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Comparison of Harvested Volume to Inventory and Slash Volumes in Midsouth Logging Operations.

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ABSTRACT

Logging utilization was studied as the forest survey progressed through Alabama in 1971 and Louisiana in 1973. Some 200 logging operations were observed to determine (1) volume used, (2) volume present according to inventory standards, and (3) nature and amount of slash volume generated.

The softwood operations sampled were for saw logs, veneer logs, and pulpwood. Hardwood saw log and pulpwood harvesting was also sampled. Samples were selected with probability of selection proportional to production. Production of each product was grouped and accumulated by county (parish) in serpentine order. Total production divided by the number of samples gave a sampling interval, and from a random starting point, subsequent samples were determined by the interval. Logging operations supplying selected saw and veneer mills were observed. For pulpwood, where production was tabulated by county of origin, the first logging operation located was sampled. At each location 20 felled trees were measured to determine inventory volume and used volume. A sample of 20 tree tops left after logging was measured intensively to develop crown volume prediction equations.

Results of the study indicate substantial waste of inventory volume offset by use of some noninventory material. For all products the utilization ratio--inventory volume

divided by used volume--approached unity. For saw logs, it was greater than one and for pulpwood, it was less than one. Veneer utilization was practically equal to inventory volume. Cutting low stumps was the most important use of noninventory volume, although some limbs and top portions were also used.

Logging for more than one product at a time was common, especially during saw and veneer logging. In general, tree sections not suitable for these two products were allocated to pulpwood. The average size of trees cut for saw and veneer logs was larger than those for pulpwood. Moreover, trees were consistently larger in Louisiana than in Alabama.

Analysis of the utilization ratio was conducted separately for softwoods and hardwoods. For both species groups no difference was detected between states, but orthogonal comparisons revealed differences by product logged.

Residual top volumes ranged from 13 to 35 percent of above-ground tree volume depending upon the product being logged. Proportionately more slash volume was generated during pulpwood logging because of the small size of trees being cut. Hardwood slash volumes were highest of all and averaged 23 cubic feet per tree on saw log operations in Louisiana and 15 cubic feet in Alabama.

Current utilization is roughly equivalent to inventory volume. Logging for multiple products and cutting of low stumps presently serve to bolster utilization. An appraisal of the extended resource, including limbs and top volume down to 1-inch minimum diameter, is possible through development of equations to predict top volumes from merchantable top diameter.

INTRODUCTION

The growth in world population is fostering an increase in demands upon resources to satisfy the human needs for food, clothing, and shelter. While the economics of production may vary with demand, many resources are fixed quantities.

Sunlight is our only external source of energy. From it we obtain much of our sustenance and must increasingly turn to it for our needs. Resources which directly or indirectly depend upon sunlight are termed renewable resources. These include green plants, which in turn form the basis for all food chains. Much of our clothing comes from the natural fibers produced by plants. And finally, shelter depends heavily upon forests of green plants producing timber for shelter and fuel. These resources, and our stewardship of them, hold the promise for continued high quality of living.

Two hundred years ago the United States was in its infancy. There were few people and vast expanses of virgin forests. Wood, in large measure, fueled the development of America. It was always there, abundant and versatile. Now the old growth stands of virgin timber are nearing exhaustion. Demand, however, has not decreased, and must be met by younger, managed forests.

The biological requirements for timber production include space and time. Continued development and population growth represent constraints on both these requirements. Foresters faced with the prospect of producing more wood on less space are trying various approaches. Genetic improvement of growing stock promises to increase timber supplies. Intensive management, such as fertilization and planting, offers some hope. Efforts to increase output from existing timber resources through silvicultural practices will require considerable time. Depletion of the growing stock to supply current demands will hamper later productivity.

Increased utilization offers an immediate way of ameliorating increased demand. As economics and technology permit, more and more of each tree is becoming useable. Useable implies merchantable, but for what one logger will pay another considers as waste. Thus, some standard to which current utilization can be compared is a necessary component in this study. Ideally, the standard should be relatively constant over time and varying timber stands. Furthermore, assessment of timber use during logging in a regional context implies use of a standard which is applied on a wide scale.

In 1928, the McSweeny-McNary act authorized the Forest Survey. Its nationwide mission is to conduct a series of continuing surveys of all states to provide up-to-date information about the nation's forest resources. This information is useful for planning and the formation of national policy. The primary thrust of the survey has been determination of the timber resource or forest inventory according to the various standards of size, shape, and quality. The limits to which the inventory is defined were initially established to reflect utilization practices shortly after World War II. Standards were developed to be uniform throughout the eastern United States, and another set of criteria is uniformly applied in the West. The effect of timber removals upon the resource thus defined can be evaluated only in light of utilization with respect to these same criteria.

The goal of this study was quantification of logging utilization practices for five major timber product categories in the Midsouth. Samples of trees felled during logging were measured to determine used and inventory volumes. The ratio of inventory volume to used volume was analyzed separately for softwoods and hardwoods. Tree volumes not classified as part of the inventory were also studied.

Definition of Terms

Terms commonly used in this thesis plus terms having specific inference are defined as follows:

1. Allometric - Relating to the size of a part relative to an entire organism.
2. Bucking - The cutting of tree boles into sections for products such as saw logs, veneer logs, etc.
3. Cull trees - Live trees that are unmerchantable for saw logs now or prospectively because of defects, rot, or species.
4. Deliquescent - A crown form where stems divide repeatedly ending in fine divisions.
5. Diameter breast high (dbh) - The outside bark diameter of a tree at 4.5 feet above average ground level.
6. Diameter breast high outside bark (dbhob) - Tree diameter outside bark at 4.5 feet above average ground level.
7. Diameter outside bark (dob) - The diameter at any specified point outside bark.
8. Excurrent - A crown form having the axis prolonged to form an undivided main stem.
9. Forest Survey - That arm of the U.S.D.A. Forest Service that fulfills the directives of the McSweeny-McNary Act of 1928, i.e., a series of continuing surveys of forest resources in all states.
10. Growing stock trees - Live trees of commercial species having no serious defects in quality limiting present or prospective use for timber products.
11. Inventory volume - That portion of the bole of growing stock trees greater than 5.0 inches in diameter breast high from a 1-foot stump to a minimum 4-inch top outside bark or to the point where the central stem breaks into limbs.

12. Logging chance - An area being logged.

13. Logging residues - The unused portions of trees cut or killed by logging.

14. Lopped limbs - Limbs trimmed from a tree during logging.

15. Merchantable top diameter - Up to 4 inches in dob or diameter where the central stem is terminated by branches, rot, etc.

16. Midsouth - The region including Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.

17. Noninventory volume - Sections in trees which do not meet inventory specifications of size and quality. Included is volume in stumps up to 1 foot in height, limbs, and crowns above merchantable top diameter.

18. Poletimber trees - Live trees of commercial species 5 to 9 inches in dbh for softwoods and 5 to 11 inches for hardwoods, and of good form and vigor.

19. Saw-log top - The point on the bole of sawtimber trees above which a saw log cannot be produced.

20. Sawtimber portion - That part of the bole of sawtimber trees between the stump and the saw-log top.

21. Sawtimber trees - Live trees of commercial species containing at least a 12-foot saw log meeting grade specifications. Softwoods must be at least 9 inches and hardwoods must be at least 11 inches in diameter breast high.

22. Slash - Debris left after logging. It includes tree tops, limbs, and stumps.

23. Upperstem portion - The part of the bole of sawtimber trees above saw-log top to a minimum top diameter of 4 inches outside bark or to the point where the central stem breaks into limbs.

24. Utilization ratio - The inventory volume (cubic feet) in a particular tree or group of trees divided by the used volume (cubic feet).

25. Saplings - Trees from 1.0 inches dbh to 5.0 inches dbh.

REVIEW OF LITERATURE

Interest in utilization of timber in logging is a fairly recent phenomenon and is related to concern for timber supplies. During the early development of the United States timber harvesting was regarded largely as a mining operation. Only the choicest material was manufactured into products, with little regard for waste. As logging spread across the continent, the last bastion of virgin forest reserves began to topple. The threat of a timber shortage began to foster concern for future timber supplies and in turn for better use of resources presently being harvested.

In 1896, there was still large areas of virgin southern pine. Most of the primeval forest, however, was already culled of its best timber, over-run by turpentine gatherers and subjected to repeated fires which left thousands of square miles as blackened wastes (Mohr 1896). The South was becoming the major timber supply region as northern forests were being cut out. There were some stirrings of concern for timber supplies, but the establishment of the national forests in 1905 was the first formal attempt to extend forest management to large forest areas (Davis 1954). Forest management developed slowly in the first half of this century. By 1950, however, forest management had become a fairly common business practice. The idea

of growing forests on a continuous sustained-yield basis was accepted widely. During this development period of about two decades there was a stirring of interest in reducing logging waste. In 1939 making pulpwood from tree tops left after saw logging was proposed, tested, and found suitable (Texas Forest Service 1939).

There was a crest of logging activity in the Pacific Northwest in the 1930's and logging waste there commonly exceeded the volume present before logging in many other areas of the country (USDA Forest Service 1947). In the first study of its kind in the Douglas-fir region, residue volumes were estimated in the neighborhood of 42 cords, or more than 21 M bd.ft. per acre (Hodgson 1930). This was about one-fifth of the original stand. Heavy losses in the region were attributed to large numbers of over-mature trees with associated defects plus the great distance from eastern markets. Only the high quality material could be processed profitably due to the high transportation costs. In 1944, during the razing of many western virgin forests, logging waste was about 32 percent of the total drain (USDA Forest Service 1947). For the South, the rate was about two percent (USDA Forest Service 1948).

Certainly, there were some differences in definition as to what actually comprised wasted volume. In the development era merchantability standards were high, and

with little incentive for close utilization, loggers produced colossal wastes of what would now be assessed as growing stock.

In the early thirties overproduction to supply a building boom which never materialized had forced lay-offs of thousands of men (Compton 1931). This was hardly a time for increased logging utilization. Furthermore, misjudgment of timber supply prospects aggravated uncertainty in the lumbering industry. Compton advocated a periodic survey of lumber production and condition of inventories to help stabilize the industry.

In Virginia about 24 percent of the volume in each tree was lost in logging (U.S. Department of Commerce 1929). Losses included stumps, tops, broken trees, small and defective logs, unused species, waste from bucking carelessness, and other logging damage. There was some discussion of minimum sizes that would warrant harvesting. In logging the southern pines some companies cut all trees larger than 8 inches diameter at the stump (Forbes 1930).

In the 1920's early efforts to determine logging waste for hardwoods were in progress in Louisiana (Lentz 1929). A general emphasis on better utilization of forest resources from logging through primary manufacture was on its way. Planning for future timber supplies required basic information on the present resource, its utilization, and distribution.

Early reports of merchantability standards are few and often sketchy. In 1928, however, the McSweeny-McNary Act authorized the Forest Survey, and a standard by which the resource could be measured was necessary. In the original survey, growing stock included all suitable trees greater than 5 inches dbh. Sawtimber began at 9 inches for softwoods and 13 inches dbh for hardwoods. After interruption by World War II, the Survey resumed, and the limits for growing stock were set to reflect merchantability (Mesavage 1944). There was some ambiguity for hardwood sawtimber, with the minimum for sawtimber stated as 13 inches dbhob. There were additional exceptions for cypress (Taxodium spp.) with the minimum sawtimber dbhob being 13 inches in the Mississippi River Delta and 9 inches elsewhere (Figure 1). For hardwoods no volume was recorded in sawtimber trees above saw log height.

These early original standards correspond closely with those in use today. The threshold now for inventory volume is 5.0 inches dbhob. Softwood sawtimber begins at 9.0 inches; hardwood sawtimber at 11.0 inches dbhob. Current merchantability standards for the eastern United States are detailed in the Appendix.

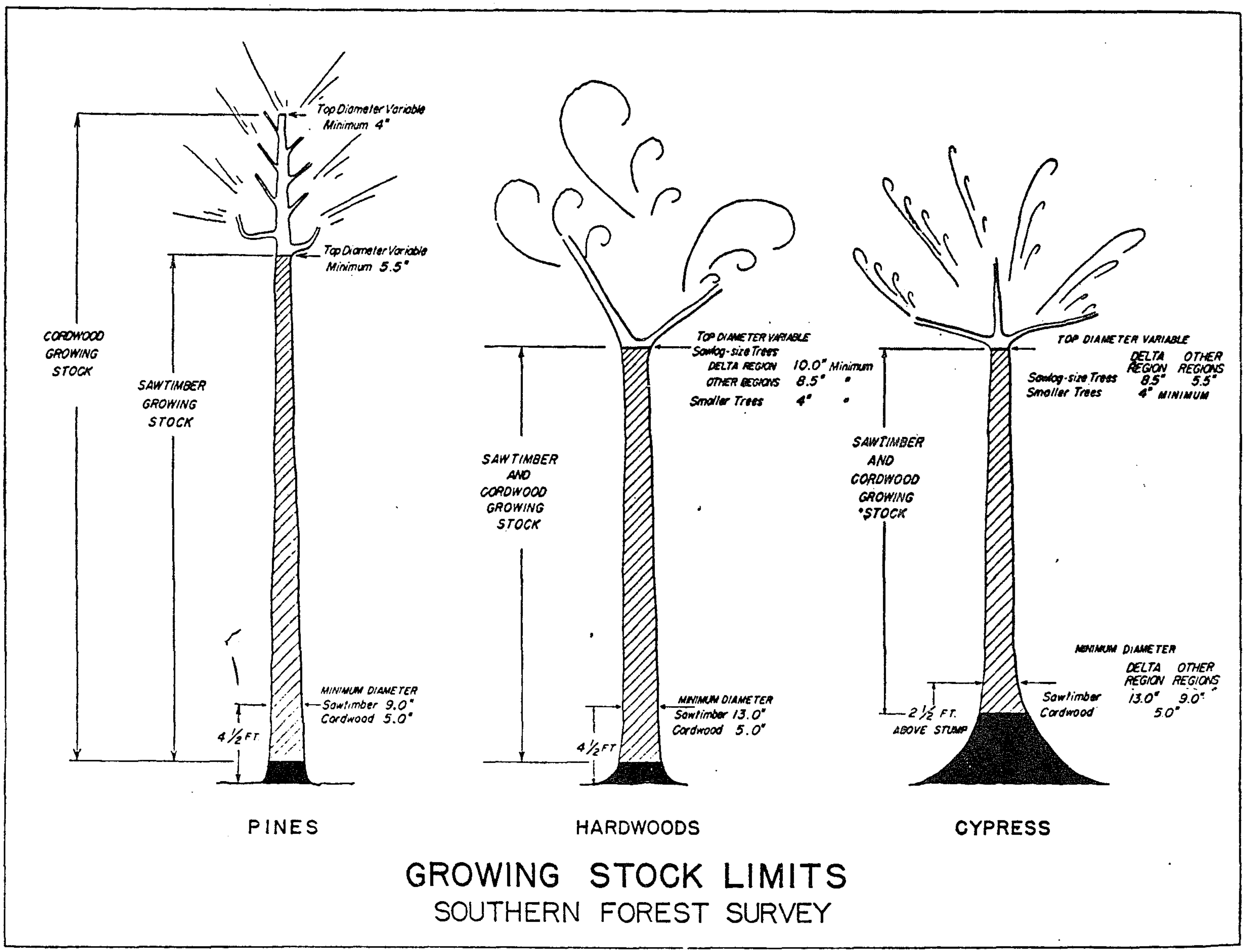

Figure 1. Growing stock as measured by the forest survey (Mesavage 1944).

Methods of assessing residues

The problem of assessing logging wastes is complex because of the inherent variability in logging. In addition to the individual and generally diverse practices of loggers, there is a multitude of different species, tree forms, and timber products. Moreover, stand structure and composition can vary widely. Additional considerations must be made for the type and degree of harvesting (Olson 1953).

There have been various approaches--the earliest of which used crude approximations. Measurement of logging slash on a particular tract was done in the Lake States around 1930 (USDA Forest Service 1931). The method used sample area plots and measurement consisted of determining the average depth of the slash. Even with such crude approximations, logging waste was found to be substantially lower on plots where more than one product was obtained.

For the South little published information is available. Most of the early work was done in connection with Forest Survey efforts. During the first Forest Survey of the Mississippi Delta loggers were using less than one-half of the total height of most hardwoods (Lentz 1929).

An alternative to taking sample plots is to predict waste on an individual tree basis. Theoretically, the amount of logging slash per acre depends upon the volume

removed. An individual tree approach circumvents the problem of varying levels of cut, i.e., thinnings, selection, or various types of harvest cuts. Some of the early work in developing the individual tree approach was done by researchers interested not in using the logging slash, but in how the residue contributed to the forest fuels and to the fire hazard (Storey, Fons, and Sauer 1955). The individual tree basis was the first objective attempt at calculating slash quantity and was vastly superior to the guesswork used previously (Fahnstock 1960).

A few years later, the concept of relating weight and size distribution of logging slash to tree size was commonly accepted. Some estimates were based on tree attributes of species and merchantable volume (Kiil 1965). Others were somewhat refined, and included dob at the base of the crown and crown ratios (Wade 1969).

The practical aspects of residue use in the final analysis will determine whether or not logging slash will be used and to what extent. Gill (1966) observed that it must be economically feasible to harvest and use this material and that measurement effort must be low for low-value products. Most of his comments relate to use of logging slash after logging is completed. Studies of slash harvesting indicate that the profit per ton delivered green to the mill is only $1.20 (Steinhilb

and Dye 1973). An alternate approach to harvesting logging slash is to never generate it. This is the basis for complete tree harvesting.

The feasibility of complete tree harvesting is already proven in some respects. The above-ground parts of trees are being chipped and used as raw material for hardboard and in some instances mixed with other bark-free chips for making kraft linerboard. What remains is to integrate logging for other products such as saw and veneer logs with chipping of tops, limbs, and cull sections for pulpwood.

To assess the gains from such integrated use an approximation of the volume of logging slash being generated by current practices is essential.

Lamb (1966) estimated that in Canada about 30 percent of the hardwood stands and 20 percent of the softwood stands were left after logging. For both, tops comprised the greatest amount of waste material. Next in importance was the volume left in merchantable trees. Red spruce (*Picea rubens* Sarg.) and red maple (*Acer rubrum* L.) wastes were found to be even higher (Young, Gammon, and Hoar 1963). For each 100 pounds of wood used, about 42-43 pounds of material greater than one inch was left in the woods. On a weight basis, the merchantable bole for conifers in the northeastern United States is more than half of the total tree weight (Young, Gammon, and Ashley 1964). In a study of white

spruce (Picea spp.) and lodgepole pines (Pinus contorta Dougl.), Kiil (1965) found that the ratio of slash weight to merchantable cubic foot volume varied inversely with diameter breast high. Kerbes and McIntosh (1969) found that approximately 37 percent of the total stem is recovered as lumber. Of the remainder, 18 percent is chippable residue available at sawmills and the balance (45 percent) is lost in various stages of conversion.

Gardner and Hann (1972) studied lodgepole pine logging residues in Wyoming. They compared fiber yields of conventional and nearly complete-tree harvesting. By on-site chipping of tops, residual trees, and other logging residues, fiber yield was increased by 35 percent over conventional harvesting.

Hamilton (1928) was an early advocate of using all but the whispers of the pines, but he dealt only with waste as a consequence of manufacturing logs into products. By the early 1960's much of the manufacturing waste was being used for other products such as pulpwood. The concept of using logging slash, or logging in such a manner as to reduce or eliminate woods waste, was a logical consequence of concern for future timber supplies. But first, the technical feasibility of using limb wood and other forms of logging waste had to be established. Many studies have dealt with pulping characteristics and the yields of various parts of trees. It is, however, beyond the scope of this paper to treat them exhaustively. The feasibility of using logging waste

for pulping has been demonstrated, with some loss of brightness and strength properties (Kurrle 1963). For southern pine, pulp yield from branches is about 10 percent lower than stem wood (Fleischer 1968).

Thus, in the 1960's, three broad approaches to logging waste estimation began to evolve. They are quite different in application and results, with each bearing discussion. The area approach provides estimates for a given area in which samples are taken. Individual tree methods are useful for timber sales, especially for partial cutting. The output method depends upon a series of ratios which express the amount of waste generated per unit of output. This last approach embodies the concept of merchantability and is useful in evaluating logging waste on extensive areas for which product output information is tabulated.

Area methods. One of the more popular methods of measuring slash quantity for a given area was introduced in New Zealand by Warren and Olsen (1964). The sampling procedure consists of tallying individual pieces of logging slash which intersect a sample line. This method was reportedly easier, faster, and provided better estimates than plot methods. Thus, it has rapidly gained favor in the United States. Bailey (1969) compared the line intersect method with sample plots for estimating logging residues and found it to be superior to older methods in both accuracy and ease of application. Van Wagner (1968) tested

the method for evaluating slash as a forest fuel. The technique has been applied to clear cut areas in the Douglas-fir region (Dell and Ward 1971). Howard and Ward (1972) used a random orientation of the sample line to estimate residue volume in cut-over areas where topography and logging had created an orientation pattern. Estimates of residue volume within ± 15-20 percent of actual volume was realized on a 40-acre block in an eight-hour day. Howard (1973) used the same method to evaluate logging residues by type of forest land ownership in Washington, Oregon, and California.

There are assumptions inherent in these estimates that detract from their utility. Average or per acre values are expanded to reflect values for the entire ownership. In so doing, certain assumptions must have been made as to type of cutting, area cut over, and volumes per acre. In the South, these assumptions are not supportable in view of the differences in the forest resource and harvesting practices. Ownership and species composition of southern forests are more diverse than in western forests. Clear-cutting is not so prevalent, and the area logged is often a nebulous quantity.

Individual tree and biomass studies. A second approach to determining logging residue volume is to first determine the amount generated by each tree and sum the amount for

all trees in the population. While complete enumeration is impractical, sample surveys are commonly designed to show numbers of trees by dbh class and species. With such data as a base, the estimation of potential logging residues is straightforward. In the particular case of timber sales, the purchaser is in an excellent position to apply such a method to evaluate potential revenue from residue volumes.

The idea of a tree developing its form according to certain laws is not new. Among the first attempts to relate crown weight and stem dimensions was a study made on fruit trees (Tufts 1919). Whittaker (1965) found that the strongest correlations for shrub branch weights were linear correlations with powers of branch diameter. Other disciplines pursue the method to determine dry matter production, fire hazard due to logging slash, and foliage surface area.

Doerner (1965) postulated some dimensional relationships and form determinants of trees. He believed that the upper and lower limits for the component parts of trees could be defined mathematically and that the equation was appropriate for all trees. Certainly trees are not exempt from the laws of physics. The strength and consequently the size of a supporting part of the tree is related to the stress upon it. This relationship is evident repeatedly in the practice of forestry. Trees on the edges of stands are subject to more wind stress than

interior trees. Form class, an expression of taper, is reduced. Open-grown tolerant trees are an example of this same concept. With large crowns, and no sheltering neighbors, these trees have extremely high taper due to the horizontal stress upon the stem. Attiwell (1966) studied crown weights in eucalyptus (*Eucalyptus obliqua* L'Herit). Allometric relationships between branch diameter and branch weight led him to two conclusions: (1) that the girth of the branch at minimum diameter before branching further is related to the mechanical strength required for support, and (2) that each component of a tree acts as a branch, i.e., must support its weight.

Use of the concept of tree form is evidenced by the use of diameter volume tables. A logical extension of this concept is to estimate branch volume from branch diameter. The correlation of branch weight and branch diameter two inches from the bole is excellent in shortleaf pine (*Pinus echinata* Mill.) (Loomis, Phares, and Crosby 1966). Storey, *et al.* (1955) found that bole diameter inside bark at the base of the crown was the best single estimator of crown weight. Wade (1969) estimated slash quantity for standing loblolly (*Pinus taeda* L.). His best predictors were dbh and dob at the base of the crown. These separate studies have the common theme of predicting weight from some stress-related measurement, i.e., diameter of branches, at the base of crown, and at breast height.

Several attempts to predict total tree weight from dbh are documented. Ovington and Madgwick (1959) predicted the weight of Scots pine (*Pinus sylvestris* L.) trees (less rootless less than .5 cm) from diameter breast height. The regression equation for total living tree as well as component parts was presented in $\log_{10}$ form. Attiwell (1962) developed an equation of the same form to predict eucalyptus branch weights given girth, i.e., diameter at the point where the limb begins to subdivide into smaller branches. He further concluded that by measuring the girths of the branches of a tree, the dry weights of all components of the crown can be estimated.

In other parts of the world, interest in maximizing forest products output is growing. In many respects, the United States has followed trends in European countries. Many concepts in the practice of forestry have originated in Europe. Now we find the timber supply in northern Europe becoming critical and increased use of residues is being intensely pursued. In 1969 a joint Scandinavian research project to find additional fiber from logging residues was started (Hakkila 1972). Nearly 40 percent of the biomass was being left in the forests in the form of branches, stumps, roots, tops, and wasted bole sections.

In 1963, the line intersect method of estimating logging residues was developed in New Zealand. In the Solomon Islands, Self and Trenaman (1972) have explored the use of logging residues for pulping. Thus, logging waste is a world-wide concern.

Output method. The third approach to estimation of logging residues depends upon a series of ratios which express the amount of residues generated per unit of output. It embodies the concept of merchantability and is useful for evaluating logging waste on extensive areas for which product output information has been tabulated. Theoretically, the growing stock volume contained in the harvested products plus the wasted growing stock volume amounts to the drain or removals upon the forest resource due to products output. Forest Survey estimates of product removals are based on product output. There are other components of removals such as mortality, land clearing, and the like, but these are considered separately.

Logging residues is an ambiguous term and is used freely to denote several quantities. By definition, such items as limbs, crowns, and cull sections are excluded from Forest Survey estimates of logging residue (Setzer 1973).

While earlier utilization studies were designed to relate output of a given product to the waste of growing

stock material, a logical extension of this practice is to estimate slash quantity from timber products output.

During studies of logging utilization, many measurements are taken which can be utilized in the assessment of all logging slash, including limbs and tops. If it is possible to estimate biomass from such items as dbh (Baskerville 1965) within acceptable error limits, then surely an estimate at least as good can be derived from more intensive measurements such as merchantable top diameter, limb diameters, and the like (Madgwick and Jackson 1974). Branch weight is so closely correlated with branch diameter that Loomis et al. (1966) used diameter to obtain weight for their samples.

Martin (1975) estimated logging residues on an individual tree basis. If trees were uniform, this method could be extended to approximate the additional fiber potential of the forest inventory. But, as Martin noted, the procedure would have to be developed for a full range of species-site relationships. Optimally, a refined technique applying to inventory data would serve best to approximate an extended fiber resource.

THE STUDY AREA

This study was an integral part of the Forest Surveys of Alabama and Louisiana. The results play a large part in the appraisal of the forest resources of these two states when used in conjunction with the survey data. Thus, the research area coincides with the states being surveyed--Alabama in 1971 and Louisiana during 1973.

Alabama is one of the leading states in the Midsouth timber economy. Forests occupy 65 percent of the state. Most of Alabama's forest land is suited for growing southern pine. These areas are mainly in the coastal plain and in the drier, upland sites. In addition to the bottom-land sites, hardwoods occupy many of the areas suitable for softwoods. The total inventory of growing stock in Alabama is 20.2 billion cubic feet, with 44 percent hardwood and 56 percent softwoods (Murphy 1973).

Output of forest products in the State totaled 718 million cubic feet during 1971 (Bertelson 1972). Softwoods, primarily pine, made up 70 percent of the output. Pulpwood was the leading product in terms of volumes harvested, with saw logs second.

Technological development within the industry compares well with that of other Midsouth states. Large, efficient sawmills process most of the saw logs. Eleven of the sawmills have chipping headrigs, and they account for 28 percent of all saw logs sawn in the state. Alabama has six southern pine plywood plants with the capacity to produce

almost 600 million square feet of plywood annually (three-eighth inch basis).

Louisiana, though somewhat below Alabama in output of forest products, is still a vital sector of the forest economy of the region. The forested area in the state is 14.5 million acres and supports an inventory of 9 billion cubic feet of softwoods and 7.7 billion cubic feet of hardwoods (Murphy 1976).

Pulpwood dominates the output of roundwood in Louisiana. A record 3.2 million cords of round pulpwood was produced during 1973, accounting for 46 percent of the total production of forest products (Bertelson 1973a). Saw logs were second in volume of output, followed by veneer production. The trend in processing is toward larger, more efficient mills (Bertelson 1973b). The two states are representative of the Gulf Coastal plain in timber types, topography, and production of forest products. The level of logging technology and practice plus the similarity of the timber economy of the two states will allow a valid test of tree utilization for Midsouth logging operations. In each state about 75 percent of total output is softwood and 25 percent is hardwood.

OBJECTIVES

The primary goal of this study is to quantify timber utilization in logging operations for the major forest products in the Midsouth. The forest inventory is defined in terms of growing stock and sawtimber. The limits to which each is measured defines the resource and approximates that quantity of the forest inventory that can be expected to end up as forest products. These limits provide a standard by which logging utilization may be assessed.

Current interest in using more of each tree indicates a need for assessing tree volumes beyond present inventory standards. Portions of trees in stumps, crowns, and other sections outside the bole constitute a valid resource given the technology and economic climate in which it can be utilized. Thus, in addition to appraisal of use rates for various products with respect to the inventory, an auxiliary aim of this study is to make an initial attempt to gauge these extra resource volumes.

METHODS AND PROCEDURES

Obtaining a representative sample of logging operations for the timber products under consideration in this study proved to be a major feat. Sampling units of unequal size are common in forestry, and can introduce considerable bias. The contribution of an individual logging operation to overall utilization levels depends upon the volume produced from that operation. A simple random sample would give as much weight to small producers as to large ones. An appropriate procedure in the case of unequal to size sampling units is sampling with probability of selection proportional to size.

The size of each individual in the population is required to accomplish this type of sampling. Since a suitable list was not available for individual logging operations, sample selection was based on production of each product. The information available for sample selection varied by state and product so the sampling procedure in each state and product category is outlined below. In general, mills were sampled according to their consumption of the raw wood product under consideration. A logging operation supplying the product to the selected mill was the sample measurement site. Each sample consisted of 20 trees cut for the product under consideration. A total of 200 such operations in Alabama and Louisiana were sampled in 1972 and 1973 (Table 1).

Table 1. Number of samples by state and product

Product	Alabama	Louisiana	Total
Softwood saw logs	20	19	39
Softwood veneer logs	10	12	22
Softwood pulpwood	30	20	50
Hardwood saw logs	20	19	39
Hardwood pulpwood	30	20	50
Total	110	90	200

Alabama. Results of a canvass of all primary forest industries were available in Alabama. Thus, probability proportional to size sampling was done on an individual mill basis for each product.

Saw logs--Probability proportional to production sampling for Alabama saw logs was accomplished as follows: First, counties were listed in the order shown in Figure 2 to eliminate locational bias. Then mills were listed by county along with their respective receipts of saw logs for calendar year 1971, and the cumulative sum. The receipts were converted to International 1/4 inch rule log scale for consistency. A random number less than total output of saw logs in the state was used to select the first mill. The mill having a cumulative sum of receipts closest to but greater than the random number was selected as the first sample mill. Total production in the state divided by the number of samples desired gave an interval, which when added to the random starting point, selected subsequent sample mills. A simplified example is given in the Appendix (Table 8). A logging operation supplying saw logs to each of the selected mills was located by following a truck back to the woods or any other means at hand. For each sample, 20 trees were measured to determine inventory volume, used volume, and slash volume.

Veneer logs--Ten softwood veneer logging operations were sampled in the same fashion as saw logs. Only 10

softwood veneer plants were operating in the state at the time, and 10 samples were deemed adequate.

Pulpwood--Sample selection for pulpwood logging was based on softwood and hardwood pulpwood production by county. For each county, the production and cumulative production of softwood and hardwood pulpwood was listed in the order shown in Figure 2. Sample counties were selected separately for softwoods and hardwoods in the same manner as mills were selected for saw logs. Pulpwood logging operations were located by following trucks from pulpwood yards, by inquiry at same, or any other means at hand.

Louisiana. At the time of the utilization study in Louisiana the canvass of mills was not complete and sample selection had to be based on other information.

Saw logs--The basis for selecting saw log samples was severance tax data released by the Louisiana Forestry Commission (1973). These data show roundwood production by parish and species groups. Parishes were listed in serpentine order as shown in Figure 3 and production was accumulated as in Alabama. Sample parishes were selected using the same procedure given for Alabama pulpwood. Once a parish was selected, a sawmill within the parish was randomly selected from a comprehensive list of sawmills. If no logging operations supplying the selected mill were active, an alternate mill was selected. In the unlikely event of no mills being in the selected parish, a mill in

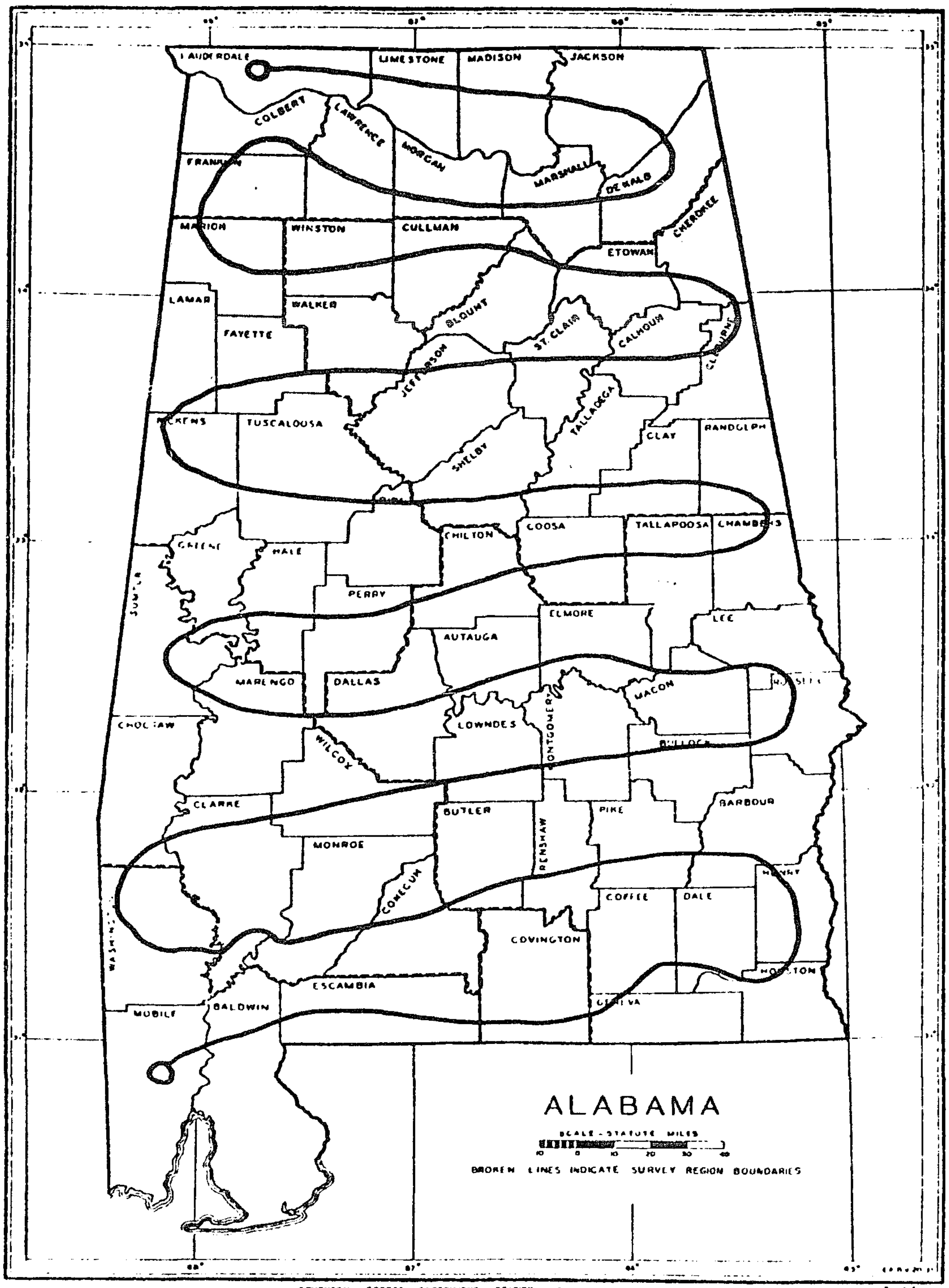

Figure 2. Alabama counties in serpentine order for sampling.

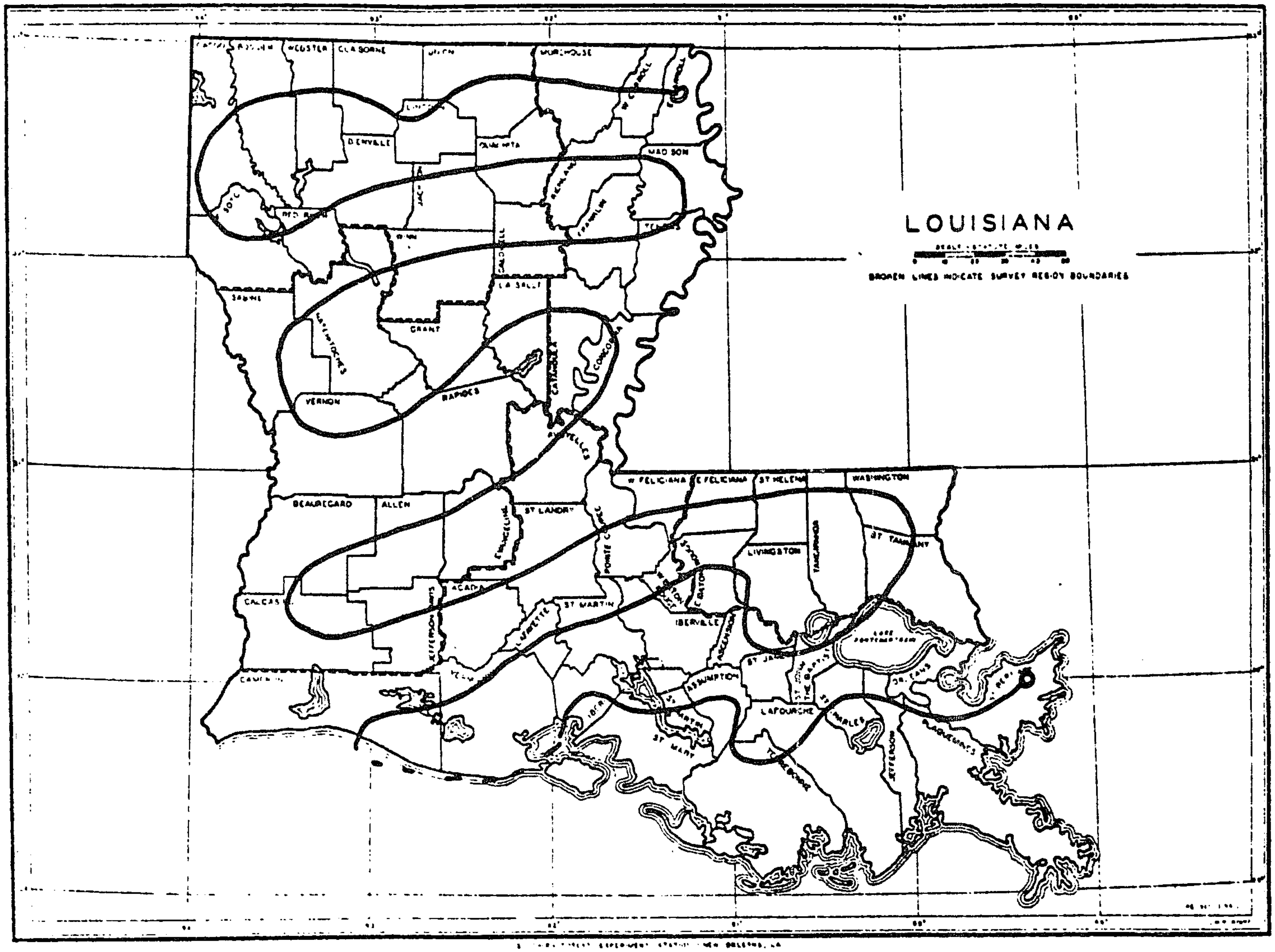

Figure 3. Louisiana parishes in serpentine order for sampling.

a neighboring parish or one procuring roundwood from the selected parish was used as a starting point to find a logging operation.

Veneer logs--Veneer samples were allocated among individual mills in the state on the basis of plant capacity. Logging operations supplying veneer logs to the selected mills were sampled.

Pulpwood--Samples of Louisiana pulpwood logging were selected like those in Alabama, but 20 samples in each species group were deemed adequate in view of the results in Alabama.

Sample locations for all products and states are shown in Figures 4 through 6.

Location of logging operations for particular products was the most difficult phase of data acquisition. Mill receipts were available by product, and the mechanics of selection were designed to apply to individual products. Many mills, however, received a mix of timber products. This posed little difficulty in selecting mills, but it should be noted that the same mill could be selected for more than one product or more than one sample. Furthermore, logging operations, especially large ones, tend to be integrated to the point of producing several timber products, and a given logging operation could be selected repeatedly for different products. In practice, the intended use for trees in a given sample was apparent to the field team in

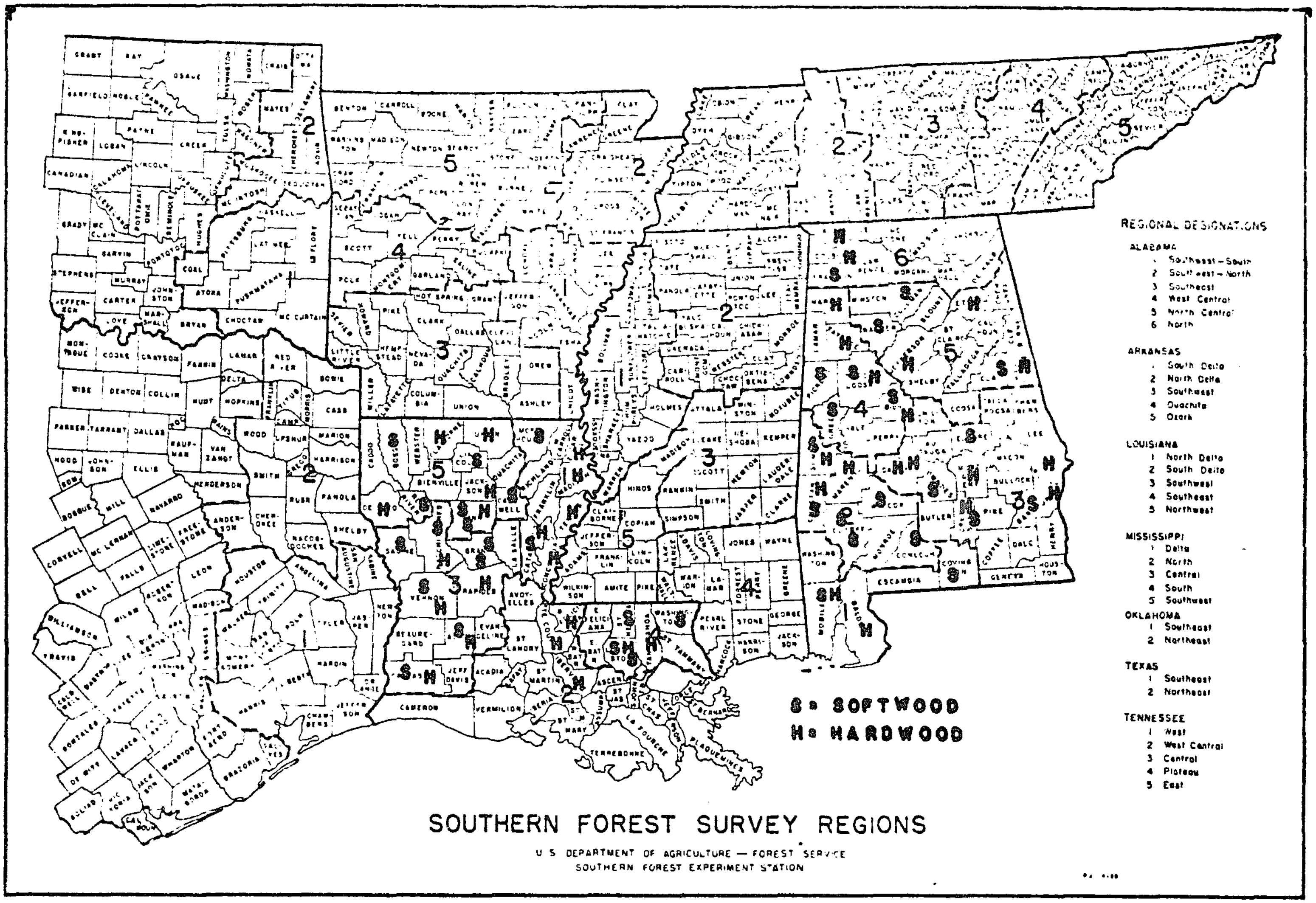

Figure 4. Location of softwood and hardwood saw log samples.

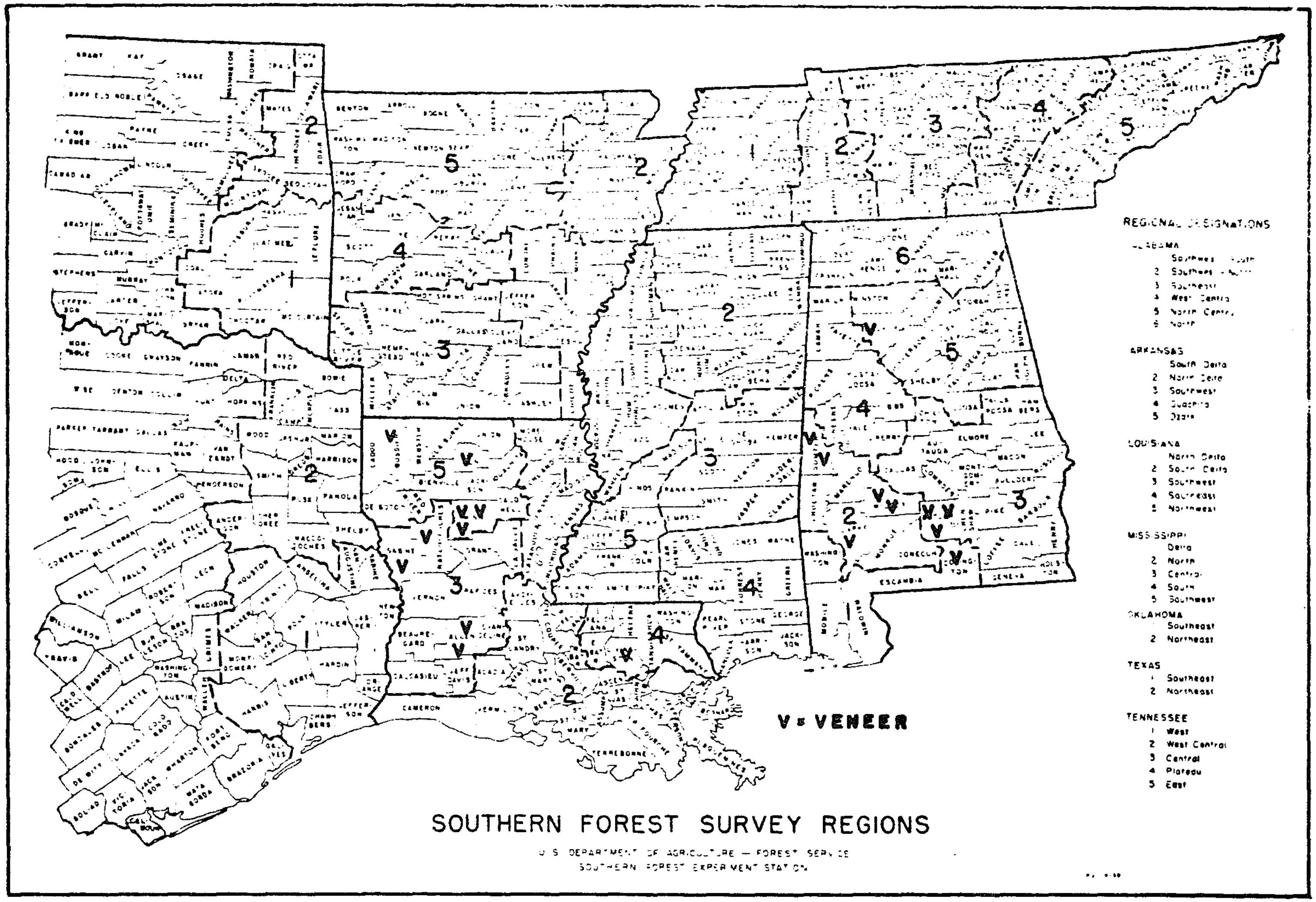

Figure 5. Location of softwood veneer samples.

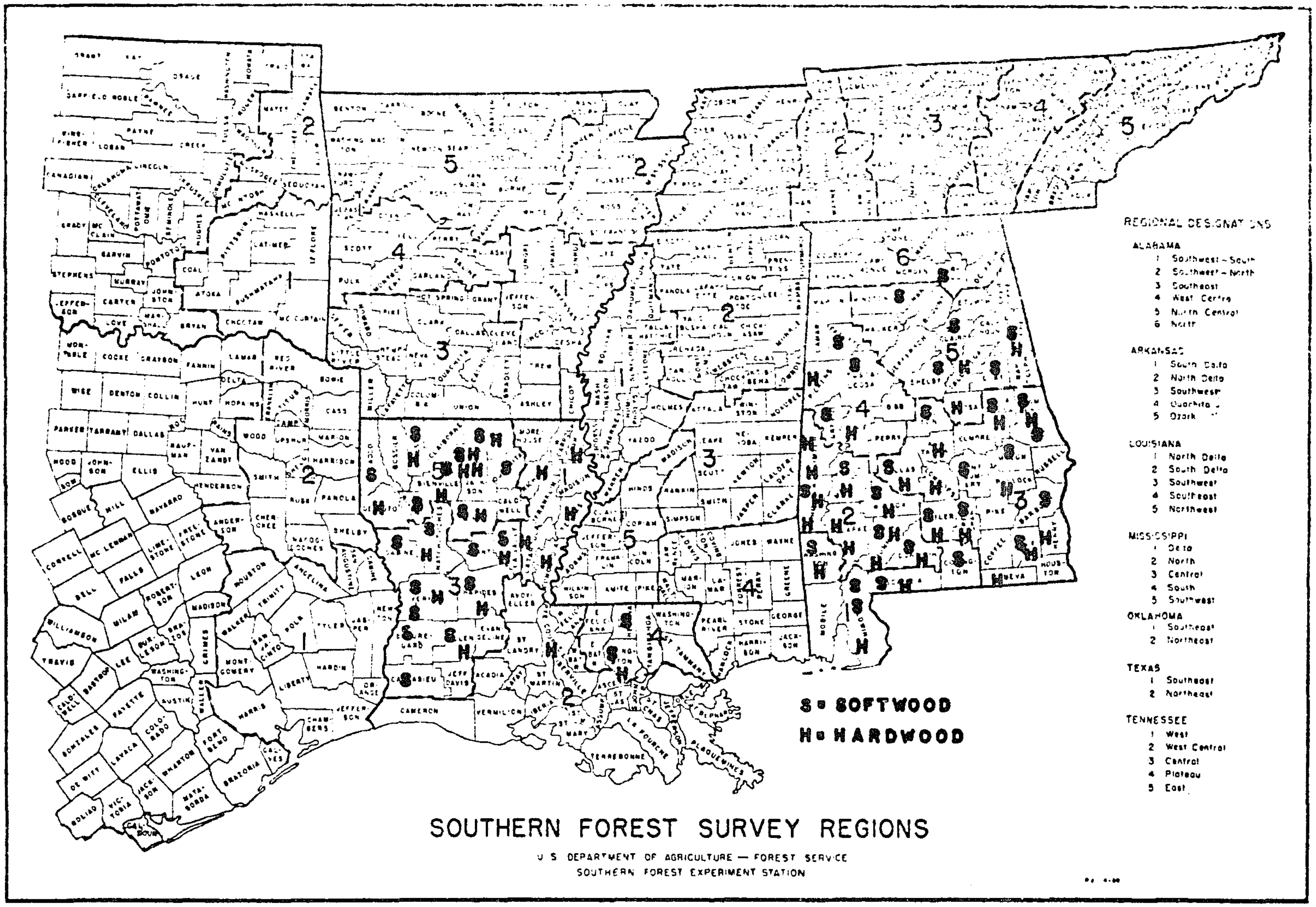

Figure 6. Location of softwood and hardwood pulpwood samples.

(1) hardwood and softwood species were separable and (2) saw and veneer log production seldom overlapped. When both saw and veneer logs were being hauled from the same logging operation, the veneer logs were generally set aside for hauling to a separate destination. Size and quality requirements were sufficient to discern pulpwood from saw and veneer logs. A common practice of loggers was to log the same stand in several stages, one for each product produced. This also helped separate logging for specific products in the same timber stand.

Field Procedure

Field teams normally engaged in measurement of survey plots were given additional training during a three-day training session to familiarize them with the requirements of the utilization study. Upon arrival at a cutting area field teams were to measure the next 20 trees felled. If felling was not in progress, 20 felled trees were selected at random. The sample trees were measured to reflect (1) the volume according to survey standards, and (2) the actual volume used.

Teams were instructed to assess inventory volume as if the tree were still standing. In some instances, this would require ignoring defects such as rot which became obvious as a result of felling and bucking. Diameters were measured at breast height, saw-log top, merchantable top, and all points where the bole was severed. No section was

allowed to be longer than 18 feet between diameter points. Thus, some diameters were measured between cutting points. Length measurement extended from the ground to the terminal bud, and was recorded at each diameter point. All measurements of diameter to the last whole 0.1-inch were taken with calipers, and lengths were measured with a steel tape to the last whole 0.1-foot. Bark thickness was taken and recorded at each diameter point. Various additional measurements were taken to approximate volumes in lopped limbs, residual tree crowns, and other non-inventory sections. Limbs lopped during bucking were tallied by 2-inch diameter classes--measured at the bole just beyond the limb collar--and 2-foot length classes. Those lopped limbs larger than 7 inches dob at the bole were measured to a minimum dob of seven inches. The remainder of the limb was dot tallied as a 6-inch limb of estimated length.

Residual crowns were measured for length, maximum width, and base diameter of the central stem. Branches greater than one-inch dob just beyond the limb collar were counted and their average diameter was estimated ocularly.

Office computations

A comparison of tree use in each of the sampled states was made to test the hypothesis of no difference in utilization of inventory volumes. The variable used in the tests of hypothesis was defined as follows:

$$R_{ijk} = \frac{\sum_{i=1}^{n} I_{ijkn}}{\sum_{i=1}^{n} U_{ijkn}}$$

where R_{ijk} = Utilization ratio for the kth sample, jth product, and ith state.

I_{ijkn} = Inventory volume of the nth tree, kth sample, jth product, and ith state.

U_{ijkn} = Used volume from the nth tree, kth sample, jth product, and ith state.

It is possible for a tree to have no inventory volume and be used. It is likewise reasonable to expect some trees having inventory volume to be wasted. Therefore, the experimental unit to be examined is the sample of 20 trees where the summation of tree attributes minimizes the probability of having the ratio being undefined.

Both inventory and used volumes were calculated from measurements of felled trees. Unless otherwise noted, all volumes were calculated according to the following equation (Grosenbaugh 1952):

$$V = .005454\ L\ [\ Dd + \frac{(D-d)^2}{K}\ ]$$

where V = Volume (cubic feet)

L = Length (feet)

D = Large end diameter (inches)

d = Small end diameter (inches)

K = Constant (conoidal form assumed; K=3)

Because of the difference in inventory standards and the inherent differences in form, hardwood and softwood products were treated separately. Statistical analysis was performed with a completely random design using a two-way classification and disproportionate sub-class numbers.

The extension of field measurements to cover non-inventory sections of felled trees was done in the most expedient manner possible. Forest Survey results are timely and must be released as soon as possible. Therefore, field measurement of these portions which comprise a sizeable part of the logging residue are crude with respect to those measurements of the used and inventory sections. Measurement intensity, however, should be a function of the value of the material being surveyed. For example, stump volume was calculated by use of the volume equation. Diameter at the ground line (D) was approximated from stump height (L), top diameter (d), and an average stump taper deduced empirically for softwoods and hardwoods.

An attempt to approximate wood volume in residual crowns was made using information collected while measuring felled trees. Volume in pieces less than 1 inch in diameter was disregarded. Volume in the central or main stem was estimated using the base diameter and recorded length of the crown. With respect to Grosenbaugh's equation, the large end diameter (D) was known, the top diameter (d) of

1 inch was assumed, and length (L) was reduced proportionately to reflect the 1-inch dob rather than length to the tip of the crown. For branches, the volume for the average limb was estimated in the same way, and the result was multiplied by the number of branches. Attributes for the average branch were determined as follows: branch diameter (D) was the estimated mean limb diameter at the limb collar; branch length (L) was measured crown width divided by 2 and reduced proportionately to estimate average branch length to 1-inch dob. Again, (d) was assumed to be 1 inch.

The validity of volumes determined in this manner were somewhat suspect, so a test comparison of volumes estimated thusly versus "actual" volume was conducted. A sample of 20 residual tree crowns was measured at a logging operation in Livingston Parish, Louisiana in the summer of 1974. The same measurements taken during the felled tree samples in both Alabama and Louisiana were again made on the test sample of residual tree crowns.

In addition, the subsample of residual tree crowns was measured intensively to determine the best possible approximation of actual volume. Beginning at the base of the crown, diameter and length were measured at several points along the principal stem where excessive taper was evident. Measurement ceased at the point where the dob decreased to 1 inch. Volume of each of these measured sections was computed and summarized to obtain central stem volume. For each live

limb originating from the central stem in the crown, volume was determined similarly, including volume in any sub-branches greater than 1 inch in diameter. The summation of all measured sections comprised the actual or test volume for comparison with that volume estimated via calculations based on crown width, base diameter, number of branches, and average diameter of the limbs in the crown.

RESULTS

Since the outcome of crown volume estimation versus measurement was a necessary component for analysis of the results of the utilization study, crown results are discussed first.

Crowns

In the sample of 20 residual tree tops, eight of the excurrent crowns were southern pine species, and the balance of 2 excurrent and 10 deliquescent tops were hardwood species. Though meager, the samples were adequate to abolish the notion of estimating crown volumes from measurement of length, width and number of limbs of an estimated mean diameter. For example, estimated volume for all 20 crowns in the sample amounted to only 78 percent of measured volume (Table 2).

Further analysis of the crown measurements indicated that, in excurrent crowns, volume was concentrated in relatively small limbs, 2 to 3 inches in diameter next to the limb collar. For deliquescent crowns, limb volume peaked in the 6-inch class (Appendix, Table 9). Higher branching orders were more important in deliquescent crowns. On a percentage basis, the volume in limbs above the first branching order in deliquescent crowns was roughly double that of excurrent crowns. In excurrent crowns, branches comprised about 40 percent of the wood volume. For deliquescent crowns, limbs accounted for 54 percent.

Table 2. Sums of estimated and measured volume for 20 sample crowns

Crown type	Estimated			Measured		
	Stem	Branches	Total	Stem	Branches	Total
	- - - - - - - - - -	- -Cubic feet- -	- - - - - - - - - -			
Excurrent	24.3	9.8	34.1	28.2	17.9	46.1
Deliquescent	59.9	27.4	87.3	50.2	59.1	109.3
Total	84.2	37.2	121.4	78.4	77.0	155.7

Regression analyses of the 109 hardwood and 81 softwood limbs indicate that branch volume is closely related to powers of diameter of the limb, regardless of crown type or species (Table 3). The equations used to predict branch volume to a minimum 1-inch dob are as follows:

Softwoods $\hat{Y} = -.0083 + .0116\ D^3$

Hardwoods $\hat{Y} = .1672 + .0133\ D^3$

where Y = volume in cubic feet and D = diameter of the limb just beyond the limb collar. For softwoods, the r^2 was .99; for hardwoods it was .97.

Further analysis leads to the corollary proposition of estimating top volume from diameter of the base of the central portion of the top. For the 20 sample crowns the modified equations become:

Softwoods $\hat{Y} = .0113\ D^3$

Hardwoods $\hat{Y} = .0121\ D^3$

where D = diameter of the base of the crown. These equations account for 99 percent of the variation in softwood tops and 95 percent in hardwood tops. They were forced through the origin since it is logical to expect trees having zero diameter at the base of the crown to have no top volume (Table 4).

Base diameters of the softwood crowns sampled were generally less than eight inches, and no observations were recorded in the 8 to 12-inch range (Figure 7). To test the performance of the prediction equation, five softwood tops

Table 3. Analyses of variance for the regression of branch volume on limb diameter cubed

Source	Degrees of freedom	Sum of squares	Mean square	F
Softwood:				
Regression	1	28.288	28.288	14039.523**
Error	79	.159	.002	
Total	80	28.477		
Hardwood:				
Regression	1	78.937	78.937	3035.900**
Error	107	2.782	.026	
Total	108	81.719		

**P < .01

Table 4. Analyses of variance for the regression of top volume on base diameter cubed

Source	Degrees of freedom	Sum of squares	Mean square	F
Softwood:				
Regression	1	486.98	486.98	2029.08**
Error	6	1.44	.24	
Total	7	488.42		
Hardwood:				
Regression	1	1750.41	1750.41	174.10**
Error	10	100.54	10.05	
Total	11	1850.95		

**P $\leq$ .01

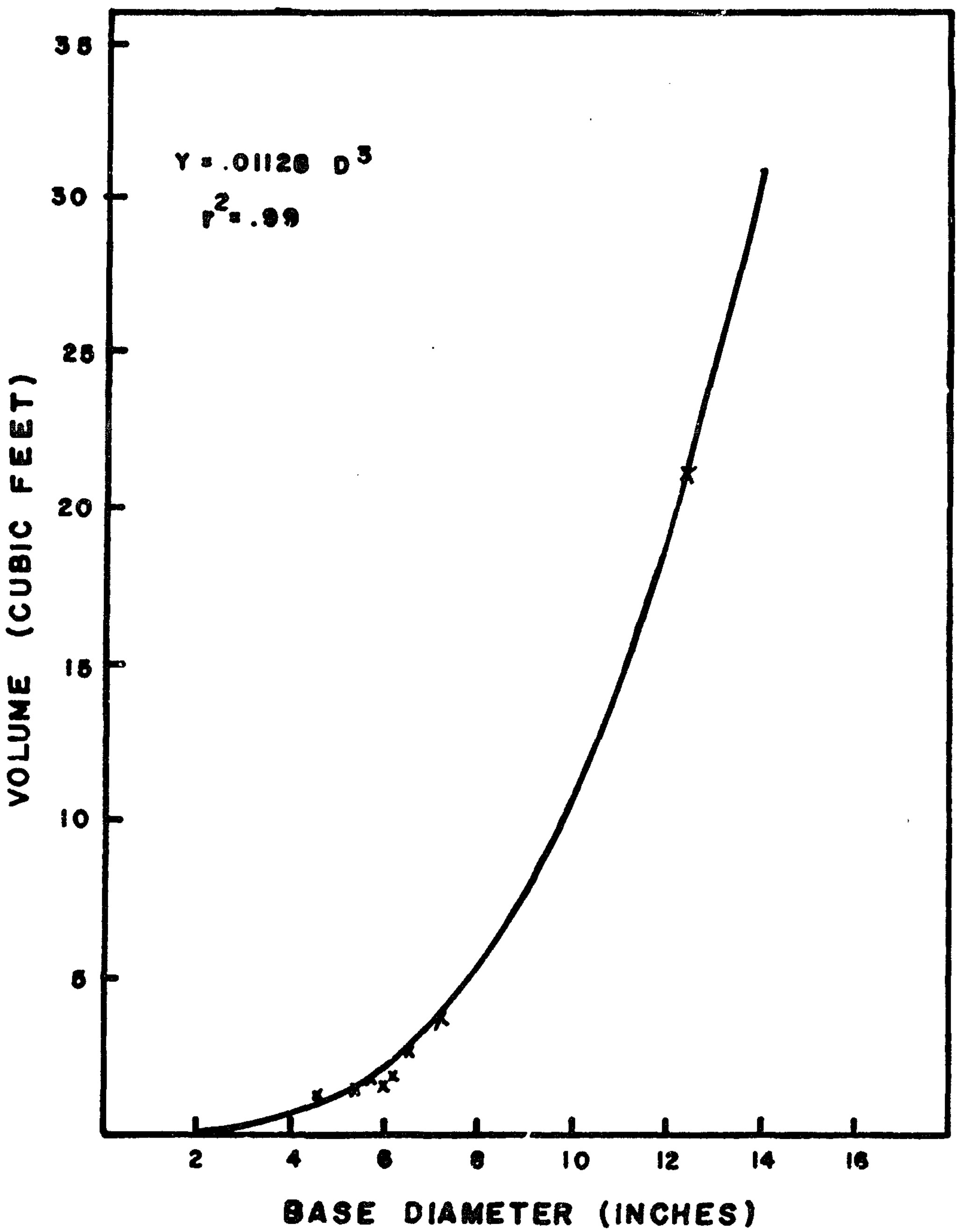

Figure 7. Softwood residual crown volume as related to base diameter of the central stem.

ranging from 6-to 8-inches base diameter were measured in St. Tammany Parish. The sum of predicted volume exceeded actual volume by less than two percent.

Since the base diameters of the hardwood tops sampled were evenly distributed over the range of 5- to 12-inches (Figure 8), no additional hardwood tops were measured. Although the r^2 was 95 percent, much less reliability can be placed in the hardwood regression equation. While softwoods can be expected to exhibit a regular pattern in crown development, hardwoods can be expected not to. The standard error of $\bar{y}$, in percent, was about 4 for the softwood tops but rose to more than 30 for hardwoods. Unlike softwoods, the sum of predicted volumes was two percent less than observed volume.

The regression equations developed from the auxiliary sample of tree tops in Livingston Parish are used in presentation of subsequent results regarding tree component parts.

Stump height and merchantable tops

An overview of utilization during logging for the products studied may be gained from examination of the sample summary statistics. They indicate some utilization to be different from inventory standards. Stump height, for example, averaged lower than one foot for all categories except hardwood saw logs in Louisiana (Appendix, Table 10). The average stump height was lowest for softwood pulpwood

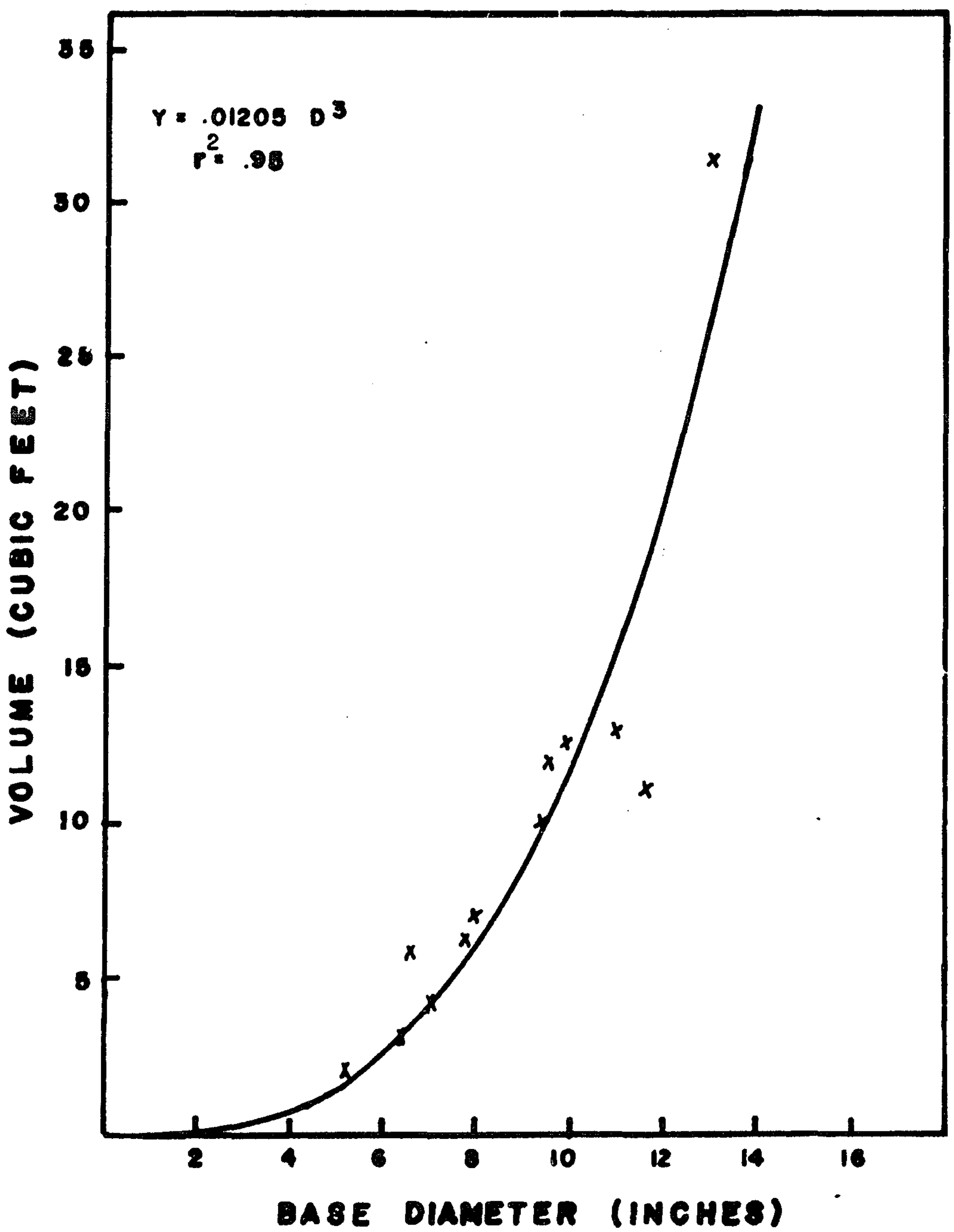

Figure 8. Hardwood residual crown volume as related to base diameter of the central stem.

and highest for hardwood saw logs. Upper diameters to which loggers cut and used trees for various products ranged from a low of slightly less than four inches for softwood pulpwood to a high of more than eight inches for hardwood saw logs (Appendix, Table 11). Softwood pulpwood logging appears to duplicate the nominal upper limit of 4-inches dob for inventory volume. The larger average diameters for other products is related to tree size logged and the propensity of trees to meet other limiting criteria such as excessive taper, branching, or the like.

The deviation of logging practices from inventory criteria may be regarded as impetus to change Forest Survey standards. For example, the means indicate that stump height varies with the product being logged. But, in addition to complicating the interpretation of past survey data and data collected with revised standards, setting stump height based upon product logged requires a subjective assessment of what product might be logged sometime in the future.

Inventory volume should be determined as usual, and volume in residual stumps, crowns, and limbs can be related to inventory volume. Tables of mean volumes for each of these categories are listed in the Appendix (Tables 12-15). For simplicity, subsequent results are presented by product. A table of the values discussed by product is listed in the Appendix (Table 16).

<u>Softwood saw logs</u>

Softwood cut for saw logs in Louisiana averaged 49 cubic feet including the stump above ground level, limbs, bole, and residual crown. In Alabama, the mean was about 36 cubic feet. In both states, the used volume was approximately 87 percent of the total volume. The great bulk of this used volume is obtained from sawtimber portions of the trees (Appendix, Tables 17 and 18). The distribution of board-foot volume by 1-inch dbh class (Figure 9) again points out the difference in tree size by state. For example, nearly 60 percent of the board-foot volume in Louisiana comes from trees greater than 15 inches dbh. For Alabama, the figure is 46 percent.

About five percent of the used volume was in sections above sawtimber limits. Most of this volume, however, was used for pulpwood. Slight amounts of noninventory volume were used, principally due to the cutting of stumps lower than the nominal height of one foot.

On an individual tree basis, slash volumes were about 6 cubic feet in Louisiana versus 5 cubic feet in Alabama. In both states, unused inventory volume was roughly four-tenths of the residue. The waste of inventory was largely in upperstem sections in Alabama, but sawtimber waste was substantial in Louisiana. The cutting of high stumps can be dismissed as a source of inventory waste.

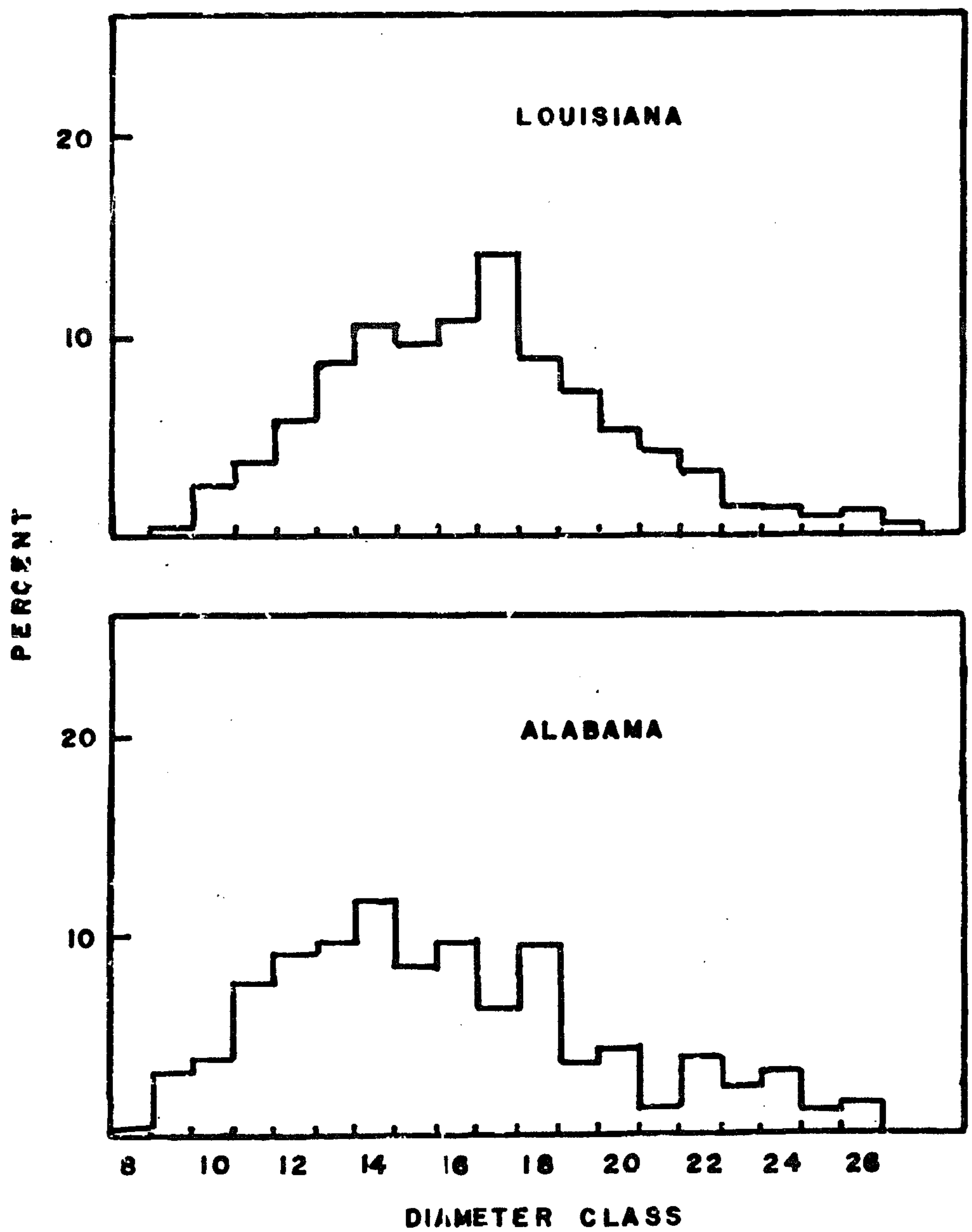

Figure 9. Distribution of saw log board-foot volume by 1-inch dbh class.

The balance of the residue from cutting softwood saw logs was due to tree components not classified as part of the growing stock inventory. The greatest single source of woody logging slash is residual crowns. This unused upper part of the bole plus connected branches greater than 1 inch in diameter accounts for more than half of the logging slash. Limbs trimmed from the bole ranked second in slash volume and stumps followed closely.

Veneer logs

Trees cut during veneer logging were generally larger than those cut for saw logs. The proportion of the tree used, however, was the same. More than 90 percent of the used volume was from sawtimber sections (Appendix, Tables 19 and 20). In Alabama nearly 20 percent of the used volume was allocated to saw logs. For Louisiana this form of use was less than 10 percent. In both states, much of the upper-stem volume was used for pulpwood. Very little over-use or use of noninventory material was detected.

The preference for larger trees for veneer is obvious from the difference in board-foot volume distribution by 1-inch diameter class. When compared to saw logs, a greater share of the volume comes from trees greater than 15 inches dbh for both states (Figure 10). In Louisiana, with its larger trees, the distribution is shifted even more to the larger diameters.

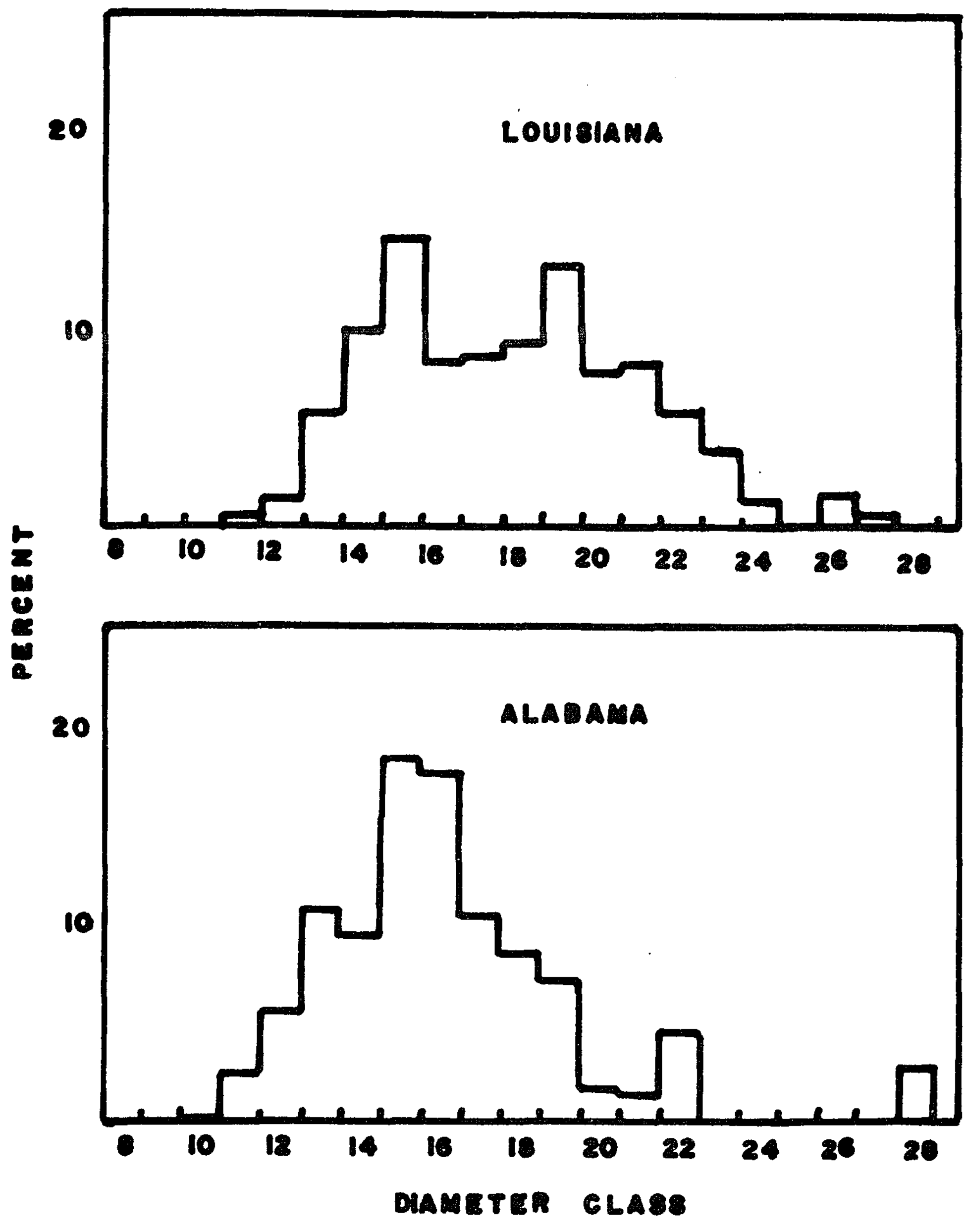

Figure 10. Distribution of veneer log board-foot volume by 1-inch dbh class.

Volume of residue after veneer logging was 6 cubic feet per tree in Alabama and nearly 8 cubic feet in Louisiana. Again, the residue was related to tree size. In each state, waste of growing stock volume was less for veneer than for saw logs. Upperstem portions comprised the majority of inventory waste. Waste from high stumps was negligible.

The noninventory volume left after logging comprised 80-90 percent of the slash. Crowns were the principal component, followed by lopped limbs and stumps.

Softwood pulpwood

Trees cut for pulpwood were the smallest of the trees cut for wood products, averaging 12.5 cubic feet total volume in Louisiana and 11 cubic feet in Alabama. On logging operations for pulpwood, about 60 percent of the used volume was being cut from trees larger than 9 inches dbh (Appendix, Tables 21 and 22). Smaller trees comprised from 25-30 percent of the used volume. The balance was from noninventory sources.

Slash volume from trees cut for pulpwood was very low. The mean value for Louisiana trees was 3 cubic feet; for Alabama it was less than 2 cubic feet. In both states, inventory sections, mainly upperstems, comprised less than 10 percent of the slash. With such close use of the inventory volume, crowns comprised the bulk of the residue. Once again, limbs and stumps ranked second and third.

Hardwood saw logs

Mean gross volume of trees cut for hardwood saw logs was greatest of all products sampled. Although Louisiana trees at 58 cubic feet were larger, used volume was less than in Alabama. In Alabama 70 percent of the tree was used, while in Louisiana only 60 percent was used. The difference was primarily the result of larger crowns being left behind during harvesting in Louisiana.

The minimum diameter for hardwood sawtimber is greater than that of softwoods, and the distribution of used board-foot volume is shifted toward higher diameter classes. Once again, the average difference in tree size by state is indicated by the board-foot distribution. In Alabama more board-foot volume originated from 14-inch class trees than any other class. For Louisiana the dominant class was 16 inches (Figure 11).

For both states, about 85 percent of the used volume was in sections classed as sawtimber (Appendix, Tables 23 and 24). Small amounts of this volume were used for pulpwood. Use of upperstem sections of sawtimber trees was primarily for pulpwood. The use of cull trees during hardwood saw log operations was notably higher than for softwoods. Even so, the contribution of cull trees to the output of hardwood saw logs is only around 2 percent. Portions of the tops and limbs were used for pulpwood.

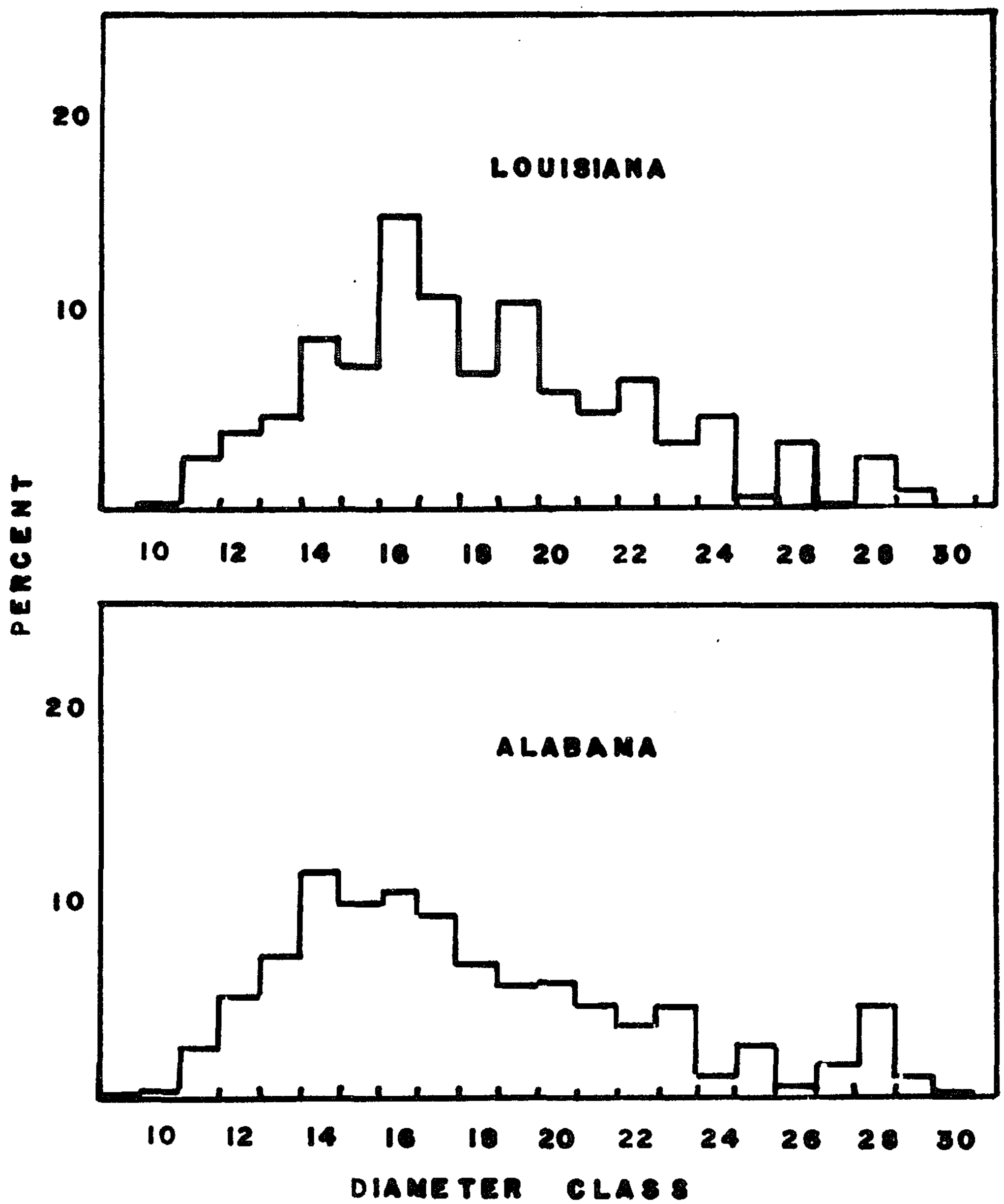

Figure 11. Distribution of hardwood saw log board-foot volume by 1-inch dbh class.

Slash volumes after hardwood saw log operations are easily the heaviest of all products sampled. In Louisiana current logging practices leave as waste more than 23 cubic feet per tree. Although Alabama slash is somewhat lower, the average is more than 15 cubic feet per tree. Even with large unmerchantable crowns, waste of inventory sections comprised over one-fifth of the residue. The poor quality upperstem sections were foremost in inventory waste and often were left as part of the residual crown.

Residual tree tops were the single most important source of logging slash. Nearly two-thirds of all the logging residue was due to top volumes. Limbs trimmed while bucking the bole into logs were relatively minor sources of slash volume. The failure of loggers to use limby portions of the upper bole kept lopped limb volume low. Crown volumes were correspondingly higher since the limby, upperstem sections were left as part of the residual top.

Hardwood pulpwood

Trees generally cut for pulpwood were half as large as those cut for saw logs. Louisiana trees averaged 28 cubic feet; Alabama 19 cubic feet. From 15 to 20 percent of the total volume was in tree tops, roughly 5 percent in lopped limbs, another 5 percent in stumps, and the balance of 70 to 75 percent was used.

About one-half of the used volume came from trees classed as sawtimber. The rest came primarily from pole-

timber trees, but culls, noninventory sections in growing stock trees, and limbs were used frequently (Appendix, Tables 25 and 26).

Utilization of inventory sections of trees cut during pulpwood harvesting was fairly complete. Only about one cubic foot per tree was wasted in Louisiana and less than one-half cubic foot in Alabama.

Utilization ratios

In all products sampled, there was some waste of growing stock and some use of non-growing stock volume. The mean utilization ratio should be arbitrarily close to unity. By analysis of this relationship, the efficiency of harvesting various products in the two states can be appraised. In Table 5 the ratio appears to cluster about 1.0. The waste of inventory volume is offset by over-use. Pulpwood harvesting gleans more useable wood than is inventoried. Hardwood harvesting was more variable than that for softwood products. In general, there was less variation in the utilization ratio in Alabama than in Louisiana.

Statistical analysis of the softwood results reveals no significant differences among states (Table 6). Products, however, were found to differ significantly. Orthogonal comparisons indicated significant differences in the ratios for saw and veneer logging versus pulpwood and for saw versus veneer logging. For saw logs, logging was significantly the least efficient, requiring 1.062 cubic feet of inventory

Table 5. Mean utilization ratios and coefficients of variation by state and product

Product class	Alabama		Louisiana	
	Mean	Coefficient of variation (%)	Mean	Coefficient of variation (%)
Softwood:				
Saw logs	1.05727	5.9	1.06701	10.0
Veneer	.99788	2.5	1.02157	6.1
Pulpwood	.95522	8.0	.94294	9.5
Hardwood:				
Saw logs	1.09133	12.0	1.15049	13.9
Pulpwood	.92276	10.2	.95931	10.3

Table 6. Analysis of variance, softwood utilization ratios

Source	Degrees of freedom	Sum of squares	Mean square	F
State (adj. for products)	1	.00022	.00022	.036
Product (adj. for state)	2	.27246	.13623	22.296**
State x product	2	.00557	.00279	
Error	105	.64787	.00617	
Total	110	.92944		

**P < .01

volume for every cubic foot of product output. For veneer, the ratio at 1.011 was slightly but significantly lower than that for saw logs. Pulpwood logging represents the maximum use of forest trees. The utilization ratio of 0.950 was significantly less than the other products, and implies that 1000 cubic feet of pulpwood output requires cutting of only 950 cubic feet of the forest inventory.

Since the effect of state was not significant, the sample results were combined to obtain the overall mean ratios reported above.

For hardwoods, the results were similar. There was no significant difference between the two states, but the ratio for saw logs was significantly larger than that for pulpwood (Table 7). The saw log utilization ratio for both states combined was 1.100. For pulpwood, the ratio was 0.933.

Table 7. Analysis of variance, hardwood utilization ratios

Source	Degrees of freedom	Sum of squares	Mean squares	F
State (adj. for products)	1	.03753	.03753	2.601
Product (adj. for state)	1	.69438	.69438	48.121**
State x product	1	.00275	.00275	0.191
Error	85	1.22651	.01443	
Total	85	2.00855		

**p < .01

DISCUSSION

The study results highlight the complex structure of timber harvesting in the South. The diversity ranges from highly mechanized operations subsidized by companies receiving the roundwood products to independent contractors logging for single products on an intermittent basis. While geography of the region is fairly homogeneous, the timber stands are exceedingly diverse in species and structure. Ownership is largely of the miscellaneous private classification, and timber sales may be closely supervised or not supervised at all. All of these factors serve to influence utilization during logging. There is, however, no straightforward way to relate these influences to removals on a broad scale. The technology of logging is in a constantly evolving state with a bent toward greater efficiency in obtaining maximum output at minimum cost. The application of new techniques and equipment is not general. Studies such as this one serve to assess the impact of current practices and for a limited time obviate the need to consider these extra, generally unmeasurable, factors.

In this study integrated logging was common to both states. Size and quality requirements for the products sampled were expressed in logging for more than one product at a time. Veneer appeared to have the most demanding requirements of the products sampled. Only 70 to 80 percent of the used volume on veneer logging operations went into

veneer logs. The rest was used for saw logs and pulpwood. Very little noninventory volume was destined to become veneer. Some was used as a consequence of cutting stumps less than one foot high. The rougher bole sections were allocated largely to saw logs, with pulpwood claiming the bulk of the used upperstems of the saw-log size trees.

There was considerably less cross-product movement in softwood saw log operations than veneer operations. Roughly 90 percent of the volume used in these operations was saw logs. Occasionally high quality logs were set aside for veneer, but pulpwood generally became the end product of the tree sections not used for saw logs.

Utilization on hardwood saw log operations was the poorest of all logging sampled. Among difficulties in hardwoods is the selection of bole sections for quality requirements. Grade specifications for hardwood logs are more stringent than for softwoods. In addition to limitations for limbs and knots common to both species groups, hardwood log grades take into account such items as insect holes, bird peck, and a host of other criteria. Even low-value uses such as cross ties have potentially restrictive requirements. Where certain amounts of rot may be permitted in factory and shop grades, none is permitted in the tie and timber grades which will enter into the contained tie or timber (Appendix, page 87).

By nature hardwoods are more variable in form than softwoods, and hardwoods are susceptible to many types of damage which detract from their quality. Excessive thinning in a hardwood stand can produce epicormic branching, thus adversely affecting potential uses. Fire in hardwood stands can be lethal, and usually causes fire scars and subsequent butt rot in surviving trees.

Although half the timber resource in the Midsouth is hardwoods, management practices have lagged far behind softwoods. Adverse practices have reduced quality on many sites. Furthermore, the clearing of land for agricultural crops such as soybeans has decimated the land base which can support the growth of quality hardwoods. They do not develop well on most upland sites in the Midsouth, and the general approach has been to convert these upland hardwood types to more productive pine types. Use of the hardwood volume on these converted sites poses problems because of its low quality. Pulpwood, with few quality requirements, has generally been the only substantial market for this volume. There is, however, a limit to the amount of hardwood pulpwood required, and pressure for site conversion may create huge volumes of hardwood waste. In recent land clearing operations, for example, much of the hardwood volume was of good quality and still it was windrowed and burned.

The outlook for hardwood utilization is not bright. The industry has been lagging in adaptation to the resource. While adamantly requiring quality input to the mills, industry has done little to improve the quality by using silvicultural treatments.

The production of pulpwood improves utilization of Midsouth forests. On operations primarily for pulpwood, waste of inventory volume is less than utilization of noninventory volume. Moreover, much of the efficiency in logging for other products stems from the use of leftover pieces for pulpwood.

Technology has served the pulping industry well. By using poor quality trees and less valuable sections in trees logged for other products, the available supply of pulpwood is conserved. For example, the chipping and subsequent use of slabs and edgings, formerly wasted at sawmills, contributes heavily to the output of pulpwood. The use of tree parts generally wasted during harvesting serves to expand the resource. Crowns comprise about half of the logging slash, and the feasibility of using this volume has already been demonstrated on a limited basis. Indiscriminate whole tree chipping is not recommended because the bole may be more valuable for dimension products such as lumber or handlestock. The practice does, however, offer a way to substantially increase fiber output without additional drain upon the forest resource.

Estimates of volume in residual hardwood tree crowns are inadequate and serve primarily to indicate the magnitude of a potential resource. Optimally, a separate equation should be developed to apply to specific species or groups of species within which crown form is fairly homogeneous. For softwoods the procedure developed in this study gives reasonably accurate results. Although there is danger of encountering tops whose diameter is outside the range for which the equation was developed, the generally close utilization of softwoods minimizes this source of error. For hardwoods, the chances to go astray are far greater. Larger tops are commonly left behind during logging, and as a group, hardwood crowns are extremely variable. Some hardwoods exhibit branching habit quite like softwoods, maintaining a central stem to the terminal bud. Others, however, are deliquescent in form and no central stem is apparent. Furthermore, it is this type of crown that is most often left unused and contains the most volume.

There is some question that the estimation of crown volume can be approached from a mensurational standpoint. The most common method is to weigh the crown and take specific gravity samples to determine dry weight. This is perhaps prohibitively expensive for common application to such a low value commodity. It has been demonstrated that the branch volume can be closely approximated from measurement of limb diameters at the bole. Predicting

crown volume from stem diameter at the point where the crown is severed from the bole worked reasonably well in this study. Doubtless, the procedure would be better when applied to species groups having more homogeneous crowns.

In the samples taken, Alabama trees were consistently smaller and used more completely than in Louisiana. According to the stand tables from the most recent surveys (Murphy 1973, 1976), the average tree in Louisiana is larger than its Alabama counterpart. The explanation for these apparent differences is not readily apparent. Both states currently have an excess of growth over removals for both hardwoods and softwoods. The impetus for close utilization may fall in more localized areas where forest industries are concentrated and the drain exceeds growth (Beltz 1975). Close utilization appears closely related to pulpwood production, for most of the smaller tree parts on other logging operations are allocated to this use. Pulping capacities in the two states are roughly equivalent (Bertelson 1975). Pulpwood production in Alabama, however, is half again that of Louisiana.

The capability of southern forests to continue to supply the needs of industry is increasingly dependent upon efficient conversion of standing trees to useable products. Efficiency implies little waste, and waste has many connotations. To a lumber manufacturer, any trees or tree parts too small to produce lumber may be considered

waste. From an opposite perspective, an environmentalist may view logging slash as an aesthetic detriment, or even oppose cutting trees in principle. While not so evident in the South as in the West, pressure from various interests promises to influence forest practices. The forest land base to produce timber products is shrinking through withdrawals for non-timber uses, such as parks, recreation areas, and farming. Moreover, the economic and technological environment of forest harvesting is continually changing. New machinery for harvesting timber products is bringing closer the possibility of complete tree harvesting. As the resource approaches maximum sustainable level of output, economic factors will favor the more complete harvesting that is now physically possible.

Single product logging is an inefficient way to harvest forests. The trend has been increasingly toward integrated operations, where portions of tree boles can be allocated to various end uses. Often, the tree is limbed and topped and the entire stem hauled to a central point for bucking into pieces destined for various products. Such practices minimize the woody material left behind in the woods. However, a substantial proportion of each tree is comprised of branch and top wood, plus the amount left in stumps. In limited applications, field chipping of the above-ground portion of trees is accomplishing virtually total utilization.

Total utilization is not necessarily optimal. If the entire bole must be comminuted, such use detracts from higher value dimension products which could be produced. There is some concern that removal of the entire dry-matter production will lead to nutrient depletion of the site. There is little danger of nutrient depletion given current utilization levels, but the outlook is for continued improvement toward harvesting total fiber yield from southern forests. Management and use of forests will grow more intensive and fertilization may well be required as an integral part of silviculture.

SUMMARY AND CONCLUSIONS

A study of logging utilization was begun in Alabama concomitant with the 1972 forest survey. As the survey progressed into Louisiana in 1973, the study was repeated to assess current utilization in the Midsouth. A total of 200 logging operations were sampled in the two states. Samples were selected with probability of selection proportional to size. For saw logs and veneer logs, selection was based on output of receiving mills. For pulpwood, production by county or parish was the basis for selection. At each sample location, 20 felled trees were measured to determine volume according to Forest Survey standards and the volume actually used.

An initial attempt was made to estimate residual crown volume from base diameter, length, width, number of limbs, and an estimate of the average limb diameter. A sample of 20 tree tops left after logging was measured intensively to check the first approximation. Since the first approach was inadequate, a new method using regression equations developed from the intensively measured sample was used. The regression equations, based only on crown base diameter, are more precise and easier to apply than the original estimates. These equations were used to predict crown volumes reported in this study.

Trees cut for softwood veneer were larger than those cut for saw logs. Softwood pulpwood trees were smallest of all. Hardwoods cut for saw logs were as large as those cut for softwood veneer, but used volume was only two-thirds of gross volume.

Slash volumes were higher for hardwoods than for softwoods, with crowns and stumps comprising the bulk of the difference. Lopped limbs were a larger component of gross volume in softwoods than in hardwoods. This is an expression of intensity of utilization in that loggers seldom used hardwood sawtimber sections having excessive limbs. Quality requirements are different for the two species groups, and knots damage hardwood quality more than softwood.

No differences in degree of utilization of the forest inventory were detected between states. There were, however, significant differences among products. The utilization ratio (ratio of inventory volume to used volume) was highest for saw logs and lowest for pulpwood. Veneer logging, sampled only for softwoods, was intermediate in its utilization ratio.

The results of this study could have considerable impact. Since no difference was detected between states, regional analysis of Forest Survey data is facilitated. In feasibility studies, the results can play a decisive role in site selection. Tree records in the inventory can be processed

to obtain estimates of crown volume. The volume in tops and wasted inventory sections may constitute a valid resource for certain types of forest industries. Saw and veneer loggers can view the results as incentive to increase utilization.

Results of this study will be used in subsequent studies designed to develop efficient means of evaluating the additional volume not currently tabulated in forest surveys.

Although the results varied, some general conclusions about utilization can be drawn. They are as follows:

1. Present Forest Survey inventory standards are adequate for the purpose intended--estimation of timber volumes that can be harvested economically in a region. Current logging practice is obtaining as much output as is catalogued in the Forest Survey. Pulpwood operations consistently used more volume than was included in the inventory, and much of this extra volume was obtained by cutting lower stumps and leaving less volume in crowns. This gain in utilization was offset by waste of inventory volume on saw and veneer operations where much of the waste was in inventory sections left in large crowns.
2. Hardwood logging is more variable than that for softwoods. Slash volume is greater, and the

potential for increasing timber supplies through better use is greater for hardwoods than for softwoods.

3. For a given product, utilization of the inventory volume during harvesting was the same in Alabama as in Louisiana. Thus, the results for both states can be combined to obtain ratios applicable to the Midsouth.
4. Although the samples used to develop softwood and hardwood prediction equations for crown volumes were small, reasonably accurate results were obtained. By adequate sampling in homogeneous strata of crown form and species, crown volume can be predicted from merchantable top diameters collected during forest surveys.

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APPENDIX

MERCHANTABILITY STANDARDS

In addition to the requirements for growing stock as outlined in the definition of terms in the introduction, the following field instructions and illustration outline current Forest Survey methods of determining inventory volume in the eastern United States.

Record the length to the last whole foot of the bole of all sawtimber-size live and salvable dead trees, i.e., softwoods 9 inches d.b.h. and larger, and 11 inches d.b.h. and larger for hardwoods. Measure from a 1-foot stump to the point above which no saw log can be produced to meet log grade standards or to a minimum top of 7 inches d.o.b. for softwoods and 9 inches d.o.b. for hardwoods.

Saw log length should not extend above a point where taper becomes excessive as evidenced by (1) a fork with less than an 8-foot saw log above it (12 feet if this is the only log in the tree) and (2) a limb with a base diameter equal to one-half or more of the stem diameter below the limb, or a group of smaller limbs with equivalent diameter which collectively influence taper to the same degree. Also, saw log length should not extend above a saw log section that does not meet minimum log grade specifications and which has less than 8 feet of saw log length above it (12 feet if this is the only log in the tree; see Figure 12, bole illustration B).

To qualify as a "sawtimber tree" the tree must contain at least a 12-foot log meeting grade, diameter, and length specifications.

Cubic-foot cull is the volume of decayed or missing wood in live or salvable dead trees, and the volume in sections of the bole that is too rough to be utilized as pulpwood, including short sections with extreme crook, large forks, or numerous limbs.

Cull any 5-foot section if a line between the centers of the ends falls outside the bark at any point. Cull any section if it has a limb whose knot collar exceeds the stem d.o.b. at that point, or has several limbs over 2 inches d.o.b. within a 1-foot span whose aggregate knot collar diameters exceed the stem d.o.b. at that section.

The classification of trees in figure 12 is as follows:

A. A sawtimber tree. Saw log length terminates at 9-inch top d.o.b. Meets minimum qualifications of a 12-foot saw log. Upperstem portion contains no cull and terminates at 4 inches d.o.b. Saw log length is recorded as 12 feet; bole length as 21 feet.

B. A sawtimber tree. Saw log portion terminated by limbs at 13 inches d.o.b. Contains no cull and meets minimum grade specifications. Both bole length and saw log length 14 feet. Portion between whorls of limbs is large enough in diameter but not

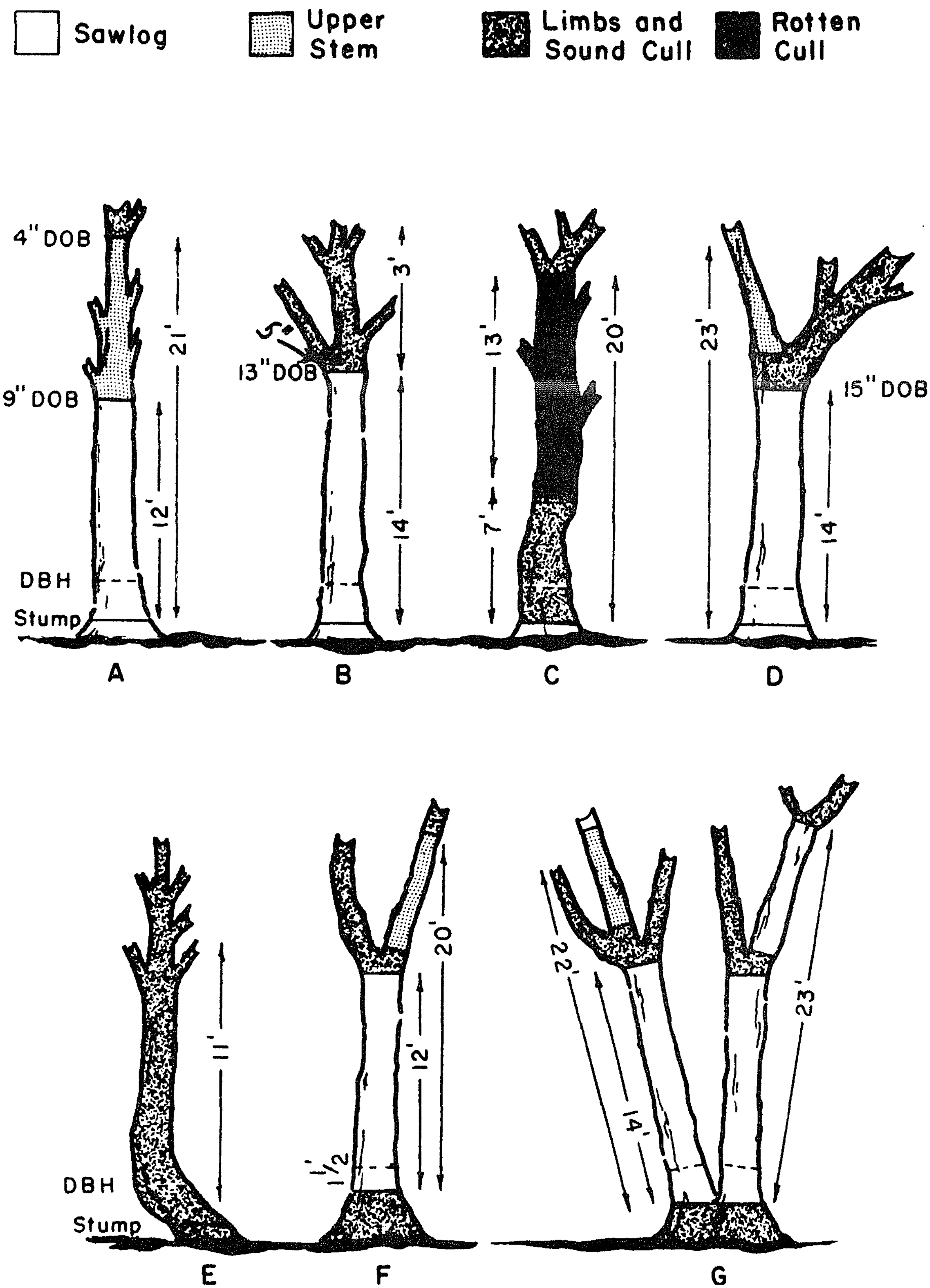

Figure 12. Bole lengths.

in length to qualify as upperstem, i.e., is less than 4 feet long.

C. A rotten cull tree. Although saw log portion is 20 feet long, a 13-foot section of rotten cull prevents utilization of a log meeting minimum grade specifications; thus whole saw log portion is culled. Because more than half the volume in that portion is rotten, the tree is classed as a rotten cull tree.

D. A sawtimber tree. Saw log portion terminating because of branching at 15-inch top d.o.b. meets minimum specifications. Right-hand fork is too limby to qualify as upperstem, but 7 feet of left-hand fork qualifies as upperstem. Bole length is 23 feet.

E. A rough tree. Saw log top terminates by branches 11 feet above crooked butt. No saw log meeting minimum qualifications present.

F. A sawtimber tree. Despite sound cull in the saw log portion due to butt swell, a 12-foot saw log is present. Seven feet of right fork qualifies as upperstem. Left fork does not qualify due to crook.

G. Two sawtimber "trees". Since lowest fork is below dbh each fork is appraised and recorded as a separate tree. The lower 14-foot section in the

left fork meets requirements for a sawtimber tree. A 6-foot portion of the largest stem in upper fork qualifies as upperstem material. In the main right fork, a 13.5-foot saw log plus a 9-foot saw log (with an intervening 1-foot section of sound cull) is recorded as 23 feet of saw log length. Bole length is the same.

SOUTHERN PINE LOG GRADES

Grade	Number clear faces	Definitions	Exceptions
1	3, 4	A face is one-fourth of the circumference extending full length of the log.	a. Lower one grade any log not grade 3 having 3 inches or more of sweep if such sweep is 1/3 or more of log diameter.
2	1, 2	Clear faces are those free of: Knots measuring more than one-half inch in diameter, overgrown knots of any size, holes more than one-fourth inch in diameter	b. Lower one grade any log not grade 3 if heart-rot fruiting has occurred or is imminent, as indicated by conk or visible, massed, heart-rot hyphae.
3	None		

HARDWOOD LOG GRADES FOR STANDARD LUMBER, TIES, AND TIMBERS

Grade factor	Standard lumber logs 1			Standard lumber logs 2	Standard lumber logs 3	Tie and timber logs
Position of log in tree	Butt	Butt or upper		Butt or upper	Butt or upper	Butt or upper
Diameter - inches	13-15 1/	16-19	20+	11+ 2/	8+	8+
Minimum length - feet	Butt log 12; upper half log 5					
Clear cuttings on 3 best faces Minimum length of cuttings - feet	7	5	3	3	2	No requirements. Not graded on cutting basis. Sound surface defects permitted: Single knots - any number, if none has an average collar diameter exceeding 1/3 log diameter at point of occurrence. Whorled knots - any number, if sum of collar diameters does not exceed 1/3 log diameter at point of occurrence. Holes - any number not exceeding knot specifications, if do not extend over 3 inches into contained tie or timber. Unsound defects permitted: Surface - any number and size if do not extend into contained tie or timber, or if do extend shall not exceed sound knot limitations. Interior - none except 1 shake not more than 1/3 width of contained tie or timber, and 1 split not over 5 inches long.
Maximum number on any face	2			1/2 log: 2; 1 log: 3 3/	No limit	
Minimum portion of each face	5/6			2/3	1/2	
Maximum sweep and crook deduction	15% 4/ Sweep deduction formula:			30% 4/ Total sweep - 2 / Scaling diameter	50% 4/	Sweep shall not exceed 1/2 small end diameter of 16 ft. log or 1/4 small diameter of half log.
Maximum cull deduction, including sweep	40%			50% 5/	50% 6/	No specification.
End defects	See Field Instructions, pages 28 - 29					No specification.

Exceptions:

1/ 12-inch minimum for ash and basswood butt logs, grade 1.

2/ 10-inch minimum for grade 2 if log is of grade 1 surface quality.

3/ Grade 2 11-inch-log limited to two cuttings, 3/4 yield.

4/ Reduce sweep and crook allowance 1/3 in logs with more than 1/4 diameter in sound end defects.

5/ 60% cull deduction permitted in grade 2 if otherwise grade 1 quality.

6/ 60% cull deduction permitted in grade 3 if otherwise grade 2 quality.

Table 8. Example of probability proportional to size sample selection

Mill number	Production (any units)[a]	Cumulative sum	Sample value	Sample number	Comments
1	10	10	3	2	$83+20-100=3$; $0<3\leq 10$
2	5	15	...	...	
3	20	35	23	3	$15<23\leq 35$
4	3	38	...	...	
5	1	39	...	...	
6	2	41	...	...	
7	25	66	43, 63	4, 5	$41<43\leq 66$; $41<63\leq 66$
8	7	73	...	...	
9	9	82	...	...	
10	18	100	83[b]	1	$82<83\leq 100$

[a]Note that unit of measure is indeterminate but must be consistent among all mills.

[b]When starting point plus interval exceeds total production, subtract total production to obtain next sample.

Samples desired: 5
Total production: 100
Number of mills: 10
Random start: 83
Sampling interval: 100/5=20

Table 9. Branch volume to minimum 1-inch dob for 10 excurrent and 10 deliquescent crowns

Diameter	Total	Excurrent	Deliquescent
Inches		- - - - Cubic feet - - - -	
1.0-2.0	3.642	2.553	1.089
2.1-3.0	14.830	5.931	8.899
3.1-4.0	12.649	3.386	9.263
4.1-5.0	13.547	0.774	12.773
5.1-6.0	20.697	...	20.697
6.1-7.0	...	...	...
7.1-8.0	11.658	5.299	6.359
	77.023	17.943	59.080

Table 10. Stump height summary statistics in feet

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	0.59	0.243	0.85	0.205
Softwood veneer	.55	.216	.83	.194
Softwood pulpwood	.37	.203	.50	.268
Hardwood saw logs	.96	.313	1.15	.300
Hardwood pulpwood	.68	.333	.91	.326

Table 11. Merchantable top diameter summary statistics in inches

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	5.42	1.970	5.91	2.055
Softwood veneer	5.87	1.839	6.35	2.328
Softwood pulpwood	3.84	.875	3.92	1.689
Hardwood saw logs	8.71	3.546	10.67	3.716
Hardwood pulpwood	5.38	1.994	6.57	2.538

Table 12. Inventory volume summary statistics in cubic feet

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	32.63	21.235	45.17	27.243
Softwood veneer	40.35	19.139	52.01	26.570
Softwood pulpwood	9.45	9.199	9.29	9.787
Hardwood saw logs	39.16	25.685	39.04	27.657
Hardwood pulpwood	12.81	11.461	18.37	16.194

Table 13. Stump volume summary statistics in cubic feet

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	0.97	0.947	1.39	0.868
Softwood veneer	.85	.646	1.46	.806
Softwood pulpwood	.22	.220	.39	.443
Hardwood saw logs	2.33	2.017	2.51	1.595
Hardwood pulpwood	.96	3.838	1.17	1.000

Table 14. Residual crown volume summary statistics in cubic feet (a)

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	2.72	5.171	3.29	4.355
Softwood veneer	3.08	4.157	4.23	5.622
Softwood pulpwood	.72	.635	1.61	16.145
Hardwood saw logs	12.52	18.841	20.32	22.003
Hardwood pulpwood	2.83	5.477	5.11	7.296

(a) Crown volume was estimated from base diameter using a regression equation having an error term.

Table 15. Limb volume summary statistics in cubic feet

Product	Alabama		Louisiana	
	Mean	Standard deviation	Mean	Standard deviation
Softwood saw logs	1.24	2.237	1.59	1.946
Softwood veneer	2.01	2.662	2.05	1.902
Softwood pulpwood	.49	.810	.91	3.620
Hardwood saw logs	.68	1.276	.69	1.326
Hardwood pulpwood	1.00	9.243	1.16	6.719

Table 16. Mean tree volume by state and product in cubic feet

Product class	Inventory volume	Used volume	Slash volume	Above ground volume	Percent used
Softwood saw logs					
Alabama	32.63	31.00	4.93	35.93	86
Louisiana	45.17	42.80	6.27	49.07	87
Softwood veneer logs					
Alabama	40.35	40.46	5.94	46.40	87
Louisiana	52.01	51.10	7.74	58.84	87
Softwood pulpwood					
Alabama	9.45	9.63	1.43	11.06	87
Louisiana	9.29	9.61	2.91	12.52	77
Hardwood saw logs					
Alabama	39.16	36.76	15.53	52.29	70
Louisiana	39.04	34.25	23.52	57.77	59
Hardwood pulpwood					
Alabama	12.81	14.07	4.79	18.86	75
Louisiana	18.37	19.17	7.44	26.61	72

Table 17. Source of used volumes on Alabama softwood saw log operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
	- - - - - - -	-Percent-	- - - - - - -	
Sawtimber	87.81	0.68	2.45	90.94
Upperstem	1.63	...	3.78	5.41
Poletimber	.42	...	.59	1.00
Cull trees	.38	...	...	.38
Dead trees	.25	...	...	.25
Noninventory	.02	...	.46	.48
Saplings	...	...	...	...
Tops & limbs	.03	...	.03	.06
Stumps	1.48	...	...	1.48
Total	92.02	.68	7.30	100.00

Table 18. Source of used volumes on Louisiana softwood saw log operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
	- - - - - - -	Percent	- - - - - - -	
Sawtimber	85.65	4.41	3.77	93.83
Upperstem	1.07	.05	3.55	4.67
Poletimber	.10	...	.39	.49
Cull trees	.10	...	.08	.18
Dead trees	.05	...	...	.05
Noninventory	...	...	.15	.15
Saplings	...	...	...	...
Tops & limbs	...	...	.14	.14
Stumps	.49	...	...	.49
Total	87.46	4.46	8.08	100.00

Table 19. Source of used volumes on Alabama softwood veneer operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
	- - - - - - -	Percent	- - - - - - -	
Sawtimber	19.38	70.31	2.12	91.81
Upperstem	1.24	.40	3.52	5.16
Poletimber	.24	...	.21	.45
Cull trees	...	...	...	...
Dead trees	...	...	...	...
Noninventory	.14	.77	.28	1.19
Saplings	...	...	...	...
Tops & limbs	...	...	...	...
Stumps	...	1.39	...	1.39
Total	21.00	72.87	6.13	100.00

Table 20. Source of used volumes on Louisiana softwood veneer operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
	- - - - - - -	Percent	- - - - - - -	
Sawtimber	8.31	78.69	5.70	92.70
Upperstem	.37	.37	4.68	5.42
Poletimber	...	...	...	...
Cull trees	...	.82	.09	.91
Dead trees	...	...	...	...
Noninventory	.02	...	.30	.32
Saplings	...	...	...	...
Tops & limbs	...	...	.17	.17
Stumps	...	.48	...	.48
Total	8.69	80.35	10.64	100.00

Table 21. Source of used volumes on Alabama softwood pulpwood operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
		-Percent-		
Sawtimber	0.17	...	55.92	56.09
Upperstem	...	...	6.99	6.99
Poletimber	...	...	30.76	30.76
Cull trees	...	...	.75	.75
Dead trees	...	...	.16	.16
Noninventory	...	...	2.48	2.48
Saplings	...	...	...	...
Tops & limbs	...	...	...	...
Stumps	...	...	2.77	2.77
Total	.17	...	99.83	100.00

Table 22. Source of used volumes on Louisiana softwood pulpwood operations by product

Source	Saw logs	Veneer logs	Pulpwood	Total
	- - - - - - - -	Percent	- - - - - - -	
Sawtimber	...	...	59.66	59.66
Upperstem	...	...	8.04	8.04
Poletimber	...	...	25.62	25.62
Cull trees	...	...	.54	.54
Dead trees	...	...	...	...
Noninventory	...	...	2.67	2.67
Saplings	...	...	...	...
Tops & limbs	...	...	.20	.20
Stumps	...	...	3.27	3.27
Total	...	...	100.00	100.00

Table 23. Source of used volumes on Alabama hardwood saw log operations by product

Source	Saw logs	Pulpwood	Total
	- - - -	-Percent-	- - - -
Sawtimber	84.90	0.90	85.50
Upperstem	3.60	3.50	7.10
Poletimber	2.80	.20	3.00
Cull trees	1.40	.40	1.80
Dead trees	.10	...	.10
Noninventory	...	1.40	1.40
Saplings	...	...	...
Tops & limbs	...	.30	.30
Stumps	.50	...	.50
Total	93.30	6.70	100.00

Table 24. Source of used volumes on Louisiana hardwood saw log operations by product

Source	Saw logs	Pulpwood	Total
	- - - - - Percent- - - - -		
Sawtimber	83.80	2.50	86.30
Upperstem	2.10	6.00	8.10
Poletimber	1.60	...	1.60
Cull trees	2.10	...	2.10
Dead trees	...	...	...
Noninventory	.20	.20	.40
Saplings	...	...	...
Tops & limbs	...	1.40	1.40
Stumps	.10	...	.10
Total	89.90	10.10	100.00

Table 25. Source of used volumes on Alabama hardwood pulpwood operations by product

Source	Saw logs	Pulpwood	Total
	- - - - -	-Percent-	- - - - -
Sawtimber	1.05	38.80	39.80
Upperstem	...	9.56	9.56
Poletimber	...	38.97	38.97
Cull trees	...	5.81	5.81
Dead trees	...	.05	.05
Noninventory	...	3.52	3.52
Saplings	...	...	...
Tops & limbs	...	.20	.20
Stumps	...	2.04	2.04
Total	1.05	98.95	100.00

Table 26. Source of used volumes on Louisiana hardwood pulpwood operations by product

Source	Saw logs	Pulpwood	Total
	- - - - -	Percent-	- - - -
Sawtimber	3.00	55.80	55.80
Upperstem	...	9.80	9.80
Poletimber	...	23.30	23.30
Cull trees	...	2.50	2.50
Dead trees	...	.30	.30
Noninventory	...	3.50	3.50
Saplings	...	...	...
Tops & limbs	...	1.30	1.30
Stumps	...	.50	.50
Total	3.00	97.10	100.00

VITA

Roy C. Beltz was born April 10, 1942 in Leesville, Louisiana. He was the fifth of six children born to Daniel and Achsah Beltz. After graduation from Leesville High School, in 1960, he entered Louisiana State University. Roy graduated in 1964 with a Bachelor of Science in Forestry and found employment with the Southern Forest Experiment Station. After working two years on the forest surveys of Louisiana, Texas, Oklahoma, and Arkansas, he spent six months on the Bankhead National Forest at Double Springs, Alabama. He then transferred back to the Southern Station's Forest Survey staff.

Roy was accepted by the L.S.U. Graduate School and began course work in January 1973. He is now a candidate for a Ph.D degree in Forestry with a split minor in Experimental Statistics and Quantitative Methods.

EXAMINATION AND THESIS REPORT

Candidate: Roy Chester Beltz

Major Field: Forestry

Title of Thesis: Comparison of harvested volume to inventory and slash volumes in Midsouth logging operations

Approved:

Thomas D. Keister
Major Professor and Chairman

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Date of Examination:

July 15, 1976