Of Trees, Space, Time, and Knots

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Many people are enthusiastic advocates of having forest landowners grow "high-quality" timber. They feel that short-sightedness and ignorance are the principal reasons why silviculture aimed at such timber is not more popular. The purpose of this paper is to point out that timber quality is not a variable measured on a single scale ranging from low to high, but instead is a collective term for numerous attributes and variables affecting either end-product serviceability or manufacturing cost. An attribute of timber considered desirable by manufacturers of certain end-products may be considered unimportant or even undesirable by manufacturers of others. Before landowners incur the added silvicultural costs required to produce timber with certain attributes, they naturally wish to be assured that these costs will be repaid with interest when stumpage is sold or manufactured. Such repayment depends on whether cheaper processing of more costly wood produces a more serviceable or a cheaper end-product than can be produced by more costly processing of cheaper wood, or by using materials other than wood.

Some of the attributes or variables known to affect different timber end-products differently are size (or age), rate of growth, species (or genus), linearity, amount and distribution of unsound wood (or holes), and knottiness. Forest management of existing stands (i.e., not considering the possibility of controlled breeding, planting, or direct seeding) is based largely on deferring harvest of promising individual trees until they have attained desired size and on shortening the time needed to attain that size (1) by harvest or elimination of less desirable stems and concentration of spatial growth-potential on more desirable stems; (2) by amendment of sites, through fertilizer, drainage, irrigation, cultivation, or fire; and (3) by physiological stimulation of individual tree growth through hormones or auxins. In addition, the amount of knot-free bole surface can be increased by pruning limbs.

Within limits, composition of the residual stand is influenced by deadening and harvest operations, especially with respect to visibly recognizable genotypic attributes such as genus or species (often called "stand composition"), and with respect to phenotypic variables or attributes such as vigor, size, straightness, and freedom from knots and other defects. These facts are well known. In most cases, influencing the future stand in a desirable direction requires investment — in the form either of direct input or of deferred returns. Consequently, the decision of a forest manager to modify the future quality of a stand depends on economic considerations: the comparative returns from alternative uses of time, growing space, and funds, along with the penalty or gain incurred in deferment of returns.

There are really two kinds of attributes or variables included in the term "quality." One kind affects the utility or serviceability of the end-product. The other kind affects the cost of manufacturing a unit of end-product of specified quality. Knotty logs generally yield construction lumber somewhat less serviceable than lumber from clear logs, because knots may develop into holes which leak, because knots do not paint well, because knots decrease strength, and because knots cannot be worked smoothly with certain tools. Certain other end-products are equally as serviceable whether made from knotty logs or from clear logs, from small logs or from large logs, but use of small and knotty logs usually involves a higher cost per unit of end-product. It is quite obvious, then, that there are thresholds for some variables or attributes below which utility for certain end-products disappears, while other variables merely affect end-product yields or costs of manufacture. As derived chemicals or reconstituted fibers become increasingly important products of the forest, threshold utility levels of a given attribute or variable are much less often encountered, and marginal or threshold costs are much more often the criteria on which quality assessment is based.

Other things being equal, costs of manufacture decrease and product yields of all end-products improve as tree size increases (up to equipment capacity) and as proportion of knot-free, non-defective wood increases. However, 6 major groups of end-
products are affected somewhat differently by type and distribution of defects, including knots. These groups are: poles and piling, yard and structural lumber, factory lumber and dimension stock, veneer and staves, fiber, and chemicals.

Species, diameter, taper, and length to some cut-off point are attributes or variables which can be determined for any tree or portion of a tree. Major imperfections should each be expressed quantitatively and separately because the different end-product groups may be affected quite differently by a given defect. Thus:

1. Curvature or sweep decreases utility of poles, piling, yard, and structural lumber. To quantify, measure middle ordinate of affected arc.
2. Internal rot or hollow decreases utility of poles, piling, and fiber bolts.
3. Aggregate diameter and character of knots or knot-indicators per unit of surface decrease utility of yard and structural lumber.
4. Circumferential distribution of surface defects including knot-indications affects costs of short-length products such as veneer and staves.
5. Combined longitudinal and circumferential distribution of surface defects including knot-indications affect costs of factory lumber and dimension stock. To quantify circumferential and longitudinal distribution separately, take systematic sampling points along the tree bole and determine at each point the proportion of circumferential strip which is continuously clear in a band 3 feet wide and also determine the length of longitudinal strip which is continuously clear on the single face on which the sampling point appears. Weighted mean proportion clear and weighted mean length clear with coefficients of variation will be the most important parameters of spatial distribution of imperfections.
6. Externally inferable fiber defects such as char, rot, pitch soak, lean decrease utility of fiber bolts.
7. Other expense-increasing factors such as crook, breakage, burls, extreme limbiness may increase costs beyond economic limits even for chemical wood.

If these 7 variables were each quantified or expressed as ranks or grades, with the most useful or desirable rank denoted “1” in each case, a cow oak 24 inches in d.b.h. and 48 feet from stumps to a 14-inch cut-off point might be described as 1:2:1:1:3:1:1. This could be interpreted as meaning that it was the best 24-inch cow oak class with respect to freedom from sweep, low aggregate knot diameter, freedom from circumferential defect, freedom from external fiber defect, and freedom from miscellaneous defects, but that internal rot was bad enough to put it in the second-best class, and it was in the third-best class with respect to longitudinal distance between defects. Because of slight internal rot which would have to be junk-buttoed, such a tree would probably make marginal short piling. Because of uniform close longitudinal and circumferential spacing of defects, such a tree would not make high grade factory lumber or dimension stock. It might, however, yield some choice short stave bolts or veneer blocks. Such a multiple-digit characterization within a species and size class would give a far better picture of quality than any single set of grades. Other variables involving internal wood characteristics can be added to the 7 listed variables, if desired.

Now that pulping, lamination, gluing, patching, and paper-facing have become feasible even for structural uses, we are faced with some new questions. Is it more profitable to grow near-perfect but expensive wood that can be processed at low cost, or is it more profitable to grow wood at maximum rates for a given level of investment, and then to spend more money processing it (during the course of which we can give it properties which even a “high” grade of lumber or veneer does not naturally possess)? Now that wood must bear the costs of growing, can it still be produced cheaply enough to compete (as sawn boards) with structural materials technologically more desirable and currently only slightly more expensive? Will we not have to build into wood (through processing) attributes we can never hope to create through silviculture? People who believe in quality for quality’s sake avoid these questions.

**TIME AND SPACE**

Let us consider the two easily controllable major factors affecting characteristics of a growing tree. They are time and space (or density if space be regarded as fixed). Desirable genotypes or phenotypes should be allocated additional time and as much space they can efficiently use in the interval between harvests until they reach the desirable size.

Less desirable phenotypes or genotypes are harvested or deadened if close enough to desirable trees so that their growing space can be used by those trees, or if it is desired to create space for regeneration. Ultimately, this process results in allocating longer time and more space to the better trees, and shorter time and less space to the poorer trees.

Except where tree regeneration is desired and secured, too low a density of trees is wasteful of space. In the South, for example, the lower limits of desirable growing stock density probably lie between 50 and 70 square feet of basal area per acre (regardless of species, site, and tree size). Below this level, growing stock cannot fully utilize the site and loses control of it to other vegetation without special cultivation, prescribed burning, or chemical applications.

The upper limits of density are not determined solely by biological behavior. Owner objectives, interest rates, and premiums paid for large trees all help set the limits. However, when densities are permitted to exceed 100-120 square feet per acre (regardless of species, site, and tree size), low interest rates and excessive mortality tend to render the prospect unattractive to most southern forest owners.
Hence, the desirable basal area density limits within which the southern silviculturist will try to maintain his stands are 50-120 square feet at the extremes, but are more commonly 70-100 square feet. Lower limbs are shed more quickly at high densities than at low densities, but large diameters are obtained more quickly at low densities than at high densities, and capital investment is less.

The other important silvicultural variable is time. The major question is: How long are we willing to defer individual tree harvest in order to increase tree size and the quantity of knot-free wood. At this point it is convenient to consider an 18-year period, and to remember that 2 percent compound interest multiplies original costs or returns in that time by 1.5, 4 percent doubles them, 6 percent triples them, and 8 percent quadruples them (all multipliers are approximate). Doubling the time interval means squaring each multiplier, halving the time interval means taking the square root of each multiplier.

Growing a tree for an additional 18 years means that final tree value (minus a regeneration cost of roughly 25 cents per square foot of basal area) must be 1.5, 2, 3, or 4 times as much as initial tree value (minus a regeneration cost of 25 cents per square foot of basal area). Although it is easy for small trees to double, triple, or quadruple their value in 18 years, it would require biologically impossible growth rates for very large trees to do this. An alternate approximation, based on Schneider's useful growth-percent formula, would prescribe the harvest of any tree whose rate of current growth was as slow as that implied by a product (rings per inch times inches of d.b.h.) exceeding 200 for 2 percent growth, 100 for 4 percent, 67 for 6 percent, and 50 for 8 percent growth. If 6 rings per inch is accepted as about the most rapid volume growth to be expected from well-managed stands, then 33 inches, 17 inches, and 8 inches are the tree sizes at which volume growth would drop below the specified interest rates (disregarding regeneration costs). Quality increment and increment in merchantable height might reasonably be expected to balance moderate risk or insurance rates.

The biological ramifications of economic space-time functions have not been fully explored. Irrigation, cultivation, and fertilization in particular may become economic forest practices. Local stand-structure studies, to correlate growth with quantitative variables describing stand distribution in space and size, are badly needed to permit more refined calculations. A few generalizations about trees, space, and time seem reasonably safe, however, space affects diameter growth principally, time affects both height and diameter growth, and site quality affects mainly height growth.

KNOTS

And now for knots. In the South (to keep in the same region from which our earlier example was chosen), it will take about 36 years of very rapid growth to add 10 inches to a 6- or an 8-inch pine tree. If money is spent for pruning, harvesting the tree prior to attaining a 10-inch diameter increment will hardly be worthwhile. Pruning one 16-foot log on a hundred 6-inch trees per acre might cost about $10 per acre. After 36 years, the difference in stumpage price per acre between a pruned and an unpruned stand would have to be $20, $40, $90, or $160 at interest rates of 2, 4, 6, or 8 percent. If crop-tree yield were 10,000 board feet (40 trees averaging 3 logs in height and 16 inches in d.b.h.), the stumpage price premium for the 40 pruned final crop trees would have to be $2, $4, $9, or $16 per MBM to earn 2, 4, 6, or 8 percent on the original investment. Currently, it is doubtful whether more than 6 or 8 percent could be earned, in view of the well-known difficulty of maintaining an average growth rate of 3 inches in 10 years over a 36-year period on a stand with a terminal volume of 10,000 board feet (basal area 56 square feet per acre), and in view of the trend toward a narrower gap between prices pair for “high” and “low” quality stumpage of medium size.

Consequently, the returns from increasing the amount of knot-free wood through pruning are attractive in the South only where landowners have taken advantage of all high-return, low-risk, short-term investment opportunities such as planting or releasing potential crop trees from weed- or wolf-tree competition.

In southern hardwoods, three additional factors operate to make pruning even less attractive. First, the danger of rot or insect infestation is increased by the exposure of branch stub cross-sections. Second, many species such as oak and sweetgum feather out with epicormic or adventitious branches after pruning and thinning. Third, since most hardwood products can utilize short clear lengths, the difference in value between long clear lengths secured by pruning and short clear lengths obtained in the absence of pruning would not justify pruning expense for many products.

To put it bluntly, these are some of the reasons why southern forest land managers are spending most of their limited silvicultural budget on artificial or natural regeneration and cull tree control. The recent Timber Resources Review of the U.S. Forest Service indicated that far more funds are needed for highly profitable planting and cull-tree control alone than are in prospect.

Two things might just possibly make pruning more attractive in the future. One is an unlikely increase in the spread between pruned and unpruned stumpage. The other is greatly improved mechanization so that standing trees can be limbed nearly as cheaply as felled trees can or as knots can be excised or screened out in manufacture. Tractor-borne hydrau-
lic lifts and electric or hydraulic saws could make 2, 3, or 4-log pruning almost as cheap as 1-log pruning. Research on this phase of pruning is long overdue.

In summary, it would seem that the silviculturist in the South has economic inducements to maintain densities of from 70 to 100 square feet of desirable well-distributed basal area. This statement applies regardless of species, site, size, or age. Fluctuation within that range will not cause notable changes in wood quality, yield, or biological behavior.

The major influence that the silviculturist can bring to bear on wood quality is the elimination of less desirable phenotypes or genotypes by early harvest cuts or deadening, to the end that more space can be made available to and more growth concentrated on the better phenotypes or genotypes. His other important influence is in deferring harvest of crop trees to allow them to gain in size and in amount of knot-free wood. The extent to which he will continue to thus defer returns depends on the premium paid for large clear trees, and this in turn depends on how much more cheaply the desired end-products can be manufactured from large, clear trees. It is hard to see any economic justification for deferring returns so that southern trees might be grown larger than 16 to 30 inches in diameter. Where fiber or chemical yields are the end-product, sizes somewhat smaller than that may be more profitable unless regeneration costs or risks are exceptionally high, or mechanized harvesting of pulpwood develops in the direction of handling large single stems (as in harvesting sawtimber) instead of numerous small stems (as in harvesting sugarcane).

Pruning will not be as economically attractive as alternative forestry measures unless pruning costs are lowered, unless the premium paid for pruned stumpage is increased, or unless alternative opportunities for planting and cull-tree control are exhausted.

About the Author

Lewis R. Grosenbaugh has been active in forest management research at the U.S. Forest Service Southern Forest Experiment Station in New Orleans for over 14 years. Prior to that, he worked in timber management on the Florida, Ozark, and Quachita National Forests. He received a B. A. from Dartmouth in 1934, an M. F. from Yale in 1936, and while at school was elected to Phi Beta Kappa and Sigma Xi. Since then, he has been continuously employed by the U.S. Forest Service except for a 4-year hitch on destroyers in the Pacific during World War Two. Some of his better known publications have involved methods for determining tree volume; development of log grades; plot-sampling efficiency with various spatial arrangements; point- and line-sampling theory and application; diagnostic tallies for silvicultural prescription; growth and allowable cut formulae; and electronic data processing programs with forestry applications.