The Rate of Value Increase for YELLOW-POPLAR and BEECH

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Introduction

AN IMPORTANT OBJECTIVE in forestry is to earn the highest return on capital invested in growing timber. To achieve this objective, timber growers not only must know the proper silvicultural methods to employ, but also must be able to determine when the timber is ready to harvest so as to obtain the maximum return.

The financial maturity concept is a method of economic analysis that can be used to determine not only the rate at which trees increase in value but also when that rate of value increase falls below the rate of return desired by the timber grower. This is the point of financial maturity, the time when the timber is ready to be harvested.

By calculating the rate at which trees increase in value, timber owners will be able to prepare marking guides for prescribing the diameters at which trees of given vigor, grade, and merchantable height are financially mature. It is not designed to supplant professional judgment based on such natural factors as growth, vigor, and log quality. Rather, it blends an economic factor with the natural factors so that a more refined definition of tree maturity can be made.

This paper describes the methodology and develops the basic data from which the rates of value increase over a 10-year period were calculated for yellow-poplar (*Liriodendron tulipifera* L.) and beech *(Fagus grandifolia* Ehrh.)

The Rate of Value Increase

The rate of value increase is, as the name implies, the rate at which trees increase in value. The cornerstone of the financial maturity concept, it is determined by three components: (1) the present value of the tree; (2) the prospective future value of the tree, considering growth increase in diameter and in merchantable height and possible improvement in quality; (3) the time period between the determinations of present value and prospective value. Given this information, the timber grower can determine the rate of value increase by solving for r in the compound-interest formula:

$$(1 + r)^n = \frac{V_n}{V_o}$$

where r is the rate of interest.

n is the time period.

V_n is the prospective value.

V_o is the present value.

Despite the relative simplicity of this compound-interest formula, considerable work is necessary to develop the present and prospective values. To determine present value, basic data on lumber grade yields and prices had to be developed. And to establish prospective value, data on growth and quality improvement were necessary for projecting the development of the tree over a 10-year period.

Determining Present Value

Present value of a single tree is related to its volume and quality, lumber prices, and conversion costs. Tree volume was expressed in board feet, International ¼-inch kerf rule. Quality evaluations were based on log grades developed by the U. S. Forest Products Laboratory for factory-lumber logs and defined in the field manual. *A Guide to Hardwood Log Grading (revised) (Ostrander and others 1965).*

The observations made in the field included diameter (d.b.h.) by 2-inch classes, log length in the tree by ½-log heights to top of merchantability (8 inches d.i.b. or crown), and the grade of each log. In addition to the three factory-lumber log grades (1, 2, and 3), a fourth class was recognized that included both construction and local-use logs. These logs, though better than those in the cull-log class, are too rough or knotty for use as lumber.

Lumber grade yields for different species—log grades—and size-class combinations were obtained from the U. S. Forest Products Laboratory publication, *Hardwood Log Grade for Standard Lumber (Vaughan, Wollin, McDonald, and Bulgrin 1966).* Prices used were those reported in the *Hardwood Market Report (Lemsky 1962-1966).*

In computing present value, we used the quality-index system to determine the log value in terms of the amount and value of the lumber the trees contain. The procedure was: (1) develop log quality indexes and tree quality indexes, and (2) determine the conversion value, present tree value.

LOG QUALITY INDEXES AND TREE QUALITY INDEXES

The quality-index system (Q. I.), originated by A. M. Herrick in 1946 and refined by other researchers since then, was used to put log grades on a lumber-value basis *(Herrick 1946).* Q. I. is a single number that expresses the relative value of a log or tree as determined by the amount and value of the different grades of 4/4 lumber (1 inch thick) that can be sawed from the log or tree. In formula form it reads:

$$\text{Q. I.} = (\%\ \text{FAS} \times \text{P.R.}_{\text{FAS}}) + (\%\ \text{SEL} \times \text{P.R.}_{\text{SEL}}) + (\%\#1\text{C} \times \text{P.R.}_{\#1\text{C}}) \text{ --- } + (\%\ \#3\text{A} \times \text{P.R.}_{\#3\text{A}})$$

where —

% FAS is the percentage of the total volume of the lumber that could be sawed from the log or tree that would grade First and Seconds.

P.R._{FAS} is the standard price relative for FAS lumber *(Herrick 1956).*

Thus two sets of data are essential for developing Q.I.: (1) lumber grade yields by log grade, log diameter, and species; and (2) lumber price relatives (price ratios with No. 1 Common as the base grade) derived from regional price reports and averaged for 5 years.

Lumber grade yields were obtained from the Forest Products Laboratory guide, *Hardwood Log Grades for Standard Lumber.* Because of the erratic nature of the published yields—due mainly to the small sample, especially in the larger diameter classes—it was necessary to resort to hand-curving the information to make it useful in developing the Q.I.

Price relatives were derived from the *Hardwood Market Report* for the base period 1962-66. Prices were averaged over the 5-year period, and the price relatives between these average prices for the various grades and the average price for No. 1 Common lumber were computed. Thus the price relatives for No. 1 Common are always 1.00, whereas the price relatives for lumber grades FAS and SEL are above 1.00; and the price relatives for No. 2 Common, 3A, and 3B are below 1.00 (table 1).

Log quality indexes were then computed for each species by log grade and diameter.

The next step was to develop tree quality index, using the formula:

$$\text{Tree quality index} = (\% \text{ of tree volume in 1st log} \times \text{log Q.I.}_{\text{1st log}}) + (\% \text{ of tree volume in 2nd log} \times \text{log Q.I.}_{\text{2nd log}}) + (\% \text{ of tree volume in nth log} \times \text{log Q.I.}_{\text{n log}})$$

The percentage of tree volume in each log was determined by means of a hardwood taper table, which provides the diameter inside bark at the small end of each log, and the International ¼-inch kerf volume table, which provides the volume of each log as well as the volume of the total merchantable height of the tree.

Tree quality indexes were developed for each of the sample trees; and by means of regression analysis, they were developed for each species by butt-log (for log grades 1, 2, and 3), diameter and merchantable height (appendix, tables 9 and 10). Examination of the log-grade data for trees with butt-log grades below

Table 1.—*Lumber price relatives for two species of Appalachian hardwoods**

Lumber grade	Yellow-poplar	Beech
FAS	1.45	1.28
FIF	—	1.21
SEL	1.38	—
SAPS	1.31	—
1C	1.00	1.00
2A	.69	—
2B	.47	—
2C	—	.53
3A	.25	.40
3B	.25	.36

*Based on *1962-66 Hardwood Market Report* prices for Appalachian hardwoods (f.o.b. mills in the Johnson City, Tennessee, area), with 4/4 thickness, plain-sawed No. 1 Common grade as reference.

3 showed that in almost all cases such trees had a tree grade below 3 regardless of species, diameter, or log height. Therefore a tree Q.I. of 0.400 was assigned to all such trees.

DEVELOPING PRESENT VALUES

The ease in using tree quality indexes is well illustrated in determining conversion values—present tree values. Only the volume of the tree and the price of No. 1 Common lumber is needed to convert the tree quality index into monetary terms. The procedure is relatively simple.

The *Hardwood Market Report* of 6 January 1968 *(Lemsky 1968)* was used to obtain prices of 4/4 No. 1 Common lumber. Appalachian hardwood prices f.o.b. at mills in the Johnson City, Tennessee, area were used. Prices were $162.00/M board feet for 4/4 No. 1 Common yellow-poplar and $133.00/M for 4/4 No. 1 Common beech.

The gross value per M of the lumber in trees of various diameters and merchantable heights was determined by multiplying the tree quality index by the appropriate price per M.

To determine the net value/M of the lumber in the tree, it was necessary to deduct conversion costs. These are all the direct costs involved in converting the standing tree into lumber. These costs consist mainly of labor and materials used in felling the tree; and making, transporting, and sawing the logs into lumber.

Conversion costs can account for the greatest variation from any norm that might be established here. Every logging chance will differ in terms of topography, need for woods roads, and proximity to a main haul road as well as distance to the mill. Logging crews will vary in efficiency of both men and equipment. Similarly, milling costs will vary according to the efficiency of personnel and equipment. Also in some cases, allowances for profit and risk, as well as brokerage fees for marketing, are regarded as logical costs and should be included as part of the conversion costs. However, it should be recognized that in some cases such charges are not made and that brokerage fees are avoided by selling direct. For this study, an average conversion cost of $70.00 per M board feet for a 16-inch d.b.h. tree was used. Costs were adjusted and curved by tree d.b.h., and the resulting values were considered applicable (table 2).

After we determined the net value/M of the lumber in the tree, we calculated conversion value by multiplying the net value/M by the appropriate tree volumes.

Thus, once tree quality indexes are established, the calculation of present value can be summarized as follows:

1. (Tree Q.I. × price for #1C/M) = gross value/M
2. (Gross value/M — conversion costs) = net value/M

Table 2.—*Conversion costs for hardwood trees*

Tree d.b.h. (inches)	Cost per thousand bd. ft.
12	$78.85
14	74.50
16	70.00
18	65.70
20	61.35
22	57.00
24	53.50
26	52.25
28	51.95
30	51.85

3. (Net value/M $\times$ volume in tree) = conversion value
or present tree value

Determining Prospective Value

Prospective value was based on a calculated increase in tree value over the next 10 years, assuming there would be no change in the market price of lumber. (An increase in price would result in a higher rate of value increase, while a lower market price for lumber would result in a lower rate). Prospective value is the present value plus the increase in value due to diameter growth, the increase in merchantable height, and possible improvement in quality.

D.B.H.-GROWTH PREDICTIONS

To put growth on a basis that the forest manager can apply to his particular situation, we took into account: (1) the ability of an area of forest land to grow trees—site quality; (2) the competitive condition of a tree in the stand—vigor class; and (3) the size of the tree. Diameter-growth data was developed differently for the two species, and the methodology is discussed separately.

Yellow-Poplar

The basis of our d.b.h. growth computations was a study by Holcomb and Bickford *(1952)*. In this study, 10-year d.b.h. growth rates were determined from core data for 900 trees by vigor class (see appendix for definitions) and tree size. We recognized that site quality influences diameter-growth rates, but unfortunately the data were taken without identification of site. However, yellow-poplar, as an important component of stands in this general area, is largely restricted to site indexes between 75 and 95 (70 to 85 for oak); and within this range of sites, diameter growth differences due to site quality are relatively small.

The data were taken in well-stocked even-aged stands. The effect of stand density variations was not measured, but it is strongly reflected in tree vigor classes. Only for vigor class I trees did growth vary with d.b.h.; it decreased as tree size increased. Though this trend was detected only for vigor I trees, we know that it is a natural one; and adjustments were made so that it was reflected in the growth rates of the other vigor classes also—except vigor IV, which was eliminated from consideration because vigor IV yellow-poplar would never be left as crop trees (appendix, table 11).

Beech

Beech is a slow-growing tree under the best conditions *(Campbell 1955; Trimble 1968)*. Moreover, beech improves very slowly in log grade as diameter increases *(Trimble 1965)*. For this reason we felt that a detailed comprehensive growth study to determine financial maturity was unwarranted.

Growth was studied on 63 sawtimber-size stems. About half the data came from repeat measurements, and half came from core sampling. By using the oak site index scale *(Trimble and Weitzman 1956)*, we found samples on sites 60, 70, and 80. Most were on site 70; this is the typical site where beech—and sugar maple—are most common in this area. Ten-year d.b.h. growth by vigor classes, all diameters included, averaged: vigor I—1.27 inches; vigor II—0.92 inches; and vigor III—0.86 inches. Vigor IV beech of sawlog size are rare—except for cull trees—and we found no examples. The growth data were adjusted to reflect an effect of increasing tree size on d.b.h. growth (appendix, table 12).

In applying the diameter growth predictions to the calculation of the rate of value increase, we made two assumptions:

- That vigor classes remained the same during the next ten years, which is conservative. Under a forest-management cutting program, vigor would improve.

- That vigor IV trees would never be considered as leave trees, so no calculations of rate of value increase need be made for this class.

HEIGHT-GROWTH PREDICTIONS

A further consideration involved in determining prospective value is that trees may increase in merchantable height. To guide the projection of log-height increase during the 10-year period for which value increases are projected, the following assumptions were adopted:

- That trees with a d.b.h. growth of 2.0 inches or more during the 10-year period could increase a full 16-foot log in merchantable height. Trees growing less than 2.0 inches d.b.h. in 10 years were limited to a half-log increase in merchantable height.
- That log-height increases are related to d.b.h. For example, a tree that has a 16-foot merchantable stem at 20 inches d.b.h. is limited in its merchantable length by stem breakup into crown; and its merchantable length will not increase with d.b.h. growth. The following log-height-increase limitations were set for computation purposes:

Present d.b.h. (inches)	*Tree height classes that will not increase in height in next 10 years*
16	1-log trees.
18	1- and 1½-log trees.
20	1-, 1½-, and 2-log trees.
22	1-, 1½-, 2-, and 2½-log trees.
24	1-, 1½-, 2-, 2½-, and 3-log trees.
26	No increase in log height for any tree 26 inches d.b.h. or larger.

- That maximum log height used in the computations was 64 feet for yellow-poplar and 48 feet for beech.

QUALITY-IMPROVEMENT PREDICTIONS

Quality denotes value, and in the development of a tree any improvement in quality will result in an appreciable increment in the rate of value increase. Early determination of trees most likely to improve in quality is probably the most important consideration that can be made by the timber grower to attain the greatest rate of value increase. We used these assumptions to guide our quality-improvement predictions:

- That the maximum butt-log grade improvement in the 10-year period is one grade class. This may be a conservative estimate for the better sites.
- That for yellow-poplar there is little prospect of grade improvement for butt-log grade 3 stems above 22 inches d.b.h. (*Trimble 1965*). So no grade improvement was computed for stems larger than 22 inches that were rated butt-log grade 3. Moreover, there is little likelihood that yellow-poplar stems larger than 26 inches d.b.h. that are now grade 2 will improve. So no grade improvement was computed for those trees that were larger than 26 inches. In trees larger than 15 inches d.b.h., no improvement in butt-log grade was computed for trees with butt-log grade below 3—the construction or local-use logs.

Beech apparently has grade-improvement potential, for both grade 3 and grade 2 logs, to larger size than yellow-poplar; so grade-improvement possibilities were computed for grade 3 and 2 beech butt-logs through the 32-inch d.b.h. class. Butt-log grades below 3—construction and local-use logs—in beech continue to improve in grade into higher d.b.h. classes than most species. Quality increases of butt-log grade below 3 were computed up to the 18-inch d.b.h. class.

DEVELOPING PROSPECTIVE VALUE

Three factors were considered in the development of the tree over the 10-year projection period to determine the prospective value; diameter growth, height growth, and quality improvement. Given these factors, with full consideration of the extent and occurrence of the restrictions, we could project the development of the tree and estimate its diameter, grade, merchantable height, and conversion value at the end of the 10-year period. Several combinations of these factors are possible, such as no increase in grade or merchantable height, an increase in both grade and merchantable height, or an increase in grade but not height.

The number and extent of these combinations are limited only by our assumptions concerning these factors (table 3).

For example, assume a yellow-poplar vigor I tree of 16-inch d.b.h. butt-log grade 2 with 24 feet of merchantable height. We can expect a 10-year growth of 2.6 inches (table 11, in appendix); so the predicted future d.b.h. of this yellow-poplar is 18.6 inches. Our quality-improvement assumptions indicate that this tree can improve one log grade in the 10-year period; the future tree can have a butt-log grade of 1 or 2. With regard to merchantable height, our assumptions permit an increase up to a full 16-foot log; so we have three possible merchantable heights —24, 32, and 40 feet. Thus six possible combinations of these factors exist:

Diameter (inches)	*Butt-log grade*	*Merchantable height (feet)*
18.6	2	24
	2	32
	2	40
	1	24
	1	32
	1	40

Future conversion values for these possible combinations are calculated in the same manner as present value.

Determining Rate of Value Increase

Computation of rate of value increase is based on the relationship between the present value and the prospective value 10 years hence, as depicted in the compound interest formula

$$(1 + r)^n = \frac{V_n}{V_o}$$

which has been previously explained.

Continuing with the example of the 16-inch yellow-poplar used above, we could now calculate the rate of value increase for the six possible future combinations. Given the units of present tree value (table 3, column 4) and prospective tree value (column 8), it was relatively easy to determine the value for V_n/V_o

Table 3.—*Determining rate of value increase for 16-inch d.b.h., vigor I, yellow-poplar, with site index 85*

Present				Future						
D.b.h. (1)	Butt-log grade (2)	Log height, feet (3)	Conversion value, dollars (4)	D.b.h. (5)	Butt-log grade (6)	Log height, feet (7)	Conversion value, dollars (8)	Ratio V_n/V_o (9)	Percent rate of return (10)	10-year value increase, dollars (11)
16	1	16	5.48	18.6	1	16	9.75	1.780	5.9	4.27
16	2	16	4.83	18.6	2	16	8.38	1.734	5.7	3.55
					1	16	9.75	2.018	7.3	4.92
16	3	16	2.08	18.6	3	16	4.44	2.136	7.9	2.36
					2	16	8.38	4.027	14.9	6.30
16	1	24	7.69	18.6	1	24	13.66	1.777	5.9	5.97
					1	32	16.49	2.145	7.9	8.80
					1	40	18.83	2.450	9.4	11.14
16	2	24	6.34	18.6	2	24	11.08	1.748	5.7	4.74
					2	32	12.53	1.977	7.1	6.19
					2	40	13.26	2.093	7.7	6.93
					1	24	13.66	2.155	8.0	7.32
					1	32	16.49	2.602	10.0	10.15
					1	40	18.83	2.971	11.5	12.49
16	3	24	2.76	18.6	3	24	6.03	2.184	8.1	3.27
					3	32	7.04	2.547	9.8	4.27
					3	40	7.73	2.798	10.8	4.97
					2	24	11.08	4.011	14.9	8.32
					2	32	12.53	4.534	16.3	9.77
					2	40	13.26	4.800	17.0	10.50

16	1	32	9.63	18.6	1	32	16.49	1.711	5.5	6.85
					1	40	18.83	1.954	6.9	9.20
					1	48	21.19	2.199	8.2	11.56
16	2	32	7.34	18.6	2	32	12.53	1.707	5.5	5.19
					2	40	13.26	1.807	6.1	5.92
					2	48	13.66	1.861	6.4	6.32
					1	32	16.49	2.246	8.4	9.15
					1	40	18.83	2.565	9.9	11.49
					1	48	21.19	2.887	11.2	13.85
16	3	32	3.25	18.6	3	32	7.04	2.165	8.0	3.79
					3	40	7.73	2.379	9.1	4.48
					3	48	8.33	2.563	9.9	5.08
					2	32	12.53	3.855	14.4	9.28
					2	40	13.26	4.081	15.1	10.01
					2	48	13.66	4.203	15.4	10.41
					1	48	21.19	1.949	6.9	10.32
16	2	40	7.54	18.6	2	40	13.26	1.759	5.8	5.72
					2	48	13.66	1.811	6.1	6.12
					1	40	18.83	2.497	9.6	11.29
					1	48	21.19	2.810	10.9	13.65
16	3	40	3.40	18.6	3	40	7.73	2.271	8.5	4.33
					3	48	8.33	2.446	9.4	4.92
					2	40	13.26	3.896	14.6	9.86
					2	48	13.66	4.012	14.9	10.26

(column 9) and then to seek out the rate of value increase in compound-interest tables for $(1 + r)^{10}$ (column 10) which equates the compound-interest formula.

Thus, in our example of a 16-inch d.b.h. vigor I butt-log grade 2 yellow-poplar, 24-foot merchantable height, we determined that the rate of value increase over the 10-year period could vary from 5.7 to 11.5 percent; and we could expect dollar value increases ranging from \$4.74 to \$12.49, depending on changes in merchantable height and quality. Considering diameter growth alone, we could expect a rate of value increase of 5.7 percent. Diameter growth plus an increase of one log in merchantable height would result in an estimated 7.7 percent rate of value increase. When quality was increased one grade, the greatest gains in rate of value increase were achieved, ranging from 8.0 to 11.5 percent.

Throughout the development of the rate of value increase it was constantly apparent that the final tables that resulted would not depict the situation for all users of these tables and that the rate for any specific tree was only an estimate. There are several reasons why these calculations are merely estimates. In producing the quality index, a major factor in variation is the assumption of lumber grade recovery of 4/4 factory-grade lumber. Few, if any, mills would duplicate this recovery. They might increase the value of products recovered by producing different thicknesses or other products.

The use of a specific set of conversion costs (table 2) is but another necessary generalization that may or may not fit the existing situation for a timber stand or logging crew. The timber stand may be readily accessible or very remote, and average figures for conversion costs would not fit the situation. Similarly, a logging crew could be very efficient and well equipped or they could be inefficient and poorly equipped, and either factor would cause wide variations from these average conversion costs. Furthermore, market prices for lumber vary widely by locality and season, depending on supply and demand. Variations in price will cause wide variations in the rates of value increase.

For the above reasons any presentation of exact rates of value increase would be illusory and could possibly lead to improper use. Thus tables 4 and 5 show the rates of value increase as a range of rates for ranges of sites. The person using this information need only determine the diameter and vigor of the tree to determine the range of rates of value increase due only to growth that can be expected in the next 10 years. If he estimates that the tree will improve in quality due to a higher butt-log grade class during this period, he can look for a value increase rate due to growth and quality increase.

Table 4.—*Expected rate of value increase for yellow-poplar trees*[1]
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase[2]		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
12	—	—	—	27-32[3]	24-30[3]	22-27[3]
14	7-11	5-8	3-6	8-24[3]	6-22[3]	4-19[3]
16	5-9	4-6	3-5	7-17[3]	6-15[3]	4-13[3]
18	4-7	3-5	2-4	6-13[3]	5-11[3]	4-9
20	4-6	3-4	1-3	6-11	5-9	4-8
22	3-5	2-4	1-3	5-10	4-9	4-8
24	2-4	2-3	1-2	4-9	4-8	3-7
26	2	1-2	1	4-7	4-7	3-8
28	2	1	1	([4])	([4])	([4])
30	1-2	1	1	([4])	([4])	([4])
32	1-2	1	1	([4])	([4])	([4])

[1] Based on 4/4 factory-grade lumber recovery. These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2] The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o. For this reason, butt-log grade 3 logs have not been considered in the estimates due to growth only.

[3] The high rates of value increase in the 12- to 18-inch diameter classes are due to two factors: the butt-log grade 3 trees becoming positive in present value, and the butt-log grade 3 trees improving to butt-log grade 2.

[4] No quality increase from trees larger than 26 inches.

Some Interpretations of the Rate-Of-Value-Increase Concept

Diameter growth, increase in merchantable height, and improvement in quality occur singly or in combination to add value to the tree and hence the stand. This value increment is the basis for determining the possible financial returns as measured by the rate-of-value-increase concept.

As we said earlier, the concept does not provide the complete solution for the financial investment in timber growing. Such a solution encompasses a much greater realm involving land costs and owner objectives, to name but a few, and is beyond the scope of this paper.

Though the rate-of-value-increase concept does not accurately reflect the situation for every logging chance and every sawmill,

Table 5.—*Expected rate of value increase for beech trees*[1]
(In percent)

D.b.h. (inches)	Due to growth only			Due to growth and quality increase[2]		
	Vigor I	Vigor II	Vigor III	Vigor I	Vigor II	Vigor III
14	(3)	(3)	(3)	(3)	(3)	(3)
16	2-15	1-12	0-10[4]	24-37[5]	23-34[5]	22-33[5]
18	2-8	0-5[4]	0-5[4]	11-46[5]	9-43[5]	9-42[5]
20	2-4	1-3	0-2[4]	7-14	6-13	5-12
22	2-3	1-2	1-2	5-11	4-10	4-10
24	1-2	1	1	4-9	3-8	3-8
26	1	1	1	3-8	3-8	3-8
28	1	0-1	0	3-8	3-8	2-8
30	1	0-1	0	3-8	2-7	2-7
32	1	0	0	2-7	2-7	2-7

[1]Based on 4/4 factory-grade lumber recovery. These rates can have a variation of 1 to 2 percent due to differences in location, volume estimates, and quality estimates.

[2]The high portion of the range in rates is due largely to low-grade trees that have a low present value and thus produce a relatively high rate of value increase when considered in the ratio V_n/V_o. For this reason butt-log grade 3 logs have not been considered in the estimates due to growth only.

[3]Negative rate.

[4]Low value due to increase in ½-log height, where upper ½-log has minus value due to conversion costs.

[5]The high rates of value increase in the 16- and 18-inch diameter classes are due to two factors: the butt-log grade 3 trees becoming positive in present value, and the butt-log grade 3 trees improving to butt-log grade 2.

it does reveal certain generalities about the financial development of a tree:

Rate of tree earning power decreases with increasing tree size.—This is well illustrated in tables 4 and 5, which chart the gradual reduction of the expected rate of value increase as larger diameter trees are considered. Thus a 14-inch d.b.h., vigor I yellow-poplar, has the potential of earning during the next 10 years an annual rate as high as 11 percent, based on growth alone, and 24 percent based on growth and possible quality improvement. On the other hand, a 26-inch d.b.h. yellow-poplar of the same vigor class will earn about 2 percent in growth alone and a maximum of 7 percent if grade improvement occurs.

We must emphasize that the preceding discussion refers to the *rate* of tree earning power and not to earning power itself. Whereas the smaller diameter tree has higher expected rates of value increase (table 6, column 10) than larger diameter trees, the latter provide greater dollar value increase (table 6, column 11). Therefore earning power can be analyzed on the basis of either rate or dollar increase, depending upon the timber owner's objectives.

Improvement in log quality greatly increases earning power in both rate and dollar value.—As trees develop, many of them can be expected to improve in quality. It is important that the potential for quality improvement be recognized in selecting trees to remain in the stand. For example, an 18-inch vigor-I yellow-poplar can have a rate of value increase of 7 percent due to growth alone (table 4). However, if a log-grade improvement takes place in the next 10 years, a rate of value increase of as much as 13 percent annually can be expected.

Table 6 also illustrates the dollar gains to be made by improvement in quality. For example, a 14-inch vigor-I yellow-poplar, butt-log grade 2 with a 16-foot merchantable height, will have a future value increase of $2.82 due to growth alone. However, if an improvement in quality occurs, the same tree will have an increase of $3.66. This amounts to a gain of $0.84 due

Table 6.—*A comparison of the rates of value increase and the dollar-value increase of some 14- and 26-inch d.b.h., vigor I, yellow-poplar trees*

Present				Future						
D.b.h. (1)	Butt-log grade (2)	Log height, feet (3)	Conversion value, dollars (4)	D.b.h. (5)	Butt-log grade (6)	Log height, feet (7)	Conversion value, dollars (8)	Ratio V_n/V_o (9)	Percent rate of return (10)	10-year value increase, dollars (11)
14	2	16	3.03	16.8	2	16	5.85	1.93	6.8	2.82
					1	16	6.69	2.21	8.3	3.66
	3	16	.98	16.8	3	16	2.72	2.77	10.7	1.74
	2	24	3.98	16.8	2	24	7.64	1.92	6.8	3.67
					1	24	9.32	2.35	8.9	5.35
	3	24	1.26	16.8	3	24	3.62	2.88	11.2	2.36
	2	32	4.43	16.8	2	32	8.67	1.96	6.9	4.23
					1	32	11.38	2.57	9.9	6.95
	3	32	1.36	16.8	3	32	4.20	3.10	12.0	2.85
26	2	16	24.27	28.1	2	16	29.38	1.21	1.9	5.11
					1	16	36.59	1.50	4.2	12.32
	3	16	16.62	28.1	3	16	20.69	1.24	2.2	4.07
	2	24	31.16	28.1	2	24	38.64	1.24	2.2	7.48
					1	24	50.15	1.61	4.9	18.99
	3	24	21.98	28.1	3	24	28.03	1.27	2.5	6.04
	2	32	36.73	28.1	2	32	45.68	1.24	2.2	8.94
					1	32	62.05	1.69	5.4	25.32
	3	32	26.80	28.1	3	32	34.25	1.28	2.5	7.45

to quality improvement alone. Had this improvement occurred on a 26-inch butt-log grade 2 yellow-poplar, the gain would have amounted to $7.21. Thus again, with increasing tree size we find a trend toward lower rates of value increase but higher dollar returns.

Many small sawtimber trees with grade 3 butt-logs have low or even negative stumpage values. Though these low-grade trees may earn a high interest rate, the actual monetary gain is small and stand earning power for a forest of such trees would be low. When such trees are vigorous and are low grade only because *they are small,* they may be retained in the stand; but if they do not have potential for grade improvement they should be removed as soon as possible.

We repeat: that the probability of grade improvement decreases with increasing tree size. However, this tendency varies appreciably in the two species considered. Generally, the likelihood of future grade improvement for trees of the larger sizes in managed stands in which improvement cuttings (or thinnings) have been made would be slight because the best stems would have been favored in previous markings *(Trimble 1965)*. In managed stands the financial-maturity diameter is lower than in unmanaged stands.

Trees with greater merchantable height have, on the average, slightly higher earning rate potential if vigor class, butt-log grade, and site quality are the same.—The effect of log-height increase in a tree may increase the earning rate or it may decrease it. If the volume added in height growth has a positive conversion value, the percent of return will increase; however, if it has a negative value—as small grade 3 logs do—the percent of return will decrease. In general, log-height increases will be limited to the smaller trees; and the volume added will decrease tree earning power over the 10-year period even though the tree may have potential for increasing earning power over a longer period. In comparing two trees with similar characteristics except for height, the tree with the greater merchantable height will increase more in value in a given time.

Marking Guides

Marking guides, based on tree earning power—and to some extent on generally recognized marking principles—are suggested as: (1) guides for selection cutting under uneven-aged systems, for improvement cutting in previously unmanaged stands, and for sawlog thinnings in stands managed under an even-aged system; and (2) guides for setting average tree diameters for harvest cuttings (rotation tree size) under even-aged management.

For this latter use, these guides can be assumed appropriate only for stands now at or nearing financial maturity. Extending their use beyond 10 to 15 years in the future is risky because probable changes in markets and utilization practices may completely alter rates of return.

Because most hardwood stands that will be cut in the near future are some combination of immature, previously unmanaged, or very lightly managed stands, the guides will be most useful in marking for partial cutting—probably in improvement cuttings and thinnings in immature stands that will eventually be clear-cut under some even-aged system. Used in this way, marking guides must be considered in conjunction with residual stocking guides.

Partial Cutting

In both species, the trees that should be discriminated against are: (1) culls and near culls, (2) extremely rough trees with butt-log grade 4, (3) vigor IV trees of any sizes, (4) any trees over 15 inches with butt-log grade 4.

For both species, the trees to be favored as leave trees are: (1) those with imminent butt-log grade improvement; (2) vigor I trees over vigor II and III, and vigor II over vigor III; (3) trees of greater merchantable length over trees of less merchantable length, other factors being similar; and (4) smaller sawlog trees over larger sawlog trees of similar grade and vigor classes.

Rotation Size

The rate-of-value-increase concept can also be used to determine rotation size in even-aged stands after proper consideration is given to silvicultural and management needs. These guides, presented separately by species in tabular form (tables 7 and 8), are given for three interest-rate objectives—2, 4, and 6 percent. (The diameters given are average stand diameters.)

For example, in choosing a 2-percent interest-rate objective, say where multple-use forest values are involved, financial maturity for yellow-poplar would vary between 20 inches for vigor III trees to 27 inches for vigor I trees. For beech, the range would be between 19 and 23 inches d.b.h. In managed stands practically all final crop trees would be vigor I and II trees, and financial maturity would lie between the sizes indicated for these two vigor classes.

A commercial enterprise where timber values alone are important might choose a 6-percent interest rate. In this case, the financial maturity d.b.h. would be considerably lower for both species.

Though these data are presented as guides for harvest cuttings under even-aged management, they can serve also as guides to partial cutting where no grade improvement is in prospect for the tree in question. We emphasize that the diameters in these tabular guidelines are based on value increases due to growth rate alone and should be adjusted upward where potential log-grade increase is involved.

The blanks in the tables mean that the rate of interest cannot be obtained with any size sawtimber trees of butt-log grade 3.

Table 7.—*Yellow-poplar d.b.h. for financial maturity based on value increase determined by growth rate alone. Based on trees with butt-log grades of 1 and 2*[1]

Vigor class	For return of — 2 percent	4 percent	6 percent
	Inches	*Inches*	*Inches*
I	27	21	17
II	24	17	14
III	20	14	—

[1]The d.b.h. given is the maximum that will earn the indicated interest rate in the next 10 years.

If marking is done in areas of tree populations that fall largely under the category of low vigor, poor site, and small diameter, then the general guides given under "Partial Cutting" should govern and specific d.b.h. limitations are unimportant.

As a word of caution in interpreting this table, users should keep in mind that the interest rates are based on trees already existing in a stand and on their projected value increase over the next 10 years. Costs of growing the stand to sawtimber size were not considered.

Table 8.—*Beech d.b.h. for financial maturity based on value increase determined by growth rate alone. Based on trees with butt-log grades of 1 and 2*[1]

Vigor class	For return of — 2 percent	4 percent	6 percent
	Inches	*Inches*	*Inches*
I	23	19	17
II	20	17	16
III	19	16	—

[1]The d.b.h. given is the maximum that will earn the indicated interest rate in the next 10 years.

■

Appendix

DEFINITION OF VIGOR CLASSES

Vigor I.—A tree in this vigor class has a large, healthy, full crown in a dominant or co-dominant position. Half the crown or more is exposed to direct sunlight. The crown is typically dense, with no evidence of disease or mechanical injury. The bark and twigs have good color.

Vigor II.—A tree in this vigor class has a fair-size crown in a co-dominant position. Less than half the crown is exposed to direct sunlight. The crown is less dense and less perfect than that of a vigor I tree. This class may also include a large-crowned or dominant tree that otherwise fails to meet the requirements for vigor I.

Vigor III.—A tree in this vigor class has a medium to small crown of intermediate position. Only the top is exposed to direct sunlight. The crown may be open, with some dead or broken limbs. This class also includes trees with fair to large crowns, in a co-dominant position, but cannot meet requirements for vigor I and vigor II. It may also include overtopped trees of a tolerant species that have dense crowns of good color.

Vigor IV.—A tree in this class usually has a small crown in an overtopped position. This class includes all living trees that fail to meet the requirements of the higher vigor classes.

Table 9.—*Tree quality index for yellow-poplar trees*

Tree d.b.h. (inches)	Merchantable height in feet to an 8-inch d.i.b. top						
	16	24	32	40	48	56	64
			BUTT-LOG GRADE 1				
16.0	0.788	0.773	0.759	0.745	0.730	0.716	0.701
18.0	.818	.804	.789	.775	.760	.745	.731
20.0	.848	.834	.819	.805	.790	.775	.761
22.0	.878	.864	.849	.835	.820	.805	.791
24.0	.908	.894	.879	.864	.850	.835	.821
26.0	.938	.924	.909	.894	.880	.865	.851
28.0	.968	.954	.939	.924	.910	.895	.881
30.0	.998	.983	.969	.954	.940	.925	.911
32.0	1.028	1.013	.999	.984	.970	.955	.941
			BUTT-LOG GRADE 2				
14.0	0.731	0.698	0.666	0.633	0.601	0.568	0.536
16.0	.746	.714	.681	.649	.616	.584	.551
18.0	.762	.730	.697	.665	.632	.600	.567
20.0	.778	.745	.713	.680	.648	.616	.583
22.0	.794	.762	.730	.697	.665	.632	.600
24.0	.809	.777	.745	.712	.680	.647	.615
26.0	.825	.793	.760	.728	.695	.663	.630
28.0	.841	.808	.776	.744	.711	.679	.646
30.0	.857	.824	.792	.759	.727	.694	.662
32.0	.873	.840	.808	.775	.743	.710	.678
			BUTT-LOG GRADE 3				
12.0	0.528	0.515	0.503	0.490	0.478	0.466	0.453
14.0	.548	.535	.523	.510	.498	.485	.473
16.0	.568	.555	.543	.530	.518	.505	.493
18.0	.587	.575	.562	.550	.538	.525	.513
20.0	.607	.595	.582	.570	.557	.545	.532
22.0	.627	.615	.602	.590	.577	.565	.552
24.0	.647	.634	.622	.610	.597	.585	.572
26.0	.667	.654	.642	.629	.617	.604	.592
28.0	.687	.674	.662	.649	.637	.624	.612
30.0	.706	.694	.682	.669	.657	.644	.632
32.0	.726	.714	.701	.689	.676	.664	.651

Table 10.—*Tree quality index for beech trees*

Tree d.b.h. (inches)	Merchantable height in feet to an 8-inch d.i.b. top					
	16	24	32	40	48	56
			BUTT-LOG GRADE 1			
16.0	0.789	0.732	0.674	0.617	0.559	0.502
18.0	.823	.766	.708	.651	.593	.536
20.0	.858	.800	.742	.685	.627	.570
22.0	.892	.834	.777	.719	.662	.604
24.0	.926	.868	.811	.753	.696	.638
26.0	.960	.902	.845	.787	.730	.672
28.0	.994	.936	.879	.821	.764	.706
30.0	1.028	.970	.913	.855	.798	.740
32.0	1.062	1.005	.947	.890	.832	.775
			BUTT-LOG GRADE 2			
14.0	0.550	0.535	0.521	0.506	0.491	0.476
16.0	.571	.556	.541	.526	.512	.497
18.0	.591	.576	.562	.547	.532	.517
20.0	.612	.597	.582	.567	.553	.538
22.0	.632	.617	.603	.588	.573	.558
24.0	.653	.638	.623	.608	.594	.579
26.0	.673	.658	.644	.629	.614	.599
28.0	.694	.679	.664	.649	.635	.620
30.0	.714	.699	.685	.670	.655	.640
32.0	.735	.720	.705	.690	.676	.661
			BUTT-LOG GRADE 3			
12.0	0.495	0.477	0.460	0.442	0.425	0.407
14.0	.513	.495	.478	.460	.443	.425
16.0	.531	.513	.496	.478	.461	.443
18.0	.549	.531	.514	.496	.479	.461
20.0	.567	.549	.532	.514	.497	.479
22.0	.549	.567	.550	.532	.515	.497
24.0	.603	.585	.568	.550	.533	.515
26.0	.621	.603	.586	.568	.551	.533
28.0	.639	.621	.604	.586	.569	.551
30.0	.657	.639	.622	.604	.587	.569
32.0	.675	.657	.640	.622	.604	.587

10-YEAR D.B.H. GROWTH RATES

Table 11.—*Ten-year d.b.h. growth rate for yellow-poplar, in inches*

D.b.h. (inches)	Vigor I	Vigor II	Vigor III
12	2.9	2.1	1.4
14	2.8	2.0	1.3
16	2.6	1.9	1.2
18	2.5	1.8	1.2
20	2.4	1.7	1.1
22	2.3	1.7	1.1
24	2.2	1.6	1.0
26	2.1	1.5	1.0
28	1.9	1.4	.9
30	1.8	1.3	.8
32	1.7	1.2	.8

Table 12.—*Ten-year d.b.h. growth rate for beech, in inches*

D.b.h. (inches)	Vigor I	Vigor II	Vigor III
12	1.5	1.0	.09
14	1.4	.9	.8
16	1.3	.9	.7
18	1.2	.8	.7
20	1.1	.7	.6
22	1.0	.7	.6
24	.9	.6	.5
26	.8	.6	.5
28	.8	.5	.4
30	.7	.5	.4
32	.6	.4	.3

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