will be chosen so that the yields will be optimum in an economic as well as a physical sense.

If all these objectives can be achieved, forest managers in Eastern Oklahoma will have new information available for their management decisions. The net value of the yield from any given forest stand will be displayed with the product complex that maximizes net revenue at present prices. To the extent that management can alter forest structure on a given site, to that extent will the study indicate the gross results of differiential management assuming that the yield objective is paramount. Finally, it is hoped that the method will be general enough to be used for other locations, species and price-cost constellations.

In order to place the general objectives into their proper perspective, one must know some of the geographic, climatological, and ecological factors concerned with the Eastern Oklahoma forest area. These natural factors have an important effect on costs associated with the practice of forestry and therefore the profitability of forest operations.

## The Area Delimited

### Land Area

Most of the pine-producing acreage in Oklahoma lies in the extreme southeastern portion of the State (see Figure I). This acrease is concentrated into four political subdivisions - LeFlore, McCurtain, Pushmataha, and Latimer counties. These counties cover 5,589 square miles or 8.1 percent of the total land area of the state and support 4,652 square miles of commercial timber land of which 4,160 square miles are classified as pine or pine-hardwood types (see Table I).

### Topography

The southern part of the four-county area is an extension of the Gulf Coastal Plains. These plains are characterized by flat land of low elevation. In rainy periods some of this land becomes swampy and almost inaccessible by motor vehicle. Although the better forest sites of the four-county area occur on these coastal plains, poor drainage conditions add considerably to the costs of logging these sites.

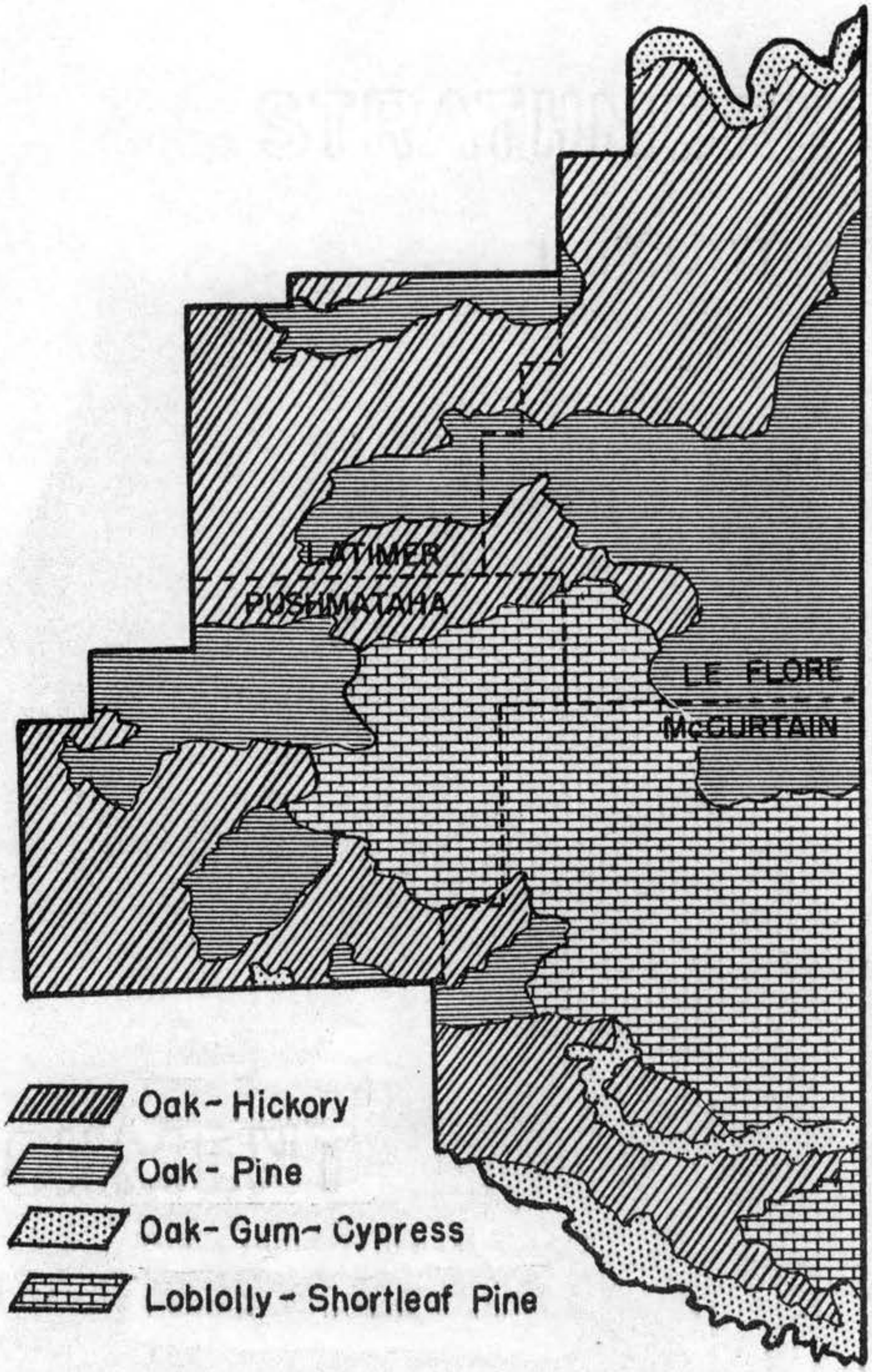


Figure 1. Major Forest Types in Southeastern Oklahoma

TABLE I

THE EXTENT OF THE FOREST LAND AREA IN FOUR SOUTHEAST OKLAHOMA PINE PRODUCING COUNTIES

| County | Total Land Area (Square Miles) | Forest Land Area (Square Miles) | Pine-Hardwood Land Area (Square Miles) |
|---|---|---|---|
| Latimer | 737 | 615 | 549 |
| LeFlore | 1,575 | 1,346 | 1,204 |
| McCurtain | 1,854 | 1,462 | 1,307 |
| Pushmataha | 1,423 | 1,229 | 1,100 |

Source: Statistical Abstract of Oklahoma, Bureau of Business Research, University of Oklahoma, 1959.

Division of Forestry, Oklahoma Planning Resources Board.

North of the coastal plains area in southern McCurtain County lie the Ouachita Mountains of southern LeFlore and northern McCurtain counties. These mountains extend west from the state line into Pushmataha County with numerous protruding arms extending into other counties. The Ouachitas consist of ridges extending almost always in an east-west direction. The most common exposures then, are north and south with the northern exposures being more gently sloped and less rugged than the southern exposures. Mountainsides are generally forested and are dotted frequently with rockslides and outcroppings. High up on the slopes of the Ouachitas, timber becomes poorer in form and quality. The rugged topography in these mountains contributes greatly to increased costs in removing timber products.

North of the mountains in the northern part of LeFlore County are hilly regions of the central lowlands. These hills, for the most part, are forested and of rugged terrain.

Temperature and Rainfall

The four-county area enjoys mildest climate of the State. Throughout the area, average daily temperatures are warmest in July and August ranging by county from 82.4° to 83.8°F. Daily average temperatures are lowest in January ranging by county from 44° to 44.6°. The year-round average temperature is approximately 63.5° in all counties (see Table 2). Average daily maximum temperatures also occur in July and August with the extremes averaging 95.5°. Average daily minimum temperatures occur in January and average approximately 32°. The growing season varies from 210 to 320 days per year.

Rainfall over the area varies from 42 to 50 inches of mean annual rainfall per year. The rainfall patterns over the area are depicted by the map in Figure II.

Given other determinants, the climate described in large part accounts for the occurance of pine and influences growth habits of the forests.

Rivers

The most important waterways in the area are the Poteau, Kiamichi, Little River and Mountain Fork rivers. The Poteau, which has its origin in LeFlore County and empties into the Arkansas River, is unique in that it is the only major river in Oklahoma that flows north. All of the rivers mentioned originate in LeFlore or McCurtain counties. The Kiamichi

River has its headwaters in the Ouachita Mountains and flows west into Pushmataha County before turning south and emptying into the Red River. Mountain Fork River also originates in the Ouachitas near the state line and drains into Little River. Little River flows out of western McCurtain east into Arkansas and then empties into the Red River. The forests of the area have had an important influence on the amount and quality of the flow of these rivers.

Soil Uses

Soils in the area have had a history of poor usage. Early settlers cleared the land and planted cotton and corn on areas that were ill suited to row-crop production. Much of the hilly land's top soil was eroded away and with it went the productive capacity of the area. Later, bermuda and native grasses were introduced on many of the "worn out" fields and other fields naturally regenerated to pure stands of shortleaf and loblolly pine. Open range prevails in the area and presently most land is utilized for grazing or forestry.

## Forestry in Oklahoma: Past and Present

In territorial days, timber as a source of income in Oklahoma became important. The southeastern area of Oklahoma was then a part of the Choctaw Indian Nation. Indians used the bountiful timber resources to build their homes and community buildings and also found in the forests a ready supply of fuel, posts for building fences, nuts and fruit for food, and game to eat. White men in the areas around the Choctaw Nation also found the possibilities of the forest very lucrative for they pirated a goodly amount of timber from the Indians.

TABLE II

DAILY AVERAGE TEMPERATURES FOR FOUR SOUTHEASTERN OKLAHOMA COUNTIES

| County | High | Month | Low | Month | Average |
|---|---|---|---|---|---|
| | | (Degrees Fahrenheit) | | | |
| Latimer[1] | | | | | |
| LeFlore | 83.8 | July | 43 | January | 63.4 |
| McCurtain | 82.4 | August | 44.4 | January | 63.5 |
| Pushmataha | 82.7 | July | 43.6 | January | 63.5 |

[1]No station reporting.

Source: Statistical Abstract of Oklahoma, Bureau of Business Research, University of Oklahoma, 1959.

TABLE III

DAILY AVERAGE MAXIMUM AND MINIMUM TEMPERATURES FOR FOUR SOUTHEASTERN OKLAHOMA COUNTIES

| County | High | Month | Low | Month | Average High | Average Low |
|---|---|---|---|---|---|---|
| | | | (Degrees Fahrenheit) | | | |
| Latimer[1] | | | | | | |
| LeFlore | 96.5 | July | 31.1 | January | 76.1 | 50.8 |
| McCurtain | 95.5 | August | 32.9 | January | 76.1 | 51.0 |
| Pushmataha | 95.0 | August | 32.4 | January | 75.4 | 51.2 |

[1]No station reporting.

Source: Statistical Abstract of Oklahoma, Bureau of Business Research, University of Oklahoma, 1959.

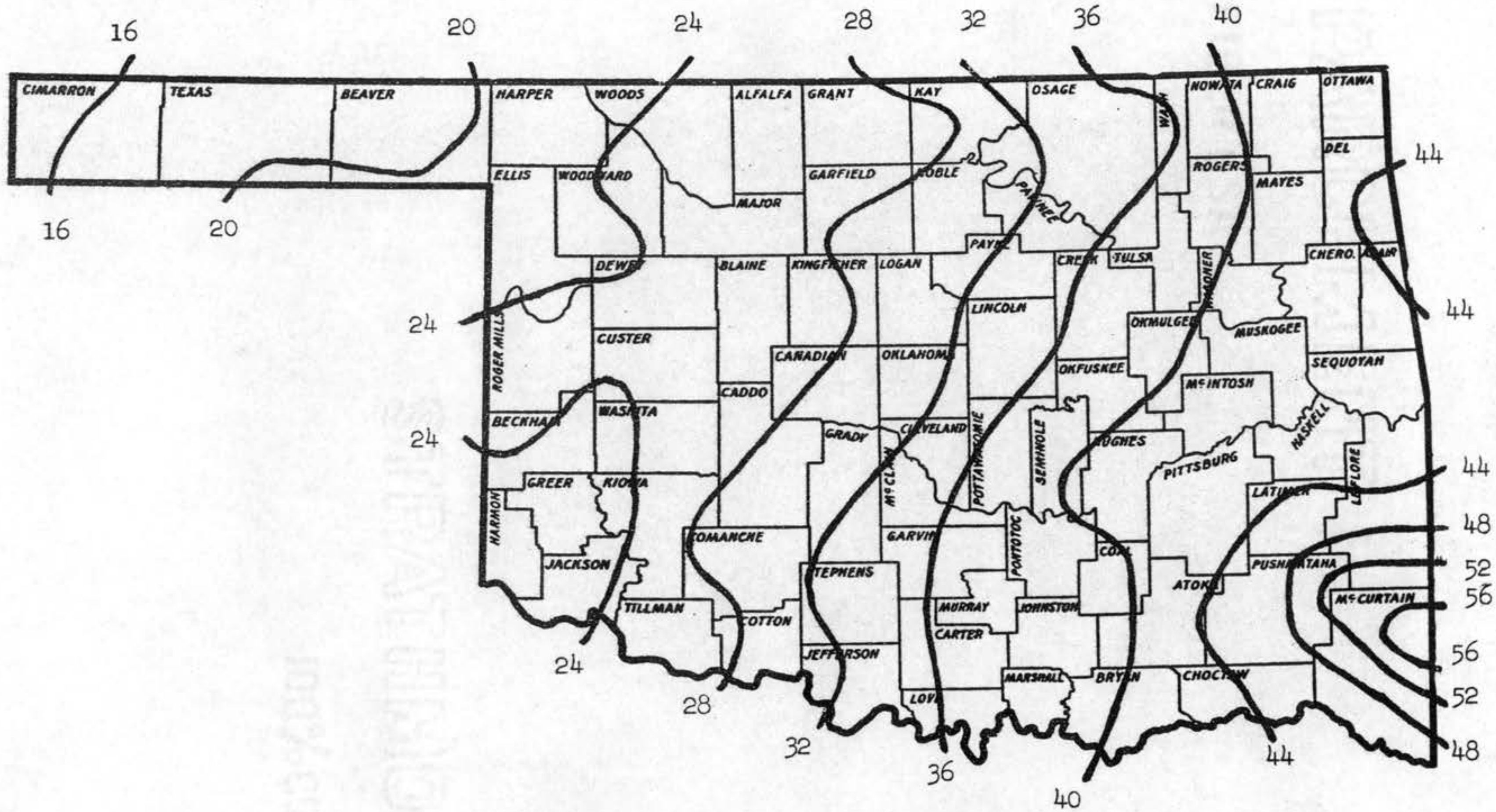


Figure II. Rainfall Areas in Oklahoma

When the Choctaw Nation in Indian Territory was incorporated in the new State in 1907, the importance of its timber resources grew in stature. Again, the forest provided the material to build homes, farms, and communities in Oklahoma and elsewhere. Lumber companies came and went as the demand for lumber varied and the forested lands were cut over. The forest policies of that day were to "cut out and get out" and to burn the woods to "get rid of the ticks and chiggers."

The great depression of the '30's undoubtedly had a great influence on the importance of forestry in the State today. It was during this period that the Federal Government and private companies acquired substantial holdings of forested lands. Private lumber companies were guided in their policies by the economic situation of the country during the depression. These firms had no choice, in most cases, but to practice clear cutting and move on to the next area. Land was cheap, it could be purchased for the price of paying back taxes, and lumber was cheap, so there was no reason for the companies to practice sustained-yield forestry. In the meanwhile, the Civilian Conservation Corps under the direction of the U. S. Forest Service was hard at work on Government-owned land. The C.C.C.'s were combating fires, improving timber stands, building roads, and developing water resources. These attempts were some of the earliest to provide a sound footing for sustained-yield management.

In the years after the depression came World War II. The nation experienced an increased demand for lumber products which both Federal and private timber owners in Oklahoma helped supply. Foresters on Federal land were cutting timber stands selectively so as not to completely denude the land, and private timber companies were beginning to see that some of the earlier cut-over lands were now beginning to produce sawlogs once more. Lumber prices were higher and private landowners could now visualize the day when sustained yield management would become economically feasible.

About the time World War II came to an end, professional foresters began to make their appearance in Oklahoma in increasing numbers. These foresters were making management plans for timber owners, selecting timber to be cut, and helping to improve forest stands. In this period, the market for forest products expanded. Pulpwood became an important by-product of logging, fence posts found a ready market, and improved techniques in processing raw materials helped to make forestry in Oklahoma more important as a source of income.

Presently, there are many professional and nonprofessional foresters in Oklahoma helping landowners expand their timber operations. There are a number of private lumber firms who own extensive forest holdings and are managing these holdings on a sustained-yield basis.

As forest managers correct some of the more evident problems associated with sustained-yield management, other problems begin to arise. These problems concern not only ecological or physical factors but also problems associated with the economical and financial aspects of forestry.

## Forest Production Functions

In many cases, given the species and location, the production of trees of a given diameter class, depends on two inputs which measure the structure of the forest stand. These inputs are the distribution of trees by diameter classes and their level of stocking. These inputs can be varied by forest management techniques over limited domains which are themselves dependent on the level of the two inputs. The nature of this functional dependence of tree output on forest structure has been well examined and tested. In Chapter III this function will be discussed in detail.

To convert the tree output into marketable products is a major concern of this study. The marketability of wood products involves economic considerations restricted by the technical possibilities of production. From the standpoint of economic theory, this problem of production is to choose the complex of products from a given tree output which satisfies not only the technical restrictions but some economic targets. The economic problem is a special case of joint production.

Concerning this joint production function, many problems arise. Of particular interest is the problem of the length of the production process and the derived present values of alternative systems of land use in forests or alternative crops. This problem will be largely ignored in the present study in favor of another problem that needs solving first; namely, how to value the possible output from a forest. To value this output requires a method of selecting a combination of products that will maximize the net revenue from a forest structure. To do this, a method of selecting the optimum joint output of possible products from each tree in the structure must be evolved. This will require the application of the following ideas from the theory of joint production.

Joint Production

Take the production of trees as input and the product use as the output and the input-output relation is quite rigid. For example, short posts from a tree measuring 4 inches in diameter breast high can be cut at 6 1/2 feet only and the tree will yield only 3 such posts. Two such trees yield six and so on. The input-output relation is thereby linear. For this tree input, short posts is the only output. From the 6 inch tree, however, diameter requirements are met for at least three kinds of posts; 6 1/2 feet, 10 feet and 20 feet. Each input-output relation is linear so that the output substitution relation, for a fixed input of trees, is also linear.

The problem of selecting the output combination which maximizes revenue, for a given price ratio between competing products, is a corner solution in Figure III. The points A, B, C, D may represent the physically possible product combinations, and the slope of the line EF is the net price ratio between products X and Y. For this price ratio, combination B maximizes revenue since the Y intercept measures revenue (in terms of Y's price).

The revenue maximization may be symbolized by:

Maximize revenue, $R = P_y Y + P_x X$

Subject to the physical restraints shown by points A, B, C and D.

However, we wish to optimize including a consideration of the differential costs of producing Y or X, i.e.;

Maximize net revenue, $R - C = P_y Y + P_x X - C(Y, X)$ subject to the same restraints.

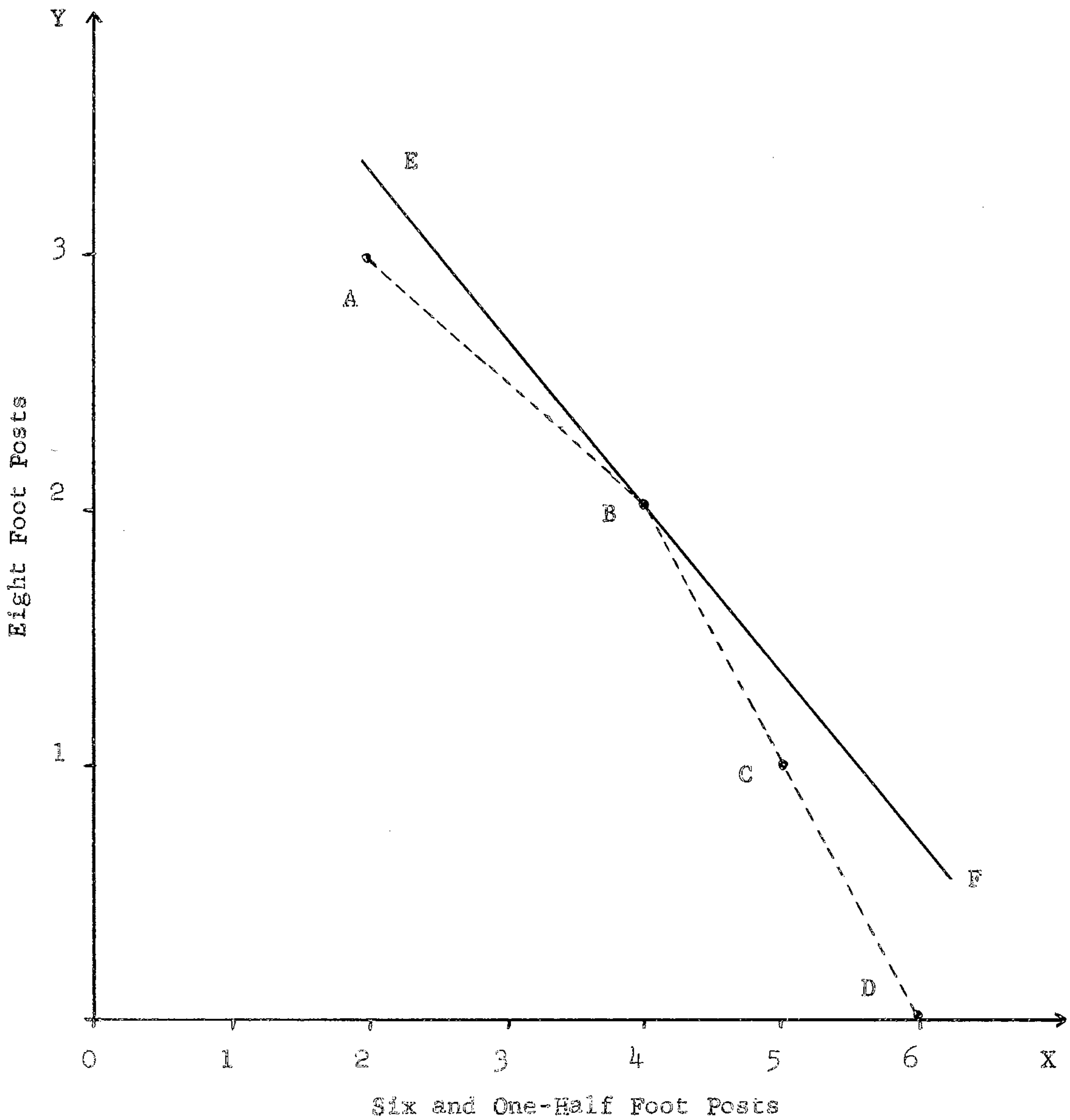


Figure III. Illustrative Example of Product Possibilities and Optimum Combinations for a Six Inch Diameter Tree

But if we assume that $C(Y, X)$ is linear and homogeneous, then we can directly;

$$\text{Maximize net revenue } R - C = (AR_y - AC_y)Y + (AR_x - AC_x)X$$

subject to the restraints.

We can think of $AR_y - AC_y$ as the net revenue of each product after subtracting from its price its average cost of production. Under the linear assumptions, we will then maximize net revenues by selecting the combination of products the sum of whose net individual revenues is a maximum.

The validity of these cost assumptions is open to question. Essentially they imply that the average cost of producing one product (with site and density of the forest held constant) does not vary with the output of the product nor with the output of any other product produced jointly. Economies of scale in single or joint production are ruled out. When variation in density of the forest yield is included, some part of possible economies of scale is accounted for.

The mill value of raw forest products is determined by a few buyers. The site-to-mill processing costs are largely determined by a few profitable logging contractors; small scale loggers and haulers tend to follow this price spread as a competitive fringe in this industry. Thus, lack of variation in costs with scale is institutionally determined.

Lack of variation in the costs of processing one product as the amount cut of other products varies can also be realistically assumed providing the acreage cut is large enough to allow for some flexibility in the cutting operation.

Unfortunately, the number of outputs for a given tree input is often large. Also, overlapping is possible between the optimum complexes from different sized trees. Sometimes there is more than one optimum combination for a given size. But the net revenue maximizing operation remains essentially the same even if the arithmetic requires a computer program to solve. The arithmetic can be solved by a linear program. However, the list of restrictions is so great, that a new program was written to compute the product possibilities, and then to select the new revenue maximizing complex of products from the stand.

## Site of the Stand

Four different sites are to be used in this analysis.[1] The sites will range from relatively poor to relatively good sites for the area under consideration. This range of sites will possibly show that the same structure and product complex may not maximize profits on all sites.

## Growth Types

Three types of growth rates are considered for every structure on each site. The types considered were all linear but one showed increasing growth, one showed constant, and one showed a diminishing growth. Again, this design is expected to show that the same structure and product complex may not maximize profits for all types of growth. Besides the three types of growth considered, four levels of each type were analyzed to exhibit the range of growth possibilities found in Oklahoma. These 12 different growth functions are to be considered for each site and for the complete range of structures.

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[1]Site is defined as an index of numbers representing the height in feet that a dominant tree will attain in a period of 50 years on a given area. A forester's definition of site implies that environmental factors distinguish between areas.

Length of the Production Period

Time, as a variable in the production function is an important determinant of forest production. Uncertainty as to the development and maintenance of product markets and their effect on future revenues and costs is a crucial component of the forest management problem.

Local economies in a forest area are dependent upon a steady, reliable flow of income from forest businesses. A forest production period[2] can last up to 50 years. Unless harvests are staggered or production periods are shortened, the spasmodic flow of income would do little to stabilize local incomes.

Markets for an area's timber products, whether existent or only potential, demand a steady and reliable source of raw material for products. A single company operating a large forest acreage in a concentrated area is constantly in danger of losing markets for its raw material or finished products if the flow to consumers is not steady or predictable.

Forest enterprise owners are also highly concerned about long production periods. Future prices, demand structures, and natural catastrophies all add to the riskiness of planning long-term production periods in forestry. A proposed forest structure that maximizes profits fifty years hence, using present prices or predicted prices, is highly speculative because the nature of prices fifty years from now is almost

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[2]Production period as used here is intended to designate that period of time which elapses between harvest operations. A forest in this case is not intended to mean individual stands but a community of stands representing nearly all age classes from age 1 to n, where n is the oldest class of trees which are present in the area in number.

impossible to predict. Aluminum may replace lumber as a building material; a market for posts may not exist; other similar market changes could occur. Enterprise owners are not often willing to gamble far beyond a time that they can predict price and demand trends.

It is evident that established local companies, existing and potential markets, and local economies display a need for steady, predictable yields from the forest. This need can only be satisfied by some form of management that takes into consideration a production period that will enable the forest to yield its products yearly. Many forest operations in Oklahoma and elsewhere in the south go over their acreages once in each 8 to 12-year period. Every area gives up a portion of its poles, pulpwood, posts or sawlogs. In areas where the timber stand has progressed to a mature state, many of the trees are harvested and reproduction is allowed to occur. The time allowed for maturity or final harvest of a forest stand is referred to as a rotation period.[3]

Again, it is not the purpose of this paper to make an attempt at specifying the length of production periods or rotation periods. The production period of ten years, common in Oklahoma, has been arbitrarily selected and an attempt will be made to maximize net revenues for yields over that time period.

[3]Rotation periods are defined in two manners by foresters. Financial rotation is an allowable age at which a forest stand reaches its maximum discounted annual yield value. A technical rotation is an allowable age at which the forest stand yields its maximum annual wood volume.

## Specific Objectives

To arrive at an economic evaluation of Eastern Oklahoma forest stand yields, a sequence of objectives must be attained.

1. An average mill price for every feasible woodlot product must be discovered.
2. From the mill price, the average cost of producing and transporting logs from stump to mill must be subtracted. Allowances need to be made for variation in these costs by type of forest.
3. For each possible tree in a forest, the product complex that will maximize net revenue must be estimated for the present constellation of prices and costs.
4. For each possible forest structure and site in Eastern Oklahoma, the number of trees and their distribution by diameter classes must be calculated.
5. The ten-year yield distribution of trees by diameter classes and lengths must be computed for several growth habits.
6. When this sequence is complete, the average net value per acre of the 10-year yield from Eastern Oklahoma forests may be estimated using the product complex that maximizes net value.
7. Optimum product complexes and their net values will then be analyzed with respect to the forest management practices they imply if the objective is to maximize the net value of the yield.

# CHAPTER II

# COSTS AND REVENUES OF WOOD PRODUCTS

Over the entire area of Southeastern Oklahoma, and through time, prices of forest production inputs and outputs show wide variation. The variation of costs over time is explained by general conditions in the economy as a whole, but the variation of costs within the State can generally be explained by the nature of the market structure and by the variability of cost-influencing features of the local topography and forest stands. The objective of this chapter will be to account for some of the cost-influencing features of topography and local forest stands and to present cost and price information obtained by interviewing price leaders in the Southeastern Oklahoma wood industry.

Costs associated with moving forest products from the stump to the point of sale vary with the length of haul, the density of the forest, the type and size of the product, and the differential terrain. To understand these costs, and their variation, one must be acquainted with the logging operations that go into the makeup of these costs.

## Logging Operations

There are four operations which a tree may undergo in its stages of being removed from the forest and moved to a point of sale. First, the tree is felled and cut into lengths satisfying the joint requirements of ease in hauling and marketing potential. This operation is commonly termed felling and bucking. Secondly, the tree may have its bark removed or "peeled" if it is to be used for posts or poles. If the tree is to be used for pulpwood or sawlogs, the bark is not removed. Next, the product will be skidded to a grouping point where trucks can pick up at least one load. Finally, the products are loaded onto trucks and hauled to their point of sale.

Felling and Bucking

The felling and bucking operation is commonly performed by two-man crews using power saws. The "feller" or cutter drops the tree in a spot where it does the least damage to surrounding trees and where it can be most easily bucked. The tree is then cut into various lengths of logs or bolts by the "feller" whose own judgment usually determines which lengths from a particular tree are actually cut. Revenue from end products is thereby greatly affected by the skill and judgment of the feller. The log cutter is hired by contract and paid by the thousand board feet felled. The second man on the crew, the helper, assists in the felling and bucking operations and is paid by the cutter. To obtain a rigid specification of product combinations, a premium is paid over the volume rate.

Peeling

The peeling operation is carried on in the woods by hand labor or at grouping yards by mechanical peelers. Hand labor is usually paid on a "piece-work" rate by the post, but sometimes on an hourly rate. A tool known as a spud is used by the peelers to remove bark from the tree. Most hand peeling is done in the spring or early summer months when bark is most easily removed.

Skidding and Hauling

Skidding is the operation of moving logs on the ground from the stump to a grouping point. This operation is performed in Oklahoma by animals or tractors. On many small woodlot operations, skidding by horse and mule appears to be the most economical. However, on large operations, where the terrain is favorable, tractor skidding is used. Horses or mules are used singly or in teams to skid the logs without use of skidding pans or other skidding aids. Tractors sometimes use skidding pans or arches and skid large numbers of logs in one haul. Skidders are paid by the thousand board foot skidded with variation possible due to length and difficulty of the operation.

Loading and Hauling

Loading may be done by mechanical loaders operated from the log truck or independent from the log truck. Cross-hauling with animals is also still prevalent. Where small numbers of logs are grouped, animals are preferred because of their abilities to move easily from one group of logs to the next. On larger operations, mechanical loaders are installed and large numbers of logs are loaded from one grouping point. Pulpwood and post loading are usually done by hand, although there are some pulpwood trucks equipped with self-loaders. The cost of loading may be included in the skidding rate or if mechanical loaders are used, the logging operator or hauler bears the cost.

Log hauling is done mainly on a contract basis by individuals who own and operate their own log trucks. Some hauling is done by owner-operators of one or more phases of the wood production and processing industry.

## Variable Cost Determinants

The effects of variable cost factors can now be analyzed and these effects described in terms of the different operations performed in logging.

### Length of Haul

This factor does not cause cost variability in all logging operations as do some other factors, but it does provide a great deal of variation in the cost of hauling. A longer haul naturally means a higher cost of contract hauling. However, the condition of haul roads and main roads enter into the variability also. For improved roads of gravel or other hard surface, the cost of hauling is lower than for roads which are unimproved and rough. The average length of haul of fifteen miles over average roads is assumed for all sites in this study.

### Density of Forest

If large numbers of trees are to be cut within a small area, the time required to cut and buck, peel, skid, and load and haul will be less than if the same numbers of trees are scattered over a large area. The time required to travel from tree to tree is lessened when the trees are dense, and if the number of trees to be operated upon is great, then costs can be reduced by increasing the logger's scale of plant through the addition of larger and heavier types of machinery. This study will account for this variance in fixed cost by establishing a density scale whereby the number of trees from any acre can be identified by density levels. The costs of the logging operation will be made to vary inversely as the density varies. All products will be classified as occurring in dense numbers, medium-dense numbers, or sparse numbers. For example, post and pulpwood trees might originate in dense numbers from a given cut for a given stand classification while the sawlog cut would be sparse. A more precise difinition of density will appear in Chapter IV when the physical characteristics of a forest are studied.

<u>Type of Product</u>

A stick of wood of a given dimension can usually be made into more than one product. However, a classification scheme was adopted for the purposes of this study which will enable any stick to be classified by the types of product for which it is suitable. Table IV portrays this classification scheme.

In addition, forest stands vary in the proportion of trees which are suitable for certain products, for such additional reasons as straightness and branching. For example in Southeastern Oklahoma, only 10 percent of the trees of classified dimensions are suitable for making long posts. For poles, the percentage suitability is around 14 percent according to the largest processor in the state. This additional criterion for long posts and poles will be incorporated into the enumeration of feasible products.

There are recent estimates of costs incurred in performing the various logging operations by each type of product. Costs for posts, poles, pulpwood, and sawlogs will be considered separately. The size of the product will not be included as a cost variant in the case of

TABLE IV

CLASSIFICATION SCHEME FOR SOUTHEASTERN OKLAHOMA PINE PRODUCTS

| Product | Trees Suitable for Products Classified | Length | Diameter Small End d.i.b. | Diameter Breast High d.b.h.[a] |
|---|---|---|---|---|
| | Percent | X Feet | Y Inches | Z Inches |
| Short Post | 100 | $6.5 \leq X < 10$ | $2.5 \leq Y$ | $4 \leq Z \leq 10$ |
| Long Post | 10 | $10 \leq X < 25$ | $2.5 \leq Y$ | $4 \leq Z \leq 10$ |
| Pole | 14 | $25 \leq X$ | | $12 \leq Z \leq 14$ |
| Sawlogs | 100 | $12 \leq X$ | $9.0 \leq Y$ | $10 \leq Z$ |
| Pulpwood[b] | 100 | $X = 5$ | $2.5 \leq Y$ | $4 \leq Z$ |

[a]The diameter quoted is the minimum breast high diameter that would produce a stick of the minimum small end diameter in the product considered.

[b]Pulpwood is considered as a residual product from cutting timber for other products. For $4 \leq Z \leq 10$, pulpwood is residual from posts, for $10 \leq Z < 12$, it is residual to sawlogs, and for $12 \leq Z$, it is residual to poles. It will be found that, at present prices, pulpwood never turns up as the one most profitable product to cut from an entire stand.

poles, posts, and pulpwood. However, the effects of size of sawlogs on the costs of handling sawlogs will be considered.

Topography

Topography also contributes to cost variability. Rough terrain increases costs of road-building, bucking and felling, skidding, and hauling. As the slope of the local topography becomes greater, better roads are needed to make the hauling operation as safe as possible. Government landowners require roads to be of certain grade requirements with properly constructed ditches and water bars. This type road construction is much more costly than roads built on flat land where trucks are often able to push through brush without the aid of a bulldozer and rains do not badly erode the soil. However, in rainy seasons the lowland areas become almost impossible to operate. Extra hauling costs are incurred on both high, rocky slopes and lowlands with the middle elevation lands having some slope probably providing the most ideal working conditions.

Skidding on steep, rough slopes is also more costly than on more moderate slopes. All skidding must be done in a down- or cross-hill direction on steep lands. This restriction is sometimes a drawback to grouping products. Many of the slopes in Southeastern Oklahoma are so rough that animals furnish the only possible means of skidding. Tractors are unable to operate because of the ledges and large rocks that are quite prevalent on mountainsides. In the lowlands, tractor skidding is now coming into vogue. The crawler-type tractors, particularly, can skid many logs at once and can be used for other purposes.

Types of terrain can be correlated to some degree with the forester's concept of site. High elevation, steep slopes, and rocky areas are associated with poorer sites while lower elevation, flatter land, and smoother terrain are thought of as better sites. The medium quality sites generally occur on gently rolling lands with good drainage and on the lower slopes of mountains and ridges. Since this study takes site indices into account in the analysis of stand structure, cost variability brought about by differences correlated to site will be prorated on the basis of site index. The lower site indexes will indicate less than average cost relationships, and the better sites with a higher index will indicate slightly higher costs because of their inaccessability during rainy periods of the year.

## Source of Data for Contract Rates

### Average Cost Data

Most of the logging operations for sawlogs and class poles in the state are contracted by wood processors and landowners. To estimate the going rates in 1960, two large wood processors were surveyed, one in the northern part of the timber country, and one in the southern part. These processors employ a majority of the forest workers used in logging operations and thus tend to set the rates for contract work on wood production. The range of rates for each operation and the average rate was thereby secured for Southeastern Oklahoma. These rates have been fairly standard for the past three years and are expected to reflect current rates at least for the period 1957-61.

For costs in the pulpwood and post operations, a recent report by the United States Forest Service was used.[1] Estimates then were modified by field checks and adapted for this study as later sections will describe.

## Adjustments for Variable Cost Determinants

Data on costs were, unfortunately, not available in a breakdown for local ranges in the determinants of variation in costs. Thus, site and density levels, which were seen previously to affect wood producing costs, are still to be taken into account. The direction of influence of these determinants is well known. No estimates of the magnitude of their influence are available. However, from the records of the larger contractors in Southeastern Oklahoma, an average range of costs for logging operations was available. Adjustments, in the known directions, were made in a manner conformable to this range.

For example, costs for all logging operations (sawlogs) were found to range from $20 to $28 over all sites, densities, and lengths of haul covered by the records. The adjustments made for sawlogs in the following section produce a range of costs from $19.60 to $29.12. (This range is from site index 75, density level I, to site index 55, density level III.) The upwards shift in the midpoint of the range is justified by the fact that firms surveyed produce wood from a distribution of density levels and sites less costly than the area average. The length

[1] U. S. Forest Service, Appraisal Guide, 1958, (Mimeographed), p. 11.

of haul was not adjusted for but assumed to average 15 miles.[2] Additional adjustments, described later, were made for log sizes.

Although the adjustments are quite arbitrary, they do fit the known direction and amount of cost variation and result in a relative pattern of costs not dissimilar from present knowledge concerning the actual range of costs in the area.

Adjustments in the costs for performing pulpwood and post operations were made in manner similar to that previously described. No range of costs for post operation was available from the Forest Service report, but a field check showed the range to vary roughly ± 16.6 percent from the average.[3] The report did, however, give a range of costs associated with pulpwood harvesting.

## Product Costs

### Sawlogs

A contract rate for performing all the logging operations to move sawlog products from the stump to the point of sale range from $20 to $28 per thousand board feet according to the density of the stand considered. The cost of logging dense stands averages $20 in Southeastern Oklahoma and the cost for sparse stands averages $24 per thousand board feet.

Since the above costs are averages for all sites, they were adjusted for each of the four sites covered by the study. It was assumed that

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[2] Robert Raunikar, "Marketing of Farm Woodlot Products in Southeastern Oklahoma," (unpub. Masters thesis, Oklahoma State University, 1958), p. 42.

[3] U. S. Forest Service, p. 11.

no interaction exists between site and density as they affect logging costs. It was further assumed that costs would be raised four percent for site index 55 and 2.5 percent for site index 85 for each density level. The higher rate of increase for site index 55 takes into account higher costs incurred because of rougher, steeper, and rockier terrain, while site index 85 is boggy and more expensive to operate in rainy periods. The average costs for operating on all density levels were lowered by two percent for site indices 65 and 75 because these sites offer more ideal working conditions.

The costs adjusted by site and density were adjusted to take log size into account. Costs for operating on logs cut from trees whose breast-high diameter are 14 inches or less were raised by four percent to account for the undesirability of working with small logs. This adjustment, although arbitrary, is thought to represent a likely estimate of actual cost increases for which data are not available. No other size adjustments were deemed necessary. The final distribution of saw-log costs is arrayed in Table V.

Pulpwood

The United States Forest Service operating in Southeastern Oklahoma has recently completed an audit of representative firms performing pulp-wood harvesting operations and has determined a range of costs for pulp-wood operations. As before, this range had its extremities assigned to certain extreme density classifications. Density Level I of the pulp-wood operation was assigned an average cost of $9.75 per cord and Density Level III was assigned a cost of $12.50 per cord. Each of these average

TABLE V

COST OF MOVING PINE SAWLOGS FROM STUMPS TO POINT OF SALE BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Density Level | Site Index 55 | Site Index 65 | Average Costs[a] | Site Index 75 | Site Index 85 |
|---|---|---|---|---|---|
| | | - Dollars per Thousand Board Feed (Doyle) - | | | |
| I | 20.80 | 19.60 | 20.00 | 19.60 | 20.50 |
| II | 24.96 | 23.52 | 24.00 | 23.52 | 24.60 |
| III | 29.12 | 27.44 | 28.00 | 27.44 | 28.70 |

[a]Costs are based on 1960 contractual rates from a small sample of forest landowners. Costs are adjusted upward four percent for Site Index 65 and 2.5 percent for Site Index 85. Costs are adjusted downward two percent for Indices 65 and 75. For logs with d.b.h. $\leq$ 14 inches, costs were further adjusted upward by four percent.

costs was then adjusted for site characteristics. Site Index 55 had the average costs adjusted upward four percent to account for the undesirable topographic features characteristic of this site and Site Index 85 had average costs adjusted upward 2.5 percent to take into consideration extra costs incurred in rainy seasons. Site Indices 65 and 75 had the average costs lowered two percent because of the more desirable logging conditions characteristic of these sites. These costs and adjustments may be seen in Table VI.

Posts

The costs of performing the post harvesting operation were obtained from a United States Forest Service report of a study conducted in Southeastern Oklahoma.[4] These costs include cutting, skidding, peeling, and hauling costs and are available for posts classified by length. A resume of these costs are shown in Table VII. The costs of harvesting each length of post were raised four percent for Site Index 55 and 2.5 percent for Site Index 85. The costs by pole and site were then adjusted for density levels. Density Level II was assumed to be the average cost and the costs obtained by the adjustments above were assigned to this density level. An adjustment of this average cost by 16.6 percent downward was used for Density Level I and the average cost was adjusted 16.6 percent upward for Density Level III.

[4] U. S. Forest Service, p. 11.

TABLE VI

COST OF MOVING PINE PULPWOOD FROM STUMP TO POINT OF SALE BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960[a]

| Density Level | Site Index 55 | Site Index 65 | Average Costs | Site Index 75 | Site Index 85 |
|---|---|---|---|---|---|
| | | | - Dollars Per Cord - | | |
| I | 10.14 | 9.55 | 9.75 | 9.55 | 9.99 |
| II | 11.70 | 11.02 | 11.25 | 11.02 | 11.53 |
| III | 13.00 | 12.25 | 12.50 | 12.25 | 12.81 |

[a]Costs are based on 1960 contractual rates from a small sample of forest landowners. Costs are adjusted upward four percent for Site Index 55 and 2.5 percent for Site Index 85. Costs are adjusted downward two percent for Site Indices 65 and 75.

Source of Average Costs: U. S. Forest Service, Appraisal Guide, 1958, (mimeographed), p. 11. This source applies also to Table VII.

TABLE VII

COST OF MOVING PINE POSTS (PEELED) FROM STUMP TO POINT OF SALE BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Density Level | Post Length | Site Index 55 | Site Index 65 | Average | Site Index 75 | Site Index 85 |
|---|---|---|---|---|---|---|
| | feet | | | - Dollars - | | |
| I | 6.5 | .1128 | .1063 | .1084 | .1063 | .1111 |
| II | | .1352 | .1274 | .1300 | .1274 | .1332 |
| III | | .1576 | .1485 | .1516 | .1485 | .1553 |
| I | 7.0 | .1475 | .1389 | .1418 | .1389 | .1453 |
| II | | .1768 | .1666 | .1700 | .1666 | .1742 |
| III | | .2061 | .1943 | .1982 | .1943 | .2031 |
| I | 8.0 | .1821 | .1716 | .1751 | .1716 | .1795 |
| II | | .2184 | .2058 | .2100 | .2058 | .2152 |
| III | | .2547 | .2400 | .2449 | .2400 | .2509 |
| I | 10.0 | .2342 | .2207 | .2252 | .2207 | .2308 |
| II | | .2808 | .2646 | .2700 | .2646 | .2767 |
| III | | .3274 | .3085 | .3148 | .3085 | .3226 |
| I | 12.0 | .3209 | .3024 | .3086 | .3024 | .3163 |
| II | | .3848 | .3626 | .3700 | .3626 | .3792 |
| III | | .4487 | .4228 | .4314 | .4228 | .4421 |
| I | 14.0 | .3816 | .3596 | .3670 | .3596 | .3761 |
| II | | .4576 | .4312 | .4400 | .4312 | .4510 |
| III | | .5336 | .5028 | .5130 | .5028 | .5259 |
| I | 16.0 | .4337 | .4087 | .4170 | .4087 | .4274 |
| II | | .5200 | .4900 | .5000 | .4900 | .5125 |
| III | | .6063 | .5713 | .5830 | .5713 | .5976 |
| I | 18.0 | .4857 | .4577 | .4670 | .4577 | .4787 |
| II | | .5824 | .5488 | .5600 | .5488 | .5740 |
| III | | .6791 | .6399 | .6530 | .6399 | .6693 |
| I | 20.0 | .5378 | .5067 | .5171 | .5067 | .5300 |
| II | | .6448 | .6076 | .6200 | .6076 | .6355 |
| III | | .7518 | .7085 | .7229 | .7085 | .7410 |
| I | 25.0 | .7589 | .7152 | .7298 | .7152 | .7480 |
| II | | .9100 | .8575 | .8750 | .8575 | .8969 |
| III | | 1.0611 | .9998 | 1.0202 | .9998 | 1.0458 |

Class Poles

The costs of processing class poles for sale at the initial market are expressed on a per-pole basis or as costs per thousand feet board measure. Since no estimates of class pole costs are available for the Southeastern Oklahoma area, this study will modify processing costs for sawlogs of similar dimensions and arrive at the class pole costs on a per thousand board feet basis.

Class poles do not require as much time in the felling and bucking operation as do sawlogs because pole lengths are usually longer than log lengths. This would serve to lower the cost of felling and bucking. On the other hand, the loading and hauling of poles is more expensive than the loading and hauling of sawlogs. Poles are of longer lengths which sometimes make the use of special hauling equipment necessary and are of small diameters which again raises the cost of hauling. The class pole debits are estimated to outweigh the credits by about three percentage points and the class pole costs will be the sawlog costs per thousand board foot plus three percent. The costs are adjusted for site and density in exactly the same manner as were sawlog costs. A resume of class pole costs per thousand board foot basis, classified by site and density may be seen in Table VIII.

The board foot volume of poles by length and diameter at the small end inside the bark was calculated for each class of pole. The inside bark diameter for each class was the midpoint of the diameter range for a given class. For example, a 30-foot, class 7, southern pine pole may have a minimum top diameter of 8.8 inches. The 30-foot, class 6 pole has a minimum top diameter of 9.5 inches. The range of diameters for

TABLE VIII

COST OF MOVING PINE CLASS POLES FROM STUMP TO POINT OF SALE BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Density Level | Site Index 55 | Site Index 65 | Average Costs[a] | Site Index 75 | Site Index 85 |
|---|---|---|---|---|---|
| | - Dollars per Thousand Board Feet (Doyle) - | | | | |
| I | 21.42 | 20.19 | 20.60 | 20.19 | 21.11 |
| II | 25.71 | 24.23 | 24.72 | 24.23 | 25.34 |
| III | 29.99 | 28.26 | 28.84 | 28.26 | 29.56 |

[a]Costs are based on 1960 contractual rates from a small sample of forest landowners. Costs are adjusted upward four percent for Site Index 55 and 2.5 percent for Site Index 85. Costs are adjusted downward two percent for Site Indices 65 and 75.

the 25-foot, class 7 pole extends from 8.8 to 9.5 inches and the midpoint of the range is 9.15 inches.[5] The volume is calculated from this midpoint diameter and the length of pole for each class.

The volumes by class and length were expressed as fractional parts of one thousand board feet and the costs per thousand board feet for sites by density levels was prorated to class poles on this basis. These costs for poles by site, density, class, and length may be seen in Appendix A, Table 1.

## Product Prices

The prices for all products are considered to be the price paid at the processing plant (sawmill, post yard, etc.) for the severed product before the product undergoes any further processing.

### Sawlogs

The average sawlog price per thousand board feet, Doyle scale, of southern yellow pine (developed from a survey of 5 sawmills) proved to be $55 for 1960.[6]

### Pulpwood

Pulpwood prices were obtained from a United States Forest Service report where the reported average price was $14.90 per cord FOB rail car.[7]

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[5]American Standards Association specifications.

[6]Leading sawmillers pay this price and most of the small mills have to meet this price in order to buy logs.

[7]U. S. Forest Service, p. 12.

Posts

The prices used for post products will be those prices paid by post buyers in Southeastern Oklahoma in March, 1959.[8] A resume of these prices is listed in Appendix A, Table II.

Poles

The prices used for class poles will be those listed in a United States Forest Service report giving the price for class poles by class and length.[9] These prices are listed in Appendix A, Table III.

## Net Values of Wood Products

The net value of a wood product is defined here as its gross value at the initial market less the cost of processing between the tree and the market. The sales value of a particular tree is the value of the products made from that tree minus all of the costs of converting that tree into a saleable product. The sales value as used above is meant to be the same as the term stumpage value used by foresters.[10]

Values for each size of each product for every site class and for every density class were arrived at by subtracting the conversion costs of the product from the market price for the product. The net value of individual products before the physical limitation of individual trees have been accounted for are listed in Appendix A, Tables III, IV, and V.

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[8] Prices taken from a listing obtained from Southeastern Oklahoma post yards in March, 1959.

[9] U. S. Forest Service, p. 12.

[10] Stumpage value = mill value of raw material - logging costs.

Sawlogs

In the final analysis of sawlog stands board feet units of measure per tree will be used. By the diameter classes utilized for the other types of products, each tree will be divided into individual products rather than units of measure. Sawlog net values will be listed here by board feet units and may be seen in Table IX.

Posts and Poles

Post- and pole-sized trees may contain many sizes of any given length of post. In order to facilitate the evaluation of trees, an average value for posts of a given length occurring in various sized trees must be determined. This average value was calculated by first consulting the taper curves for each breast high diameter class, then determining the feasible sizes of each type of post, and last by averaging the values for all possible types of posts.[11] The physical criteria used for determining average post values is displayed in Appendix B, Tables II and III. Table X shows the average value of posts occurring in various sized trees.

The net value of class poles was calculated by subtracting the class pole costs which were prorated on a per pole basis, from the class pole prices. The class pole net values are displayed in Table XI.

Pulpwood

The evaluation of pulpwood sticks occurring in a tree presents much the same problem as the post complex. Many diameter classes of five-foot

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[11]The method by which the taper curves were derived is discussed on page 61.

TABLE IX

NET VALUES OF PINE SAWLOGS BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| | Breast High Diameter of Trees 16 Inches and Larger | | | |
|---|---|---|---|---|
| Density Level | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
| | | - Dollars Per m.b.f. (Doyle) - | | |
| I | 34.20 | 35.40 | 35.40 | 34.50 |
| II | 30.04 | 31.48 | 31.48 | 30.40 |
| III | 25.88 | 27.56 | 27.56 | 26.30 |

| | Breast High Diameter of Trees 14 Inches and Smaller[a] | | | |
|---|---|---|---|---|
| Density Level | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
| | | - Dollars Per m.b.f. (Doyle) - | | |
| I | 33.37 | 34.62 | 34.62 | 33.68 |
| II | 29.04 | 30.54 | 30.54 | 29.42 |
| III | 24.72 | 26.47 | 26.47 | 25.15 |

[a]Costs of logging these trees are raised 4 percent over the costs of 16 inch d.b.h. and larger trees.

TABLE X

NET VALUES OF PINE POSTS BY LENGTH, DIAMETER, SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| | | Diameter Breast High | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 4" | | | | 6" | | | |
| | | Site Index | | | | Site Index | | | |
| Post Length (Feet) | Density Level | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 |
| | | (Dollars) | | | | (Dollars) | | | |
| 6.5 | I | .054 | .062 | .062 | .057 | .080 | .087 | .087 | .082 |
| | II | .032 | .040 | .080 | .034 | .058 | .066 | .066 | .060 |
| | III | .009 | .020 | .020 | .012 | .035 | .045 | .045 | .038 |
| 7.0 | I | .040 | .048 | .048 | .042 | .065 | .074 | .074 | .068 |
| | II | .010 | .020 | .020 | .014 | .036 | .046 | .046 | .039 |
| | III | -.018 | -.006 | -.006 | .016 | .007 | .019 | .019 | .010 |
| 8.0 | I | .078 | .088 | .088 | .080 | .093 | .103 | .103 | .095 |
| | II | .045 | .054 | .054 | .045 | .060 | .069 | .069 | .060 |
| | III | .005 | .020 | .020 | .009 | .020 | .035 | .035 | .024 |
| 10.0 | I | .066 | .079 | .079 | .069 | .216 | .229 | .229 | .219 |
| | II | .019 | .035 | .035 | .023 | .169 | .185 | .185 | .173 |
| | III | -.027 | -.008 | -.008 | -.023 | .123 | .142 | .142 | .127 |
| 12.0 | I | - | - | - | - | .399 | .418 | .418 | .404 |
| | II | - | - | - | - | .335 | .357 | .357 | .341 |
| | III | - | - | - | - | .271 | .297 | .297 | .278 |
| 14.0 | I | - | - | - | - | .528 | .550 | .550 | .534 |
| | II | - | - | - | - | .452 | .479 | .479 | .459 |
| | III | - | - | - | - | .376 | .407 | .407 | .384 |
| 16.0 | I | - | - | - | - | .606 | .631 | .631 | .613 |
| | II | - | - | - | - | .520 | .550 | .550 | .442 |
| | III | - | - | - | - | .434 | .469 | .469 | .442 |
| 18.0 | I | - | - | - | - | .684 | .712 | .712 | .691 |
| | II | - | - | - | - | .588 | .621 | .621 | .596 |
| | III | - | - | - | - | .491 | .530 | .530 | .501 |
| 20.0 | I | - | - | - | - | .862 | .893 | .893 | .870 |
| | II | - | - | - | - | .755 | .792 | .792 | .764 |
| | III | - | - | - | - | .648 | .692 | .692 | .659 |
| 25.0 | I | - | - | - | - | - | - | .785 | .752 |
| | II | - | - | - | - | - | - | .642 | .603 |
| | III | - | - | - | - | - | - | .500 | .454 |

TABLE X (CONTINUED)

| Post Length (Feet) | Density Level | 8" Site Index 55 | 65 | 75 | 85 | 10" Site Index 55 | 65 | 75 | 85 |
|---|---|---|---|---|---|---|---|---|---|
| | | (Dollars) | | | | (Dollars) | | | |
| 6.5 | I | .107 | .114 | .114 | .109 | .107 | .114 | .114 | .109 |
| | II | .085 | .093 | .093 | .087 | .085 | .093 | .093 | .087 |
| | III | .062 | .072 | .072 | .065 | .062 | .072 | .072 | .065 |
| 7.0 | I | .104 | .113 | .113 | .107 | .104 | .113 | .113 | .107 |
| | II | .075 | .085 | .085 | .078 | .075 | .085 | .085 | .078 |
| | III | .046 | .058 | .058 | .049 | .046 | .058 | .058 | .049 |
| 8.0 | I | .176 | .185 | .185 | .178 | .298 | .308 | .308 | .300 |
| | II | .142 | .152 | .152 | .142 | .265 | .274 | .274 | .265 |
| | III | .102 | .117 | .117 | .106 | .225 | .240 | .240 | .229 |
| 10.0 | I | .316 | .329 | .329 | .319 | .458 | .471 | .471 | .461 |
| | II | .269 | .285 | .285 | .273 | .411 | .427 | .427 | .415 |
| | III | .223 | .242 | .242 | .227 | .365 | .384 | .384 | .369 |
| 12.0 | I | .399 | .418 | .418 | .404 | .731 | .730 | .730 | .736 |
| | II | .335 | .357 | .357 | .341 | .667 | .689 | .689 | .673 |
| | III | .271 | .297 | .297 | .278 | .603 | .629 | .629 | .610 |
| 14.0 | I | .531 | .553 | .553 | .537 | .678 | .700 | .700 | .684 |
| | II | .455 | .482 | .482 | .462 | .602 | .629 | .629 | .609 |
| | III | .379 | .410 | .410 | .387 | .526 | .557 | .557 | .534 |
| 16.0 | I | .656 | .698 | .698 | .680 | .808 | .834 | .834 | .816 |
| | II | .570 | .617 | .617 | .595 | .722 | .752 | .752 | .730 |
| | III | .484 | .536 | .536 | .509 | .636 | .672 | .672 | .644 |
| 18.0 | I | .749 | .777 | .965 | .944 | 1.034 | 1.060 | 1.060 | 1.038 |
| | II | .653 | .686 | .874 | .849 | .936 | .968 | .968 | .944 |
| | III | .556 | .595 | .783 | .754 | .838 | .878 | .878 | .848 |
| 20.0 | I | .912 | .943 | .943 | 1.103 | 1.187 | 1.218 | 1.218 | 1.195 |
| | II | .805 | .842 | .842 | .997 | 1.080 | 1.117 | 1.117 | 1.089 |
| | III | .698 | .742 | .742 | .892 | .973 | 1.017 | 1.017 | .984 |
| 25.0 | I | 1.066 | 1.110 | 1.110 | 1.077 | 1.308 | 1.498 | 1.498 | 1.464 |
| | II | .915 | .967 | .967 | .928 | 1.157 | 1.354 | 1.354 | 1.316 |
| | III | .764 | .825 | .825 | .779 | 1.006 | 1.212 | 1.212 | 1.166 |

TABLE XI

NET VALUES OF CLASS POLES BY CLASS, LENGTH, SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Site and Density | Pole Length | Pole Class[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 |
| | - Feet - | - Dollars Per Pole - | | | | | |
| Site Index 55 | 30 | - | - | 2.29 | 2.06 | 1.79 | 1.74 |
| | 35 | 6.12 | 4.60 | 4.93 | 5.03 | 2.98 | 2.07 |
| Density I | 40 | 7.57 | 7.40 | 6.82 | 6.23 | 5.01 | - |
| | 45 | 8.51 | 8.45 | 7.70 | 6.95 | 5.55 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 1.85 | 1.72 | 1.53 | 1.54 |
| | 35 | 5.35 | 3.97 | 4.41 | 4.63 | 2.67 | 1.84 |
| Density II | 40 | 6.68 | 6.68 | 6.23 | 5.77 | 4.67 | - |
| | 45 | 7.51 | 7.64 | 7.04 | 6.44 | 5.16 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 1.41 | 1.38 | 1.27 | 1.34 |
| | 35 | 4.57 | 3.34 | 3.90 | 4.24 | 2.37 | 1.60 |
| Density III | 40 | 5.79 | 5.96 | 5.64 | 5.32 | 4.32 | - |
| | 45 | 6.51 | 6.83 | 6.38 | 5.93 | 4.77 | - |
| | 50 | - | - | - | - | - | - |

TABLE XI (CONTINUED)

| Site and Density | Pole Length | Pole Class[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 |
| | - Feet - | - Dollars Per Pole - | | | | | |
| Site Index 65 and 75 | 30 | - | - | 2.42 | 2.15 | 1.87 | 1.80 |
| | 35 | 6.35 | 4.78 | 5.08 | 5.14 | 3.07 | 2.14 |
| Density I | 40 | 7.82 | 7.61 | 6.98 | 6.36 | 5.11 | - |
| | 45 | 8.80 | 8.68 | 7.89 | 7.10 | 5.66 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 2.00 | 1.84 | 1.62 | 1.61 |
| | 35 | 5.61 | 4.19 | 4.59 | 4.77 | 2.78 | 1.92 |
| Density II | 40 | 6.98 | 6.93 | 6.43 | 5.93 | 4.79 | - |
| | 45 | 7.85 | 7.92 | 7.27 | 6.62 | 5.30 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 1.59 | 1.52 | 1.38 | 1.42 |
| | 35 | 4.88 | 3.60 | 4.11 | 4.40 | 2.49 | 1.70 |
| Density III | 40 | 6.15 | 6.25 | 5.88 | 5.50 | 4.46 | - |
| | 45 | 6.92 | 7.16 | 6.65 | 6.14 | 4.93 | - |
| | 50 | - | - | - | - | - | |

TABLE XI (CONTINUED)

| Site and Density | Pole Length | 2 | 3 | Pole Class[a] 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | - Feet - | | | - Dollars Per Pole - | | | |
| Site Index 85 | 30 | - | - | 2.33 | 2.08 | 1.81 | 1.76 |
| | 35 | 6.18 | 4.65 | 4.97 | 5.06 | 3.00 | 2.09 |
| Density I | 40 | 7.63 | 7.45 | 6.86 | 6.26 | 5.04 | - |
| | 45 | 8.58 | 8.51 | 7.75 | 6.99 | 5.58 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 1.89 | 1.75 | 1.55 | 1.56 |
| | 35 | 5.41 | 4.03 | 4.46 | 4.67 | 2.70 | 1.86 |
| Density II | 40 | 6.75 | 6.74 | 6.28 | 5.81 | 4.70 | - |
| | 45 | 7.60 | 7.71 | 7.10 | 6.48 | 5.19 | - |
| | 50 | - | - | - | - | - | - |
| | 30 | - | - | 1.46 | 1.41 | 1.30 | 1.36 |
| | 35 | 4.65 | 3.40 | 3.95 | 4.28 | 2.40 | 1.62 |
| Density III | 40 | 5.88 | 6.03 | 5.70 | 5.37 | 4.36 | - |
| | 45 | 6.61 | 6.91 | 6.45 | 5.98 | 4.81 | - |
| | 50 | - | - | - | - | - | - |

[a]Pole Class Number 1 is not relevant in the area.

sticks of pulp could be cut from any tree. However, the taper curves for trees occurring on various sites were examined and the largest and smallest sticks of pulpwood were determined for each tree. The values for the largest and smallest stick were then averaged to give an average value of pulpwood sticks occurring in a particular sized tree on a given site. Table XII shows the average value of pulpwood sticks occurring in each of the tree sizes for various sites.

Pulpwood cords are known as long cords with dimensions eight feet long by four feet high by five feet wide. A long cord contains 160 cubic feet of space but only 112 cubic feet of wood. The cubic foot volume of five-foot sticks of pulpwood of various diameters at the large and small ends inside the bark was calculated.[12] The volume of these individual sticks of wood were then expressed as fractional parts of a long cord and the net value of pine pulpwood was prorated to the sticks accordingly. The net values of these individual sticks of wood are displayed in Appendix A, Table VI.

[12] See Appendix C, Table IV.

TABLE XII

NET VALUES OF PINE PULPWOOD BY DIAMETER CLASS, SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960[a]

| Breast High | Diameter Class: Range of Stick Size: Smallest: Small End | Smallest: Large End | Largest: Small End | Largest: Large End | Density Level | Site Index: 55 | 65 and 75 | 85 |
|---|---|---|---|---|---|---|---|---|
| | - Inches - | | | | | - Dollars - | | |
| 4 | 2.5 | 3.0 | 3.0 | 4.5 | I | .013 | .014 | .014 |
| | | | | | II | .008 | .010 | .009 |
| | | | | | III | .006 | .007 | .006 |
| 6 | 2.5 | 3.5 | 5.0 | 7.0 | I | .026 | .030 | .027 |
| | | | | | II | .018 | .022 | .018 |
| | | | | | III | .010 | .018 | .012 |
| 8 | 2.5 | 4.0 | 6.5 | 9.5 | I | .044 | .055 | .046 |
| | | | | | II | .030 | .036 | .032 |
| | | | | | III | .018 | .024 | .020 |
| 10 | 2.5 | 4.5 | 8.0 | 11.5 | I | .060 | .071 | .066 |
| | | | | | II | .043 | .052 | .045 |
| | | | | | III | .025 | .035 | .028 |

[a]Values calculated as a weighted average of smallest and largest sticks obtainable in a given class of diameter breast high.

# CHAPTER III

## STRUCTURE AND YIELD OF FOREST STANDS

The net values of wood products have now been estimated. The value of the harvest of wood products depends also on the character of the forest stand. This chapter will classify forest stand structures so that the possible harvest of wood products can be derived. The classification will be made according to tree distribution, sites, and growth characteristics. Variations in Oklahoma forest structures will be analyzed and the yields from a range of structures common to the area will be computed. From these results, the monetary value of a given stand will be estimated in the following chapter.

### Stand Structures[1]

In 1898 the French forester Francois de Lallement de Liocourt became the first forester to study the form in the frequency function of trees by diameter classes in uneven aged forests.[2] De Liocourt discovered that the ratios between the number of trees in successive diameter classes was approximately constant for a given forest at the period observed. However, this ratio may vary considerably between forests and within forests for different periods after growth has occurred.

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[1]The presentation of the information in this section is similar to the presentation of the late Arthur Meyer of the Pennsylvania State College. See H. Arthur Meyer, Forest Mensuration (Penns. Valley Publishers, Inc., State College, Pennsylvania, 1953), pp. 317-333.

[2]F. de Liocourt, De L'amenagement des Sapinieres, Bul. de la Societe Forestiere da la Franche Comte, Besancon, 1898.

So for a given forest at a given time, we may derive the equation for the number of trees per acre in successive diameter classes as follows:

Let $Y = Y(X)$ = Number of trees per acre depending on

$X$ = diameter class = 0, 1, 2 ... L with

$L$ = largest diameter class.

For the purposes of formulating a mathematical function, assume

$Y(0) = K$, a constant which will vary for different forests at different stages of growth. Let q represent the ratio between the number of trees in successive diameter classes, and assuming this ratio to be constant then de Liocourt's model can be expresses as

$$Y(1) = \frac{Y(0)}{q} = \frac{K}{q}$$

$$Y(2) = \frac{Y(1)}{q} = \frac{K}{q^2}$$

and finally,

$$= Y(X) = Kq^{-X},\ X = 0, 1, 2, \ldots, L.$$

In order to translate this discrete function into a more familiar continuous curve, logarithms may be taken on both sides.

$$\ln Y = \ln K - X \ln q$$

Now let $c = \ln K$ and

$a = \ln q$

Then $\ln Y = c - aX$.

It is in this form that the structural parameters K and q are estimated from surveys of the distribution of trees in a given forest. A least squares fit can be obtained for the logarithm of tree numbers on diameter classes or, what is more common, a free-hand straight line can be drawn carefully through the points plotted on semi-logarthmic paper.

Once c and a have been defined and estimated, we can transform the last equation to

$$Y = e^{c-aX}$$

or $Y = Ke^{-aX}$, where $K = e^c$

From this function, an approximation of the number of trees in any diameter class can be estimated as follows:

The number of trees in the unit class, $\Delta X$, will be

$$\text{Frequency } Y(\Delta X) = \int_{X}^{X+\Delta X} Ke^{-au}\,du$$

Since the definite integral of a continuous, monotonic curve can be approximated by

$$\int_{s}^{t} f(X)\,dX = (t-s)\,f\left(\frac{s+t}{2}\right)$$

for (t-s) not too large, we shall take as our approximation for the number of trees per acre in a unit diameter class, $\Delta X$, as

$$\text{Frequency } Y(\Delta X) = Ke^{-aX_o}\,\Delta X$$

Where $X_o = \frac{2X + \Delta X}{2}$, the class midpoint.[3]

The diameter classes used in this study are of two-inch size, so, for example,

$$\text{Frequency } Y(X_o = 14) = 2Ke^{-14a}$$

---

[3]For a different approach to this approximation, see H. A. Meyer and D. D. Stevenson, "The Structure and Growth of Virgin Beech, Birch, Maple and Hemlock Forest in Northern Pennsylvania," Journal of Agricultural Research, Vol. 67, pp. 465-484.

where $X_1 = 13.0$ and $X_2 = 14.9$ inches. The example is illustrated in Figure IV for a forest where $K = 20$, $a = 0.13118$ and there are around 6.4 trees per acre in the 14-inch diameter class.[4]

The frequency functions are defined on intervals starting no lower than two inches and upper bounds defined in the following manner. Observations of the last few diameter classes typically show more disturbance from the trend estimated from the first nine percentiles. The last few observations are therefore combined into a single class whose number of trees conforms to the general trend of the distribution. Above a point where radical departure from the distribution trend occurs, the basal areas of the observed trees are combined. The sum is then expressed as the basal area of Y trees in the next diameter class higher than the last trend point. Ordinarily, this plotting of Y continues the trend line, and may be accepted as the number of trees in the last or upper, diameter class. The upper bound of this new class is then taken as the upper bound L of the measured variate X.

## Variation in Stands

Among the several determinants of variation in stands are composition of the forest by species, site, and degree of balance between age classes. This study concentrates on one species and adjusts for four site indices. It is further assumed that the forest stands analyzed are in reasonable balance for uneven aged stands. Evidently, management can force a large number of distribution types on a given site.

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[4] Since $\ln q = a \Delta X$, $q = 1.3$.

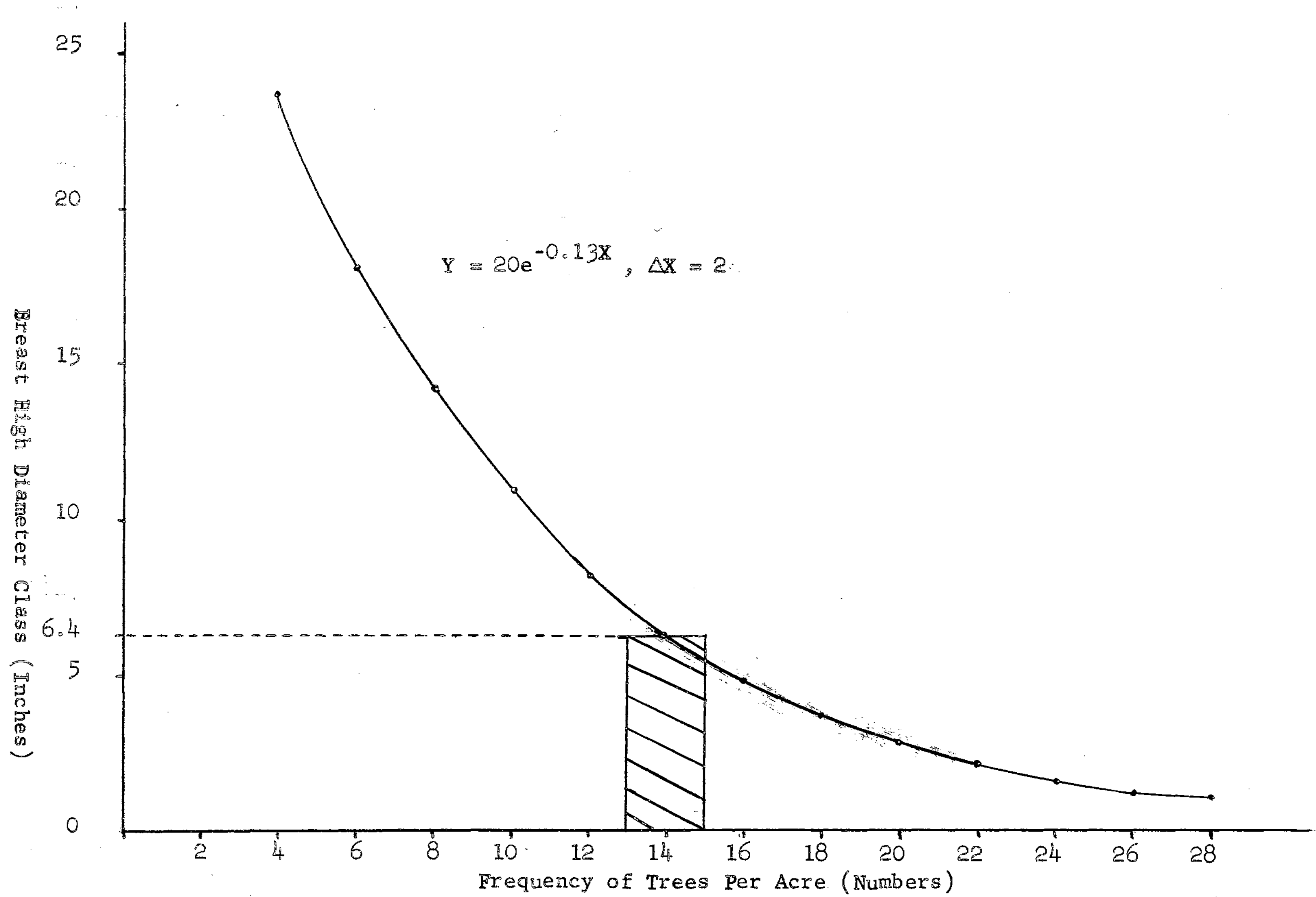


Figure IV. An Example of the Acre Distribution of Trees by Diameter Classes

Meyer and others have used De Liocourt's concept of diameter distributions to study uneven aged management in hardwood.[5] A forester's concept of uneven aged management is an acre of land supporting many different aged trees in composition and therefore many different sized trees. In contrast, even aged management strives to bring about a single aged, and therefore approximately single sized, group of trees on any given acre or other unit of land measure.[6] In sustained yield uneven aged management, the manager maintains various sizes and ages of growing trees on each acre at all times. In comparison, in even aged management the manager may have many acres with each age class of trees represented in the total land area under management yet each age class occurs in a homogeneous group. When a homogeneous group or acre reaches maturity the whole group is harvested and a new generation of trees is begun.

If the manager of an even aged forest had many individual acres, each with trees of different age and size, an average or standard acre concept could be developed by totaling the number of trees in a given size and age class for all size classes represented in the stand and then divide the totals for each class by the number of acres in the stand. The resultant standard acre would demonstrate the diameter distribution and level of stocking for the even aged manager's average or standard acre. De Liocourt's methods of analyzing diameter distributions can be used to good advantage for managed even or uneven aged forests.

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[5] Meyer and Stevenson, pp. 465-484.

[6] One may assume equal size if all trees are subject to the same hereditary and evironmental conditions.

Although the K and q values for a given forest are related in a manner that excluded the possibility of many (K, q) pairs, differential management can result in several types of distributions, especially with respect to q values, that can not be maintained. Figure V illustrates a hypothetical case of variation in distribution for one site and one species. The type of distribution assumed here is one that can be maintained indefinitely in unchanging or balanced distribution by diameter class.

Variation in density levels, however, will be allowed for in the study. Density refers to the number of trees per acre and the way in which this number is distributed between diameter classes. This variation in density can be considered mainly as affecting the level of constant K. Figure V shows this variation.

## Yields from Forest Stands

In any forest production study which assumes stands are established and costs of establishment fixed, the yields determine returns. This study will take an original forest stand and project this stand through ten years of growth. The number of trees in each diameter class of the original stand will then be subtracted from the number of trees in corresponding diameter classes after ten years of growth. The result will be the original stand's ten-year yield by numbers of trees in each diameter class. These yields will be calculated for a range of K and q values likely to be found in Oklahoma and under various growth conditions that are representative of the area.[7]

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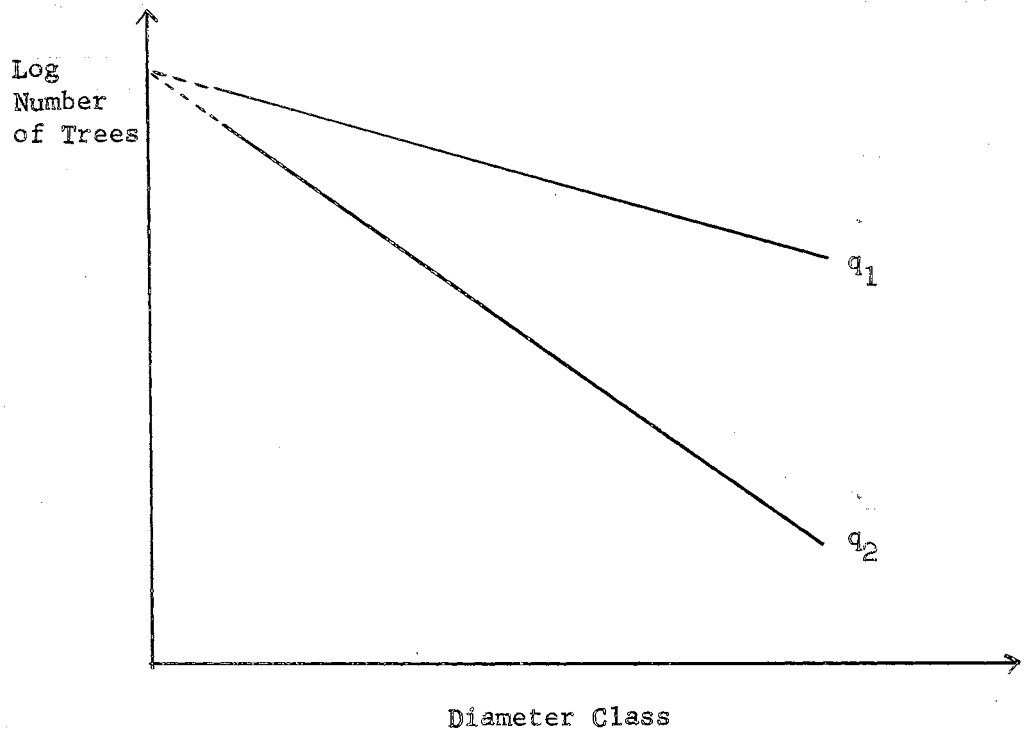
[7] H. Arthur Meyer, "Structure, Growth, and Drain in Balanced Uneven-Aged Forests," Journal of Forestry, Vol. 50, No. 2, (1952) pp. 85-92.

Variation in Balance (K, Constant; $q_1 < q_2$)




Variation in Density (q, Constant; $K_1 < K_2 < K_3$)

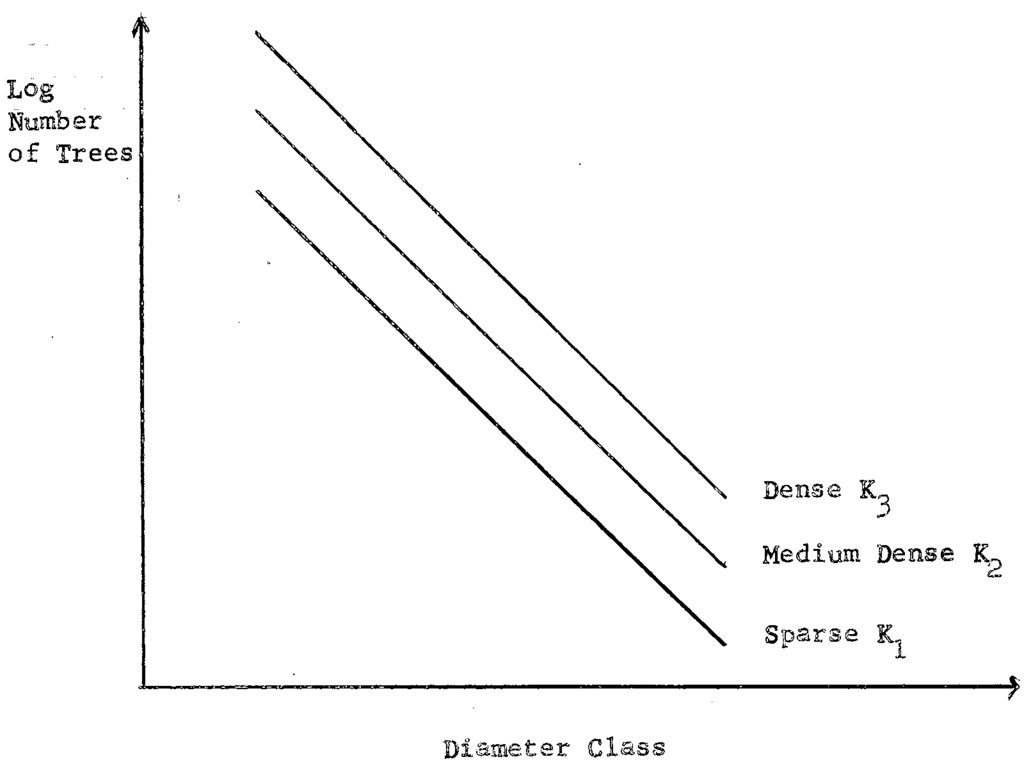



Figure V. Hypothetical Illustration of the Variation in Tree Distribution by Density Levels

Consider one midpoint $X_o$ in the formula for calculating the number of trees per acre:

$$Y(\Delta X) = Ke^{-aX_o} \Delta X.$$

Let the normal 10-year growth increment for the diameter of a tree be well approximated by the function

$$I = c + mX_o,$$

where I = the 10-year increment in diameter of a tree in the diameter class $X_o$,

c = portion of the increment unaffected by the tree size and

m = proportional increment that depends on tree size.[8]

Then the midpoint in ten years, $X_o'$, will be shifted to

$$X_o' = X_o + c + mX_o = c + (m+1)\ X_o,$$

so that our formula must be modified for

$$X_o = \frac{X_o' - c}{m + 1}\ .$$

The new diameter class, $\Delta X'$, will also change as follows:

$$\Delta X' = X_2' - X_1' = X_2 + c + mX_2 - X_1 - c - mX_1$$

$$= \Delta X + m\Delta X,$$

so that the formula will again be modified by,

$$\Delta X = \frac{\Delta X'}{m+1}\ .$$

The frequency distribution for a stand after 10 years of growth may now be written

$$\text{Frequency } Y'(\Delta X') = K'e^{-a'X_o'} \Delta X'$$

---

[8]The linear growth function has been found a reasonable approximation for short periods of time. Since the growth function is monotonically increasing for periods at least as long as the life span of the oldest tree, the approximation will not damage the order of the results providing $I > o$ for all c, m, and $X_o$ used.

where we have substituted for $X_o$ and $\Delta X$ in the manner outlined above. For

$$\text{Frequency } Y'(\Delta X') = Ke^{-a\left[\frac{X_o'-c}{m+1}\right]} \frac{\Delta X'}{m+1}$$

$$= \left[\frac{K}{m+1} e^{\frac{ac}{m+1}}\right] e^{\frac{a}{m+1} X_o'} \Delta X'$$

The 10-year yield from a given forest will therefore be distributed by diameter classes as

$$\text{Frequency Yield} = \text{Frequency } Y' - \text{Frequency } Y$$

$$= K'e^{a'X_o'} \Delta X' - Ke^{-aX_o} \Delta X$$

$$\text{where } K' = \frac{K}{m+1} e^{\frac{ac}{m+1}} \quad \text{and}$$

$$a' = \frac{a}{m+1},$$

in terms of the original coefficients of structure.

In the formula used here to calculate the frequency distribution of 10 years' yield by diameter classes, it is thus assumed that the two stands before and after growth differ only by the modification of the structural parameters implied by $I = c + mX_o$.

## Data Used for Forest Structure

The q and K values were selected in such a manner that the range of forest conditions in Oklahoma was represented. However, no q or K values were used that would portray a forest where the pine stocking was not dense enough to keep weed species from taking over the forest.

Four q values ranging from 1.3 to 1.9 were selected with four values of K for each value of q. A small value of q indicates a higher proportion of large trees to small trees than does a great q value. Since q values indicate proportionality only, some variable, K, is used to indicate the density of the structure. Thus, for a q value which indicates that there is a two to one proportion of six-inch size trees to eight-inch size trees says nothing of how many trees are in each class. A high K would indicate, for example, that the number of trees in the classes were 10 and 5 whereas a low K would indicate a sparser stocking of 6 and 3 trees. Table XIII shows the range of q values used and the four values of K for each q.

Forest growth characteristics may vary over the area and for that reason a range of growth possibilities have been chosen. It is of question whether pine forests in Oklahoma display a slightly rising, constant, or slightly falling growth curve of the linear form discussed earlier. Each type of slope has been used for four different levels of c. The c levels range from 1.75 to 2.50 inches, and the m levels from -0.009 to 0.009.

Finally, as mentioned before, the upper limits, L, of the diameter distributions for each q value must be established. Nathaniel Walker of the Oklahoma State University Forestry Department recommends that the upper diameter limits listed in Table 15 be used.

TABLE XIII

CONSTANTS USED IN DESCRIBING THE RANGE OF FOREST STRUCTURES AND YIELDS IN EASTERN OKLAHOMA

| Values of q | Values of K | | | |
|---|---|---|---|---|
| 1.3 | 20 | 30 | 40 | 50 |
| 1.5 | 42 | 59 | 75 | 81 |
| 1.7 | 74 | 93 | 113 | 132 |
| 1.9 | 155 | 182 | 208 | 235 |
| Growth Coefficients | | c | m | |
| | | 1.75 | .009 | |
| | | 2.00 | .000 | |
| | | 2.25 | -.009 | |
| | | 2.50 | | |
| Upper Diameter Limits | | q | Upper Limit | |
| | | 1.3 | 28 Inch Class | |
| | | 1.5 | 26 Inch Class | |
| | | 1.7 | 26 Inch Class | |
| | | 1.9 | 24 Inch Class | |

## CHAPTER IV

## EVALUATION OF THE FOREST YIELD

It is now possible to proceed to the basic problem of the study, namely, to evaluate the net monetary value of the yield from an Oklahoma forest stand. To do this, the product complexes that can be cut from trees of the range in size found on Oklahoma sites was first examined. Then, for each tree - by size, site, and density - the product complex was determined that yielded maximum net money returns (revenue minus costs). These optimum values were then used to evaluate the ten-year yields from the range of local forest structures.

### The Product Complex

There are four important forest products grown and harvested in Oklahoma pine forests. Poles, posts, pulpwood, and sawlogs are harvested in large enough quantities to justify the establishment of marketing facilities for these products within the state. These products are considered for calculating net values from forests in this study.

The problem of evaluating a forest stand stems from the number and types of products coming from a given stand. How to determine the product complex for a given stand is the immediate question.

The method of determining the complex devised for this study approaches the problem by looking at the physical qualities of a tree with the diameter breast high dimension corresponding to the midpoint for each of the diameter classes for each of four different sites.

First, information giving the height for each diameter class tree of each of four site indices ranging from 55 to 85 was collected from forest owners in Oklahoma. This information was then adjusted to conform to shortleaf pine taper curves of the form used by L. H. Reineke by using a double ratio adjusting technique to transform Oklahoma data to taper curves.[1] The two adjusting ratios used were the height of Reineke's curves to the height of Oklahoma trees and the ratio of Reineke's diameter to various diameters for Oklahoma pines. Reineke's curve was transformed into a family of taper curves for each of four sites and from these curves the diameter of any d.b.h. class tree can be determined at any height. For example, a four-inch d.b.h. tree on site index 75 would have a diameter of 2.98 inches at 14 feet in height.

Yield distributions for each q, K, c and site index were calculated by an IBM 650 program described in Appendix C. The results are too voluminous to be tabulated here. After net revenues were calculated, the net value of yields from several typical Oklahoma stands were tabulated in Chapter V.

## Product Classes and Density Levels

It is standard practice locally to cut sawlogs from trees of 10 inches or more at breast-high diameter measurement (d.b.h.). Poles are cut from trees in the 12 and 14 inch d.b.h. intervals, posts from trees

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[1] L. H. Reineke, "The Determination of Tree Volume by Planimeter," *Journal of Forestry*, Vol. 24 (1926), p. 188.

in the 4, 6, 8 and 10 inch intervals, and pulpwood from all tree sizes. Three product classes were thereby established; a sawlog class for trees of 16 inches d.b.h. and over, a sawlog-pole class for trees of 12 and 14 inches, and a post-pulp class for trees from 4 to 8 inches in diameter. The ten-inch size must be treated separately, since all products can be cut from this diameter interval.

The number of trees in each of the above product classes were totaled for each forest structure. The range of possible levels in the distribution of trees by sizes was then split into three equal parts. The upper level was defined as dense, the middle third as medium-dense, and the lower third as sparse. Each product class was therefore subdivided into three density levels for each forest structure. Classification by density levels involves more than just the K value of the tree distribution. Other determinants of density and the effect of density on q values were ignored.

## Sawlog and Class Pole Stand Evaluation

Sawlogs are cut from two product classes and from 10 inch size trees in the post-pulp-sawlog class. Weighted average prices were used for trees in the 10, 12, 14 inch d.b.h. class.

According to information supplied by Oklahoma foresters, only one tree out of every seven is physically suited to make a class pole or long posts in the case of 10-inch d.b.h. trees. The other six are suited to produce sawlogs. In the case of 10 inch d.b.h. trees, the value used will be the weighted average of the value of the tree's yield in sawlogs plus pulpwood and long posts plus pulpwood. In 12 and 14 inch d.b.h. trees, the value used will be the weighted average of the tree's value in sawlogs plus pulpwood and class poles plus pulpwood.

The yield of 10 inch d.b.h. trees in long posts and pulpwood was determined by the computer routine described in Appendix C. The class pole yields for 12 and 14 inch d.b.h. trees was determined by consulting the taper curves for these trees and finding the class pole yield that represents the greatest return to the tree.

The sawlog yield for trees 10 inches d.b.h. and larger was determined by using a form class volume table.[2] The form class and merchantable height of all sawlog trees were determined by the taper curves for the trees by the method outlined in the volume table. The physical criteria used to determine sawlog volumes is displayed in Appendix C, Tables 6 and 7. After these volumes were known the value criteria were applied and the net value of individual trees determined.

## Post and Pulpwood Stand Evaluation

The amount of pulpwood cut from sawlog trees 10 inches d.b.h. or larger and class pole trees 12 and 14 inches d.b.h. were determined on a per thousand board feet of sawlog or class pole basis. Oklahoma foresters estimate that pulpwood can be substituted at the rate of one cord per thousand board feet of sawlogs cut and 1.75 cords per thousand board feet of class poles cut. These ratios were used in the calculations here.

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[2] United States Department of Agriculture, Tables for Estimating Board Foot Volume of Timber, Forest Service, (Washington, D. C.), 1956.

The quantities of pulpwood occurring in the 10 inch d.b.h. trees were similarly computed and the maximum net revenue was evaluated for these products by the maximizing procedure previously discussed.

Four, six, and eight inch d.b.h. trees are physically capable of producing post products 12 feet long or longer in about one tree out of every 17 trees harvested. The value of trees in these classes is a weighted average of the maximized output of 10 foot and shorter products and a maximized output with products 12 foot or longer occurring in the product combinations.

# CHAPTER V

## RESULTS AND CONCLUSIONS

The results of estimating the net values of ten-year yields from Oklahoma forest stands may now be presented. Table XIV portrays the results for various sites, structures and growth characteristics common to Oklahoma forests. The net value per acre of forest product yields from forests of 16 structural types on 4 sites with 9 possible growth characteristics have been derived. The 576 elements of the table represent the maximum net value possible from the various wood products that can be harvested from each diameter class of the forest stands analyzed. Differential costs of harvest and fixed price constellations for the products were taken into account in the determination of maximum net values. Table XIV thus represents, and is so entitled, the optimum net value of the 10-year yields from the typical Oklahoma forest stands.

The underlying assumptions of the study must again be emphasized. Shortleaf pine is the only species considered. Possible wood products were restricted to four main classes. Prices of products and the costs of their harvest are assumed constant over the ten years of the yield. For optimum product complexes, only relative prices and costs need be assumed constant, but changes in their absolute level would affect the level of net values. Forest stand structures are assumed to change over ten years only as growth coefficients and not management practices alter them.

TABLE XIV

NET DOLLAR VALUES PER ACRE IN 1960 OF THE TEN YEAR YIELDS OF OPTIMUM PRODUCT COMPLEXES FROM OKLAHOMA FORESTS

Growth Constant c = 2.50

| Structural Parameters | Net Dollar Values of the Ten Year Yield | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m = .009 | | | | m = 0 | | | | m = -.009 | | | |
| | Site Index | | | | Site Index | | | | Site Index | | | |
| | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 |
| q = 1.3 | | | | | | | | | | | | |
| $K_1$ = 20 | 82.99 | 103.61 | 118.29 | 122.71 | 79.39 | 99.20 | 113.08 | 117.27 | 78.13 | 97.63 | 111.35 | 115.31 |
| $K_2$ = 30 | 225.71 | 321.06 | 367.36 | 332.09 | 138.37 | 169.44 | 192.93 | 203.45 | 135.25 | 165.68 | 188.74 | 198.81 |
| $K_3$ = 40 | 266.86 | 272.21 | 310.17 | 396.39 | 219.66 | 264.67 | 301.79 | 322.74 | 211.29 | 254.79 | 290.37 | 310.31 |
| $K_4$ = 50 | 284.93 | 343.22 | 391.01 | 418.73 | 272.12 | 327.76 | 373.29 | 399.21 | 263.51 | 317.64 | 361.62 | 386.47 |
| q = 1.5 | | | | | | | | | | | | |
| $K_1$ = 42 | 77.96 | 97.18 | 110.93 | 111.32 | 74.95 | 93.50 | 106.73 | 106.93 | 72.16 | 90.07 | 102.81 | 102.79 |
| $K_2$ = 59 | 126.96 | 155.17 | 176.88 | 180.76 | 122.18 | 149.44 | 170.37 | 173.79 | 117.31 | 143.57 | 163.69 | 166.65 |
| $K_3$ = 75 | 185.05 | 222.65 | 253.50 | 262.98 | 177.48 | 213.68 | 243.28 | 251.91 | 150.04 | 185.14 | 210.84 | 214.92 |
| $K_4$ = 81 | 199.63 | 240.20 | 273.49 | 283.69 | 191.67 | 230.79 | 262.75 | 272.07 | 183.87 | 221.54 | 252.23 | 260.69 |
| q = 1.7 | | | | | | | | | | | | |
| $K_1$ = 74 | 79.41 | 99.73 | 113.93 | 111.23 | 76.74 | 96.43 | 110.23 | 107.37 | 72.74 | 91.77 | 105.02 | 101.87 |
| $K_2$ = 93 | 123.20 | 152.34 | 171.68 | 170.27 | 119.28 | 147.62 | 166.34 | 164.57 | 115.08 | 142.55 | 160.57 | 158.44 |
| $K_3$ = 113 | 139.76 | 187.79 | 211.45 | 210.10 | 145.48 | 181.38 | 204.16 | 202.31 | 139.71 | 173.08 | 194.95 | 192.38 |
| $K_4$ = 132 | 195.01 | 237.72 | 267.86 | 269.69 | 188.25 | 229.72 | 258.73 | 259.88 | 164.47 | 205.22 | 230.94 | 228.33 |
| q = 1.9 | | | | | | | | | | | | |
| $K_1$ = 155 | 135.04 | 160.06 | 189.54 | 182.64 | 131.32 | 164.60 | 184.48 | 177.73 | 129.17 | 162.06 | 181.68 | 174.35 |
| $K_2$ = 182 | 183.89 | 225.77 | 255.01 | 250.37 | 180.07 | 221.16 | 249.73 | 244.86 | 173.89 | 212.48 | 240.13 | 234.35 |
| $K_3$ = 208 | 208.00 | 255.41 | 288.51 | 282.93 | 203.93 | 250.50 | 282.87 | 277.05 | 200.11 | 245.85 | 277.62 | 271.51 |
| $K_4$ = 235 | 253.63 | 306.03 | 346.78 | 343.84 | 245.35 | 296.84 | 335.24 | 331.32 | 237.66 | 287.76 | 324.92 | 320.48 |

TABLE XIV (CONTINUED)

Growth Constant c = 2.25

| Structural Parameters | Net Dollar Values of the Ten Year Yield | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m = .009 | | | | m = 0 | | | | m = -.009 | | | |
| | Site Index | | | | Site Index | | | | Site Index | | | |
| | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 |
| q = 1.3 | | | | | | | | | | | | |
| $K_1$ = 20 | 72.80 | 90.99 | 103.82 | 107.82 | 72.73 | 90.95 | 103.74 | 107.69 | 67.90 | 84.78 | 96.64 | 99.99 |
| $K_2$ = 30 | 128.50 | 157.51 | 179.54 | 189.69 | 122.49 | 149.95 | 171.07 | 180.47 | 99.87 | 124.82 | 142.27 | 147.20 |
| $K_3$ = 40 | 175.58 | 215.02 | 245.03 | 258.91 | 165.93 | 203.15 | 231.43 | 244.05 | 160.65 | 196.73 | 224.26 | 231.73 |
| $K_4$ = 50 | 252.62 | 304.44 | 346.62 | 371.30 | 238.11 | 287.14 | 327.60 | 349.70 | 237.60 | 274.77 | 313.20 | 334.36 |
| q = 1.5 | | | | | | | | | | | | |
| $K_1$ = 42 | 68.58 | 85.62 | 97.56 | 97.96 | 65.63 | 81.85 | 93.44 | 93.63 | 62.92 | 78.55 | 89.68 | 89.65 |
| $K_2$ = 59 | 111.74 | 136.57 | 155.66 | 159.09 | 106.77 | 130.64 | 148.87 | 151.83 | 102.37 | 125.31 | 142.88 | 145.43 |
| $K_3$ = 75 | 154.03 | 173.63 | 197.95 | 188.24 | 136.07 | 166.40 | 189.72 | 187.42 | 129.86 | 158.95 | 181.21 | 184.44 |
| $K_4$ = 81 | 175.56 | 211.26 | 240.52 | 249.52 | 147.40 | 181.79 | 206.98 | 211.37 | 140.34 | 171.79 | 195.84 | 199.35 |
| q = 1.7 | | | | | | | | | | | | |
| $K_1$ = 74 | 68.04 | 85.64 | 97.98 | 95.55 | 65.51 | 82.54 | 94.49 | 91.90 | 62.71 | 79.13 | 90.56 | 87.80 |
| $K_2$ = 93 | 87.04 | 109.31 | 124.88 | 121.96 | 83.54 | 105.01 | 121.29 | 116.85 | 80.47 | 101.96 | 115.76 | 112.45 |
| $K_3$ = 113 | 130.47 | 161.29 | 181.81 | 180.38 | 125.92 | 155.79 | 175.56 | 173.71 | 121.07 | 232.05 | 168.92 | 166.71 |
| $K_4$ = 132 | 153.16 | 190.78 | 214.80 | 213.46 | 147.69 | 184.11 | 207.25 | 205.43 | 141.31 | 175.02 | 197.14 | 194.52 |
| q = 1.9 | | | | | | | | | | | | |
| $K_1$ = 155 | 109.11 | 138.23 | 154.87 | 147.41 | 104.98 | 133.17 | 149.13 | 141.51 | 102.39 | 130.00 | 144.52 | 137.77 |
| $K_2$ = 182 | 140.19 | 175.33 | 196.60 | 190.16 | 131.58 | 164.99 | 184.93 | 177.49 | 128.65 | 161.44 | 180.91 | 173.32 |
| $K_3$ = 208 | 181.73 | 223.09 | 252.00 | 247.50 | 174.79 | 213.51 | 241.31 | 236.08 | 170.39 | 208.32 | 235.29 | 229.81 |
| $K_4$ = 235 | 202.98 | 258.26 | 281.47 | 276.11 | 195.88 | 240.66 | 271.79 | 265.72 | 191.16 | 234.99 | 264.57 | 258.97 |

TABLE XIV (CONTINUED)

Growth Constant c = 2.00

| Structural Parameters | Net Dollar Values of the Ten Year Yield | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m = .009 | | | | m = 0 | | | | m = -.009 | | | |
| | Site Index | | | | Site Index | | | | Site Index | | | |
| | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 |
| q = 1.3 | | | | | | | | | | | | |
| $K_1$ = 20 | 65.21 | 81.34 | 92.96 | 96.53 | 61.63 | 76.98 | 87.83 | 90.96 | 60.10 | 75.10 | 85.72 | 88.81 |
| $K_2$ = 30 | 94.57 | 118.21 | 134.73 | 139.82 | 92.96 | 116.22 | 132.53 | 137.37 | 86.40 | 107.96 | 123.00 | 127.18 |
| $K_3$ = 40 | 153.34 | 187.78 | 214.04 | 226.18 | 145.18 | 177.70 | 202.45 | 213.60 | 141.44 | 173.15 | 197.43 | 208.06 |
| $K_4$ = 50 | 221.54 | 262.30 | 304.48 | 326.22 | 209.57 | 252.68 | 287.93 | 307.95 | 170.59 | 208.85 | 237.92 | 250.52 |
| q = 1.5 | | | | | | | | | | | | |
| $K_1$ = 42 | 59.65 | 74.32 | 84.84 | 85.20 | 56.94 | 71.03 | 81.11 | 81.27 | 54.10 | 67.54 | 77.10 | 77.06 |
| $K_2$ = 59 | 86.49 | 106.07 | 120.95 | 121.54 | 80.95 | 100.74 | 114.88 | 115.21 | 77.08 | 96.20 | 109.80 | 109.81 |
| $K_3$ = 75 | 137.31 | 151.04 | 172.14 | 176.00 | 117.81 | 144.07 | 164.25 | 167.56 | 111.83 | 136.91 | 156.11 | 158.86 |
| $K_4$ = 81 | 133.32 | 162.97 | 185.78 | 189.87 | 127.06 | 155.42 | 177.21 | 180.75 | 120.68 | 147.71 | 168.39 | 171.40 |
| q = 1.7 | | | | | | | | | | | | |
| $K_1$ = 74 | 58.70 | 73.90 | 84.53 | 82.46 | 55.93 | 70.48 | 80.63 | 78.40 | 53.41 | 67.41 | 77.15 | 74.79 |
| $K_2$ = 93 | 73.76 | 92.87 | 106.25 | 103.64 | 70.42 | 88.72 | 101.55 | 98.72 | 67.25 | 84.84 | 97.15 | 94.16 |
| $K_3$ = 113 | 112.40 | 138.92 | 156.59 | 155.65 | 97.60 | 122.50 | 137.92 | 134.37 | 93.69 | 117.69 | 132.48 | 128.67 |
| $K_4$ = 132 | 132.91 | 164.18 | 185.08 | 183.91 | 126.01 | 155.90 | 175.69 | 173.84 | 120.31 | 149.07 | 167.91 | 165.59 |
| q = 1.9 | | | | | | | | | | | | |
| $K_1$ = 155 | 93.10 | 117.93 | 132.10 | 121.82 | 89.20 | 143.38 | 127.06 | 120.52 | 86.58 | 110.17 | 123.40 | 116.84 |
| $K_2$ = 182 | 107.98 | 136.80 | 153.30 | 145.63 | 104.57 | 132.63 | 148.55 | 140.78 | 102.06 | 129.59 | 145.10 | 137.24 |
| $K_3$ = 208 | 134.78 | 168.64 | 189.06 | 182.71 | 131.36 | 164.49 | 184.39 | 178.55 | 114.13 | 144.99 | 162.31 | 153.20 |
| $K_4$ = 235 | 171.10 | 208.90 | 236.18 | 231.11 | 167.66 | 204.80 | 231.45 | 226.16 | 161.21 | 197.07 | 222.68 | 217.01 |

TABLE XIV (CONTINUED)

Growth Constant c = 1.75

| Structural Parameters | Net Dollar Values of the Ten Year Yield | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m = .009 | | | | m = 0 | | | | m = -.009 | | | |
| | Site Index | | | | Site Index | | | | Site Index | | | |
| | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 | 55 | 65 | 75 | 85 |
| q = 1.3 | | | | | | | | | | | | |
| $K_1$ = 20 | 56.52 | 70.62 | 80.62 | 83.73 | 55.63 | 69.53 | 79.40 | 82.44 | 51.37 | 64.33 | 73.26 | 75.93 |
| $K_2$ = 30 | 83.35 | 104.32 | 118.81 | 123.52 | 77.95 | 97.41 | 111.09 | 115.05 | 73.59 | 92.08 | 104.84 | 108.54 |
| $K_3$ = 40 | 132.86 | 162.72 | 185.69 | 196.38 | 125.62 | 154.05 | 175.67 | 185.57 | 101.20 | 126.43 | 144.33 | 149.41 |
| $K_4$ = 50 | 164.67 | 201.81 | 229.84 | 243.02 | 156.72 | 191.88 | 218.74 | 230.85 | 146.26 | 179.06 | 204.07 | 214.84 |
| q = 1.5 | | | | | | | | | | | | |
| $K_1$ = 42 | 51.20 | 65.40 | 72.74 | 73.16 | 48.40 | 62.42 | 68.90 | 69.05 | 45.84 | 57.24 | 65.35 | 65.28 |
| $K_2$ = 59 | 71.89 | 89.61 | 102.28 | 102.73 | 68.11 | 84.94 | 96.97 | 97.15 | 64.41 | 80.40 | 91.79 | 91.74 |
| $K_3$ = 75 | 105.95 | 129.50 | 147.64 | 150.93 | 87.88 | 109.40 | 124.76 | 125.10 | 83.04 | 103.44 | 117.94 | 117.99 |
| $K_4$ = 81 | 114.44 | 139.85 | 159.44 | 163.01 | 108.14 | 132.27 | 150.79 | 153.79 | 102.01 | 124.88 | 142.38 | 144.87 |
| q = 1.7 | | | | | | | | | | | | |
| $K_1$ = 74 | 49.75 | 62.64 | 71.63 | 69.89 | 47.35 | 61.98 | 68.27 | 66.41 | 44.89 | 56.62 | 64.82 | 62.79 |
| $K_2$ = 93 | 62.66 | 78.87 | 90.22 | 88.01 | 59.52 | 75.09 | 85.81 | 83.47 | 56.47 | 71.27 | 81.58 | 79.07 |
| $K_3$ = 113 | 77.30 | 97.06 | 110.88 | 108.34 | 72.15 | 90.94 | 104.03 | 101.16 | 68.58 | 86.53 | 99.73 | 95.98 |
| $K_4$ = 132 | 90.40 | 111.48 | 129.65 | 126.70 | 89.44 | 108.15 | 123.63 | 120.43 | 81.62 | 102.73 | 117.45 | 114.01 |
| q = 1.9 | | | | | | | | | | | | |
| $K_1$ = 155 | 77.30 | 98.13 | 110.03 | 104.77 | 74.40 | 94.59 | 106.00 | 100.46 | 69.96 | 89.11 | 99.77 | 94.13 |
| $K_2$ = 182 | 92.17 | 116.75 | 130.80 | 124.53 | 86.45 | 109.90 | 123.18 | 116.63 | 83.66 | 106.49 | 119.29 | 112.65 |
| $K_3$ = 208 | 104.64 | 132.53 | 148.50 | 138.42 | 99.78 | 126.61 | 141.78 | 134.35 | 95.90 | 121.81 | 136.36 | 128.83 |
| $K_4$ = 235 | 126.93 | 158.88 | 178.12 | 171.84 | 113.34 | 143.78 | 160.99 | 152.73 | 110.18 | 139.88 | 156.60 | 148.21 |

The study in addition takes no account of several other important factors in determining optimum structures. These include the costs of waiting ten years or some other more advantageous period, the opportunity costs of not growing some other tree species or even another crop entirely and in general terms the cost of the land on which the forest grows.

Some other costs not considered in net revenues may be lumped into three general categories; costs of administration, cost of protection, and costs of management. Administrative costs may include taxes paid on lands and costs of maintaining property boundaries. Protection costs include expenditures made for detection and suppression of insect infestations and fires. Management plans, marking or designating trees to be sold, converting areas to favorable forest types, and altering the diameter distribution or density of forest stands are among costs to be considered in management.

## Net Values and Structures

In every situation presented, it can be seen that the structure with the smallest q value for a given density yields more returns. That is the structure with the highest proportion of large trees. This is true regardless of site or growth characteristics. It is always true that the K value, which measures the density or level of stocking, is directly related to net returns. What is more subtle in the relationship between q and K values with regard to net returns. Although high stocking and large proportions of older trees yields the highest net returns, the lowest returns for given site and growth characteristics are not from the most even-aged stands. It would appear that the extreme values of q are more profitable, other costs held constant, than the intermediate values. Thus, for site index 55 and growth rate of $I = 2.50 + .009X$; a structure of $q = 1.3$ and $K = 50$ yields \$285 per acre, but the second best yield from a dollar standpoint is that from $q = 1.9$ and $K = 235$, namely \$254 per acre. For the intermediate values of q, net returns do not exceed \$200.

The net value imputed to the harvest of structure $q = 1.3$, $K = 50$ was exceptionally high because of the high yields per acre of the more valuable sizes of sawlogs. The number of stems in this structure suitable for producing sawlogs is not large but the proportion of large sized stems and the absolute number of large sawlogs that could be cut was higher than for other structures. For this reason, the average value per stem was high enough to offset the small stem numbers.

As structures change from low to high q and K values, for some sites and growth rates, the proportion of smaller sized trees increases faster than the number of trees. The average value per stem is low and the net values are thus often lower. At the extremely high levels of stocking the sheer number of low valued trees yields values that are higher even allowing for low average values per stem due to the product types that can be cut from smaller trees. In other words, the number of stems increases at a faster rate than their average value declines. The graph in Figure VI illustrates that the breaking point is affected also by site index and the growth constant c. It will be noticed from the figure that it seems always true that the extremes in structure are more valuable than the intermediate structures, that the growth constant has greater effect

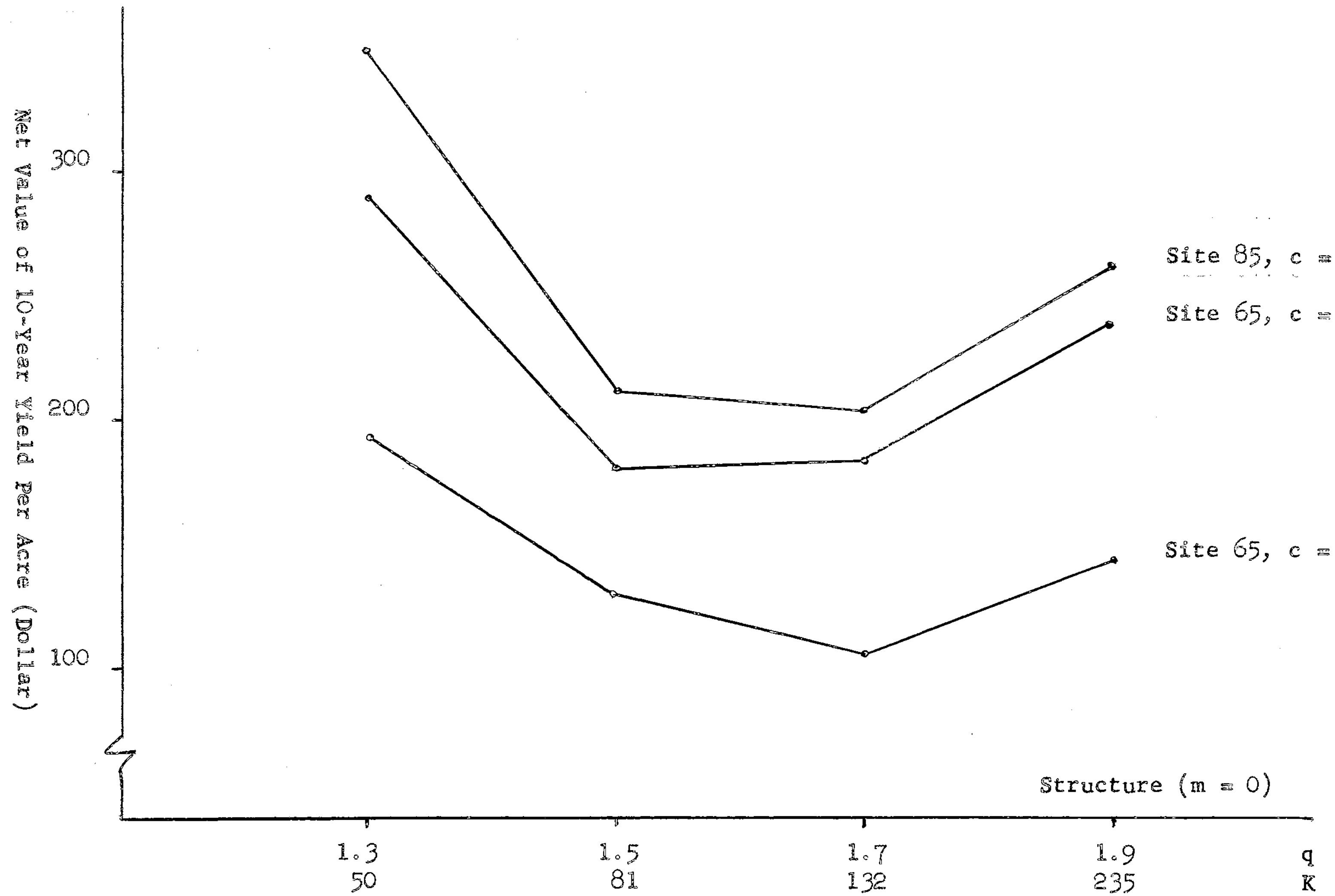


Figure VI. The Effect of Changing Structure, Site and Growth Constant on Maximum Net Values of the 10-Year Yields Per Acre From Densest Possible Levels of Stocking on the over-all level of value than does the site and that the high K value structure is always the maximum. This latter observation is only valid for the range observed and the prices used. There are indications that as structure "increases" from q = 1.9 and K = 235, net values would increase. There are, of course, physical limitations on increasing the level of stocking for a given locale. Additionally, there are economic limitations in that below a certain diameter, trees are not marketable.

The prices used in the study also condition these statements of the effect on value of changing structure. Although product complexes would not change much over considerable range in prices, it is evident that the relative price of sawlogs to pulpwood, for example, would be important in determining the level of stocking most profitable for Eastern Oklahoma stands. Even small decreases in this price ratio might make high q and K structures the most profitable.

To illustrate this point, the following tables have been prepared. Table XV depict yields, product complexes, and net revenues that might be expected from stands described by their q, K, c, m and site variables. The extreme high and low q structures were chosen and the extreme high and low K for each q was analyzed. The latter part of the table summarizes the results of the whole of Table XV.

The results show that net revenues from 4, 6, 8, 10, 12, 14 inch d.b.h. classes are greater in the high q range when compared with the net revenues from low q ranges and respective K values. However, in the 16 inch d.b.h. and larger classes the net revenue from low q structures is higher when compared with high q structures regardless of the K level. It seems apparent that density holds the key in deciding which structures

TABLE XV

OPTIMUM PRODUCT COMPLEXES AND ASSOCIATED NET VALUES OF THE TEN YEAR YIELD FROM TYPICAL EASTERN OKLAHOMA SITES AND GROWTH ON FOUR EXTREME STAND STRUCTURES[a]

High Proportion of Large Trees, (q = 1.3); High Density, (k = 50)[b]

| Diameter Class d.b.h. | 10-Year Yield on the Stand | Optimum Product Complex and Associated Net Revenues: Short Post | | Long Post | | Class Pole | Sawlog | Net Value Per Tree[g] | Net Value of the Stand Yield |
|---|---|---|---|---|---|---|---|---|---|
| | | Size[c] | Value[d] | Size[c] | Value[d] | Plus Pulp Value[e] | Plus Pulp Value[f] | | |
| Inches | Trees | Feet | Dollars | Feet | Dollars | | - Dollars - | | |
| 4 | 17.2 | 6.5(3) | .027 | | | | | .027 | .46 |
| 6 | 13.4 | 10.0(2)<br>6.5(1) | .281 | 20.0(1)<br>6.5(1) | .683 | | | .305 | 4.09 |
| 8 | 10.4 | 10.0(3)<br>6.5(1) | .731 | 20.0(1)[k]<br>12.0(1) | 1.087 | | | .752 | 7.82 |
| 10 | 8.1 | | | 20.0(1)<br>18.0(1) | 2.016 | | .687 | .877 | 7.10 |
| 12 | 6.3 | | | | | 4.300 | 1.449 | 1.968 | 12.40 |
| 14 | 4.9 | | | | | 6.100 | 3.051 | 3.614 | 17.71 |
| 16 | 3.8 | | | | | | 4.909 | 4.909 | 18.65 |
| 18 | 3.0 | | | | | | 7.169 | 7.169 | 21.51 |
| 20 | 2.2 | | | | | | 11.104 | 11.104 | 24.43 |
| 22 | 1.8 | | | | | | 15.272 | 15.272 | 27.49 |
| 24 | 1.4 | | | | | | 19.324 | 19.324 | 27.05 |
| 26 | 1.1 | | | | | | 24.116 | 24.116 | 26.53 |
| 28 | .9 | | | | | | 29.220 | 29.220 | 26.30 |

TABLE XV (CONTINUED)

HIGH PROPORTION OF LARGE TREES, ($q = 1.3$); LOW DENSITY, ($K = 20$)[h]

| Diameter Class d.b.h. | 10-Year Yield on the Stand | Optimum Product Complex and Associated Net Revenues: Short Post Size[c] | Short Post Value[d] | Long Post Size[c] | Long Post Value[d] | Class Pole Plus Pulp Value[e] | Sawlog Plus Pulp Value[f] | Net Value Per Tree[g] | Net Value of the Stand Yield |
|---|---|---|---|---|---|---|---|---|---|
| Inches | Trees | Feet | Dollars | Feet | Dollars | - Dollars - | | | |
| 4 | 6.9 | 6.5(3) | .027 | | | | | .027 | .19 |
| 6 | 5.4 | 10.0(2)<br>6.5(1) | .281 | 20.0(1)<br>6.5(1) | .683 | | | .305 | 1.65 |
| 8 | 4.2 | 8.0(1)<br>pulp (1) | .731 | 20.0(1)<br>12.0(1) | 1.087 | | | .752 | 3.16 |
| 10 | 3.2 | | | 20.0(1)<br>18.0(1) | 1.811 | | .480 | .669 | 2.14 |
| 12 | 2.5 | | | | | 4.300 | 1.010 | 1.480 | 3.70 |
| 14 | 1.9 | | | | | 6.100 | 2.130 | 2.700 | 5.12 |
| 16 | 1.5 | | | | | | 3.500 | 3.500 | 5.25 |
| 18 | 1.2 | | | | | | 5.110 | 5.110 | 6.13 |
| 20 | .9 | | | | | | 7.910 | 7.910 | 7.13 |
| 22 | .7 | | | | | | 10.880 | 10.880 | 7.62 |
| 24 | .6 | | | | | | 13.780 | 13.780 | 8.27 |
| 26 | .5 | | | | | | 17.200 | 17.200 | 8.60 |
| 28 | .3 | | | | | | 20.830 | 20.830 | 6.28 |

TABLE XV (CONTINUED)

LOW PROPORTION OF LARGE TREES, (q = 1.9); HIGH DENSITY, (K = 235)[i]

| Diameter Class d.b.h. | 10-Year Yield on the Stand | Optimum Product Complex and Associated Net Revenues: Short Post Size[c] | Short Post Value[d] | Long Post Size[c] | Long Post Value[d] | Class Pole Plus Pulp Value[e] | Sawlog Plus Pulp Value[f] | Net Value Per Tree[g] | Net Value of the Stand Yield |
|---|---|---|---|---|---|---|---|---|---|
| Inches | Trees | Feet | Dollars | Feet | Dollars | - Dollars - | | | |
| 4 | 116.4 | 6.5(3) | .162 | | | | | .162 | 18.86 |
| 6 | 62.0 | 10.0(2)<br>8.0(1) | .525 | 20.0(1)<br>8.0(1) | .925 | | | .550 | 34.10 |
| 8 | 33.0 | 10.0(3)<br>6.5(1) | 1.055 | 25.0(1)<br>10.0(1) | 1.382 | | | 1.074 | 35.44 |
| 10 | 17.6 | | | 20.0(1)<br>18.0(1) | 2.016 | | .581 | .786 | 13.83 |
| 12 | 9.4 | | | | | 5.080 | 1.226 | 1.777 | 16.76 |
| 14 | 4.9 | | | | | 7.000 | 2.579 | 3.211 | 15.73 |
| 16 | 2.6 | | | | | | 4.188 | 4.188 | 10.89 |
| 18 | 1.4 | | | | | | 6.116 | 6.116 | 8.59 |
| 20 | .7 | | | | | | 9.473 | 9.473 | 6.63 |
| 22 | .4 | | | | | | 13.030 | 13.030 | 5.21 |
| 24 | .2 | | | | | | 16.487 | 16.487 | 3.30 |
| 25 | .1 | | | | | | 18.548 | 18.548 | 1.85 |

TABLE XV (CONTINUED)

LOW PROPORTION OF LARGE TREES, (q = 1.9); LOW DENSITY, (K = 155)[j]

| Diameter Class d.b.h. | 10-Year Yield on the Stand | Optimum Product Complex and Associated Net Revenues: Short Post Size[c] | Short Post Value[d] | Long Post Size[c] | Long Post Value[d] | Class Pole Plus Pulp Value[e] | Sawlog Plus Pulp Value[f] | Net Value Per Tree[g] | Net Value of the Stand Yield |
|---|---|---|---|---|---|---|---|---|---|
| Inches | Trees | Feet | Dollars | Feet | Dollars | - Dollars - | | | |
| 4 | 76.7 | 6.5(3) | .096 | | | | | .096 | 7.36 |
| 6 | 40.9 | 10.0(2)<br>8.0(1) | .398 | 20.0(1)<br>8.0(1) | .815 | | | .422 | 17.26 |
| 8 | 21.8 | 10.0(3)<br>6.5(1) | .892 | 25.0(1)<br>10.0(1) | 1.184 | | | .909 | 19.82 |
| 10 | 11.6 | | | 20.0(1)<br>18.0(1) | 2.016 | | .479 | .699 | 8.11 |
| 12 | 6.2 | | | | | 5.080 | 1.011 | 1.592 | 9.87 |
| 14 | 3.3 | | | | | 7.000 | 2.130 | 2.826 | 9.33 |
| 16 | 1.8 | | | | | | 3.500 | 3.500 | 6.30 |
| 18 | .9 | | | | | | 5.111 | 5.111 | 4.60 |
| 20 | .5 | | | | | | 7.918 | 7.918 | 3.96 |
| 22 | .2 | | | | | | 10.890 | 10.890 | 2.18 |
| 24 | .2 | | | | | | 13.778 | 13.778 | 2.76 |
| 25 | .1 | | | | | | 15.501 | 15.501 | 1.55 |

TABLE XV (CONTINUED)

SUMMARY OF NET VALUES OF THE STAND YIELD

| Diameter Class Groups | Structure of the Forest Stand | | | |
|---|---|---|---|---|
| | q = 1.3 | | q = 1.9 | |
| | K = 50 | K = 20 | K = 235 | K = 155 |
| Inches | - Dollars - | | | |
| 4 - 8 | 12.37 | 5.00 | 88.40 | 44.44 |
| 10 - 14 | 37.21 | 10.96 | 46.26 | 27.31 |
| 16 - up | 171.96 | 49.25 | 36.44 | 21.35 |
| Total | 221.54 | 65.21 | 171.10 | 93.10 |

Footnotes to Table XV

[a]Site index, 55; and growth characteristics, c = 2.25, m = -0.0009.

[b]Post density, 3; pole density, 2; and sawlog density, 1. See page 62 for discussion.

[c]The figure in parentheses refers to the number of posts of the size indicated.

[d]Total value of the number of posts in the sizes indicated.

[e]Value of the class pole of maximum size for the trees considered. See page 63 for details. The residual volume was valued as pulpwood and added in to obtain the value of this complex.

[f]Volume of sawlogs was determined from form-class volume tables and valued accordingly. Residual pulpwood volumes were calculated as a fixed proportion of the sawlog volume per tree for each diameter class and the values added to the sawlog value.

[g]Weighted average of competing product groups in each diameter class. For weights used see page 25.

[h]Post density, 3; pole density, 3; and sawlog density, 3.

[i]Post density, 1; pole density, 2; and sawlog density, 2.

[j]Post density, 2; pole density, 2; and sawlog density, 3.

[k]Plus one stick of pulpwood.

yield greatest net revenues. In low density ranges the high proportion of small sized to larger sized trees yields greatest net revenues. However, where high densities are maintained, the larger proportion of large size to small size trees yields greatest net revenues. Since stand density is more easily altered than tree distribution, one would conclude that stands of low q and high K should be maintained to yield maximum net revenues.

If a land owner prefers to raise trees on a short rotation basis and the larger diameter classes are not well represented then the study would indicate that the high proportions of small size to large size trees should be maintained at high K levels. The net revenue associated with this class is higher than for most low density stands and is not much lower than the next best alternative, the lower q and high K. Table XVI illustrates this point in its extreme case.

## Conclusions

1. Prices for pine sawlogs, pulpwood, posts and poles delivered to mill or yard have been estimated for Eastern Oklahoma. Costs of converting standing timber to these salable products have also been estimated. From the selling prices and conversion costs, stumpage values have been calculated.
2. The 10-year growth of pine stands native to Eastern Oklahoma has been determined and this in turn was used to determine the yield of Eastern Oklahoma pine forest stands.

## TABLE XVI

### A COMPARISON OF NET DOLLAR YIELDS FROM A TYPICAL OKLAHOMA PINE FOREST BY EXTREME STRUCTURAL CHARACTERISTICS

| Diameter Class Groups d.b.h. Inches | Net Dollar Values of the Ten-Year Acre Yield[a] | | | | | |
|---|---|---|---|---|---|---|
| | Low Level of Stocking | | | High Level of Stocking | | |
| | q = 1.3 K = 20 | q = 1.9 K = 155 | Net Value Difference | q = 1.3 K = 50 | q = 1.9 K = 235 | Net Value Difference |
| 4, 6, 8 | 5.00 | 44.44 | 39.44 | 12.37 | 88.40 | 76.03 |
| 10, 12, 14 | 10.96 | 27.31 | 16.35 | 37.21 | 46.76 | 9.55 |
| 16 + | 49.25 | 21.35 | 27.90 | 171.96 | 36.44 | 35.52 |
| Total All Classes | 65.21 | 93.10 | 27.89 | 221.54 | 171.60 | 49.94 |

[a]The higher of the two values for a given density and diameter group is underlined for purposes of illustration. Site 55 and growth characteristics C = 2.25, m = -0.009.

3. Data pertaining to the size and quality of trees growing on Oklahoma sites has been collected and analyzed in order to determine product possibilities and limitations.

4. An IBM 650 computer program has been developed to analyze product complex possibilities of a tree given the size of the tree and the product specification.

5. After the product complexes for each possible tree size were determined a second computer program was devised to determine the product complex yield to maximum net returns given the product complexes and net revenues for individual products.

6. Forest stands of Oklahoma pine were classified by use of well-tested mathematical formulae used by foresters. Variables in the model described tree stands by diameter distribution and density. The forest stands were then projected through 10 years of growth and the yield in number of trees by diameter class was determined.

7. The maximum value per acre of the 10-year yield was then calculated for the optimum product complex on the basis of differing possible Eastern Oklahoma forest structures, sites and growth types.

8. For the present product price ratios, especially as long as the price ratio of sawlogs to pulpwood does not decrease too markedly and as long as the market demand for sawlogs holds at present levels, structures in the low q and high K range were found optimal for all sites and growth types. The closest to this optimum structure in terms of monetary return was the dense structure of young trees with high q and K values. The management costs of achieving these structures was ignored in this study.

9. Intermediate structures were found relatively unprofitable for present price ratios. The highest level of stocking for a given diameter distribution naturally yielded superior monetary returns. Thus, the level of stocking was a vital determinant of monetary returns, especially in structures with high proportions of large trees. High q, low K structures were always superior to low q, low K structures. Thus, for forests with high levels of stocking, large proportions of small trees yielded higher net values.

## Need for Further Research

In the introduction to this chapter, several assumptions underlying the method of this study were discussed. Since considerations of time forced these assumptions, it will be instructive to indicate at this point any conclusions that can be made concerning the usefulness of further study wherein some of the assumptions could be relaxed.

With regard to less limited objectives, but remaining in the general problem area of forest stand evaluation, the following seem to be the main gaps unearthed by this study.

### Pricing

There are no reliable price data for the raw materials used in the forest industry. This is especially true for price indexes and for price demand relationships at the retail level. If progress is to be made in developing models for evaluating optimum forest structures under changing and uncertain future demand situations, a basic requirement will be price and quantity data sufficiently observed to make estimates of retail demand relations possible. And since forest production is so lengthy a process, this lack is perhaps the most vital, since it was observed during the course of the research done in this study that optimum product complexes and therefore optimum forest structures were likely to be quite sensitive to changes in prices.

Costs

Among the costs not observed in this study is the cost of management of a forest. For some programs of thinning, costs may well be covered by returns from sale of products. Research is desirable on the problem of minimizing the over-all costs of management for a fixed or variable future market for products.

Costs associated with the lengthy production process in forestry and with the extensive use of land is another economic problem of forest management. This will be complicated in cases where alternative species or uses are available for the present forest land. Problems of uncertainity and discounting of net revenue flows were ignored in this study.

Harvest Periods

For the owner of large tracts of land, the length of time between harvests is not too important. Cutting may be done on one-tenth of the land each year of a ten-year harvest program. For the smaller forest owner, this is not true and even for the large owner this rate of total cutting is still not economically justifiable. Research into the economically optimum rate of harvest may well yield results somewhat different from rates of cut which maintain a forest of the maximum volume or other rates satisfying purely physical criteria.

For the small forest owner, the young dense forest (of high K and q values), harvested at twice the ten-year rate used in this study, might well optimize economic returns from the land use. The validity of this hypothesis needs checking especially against the costs of waiting for less frequent harvests. Certainly this study found that high K and q values were second only to high K and low q values in their ability to produce highest monetary returns from the 10-year yield. That faster rates of harvest would be more economical is therefore more than just a logical possibility; this study showed it was a likely inference.

Balance Versus Level of Stocking

At present, the demand for large sawlogs is sufficiently favorable that low q and high K structures were found invariably to produce the highest net monetary returns. Two factors may make this conclusion invalid. First, as is well known, the management costs associated with these structures are relatively high. Had the study included such costs these structures would have been found to yield much lower net returns relative to the other structures. Secondly, in the near future, the market for the products of such structures may encounter increasing competition from substitutes. The substitutes include the light metals, alloys, and minerals. But, in addition, pressed board materials are experiencing a revolution in manufacturing techniques and their associated costs. Thus, the high q, high K structures, already shown by study to hold second place in net monetary returns, will possibly take over as the highest revenue producing form of forest management in Eastern Oklahoma.

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# A P P E N D I C E S

## APPENDIX A, TABLE I

### PRORATION OF PINE CLASS POLE COSTS BY SITE INDEX, DENSITY, POLE LENGTH AND POLE CLASS IN EASTERN OKLAHOMA, 1960

| Site and Density | Pole Length | Pole Class 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | Feet | - Dollars Per Pole - | | | | | | |
| Site Index 55 | 30 | 3.94 | 3.32 | 2.70 | 2.21 | 1.69 | 1.31 | 1.01 |
| | 35 | 4.58 | 3.88 | 3.15 | 2.57 | 1.97 | 1.52 | 1.18 |
| Density I | 40 | 5.25 | 4.43 | 3.60 | 2.93 | 2.27 | 1.74 | 1.33 |
| | 45 | 5.91 | 4.99 | 4.05 | 3.30 | 2.55 | 1.95 | 1.50 |
| | 30 | 4.73 | 3.99 | 3.24 | 2.65 | 2.03 | 1.57 | 1.21 |
| | 35 | 5.50 | 4.65 | 3.78 | 3.09 | 2.37 | 1.83 | 1.41 |
| Density II | 40 | 6.30 | 5.32 | 4.32 | 3.52 | 2.73 | 2.08 | 1.59 |
| | 45 | 7.10 | 5.99 | 4.86 | 3.96 | 3.06 | 2.34 | 1.80 |
| | 30 | 5.52 | 4.65 | 3.78 | 3.09 | 2.37 | 1.83 | 1.41 |
| | 35 | 6.42 | 5.43 | 4.41 | 3.60 | 2.76 | 2.13 | 1.65 |
| Density III | 40 | 7.35 | 6.21 | 5.04 | 4.11 | 3.18 | 2.43 | 1.86 |
| | 45 | 8.28 | 6.99 | 5.67 | 4.62 | 3.57 | 2.73 | 2.10 |

APPENDIX A, TABLE I (CONTINUED)

| Site and Density | Pole Length | Pole Class | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Feet | - Dollars Per Pole - | | | | | | |
| Site Index 65 and 75 | 30 | 3.71 | 3.13 | 2.54 | 2.08 | 1.60 | 1.23 | .95 |
| | 35 | 4.32 | 3.65 | 2.97 | 2.42 | 1.86 | 1.43 | 1.11 |
| Density I | 40 | 4.95 | 4.18 | 3.39 | 2.77 | 2.14 | 1.64 | 1.25 |
| | 45 | 5.57 | 4.70 | 3.82 | 3.11 | 2.40 | 1.84 | 1.41 |
| | 50 | 6.18 | 5.23 | 4.24 | 3.45 | 2.67 | 2.06 | 1.57 |
| | 30 | 4.46 | 3.76 | 3.05 | 2.50 | 1.91 | 1.48 | 1.14 |
| | 35 | 5.19 | 4.39 | 3.56 | 2.91 | 2.23 | 1.72 | 1.33 |
| Density II | 40 | 5.94 | 5.02 | 4.07 | 3.32 | 2.57 | 1.96 | 1.50 |
| | 45 | 6.69 | 5.65 | 4.58 | 3.73 | 2.88 | 2.20 | 1.70 |
| | 50 | 7.41 | 6.28 | 5.09 | 4.14 | 3.20 | 2.47 | 1.89 |
| | 30 | 5.20 | 4.38 | 3.56 | 2.91 | 2.23 | 1.72 | 1.33 |
| | 35 | 6.05 | 5.12 | 4.15 | 3.39 | 2.60 | 2.01 | 1.55 |
| Density III | 40 | 6.92 | 5.85 | 4.75 | 3.87 | 3.00 | 2.29 | 1.75 |
| | 45 | 7.80 | 6.58 | 5.34 | 4.35 | 3.36 | 2.57 | 1.98 |
| | 50 | 8.65 | 7.32 | 5.93 | 4.83 | 3.73 | 2.88 | 2.20 |

APPENDIX A, TABLE I (CONTINUED)

| Site and Density | Pole Length | Pole Class | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | Feet | - Dollars Per Pole - | | | | | | |
| Site Index 85 | 30 | 3.88 | 3.27 | 2.66 | 2.17 | 1.67 | 1.29 | .99 |
| | 35 | 4.52 | 3.82 | 3.10 | 2.53 | 1.94 | 1.50 | 1.16 |
| Density I | 40 | 5.17 | 4.37 | 3.55 | 2.89 | 2.24 | 1.71 | 1.31 |
| | 45 | 5.83 | 4.92 | 3.99 | 3.25 | 2.51 | 1.92 | 1.48 |
| | 50 | 6.46 | 5.47 | 4.43 | 3.61 | 2.79 | 2.15 | 1.65 |
| | 30 | 4.66 | 3.93 | 3.19 | 2.61 | 2.00 | 1.55 | 1.19 |
| | 35 | 5.42 | 4.59 | 3.72 | 3.04 | 2.33 | 1.80 | 1.39 |
| Density II | 40 | 6.21 | 5.25 | 4.26 | 3.47 | 2.69 | 2.05 | 1.57 |
| | 45 | 6.99 | 5.90 | 4.79 | 3.90 | 3.02 | 2.31 | 1.77 |
| | 50 | 7.75 | 6.56 | 5.32 | 4.33 | 3.34 | 2.58 | 1.98 |
| | 30 | 5.44 | 4.58 | 3.72 | 3.04 | 2.34 | 1.80 | 1.39 |
| | 35 | 6.33 | 5.35 | 4.35 | 3.55 | 2.72 | 2.10 | 1.63 |
| Density III | 40 | 7.24 | 6.12 | 4.97 | 4.05 | 3.13 | 2.39 | 1.83 |
| | 45 | 8.16 | 6.89 | 5.59 | 4.55 | 3.52 | 2.69 | 2.07 |
| | 50 | 9.05 | 7.66 | 6.21 | 5.05 | 3.90 | 3.02 | 2.31 |

APPENDIX A, TABLE II

PRICES PAID FOR POSTS IN EASTERN OKLAHOMA ON MARCH 1, 1959
(CLEAN, PEELED, MERCHANTABLE, SOUTHERN YELLOW PINE POSTS)

| Post Length | Small End Post Diameter (Inches) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2.5 | 3 | 4 | 5 | 6 | 7 | 8 |
| Feet | - Dollars Per Post - | | | | | | |
| 6.5 | .400 | .195 | .245 | - | .306 | - | - |
| 7 | .160 | .215 | .265 | .300 | .320 | - | - |
| 8 | - | .260 | .290 | .320 | .560 | .560 | .890 |
| 10 | - | .300 | .600 | .600 | .700 | .850 | 1.100 |
| 12 | - | - | .720 | .720 | .720 | 1.250 | 1.850 |
| 14 | - | - | .910 | .910 | .920 | 1.500 | 2.190 |
| 16 | - | - | 1.040 | 1.140 | 1.140 | 1.650 | 2.720 |
| 18 | - | - | 1.170 | 1.300 | 1.800 | 1.800 | 3.060 |
| 20 | - | - | 1.400 | 1.500 | 2.000 | 2.000 | 3.900 |
| 25 | - | - | 1.500 | 2.150 | 2.550 | 2.650 | 5.500 |

Source: Price lists of Eastern Oklahoma firms.

## APPENDIX A, TABLE III

### PINE CLASS POLE PRICES BY POLE LENGTH AND POLE CLASS IN EASTERN OKLAHOMA

| Pole Length | Pole Class 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Feet | | | | - Dollars Per Pole - | | | |
| 30 | - | - | - | 4.50 | 3.75 | 3.10 | 2.75 |
| 35 | - | 10.00 | 7.75 | 7.50 | 7.00 | 4.50 | 3.25 |
| 40 | - | 12.00 | 11.00 | 9.75 | 8.50 | 6.75 | - |
| 45 | - | 13.50 | 12.50 | 11.00 | 9.50 | 7.50 | - |

Source: U. S. Forest Service, Appraisal Guide, 1958, (mimeographed) p. 12.

APPENDIX A, TABLE IV

NET VALUE OF PINE POSTS BY POST LENGTH, SMALL END DIAMETER, SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Post Length Feet | Small End Post Diameter Inches | Site Index 55 Density Level I | Site Index 55 Density Level II | Site Index 55 Density Level III | Site Indices 65 and 75 Density Level I | Site Indices 65 and 75 Density Level II | Site Indices 65 and 75 Density Level III | Site Index 85 Density Level I | Site Index 85 Density Level II | Site Index 85 Density Level III |
|---|---|---|---|---|---|---|---|---|---|---|
| | | - Dollars - | | | | | | | | |
| 6.5 | 2.5 | .027 | .005 | -.018 | .034 | .013 | -.008 | .029 | .007 | -.015 |
| | 3.0 | .082 | .060 | .037 | .089 | .068 | .047 | .084 | .062 | .040 |
| | 4.0 | .132 | .110 | .087 | .139 | .118 | .097 | .134 | .112 | .090 |
| | 6.0 | .187 | .165 | .142 | .194 | .173 | .152 | .189 | .167 | .145 |
| 7.0 | 2.5 | .012 | -.017 | -.046 | .021 | -.007 | -.034 | .015 | -.014 | -.043 |
| | 3.0 | .067 | .038 | .009 | .076 | .048 | .021 | .070 | .041 | .012 |
| | 4.0 | .117 | .088 | .059 | .126 | .098 | .071 | .120 | .091 | .062 |
| | 5.0 | .152 | .123 | .094 | .161 | .133 | .106 | .155 | .126 | .097 |
| | 6.0 | .172 | .143 | .114 | .181 | .153 | .126 | .175 | .146 | .117 |
| 8.0 | 3.0 | .078 | .045 | .005 | .088 | .054 | .020 | .080 | .045 | .009 |
| | 4.0 | .108 | .075 | .035 | .118 | .084 | .050 | .110 | .075 | .039 |
| | 5.0 | .138 | .105 | .065 | .148 | .114 | .080 | .140 | .105 | .069 |
| | 6.0 | .378 | .345 | .305 | .388 | .354 | .320 | .380 | .345 | .309 |
| | 7.0 | .378 | .345 | .305 | .388 | .354 | .320 | .380 | .345 | .309 |
| | 8.0 | .708 | .675 | .635 | .718 | .684 | .650 | .710 | .675 | .639 |
| 10.0 | 3.0 | .066 | .019 | -.027 | .079 | .035 | -.008 | .069 | .023 | -.023 |
| | 4.0 | .366 | .319 | .273 | .379 | .335 | .292 | .369 | .323 | .277 |
| | 5.0 | .366 | .319 | .273 | .379 | .335 | .292 | .369 | .323 | .277 |
| | 6.0 | .466 | .419 | .373 | .479 | .435 | .392 | .469 | .423 | .377 |
| | 7.0 | .616 | .569 | .523 | .629 | .585 | .542 | .619 | .573 | .527 |
| | 8.0 | .866 | .819 | .773 | .879 | .835 | .792 | .869 | .823 | .777 |
| 12.0 | 4.0 | .399 | .335 | .271 | .418 | .357 | .297 | .404 | .341 | .278 |
| | 5.0 | .399 | .335 | .271 | .418 | .357 | .297 | .404 | .341 | .278 |
| | 6.0 | .399 | .335 | .378 | .418 | .357 | .297 | .404 | .341 | .278 |
| | 7.0 | .929 | .865 | .801 | .848 | .887 | .827 | .934 | .871 | .808 |
| | 8.0 | 1.529 | 1.465 | 1.401 | 1.548 | 1.487 | 1.427 | 1.534 | 1.471 | 1.408 |

APPENDIX A, TABLE IV (CONTINUED)

| Post Length | Small End Post Diameter | Site Index 55 Density Level I | Site Index 55 Density Level II | Site Index 55 Density Level III | Site Indices 65 and 75 Density Level I | Site Indices 65 and 75 Density Level II | Site Indices 65 and 75 Density Level III | Site Index 85 Density Level I | Site Index 85 Density Level II | Site Index 85 Density Level III |
|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Inches | | | | - Dollars - | | | | | |
| 14.0 | 4.0 | .528 | .452 | .376 | .550 | .479 | .407 | .534 | .459 | .384 |
| | 5.0 | .528 | .452 | .376 | .550 | .479 | .407 | .534 | .459 | .384 |
| | 6.0 | .538 | .462 | .386 | .560 | .489 | .417 | .544 | .469 | .394 |
| | 7.0 | 1.118 | 1.042 | .966 | 1.140 | 1.069 | .997 | 1.124 | 1.049 | .974 |
| | 8.0 | 1.808 | 1.732 | 1.656 | 1.830 | 1.759 | 1.687 | 1.814 | 1.739 | 1.664 |
| 16.0 | 4.0 | .606 | .520 | .434 | .631 | .550 | .469 | .613 | .528 | .442 |
| | 5.0 | .706 | .620 | .534 | .731 | .650 | .569 | .713 | .628 | .542 |
| | 6.0 | .706 | .620 | .534 | .731 | .650 | .569 | .713 | .628 | .542 |
| | 7.0 | 1.216 | 1.130 | 1.044 | 1.241 | 1.160 | 1.079 | 1.223 | 1.138 | 1.052 |
| | 8.0 | 2.286 | 2.200 | 2.114 | 2.311 | 2.230 | 2.149 | 2.293 | 2.208 | 2.122 |
| 18.0 | 4.0 | .684 | .588 | .491 | .712 | .621 | .530 | .691 | .596 | .501 |
| | 5.0 | .814 | .718 | .621 | .842 | .751 | .660 | .821 | .726 | .631 |
| | 6.0 | 1.314 | 1.218 | 1.121 | 1.342 | 1.251 | 1.160 | 1.321 | 1.226 | 1.131 |
| | 7.0 | 1.314 | 1.218 | 1.121 | 1.342 | 1.251 | 1.160 | 1.321 | 1.226 | 1.131 |
| | 8.0 | 2.574 | 2.478 | 2.381 | 2.602 | 2.511 | 2.420 | 2.581 | 2.486 | 2.391 |
| 20.0 | 4.0 | .862 | .755 | .648 | .893 | .792 | .692 | .870 | .764 | .659 |
| | 5.0 | .962 | .855 | .748 | .993 | .892 | .792 | .970 | .864 | .759 |
| | 6.0 | 1.462 | 1.355 | 1.248 | 1.493 | 1.392 | 1.292 | 1.470 | 1.364 | 1.259 |
| | 7.0 | 1.462 | 1.355 | 1.248 | 1.493 | 1.392 | 1.292 | 1.470 | 1.364 | 1.259 |
| | 8.0 | 3.362 | 3.255 | 3.148 | 3.393 | 3.292 | 3.192 | 3.370 | 3.264 | 3.159 |
| 25.0 | 4.0 | .741 | .590 | .439 | .785 | .642 | .500 | .752 | .603 | .454 |
| | 5.0 | 1.391 | 1.240 | 1.089 | 1.435 | 1.292 | 1.150 | 1.402 | 1.253 | .759 |
| | 6.0 | 1.791 | 1.640 | 1.489 | 1.835 | 1.692 | 1.550 | 1.802 | 1.653 | 1.504 |
| | 7.0 | 1.891 | 1.740 | 1.589 | 1.935 | 1.792 | 1.650 | 1.902 | 1.753 | 1.604 |
| | 8.0 | 4.741 | 4.590 | 4.439 | 4.785 | 4.642 | 4.500 | 4.752 | 4.603 | 4.454 |

APPENDIX A, TABLE V

NET VALUE OF PINE PULPWOOD BY SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| Density Level | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
|---|---|---|---|---|
| | | - Dollars Per Cord - | | |
| I | 4.76 | 5.35 | 5.35 | 4.91 |
| II | 3.20 | 3.88 | 3.88 | 3.37 |
| III | 1.90 | 2.65 | 2.65 | 2.09 |

## APPENDIX A, TABLE VI

### PRORATION OF PINE PULPWOOD VALUE FOR STICKS FIVE FEET LONG, BY LARGE AND SMALL END DIAMETER, SITE INDEX AND DENSITY LEVEL IN EASTERN OKLAHOMA, 1960

| | Site Index 55, Density Level I | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
| Diameter at Large End (Inches Inside Bark) | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0076 | | | | | | | | | | | |
| 3.0 | .0090 | .0105 | | | | | | | | | | |
| 3.5 | .0105 | .0123 | .0138 | | | | | | | | | |
| 4.0 | .0128 | .0148 | .0162 | .0186 | | | | | | | | |
| 4.5 | .0153 | .0171 | .0186 | .0210 | .0233 | | | | | | | |
| 5.0 | .0181 | .0195 | .0214 | .0238 | .0162 | .0286 | | | | | | |
| 5.5 | | .0223 | .0243 | .0266 | .0291 | .0314 | .0348 | | | | | |
| 6.0 | | | .0276 | .0300 | .0324 | .0353 | .0381 | .0414 | | | | |
| 6.5 | | | | .0338 | .0361 | .0386 | .0414 | .0453 | .0486 | | | |
| 7.0 | | | | | .0400 | .0424 | .0457 | .0491 | .0529 | .0566 | | |
| 7.5 | | | | | | .0466 | .0495 | .0533 | .0566 | .0609 | .0647 | |
| 8.0 | | | | | | | .0538 | .0571 | .0609 | .0652 | .0690 | .0733 |
| 8.5 | | | | | | | | .0611 | .0662 | .0699 | .0742 | .0785 |
| 9.0 | | | | | | | | | .0714 | .0752 | .0795 | .0837 |
| 9.5 | | | | | | | | | | .0814 | .0857 | .0900 |
| 10.0 | | | | | | | | | | | .0904 | .0947 |

APPENDIX A, TABLE VI (CONTINUED)

| | Site Index 55, Density Level II — Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter at Large End (Inches Inside Bark) | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0051 | | | | | | | | | | | |
| 3.0 | .0061 | .0071 | | | | | | | | | | |
| 3.5 | .0071 | .0083 | .0093 | | | | | | | | | |
| 4.0 | .0086 | .0099 | .0109 | .0125 | | | | | | | | |
| 4.5 | .0103 | .0115 | .0125 | .0141 | .0157 | | | | | | | |
| 5.0 | .0121 | .0131 | .0144 | .0160 | .0177 | .0192 | | | | | | |
| 5.5 | | .0150 | .0163 | .0179 | .0195 | .0211 | .0234 | | | | | |
| 6.0 | | | .0185 | .0202 | .0217 | .0237 | .0256 | .0278 | | | | |
| 6.5 | | | | .0227 | .0243 | .0259 | .0278 | .0305 | .0327 | | | |
| 7.0 | | | | | .0269 | .0285 | .0307 | .0330 | .0355 | .0381 | | |
| 7.5 | | | | | | .0313 | .0333 | .0359 | .0381 | .0409 | .0435 | |
| 8.0 | | | | | | | .0362 | .0384 | .0409 | .0438 | .0464 | .0493 |
| 8.5 | | | | | | | | .0419 | .0445 | .0470 | .0499 | .0528 |
| 9.0 | | | | | | | | | .0480 | .0505 | .0534 | .0563 |
| 9.5 | | | | | | | | | | .0547 | .0576 | .0605 |
| 10.0 | | | | | | | | | | | .0608 | .0637 |

APPENDIX A, TABLE VI (CONTINUED)

| Diameter at Large End (Inches Inside Bark) | Site Index 55, Density Level III<br>Diameter at Small End (Inches Inside Bark)<br>2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0030 | | | | | | | | | | | |
| 3.0 | .0036 | .0042 | | | | | | | | | | |
| 3.5 | .0042 | .0049 | .0055 | | | | | | | | | |
| 4.0 | .0051 | .0059 | .0065 | .0074 | | | | | | | | |
| 4.5 | .0061 | .0068 | .0074 | .0084 | .0093 | | | | | | | |
| 5.0 | .0072 | .0078 | .0085 | .0095 | .0105 | .0114 | | | | | | |
| 5.5 | | .0089 | .0097 | .0106 | .0116 | .0125 | .0139 | | | | | |
| 6.0 | | | .0110 | .0120 | .0129 | .0141 | .0152 | .0165 | | | | |
| 6.5 | | | | .0135 | .0144 | .0154 | .0165 | .0181 | .0194 | | | |
| 7.0 | | | | | .0160 | .0169 | .0182 | .0196 | .0211 | .0226 | | |
| 7.5 | | | | | | .0186 | .0198 | .0213 | .0226 | .0243 | .0258 | |
| 8.0 | | | | | | | .0215 | .0228 | .0243 | .0260 | .0275 | .0293 |
| 8.5 | | | | | | | | .0249 | .0264 | .0279 | .0296 | .0313 |
| 9.0 | | | | | | | | | .0285 | .0300 | .0317 | .0334 |
| 9.5 | | | | | | | | | | .0325 | .0342 | .0359 |
| 10.0 | | | | | | | | | | | .0361 | .0378 |

APPENDIX A, TABLE VI (CONTINUED)

Site Indexes 65 and 75 Density Level I

| Diameter at Large End (Inches Inside Bark) | Diameter at Small End (Inches Inside Bark) 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0085 | | | | | | | | | | | |
| 3.0 | .0102 | .0118 | | | | | | | | | | |
| 3.5 | .0118 | .0139 | .0155 | | | | | | | | | |
| 4.0 | .0144 | .0166 | .0182 | .0209 | | | | | | | | |
| 4.5 | .0171 | .0192 | .0209 | .0236 | .0262 | | | | | | | |
| 5.0 | .0203 | .0220 | .0240 | .0268 | .0295 | .0321 | | | | | | |
| 5.5 | | .0251 | .0273 | .0299 | .0327 | .0353 | .0391 | | | | | |
| 6.0 | | | .0310 | .0337 | .0364 | .0398 | .0428 | .0465 | | | | |
| 6.5 | | | | .0380 | .0406 | .0434 | .0465 | .0509 | .0546 | | | |
| 7.0 | | | | | .0450 | .0476 | .0513 | .0551 | .0595 | .0637 | | |
| 7.5 | | | | | | .0524 | .0557 | .0599 | .0637 | .0683 | .0727 | |
| 8.0 | | | | | | | .0605 | .0642 | .0683 | .0733 | .0775 | .0824 |
| 8.5 | | | | | | | | .0701 | .0744 | .0786 | .0834 | .0882 |
| 9.0 | | | | | | | | | .0803 | .0845 | .0893 | .0941 |
| 9.5 | | | | | | | | | | .0915 | .0963 | .1011 |
| 10.0 | | | | | | | | | | | .1017 | .1065 |

APPENDIX A, TABLE VI (CONTINUED)

| Diameter at Large End (Inches Inside Bark) | Site Indexes 65 and 75 Density Level II Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0062 | | | | | | | | | | | |
| 3.0 | .0074 | .0086 | | | | | | | | | | |
| 3.5 | .0086 | .0101 | .0112 | | | | | | | | | |
| 4.0 | .0105 | .0120 | .0132 | .0151 | | | | | | | | |
| 4.5 | .0124 | .0139 | .0151 | .0171 | .0190 | | | | | | | |
| 5.0 | .0147 | .0159 | .0174 | .0194 | .0214 | .0233 | | | | | | |
| 5.5 | | .0182 | .0198 | .0217 | .0237 | .0256 | .0284 | | | | | |
| 6.0 | | | .0225 | .0245 | .0264 | .0288 | .0310 | .0337 | | | | |
| 6.5 | | | | .0205 | .0295 | .0314 | .0337 | .0369 | .0396 | | | |
| 7.0 | | | | | .0326 | .0345 | .0372 | .0400 | .0431 | .0462 | | |
| 7.5 | | | | | | .0380 | .0404 | .0435 | .0462 | .0496 | .0527 | |
| 8.0 | | | | | | | .0439 | .0466 | .0496 | .0531 | .0562 | .0598 |
| 8.5 | | | | | | | | .0508 | .0539 | .0570 | .0605 | .0640 |
| 9.0 | | | | | | | | | .0582 | .0613 | .0648 | .0683 |
| 9.5 | | | | | | | | | | .0664 | .0698 | .0733 |
| 10.0 | | | | | | | | | | | .0737 | .0773 |

APPENDIX A, TABLE VI (CONTINUED)

| | Site Indexes 65 and 75 Density Level III<br>Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter at Large End (Inches Inside Bark) | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0042 | | | | | | | | | | | |
| 3.0 | .0050 | .0058 | | | | | | | | | | |
| 3.5 | .0058 | .0069 | .0077 | | | | | | | | | |
| 4.0 | .0071 | .0082 | .0091 | .0103 | | | | | | | | |
| 4.5 | .0085 | .0095 | .0103 | .0117 | .0130 | | | | | | | |
| 5.0 | .0100 | .0109 | .0119 | .0133 | .0146 | .0159 | | | | | | |
| 5.5 | | .0124 | .0135 | .0148 | .0162 | .0175 | .0194 | | | | | |
| 6.0 | | | .0154 | .0167 | .0180 | .0197 | .0212 | .0230 | | | | |
| 6.5 | | | | .0188 | .0201 | .0215 | .0230 | .0252 | .0270 | | | |
| 7.0 | | | | | .0223 | .0236 | .0254 | .0273 | .0294 | .0315 | | |
| 7.5 | | | | | | .0260 | .0276 | .0297 | .0315 | .0339 | .0360 | |
| 8.0 | | | | | | | .0300 | .0318 | .0339 | .0363 | .0384 | .0409 |
| 8.5 | | | | | | | | .0347 | .0368 | .0389 | .0413 | .0437 |
| 9.0 | | | | | | | | | .0397 | .0418 | .0442 | .0466 |
| 9.5 | | | | | | | | | | .0453 | .0477 | .0501 |
| 10.0 | | | | | | | | | | | .0503 | .0527 |

APPENDIX A, TABLE VI (CONTINUED)

| | Site Index 85 Density Level I | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
| Diameter at Large End (Inches Inside Bark) | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0078 | | | | | | | | | | | |
| 3.0 | .0093 | .0106 | | | | | | | | | | |
| 3.5 | .0108 | .0127 | .0142 | | | | | | | | | |
| 4.0 | .0132 | .0152 | .0167 | .0191 | | | | | | | | |
| 4.5 | .0157 | .0176 | .0191 | .0216 | .0240 | | | | | | | |
| 5.0 | .0186 | .0201 | .0220 | .0245 | .0271 | .0295 | | | | | | |
| 5.5 | | .0230 | .0251 | .0275 | .0300 | .0324 | .0359 | | | | | |
| 6.0 | | | .0285 | .0310 | .0334 | .0364 | .0393 | .0427 | | | | |
| 6.5 | | | | .0349 | .0373 | .0398 | .0427 | .0467 | .0501 | | | |
| 7.0 | | | | | .0413 | .0437 | .0471 | .0506 | .0545 | .0584 | | |
| 7.5 | | | | | | .0481 | .0511 | .0550 | .0584 | .0628 | .0667 | |
| 8.0 | | | | | | | .0555 | .0589 | .0628 | .0672 | .0711 | .0757 |
| 8.5 | | | | | | | | .0643 | .0682 | .0721 | .0766 | .0810 |
| 9.0 | | | | | | | | | .0737 | .0776 | .0820 | .0864 |
| 9.5 | | | | | | | | | | .0840 | .0884 | .0928 |
| 10.0 | | | | | | | | | | | .0933 | .0977 |

APPENDIX A, TABLE VI (CONTINUED)

Site Index 85 Density Level II

| Diameter at Large End (Inches Inside Bark) | Diameter at Small End (Inches Inside Bark) 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0054 | | | | | | | | | | | |
| 3.0 | .0064 | .0074 | | | | | | | | | | |
| 3.5 | .0074 | .0088 | .0098 | | | | | | | | | |
| 4.0 | .0091 | .0105 | .0115 | .0131 | | | | | | | | |
| 4.5 | .0108 | .0121 | .0131 | .0149 | .0165 | | | | | | | |
| 5.0 | .0128 | .0138 | .0151 | .0169 | .0186 | .0202 | | | | | | |
| 5.5 | | .0158 | .0172 | .0188 | .0206 | .0222 | .0246 | | | | | |
| 6.0 | | | .0195 | .0213 | .0229 | .0250 | .0270 | .0293 | | | | |
| 6.5 | | | | .0239 | .0256 | .0273 | .0293 | .0321 | .0344 | | | |
| 7.0 | | | | | .0283 | .0300 | .0323 | .0347 | .0374 | .0401 | | |
| 7.5 | | | | | | .0330 | .0351 | .0378 | .0401 | .0431 | .0458 | |
| 8.0 | | | | | | | .0381 | .0404 | .0431 | .0461 | .0488 | .0519 |
| 8.5 | | | | | | | | .0442 | .0468 | .0495 | .0525 | .0556 |
| 9.0 | | | | | | | | | .0505 | .0532 | .0562 | .0593 |
| 9.5 | | | | | | | | | | .0576 | .0607 | .0637 |
| 10.0 | | | | | | | | | | | .0640 | .0671 |

APPENDIX A, TABLE VI (CONTINUED)

| | Site Index 85 Density Level III | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter at Small End (Inches Inside Bark) | | | | | | | | | | | |
| Diameter at Large End (Inches Inside Bark) | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | - Dollars - | | | | | | | | | | | |
| 2.5 | .0033 | | | | | | | | | | | |
| 3.0 | .0040 | .0046 | | | | | | | | | | |
| 3.5 | .0046 | .0054 | .0061 | | | | | | | | | |
| 4.0 | .0056 | .0065 | .0071 | .0081 | | | | | | | | |
| 4.5 | .0067 | .0075 | .0081 | .0092 | .0102 | | | | | | | |
| 5.0 | .0079 | .0086 | .0094 | .0105 | .0115 | .0125 | | | | | | |
| 5.5 | | .0098 | .0107 | .0117 | .0128 | .0138 | .0153 | | | | | |
| 6.0 | | | .0121 | .0132 | .0155 | .0155 | .0167 | .0182 | | | | |
| 6.5 | | | | .0148 | .0158 | .0169 | .0182 | .0199 | .0213 | | | |
| 7.0 | | | | | .0176 | .0186 | .0200 | .0216 | .0232 | .0249 | | |
| 7.5 | | | | | | .0205 | .0218 | .0234 | .0249 | .0267 | .0284 | |
| 8.0 | | | | | | | .0236 | .0251 | .0267 | .0286 | .0303 | .0322 |
| 8.5 | | | | | | | | .0274 | .0290 | .0307 | .0326 | .0344 |
| 9.0 | | | | | | | | | .0313 | .0330 | .0349 | .0367 |
| 9.5 | | | | | | | | | | .0357 | .0376 | .0395 |
| 10.0 | | | | | | | | | | | .0397 | .0416 |

APPENDIX B, TABLE I

VOLUME OF CLASS POLES BY CLASS AND LENGTH

| Pole Class | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | Midpoint of Diameter Range (Inches)[a] | | | | | | |
| Length | 13.9 | 13.1 | 12.2 | 11.4 | 10.5 | 9.7 | 9.0 |
| Feet | - Thousand Board Feet (Doyle) - | | | | | | |
| 30 | .184 | .155 | .126 | .103 | .079 | .061 | .047 |
| 35 | .214 | .181 | .147 | .120 | .092 | .071 | .055 |
| 40 | .245 | .207 | .168 | .137 | .106 | .081 | .062 |
| 45 | .276 | .233 | .189 | .154 | .119 | .091 | .070 |
| 50 | .306 | .259 | .210 | .171 | .132 | .102 | .078 |

[a]This range taken from American Standards Association Specifications.

APPENDIX B, TABLE II

LARGEST SMALL END DIAMETER POST POSSIBLE FOR PINE TREES BY SITE INDEX AND D.B.H. CLASS IN EASTERN OKLAHOMA

| Post Length | D.B.H. Class | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
|---|---|---|---|---|---|
| Feet | | - Inches - | | | |
| 6.5 | 4 | 3 | 3 | 3 | 3 |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 6 | 6 | 6 | 6 |
| 7.0 | 4 | 3 | 3 | 3 | 3 |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 8 | 8 | 8 | 8 |
| 8.0 | 4 | 3 | 3 | 3 | 3 |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 8 | 8 | 8 | 8 |
| 10.0 | 4 | 3 | 3 | 3 | 3 |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 8 | 8 | 8 | 8 |
| 12.0 | 4 | - | - | - | - |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 8 | 8 | 8 | 8 |
| 14.0 | 4 | - | - | - | - |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 6 | 6 | 6 | 6 |
| | 10 | 7 | 7 | 7 | 7 |
| 16.0 | 4 | - | - | - | - |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 5 | 6 | 6 | 6 |
| | 10 | 7 | 7 | 7 | 7 |
| 18.0 | 4 | - | - | - | - |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 5 | 5 | 6 | 6 |
| | 10 | 7 | 7 | 7 | 7 |
| 20.0 | 4 | - | - | - | - |
| | 6 | 4 | 4 | 4 | 4 |
| | 8 | 5 | 5 | 5 | 6 |
| | 10 | 7 | 7 | 7 | 7 |
| 25.0 | 4 | - | - | - | - |
| | 6 | - | - | 4 | 4 |
| | 8 | 5 | 5 | 5 | 5 |
| | 10 | 6 | 7 | 7 | 7 |

APPENDIX B, TABLE III

NUMBER OF LINEAR FEET IN PINE TREES AVAILABLE FOR POSTS OF VARIOUS LENGTHS BY SITE INDEX AND DIAMETER CLASS IN EASTERN OKLAHOMA

| | 4" D.B.H. | | | | 6" D.B.H. | | | |
|---|---|---|---|---|---|---|---|---|
| Post Length | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
| Feet | | | | - Feet - | | | | |
| 5.0 | 20.0 | 22.0 | 22.5 | 24.0 | 30.3 | 35.0 | 38.5 | 42.6 |
| 6.5 | 20.0 | 22.0 | 22.5 | 24.0 | 30.3 | 35.0 | 38.5 | 42.6 |
| 7.0 | 20.0 | 22.0 | 22.5 | 24.0 | 30.3 | 35.0 | 38.5 | 42.6 |
| 8.0 | 13.0 | 13.2 | 13.9 | 14.9 | 28.2 | 32.4 | 35.6 | 40.1 |
| 10.0 | 13.0 | 13.2 | 13.9 | 14.9 | 28.2 | 32.4 | 35.6 | 40.1 |
| 12.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |
| 14.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |
| 16.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |
| 18.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |
| 20.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |
| 25.0 | - | - | - | - | 21.5 | 24.0 | 25.0 | 28.0 |

| | 8" D.B.H. | | | | 10" D.B.H. | | | |
|---|---|---|---|---|---|---|---|---|
| Post Length | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 | Site Index 55 | Site Index 65 | Site Index 75 | Site Index 85 |
| Feet | | | | - Feet | | | | |
| 5.0 | 37.5 | 43.7 | 49.9 | 56.1 | 42.5 | 50.4 | 59.3 | 67.2 |
| 6.5 | 37.5 | 43.7 | 49.9 | 56.1 | 42.5 | 50.4 | 59.3 | 67.2 |
| 7.0 | 37.5 | 43.7 | 49.9 | 56.1 | 42.5 | 50.4 | 59.3 | 67.2 |
| 8.0 | 36.2 | 42.2 | 48.5 | 54.5 | 41.5 | 49.3 | 57.9 | 65.7 |
| 10.0 | 36.2 | 42.2 | 48.5 | 54.5 | 41.5 | 49.3 | 57.9 | 65.7 |
| 12.0 | 32.9 | 38.0 | 43.5 | 48.7 | 39.7 | 47.1 | 49.9 | 62.7 |
| 14.0 | 32.9 | 38.0 | 43.5 | 48.7 | 39.7 | 47.1 | 49.9 | 62.7 |
| 16.0 | 32.9 | 38.0 | 43.5 | 48.7 | 39.7 | 47.1 | 49.9 | 62.7 |
| 18.0 | 32.9 | 38.0 | 43.5 | 48.7 | 39.7 | 47.1 | 49.9 | 62.7 |
| 25.0 | 32.9 | 38.0 | 43.5 | 48.7 | 39.7 | 47.1 | 49.9 | 62.7 |

APPENDIX B, TABLE IV

CUBIC FOOT VOLUME OF WOOD STICKS FIVE FOOT LONG BASED ON SMALIAN FORMULA

$$\left( v = \frac{(B_1 + B_2)}{2} XL \right)$$

| Diameter at Large End (Inches Inside Bark) | Diameter at Small End (Inches Inside Bark) 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | - Cubic Feet | | | | | | |
| 2.5 | .175 | | | | | | | | | | | |
| 3.0 | .212 | .250 | | | | | | | | | | |
| 3.5 | .252 | .290 | .330 | | | | | | | | | |
| 4.0 | .307 | .345 | .385 | .440 | | | | | | | | |
| 4.5 | .362 | .400 | .440 | .495 | .550 | | | | | | | |
| 5.0 | .425 | .462 | .500 | .557 | .612 | .675 | | | | | | |
| 5.5 | | .532 | .572 | .627 | .682 | .745 | .815 | | | | | |
| 6.0 | | | .652 | .707 | .762 | .825 | .895 | .975 | | | | |
| 6.5 | | | | .792 | .847 | .910 | .980 | 1.060 | 1.145 | | | |
| 7.0 | | | | | .942 | 1.000 | 1.075 | 1.155 | 1.240 | 1.335 | | |
| 7.5 | | | | | | 1.100 | 1.170 | 1.250 | 1.335 | 1.430 | 1.520 | |
| 8.0 | | | | | | | 1.270 | 1.350 | 1.435 | 1.530 | 1.625 | 1.725 |
| 8.5 | | | | | | | | 1.470 | 1.555 | 1.630 | 1.745 | 1.845 |
| 9.0 | | | | | | | | | 1.680 | 1.775 | 1.870 | 1.970 |
| 9.5 | | | | | | | | | | 1.917 | 2.012 | 2.112 |
| 10.0 | | | | | | | | | | | 2.130 | 2.230 |

## APPENDIX B, TABLE V

## FRACTIONAL PART OF LONG CORD OF WOOD BOLTS FIVE FEET LONG LARGE AND SMALL END DIAMETER (BASED ON SMALIAN)

| Large End Diameter (Inches Inside Bark) | Diameter at Small End (Inches Inside Bark) 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | - Cubic Feet - | | | | | | | | | | | |
| 2.5 | .0016 | | | | | | | | | | | |
| 3.0 | .0019 | .0022 | | | | | | | | | | |
| 3.5 | .0022 | .0026 | .0029 | | | | | | | | | |
| 4.0 | .0027 | .0031 | .0034 | .0039 | | | | | | | | |
| 4.5 | .0032 | .0036 | .0039 | .0044 | .0049 | | | | | | | |
| 5.0 | .0038 | .0041 | .0045 | .0050 | .0055 | .0060 | | | | | | |
| 5.5 | | .0047 | .0051 | .0056 | .0061 | .0066 | .0073 | | | | | |
| 6.0 | | | .0058 | .0063 | .0068 | .0074 | .0080 | .0087 | | | | |
| 6.5 | | | | .0071 | .0076 | .0081 | .0087 | .0095 | .0102 | | | |
| 7.0 | | | | | .0084 | .0089 | .0096 | .0103 | .0111 | .0119 | | |
| 7.5 | | | | | | .0098 | .0104 | .0112 | .0119 | .0128 | .0136 | |
| 8.0 | | | | | | | .0113 | .0120 | .0128 | .0137 | .0145 | .0154 |
| 8.5 | | | | | | | | .0131 | .0139 | .0147 | .0156 | .0165 |
| 9.0 | | | | | | | | | .0150 | .0158 | .0167 | .0176 |
| 9.5 | | | | | | | | | | .0171 | .0180 | .0189 |
| 10.0 | | | | | | | | | | | .0190 | .0199 |

APPENDIX B, TABLE VI

PARAMETERS FOR SAWLOG LENGTHS IN EASTERN OKLAHOMA, 1960

| Logs | Feet | | Feet |
|---|---|---|---|
| 1.0 | 9.4 | to | 20.0 |
| 1.5 | 20.1 | to | 28.0 |
| 2.0 | 28.1 | to | 36.0 |
| 2.5 | 36.1 | to | 44.0 |
| 3.0 | 44.1 | to | 52.0 |
| 3.5 | 52.1 | to | 60.0 |
| 4.0 | 60.1 | to | 68.0 |
| 4.5 | 68.1 | to | 76.0 |
| 5.0 | 76.1 | to | 84.0 |
| 5.5 | 84.1 | to | 92.0 |

APPENDIX B, TABLE VII

LENGTH, NUMBER OF LOGS, AND FORM CLASS OF SAWLOG TREES BY DIAMETER CLASS AND SITE INDEX IN EASTERN OKLAHOMA, 1960

| | Site Index | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 55 | | | 65 | | | 75 | | | 85 | | |
| D.B.H. | Length | No. Logs | Form Class | Length | No. Logs | Form Class | Length | No. Logs | Form Class | Length | No. Logs | Form Class |
| Inches | Feet | | Percent | Feet | | Percent | Feet | | Percent | Feet | | Percent |
| 10 | 32.4 | 2.0 | 76 | 38.2 | 2.5 | 76 | 43.8 | 2.5 | 78 | 51.5 | 3.0 | 79 |
| 12 | 35.3 | 2.0 | 76 | 39.4 | 2.5 | 77 | 50.0 | 3.0 | 78 | 57.0 | 3.5 | 79 |
| 14 | 37.8 | 2.5 | 77 | 46.0 | 3.0 | 78 | 54.7 | 3.5 | 78 | 61.8 | 4.0 | 79 |
| 16 | 39.8 | 2.5 | 77 | 48.8 | 3.0 | 78 | 58.2 | 3.5 | 78 | 65.5 | 4.0 | 79 |
| 18 | 41.9 | 2.5 | 77 | 51.4 | 3.0 | 78 | 60.0 | 3.5 | 79 | 67.8 | 4.0 | 80 |
| 20 | 45.6 | 3.0 | 77 | 56.3 | 3.5 | 78 | 65.1 | 4.0 | 80 | 76.1 | 4.5 | 80 |
| 22 | 43.9 | 3.0 | 78 | 53.9 | 3.5 | 79 | 62.6 | 4.0 | 80 | 73.5 | 4.5 | 81 |
| 24 | 46.7 | 3.0 | 78 | 57.5 | 3.5 | 79 | 66.2 | 4.0 | 80 | 77.7 | 5.0 | 81 |
| 25 | 48.0 | 3.0 | 78 | 59.6 | 3.5 | 79 | 67.5 | 4.0 | 80 | 79.8 | 5.0 | 81 |
| 26 | 49.8 | 3.0 | 78 | 60.0 | 3.5 | 79 | 68.8 | 4.5 | 80 | 81.5 | 5.0 | 81 |
| 28 | 51.0 | 3.0 | 78 | 62.0 | 4.0 | 79 | 71.3 | 4.5 | 80 | 84.7 | 5.5 | 81 |

## APPENDIX C, TABLE I

## FORTRAN STATEMENTS FOR PROGRAM USED TO GENERATE STANDS AND YIELDS FROM STANDS

```
  1000 0 DIMENSION AK(20),C(6),AM(15),
  1000 1 AKP(6),Y(6)
     5 0 READ,ID
         PUNCH,ID
C 0000 0
         READ,Q1,DQ,QF
         READ,X1,DX,XF,XX
C 0000 0
         Q=Q1
         NQ=10000000
C 0000 0
         READ,NC
         DO 10 I=1,NC
    10 0 READ,C(I)
         DO 15,I=1,6
    15 0 Y(I)= 0.
C 0000 0
         READ,NAM
         DO 20 I=1,NAM
    20 0 READ,AM(I)
C 0000 0
    25 0 PUNCH,ID,Q
         READ,NAK
         DO 30 I=1,NAK
    30 0 READ,AK(I)
C 0000 0
         DO 100 I=1,NAK
         PUNCH,ID,Q,AK(I)
         DO 100 K=1,NAM
         PUNCH,ID,Q,AK(I),AM(K)
C 0000 0
         X=X1
         IDC=ID+NQ+I*10000+K*100
         IDA=IDC
         PUNCH,IDA
C 0000 0
         A=(LOG F(Q))/.8686
         Z=AM(K)+1.
         AP=A/Z
         AQP=AP*.8686
         QP=EXP F(AQP)
         W= EXP E F(-AP*X)
         DO 60 J=1,NC
    50 0 AKP(J)=(AK(I)/Z)*EXP E F
    50 1 ((A*C(J))/Z)
    60 0 Y(J)=2.0*AKP(J)*W
    65 0 IDA=IDA+1
    66 0 PUNCH,IDA,Y(1),Y(2),Y(3),
    66 1 Y(4),Y(5),Y(6)
         IF(X-XF)68,80,80
    68 0 X=X+DX
         DO 70 J=1,NC
    70 0 Y(J)=Y(J)/QP
         GO TO 65
C 0000 0
    80 0 DO 85 J=1,NC
    85 0 Y(J)=2.0*AKP(J)*EXP E F
    85 1 (-AP*XX)
         IDA=IDA+1
   100 0 PUNCH,IDA,Y(1),Y(2),Y(3),
   100 1 Y(4),Y(5),Y(6)
C 0000 0
         IF(Q-QF) 90,90,5
    90 0 Q=Q+DQ
         NQ=NQ+10000000
         GO TO 25
C 0000 0
         END
```

# APPENDIX C, TABLE II

## FORTRAN STATEMENTS FOR PROGRAM GENERATING PRODUCT POSSIBILITIES FROM TREES

```
C 0000 0 FORESTRY PROGRAM COMBINATIONS
C 0000 0 OF POLES FROM TREES
         DIMENSION CO(20),DCO(20),
       1 TYPE(20),QTYPE(20),NQ(20),
       2 MCOMB(4)
     1 0 READ,K
         READ,ID
         PUNCH,K
         DO 10 I=1,K
         READ,TYPE(I),CO(I)
    10 0 QTYPE(I)=0.
         DCO(1)=CO(1)
         DO 20 I=2,K
    20 0 DCO(I)=CO(I)-CO(I-1)
         REM=0.
         I=1
    30 0 REM=REM+DCO(I)
    40 0 REM=REM-TYPE(I)
         IF(REM) 41,42,43
    43 0 QTYPE(I)=QTYPE(I)+1.
         GO TO 40
    42 0 QTYPE(I)=QTYPE(I)+1.
         GO TO 50
    41 0 REM=REM+TYPE(I)
    50 0 IF(K-I) 51,52,53
    51 0 PAUSE 1
         GO TO 1
    53 0 I=I+1
         GO TO 30
    52 0 DO 54 I=1,4
    54 0 MCOMB(I)=0
         M=1
         J=9
         DO 55 I=1,K
         NQ(I)=QTYPE(I)

         MCOMB(M)=XPAKF(NQ(I),MCOMB(M),
       1 J,J-1)
         J=J-2
         IF(J) 56,57,55
    57 0 PAUSE 4
         GO TO 1
    56 0 J=9
         M=M+1
    55 0 CONTINUE
         PUNCH,ID,(MCOMB(I),I=1,4)
         REM=REM+QTYPE(K)*TYPE(K)
         QTYPE(K)=0,
         I=K-1
    60 0 IF(QTYPE(I) 61,62,63
    61 0 PAUSE 2
         GO TO 1
    62 0 I=I-1
         IF(I) 66,1,60
    66 0 PAUSE 3
         GO TO 1
    63 0 REM=REM+CO(I)-CO(K)
         QTYPE(I)=QTYPE(I)-1,
         REM=REM+TYPE(I)
         GO TO 53
         END
```

APPENDIX C, TABLE III

FORTRAN STATEMENTS FOR PROGRAM SELECTING OPTIMUM PRODUCT COMBINATIONS

```
C 0000 0 FORESTRY PROGRAM2 MAXIMUM
C 0000 0 PROFIT FROM POLE COMBINATIONS
         DIMENSION TYPE(20),VALUE(20),
       1 MCOMB(4),QTYPE(20),MC(25,4)
     1 0 READ,K
         DO 10 I=1,K
    10 0 READ,TYPE(I),VALUE(I)
         TOTPR=0.
         NDEG=1
    30 0 READ,ID,(MCOMB(I),I=1,4)
         M=1
         J=9
         Q=0.
         PROFT=0.
         DO 40 I=1,K
         QTYPE(I)=XNPKF(MCOMB(M),J,J-1)
         Q=Q+QTYPE(I)
         PROFT=PROFT+QTYPE(I)*VALUE(I)
         J=J-2
         IF(J) 42,43,40
    43 0 PAUSE 1
    42 0 J=9
         M=M+1
    40 0 CONTINUE
         IF(TOTPR-PROFT) 51,52,53
    51 0 NDEG=1
         TOTPR=PROFT
         GO TO 54
    52 0 NDEG=NDEG+1
    54 0 DO 55 J=1,4
    55 0 MC(NDEG,J)=MCOMB(J)
    53 0 IF(Q-QTYPE(K)) 57,58,30
    57 0 PAUSE 2
    58 0 NTOTPR=TOTPR*1000.
         DO 60 I=1,NDEG
         LCOMB=XPAKF(I,0,9,5)
         LCOMB=XPAKF(NDEG,LCOMB,4,0)
    60 0 PUNCH,ID,(MC(I,J),J=1,4),
    60 1 NTOPR,LCOMB
         GO TO 1
         END
```

VITA

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