Improvement in Butt-Log Grade *with increase in tree size, for six hardwood species*

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THE EVALUATION OF TIMBER QUALITY

MOST people who are concerned with the management of hardwood stands or the utilization of hardwood logs are aware that the quality of hardwood lumber is positively related to the size of the log from which it is sawed. Sawmill studies have frequently demonstrated that the larger logs yield a higher proportion in valuable lumber grades than the smaller logs. This is elementary; and if log size were the only criterion of potential lumber grade, estimating log value would be a simple procedure.

However, the proportion of quality lumber in a hardwood log is also affected by factors such as the number, size, and distribution of knots; the amount and distribution of rot or other interior defect; and the degree of log crook or sweep. These factors tend to vary among species.

When the basis for judging hardwood lumber grades is examined, it is readily apparent why defects — as well as log size — affect lumber grade. The following statement by Ostrander *et al.*[1] sums up the criteria for judging hardwood lumber quality:

> High-grade boards are those that will yield high percentages of clear face cuttings and relatively large individual cuttings. Low-grade boards are those that yield small percentages of clear face and sound cuttings.

Therefore, to evaluate the potential lumber-grade output of a log, we need a method of accounting for not only the effect of

[1]Ostrander, M. D., *et al.* A GUIDE TO HARDWOOD LOG GRADING. U. S. Forest Serv. Northeast. Forest Expt. Sta., 50 pp., illus., 1963.

log size but also the effects of other important factors. Such a system of log grading has been developed through years of study by the U. S. Forest Service.[2] Visible surface characteristics of logs have been related to the proportions of high-, medium-, and low-grade lumber that the log will yield. The system establishes three grades (1, 2, and 3) for factory-lumber logs — logs that are suitable for conversion into standard factory lumber. Identification of the grade of the log is based on the same criteria for all species, with some exceptions.[3] But the percentages of the different lumber grades sawed out of logs of the same log grade are not the same for all species. For example — comparing the species that differ most — grade 1 logs of white ash yield an average of 80 percent No. 1 common and better lumber while grade 1 logs of chestnut oak and hickory yield only about 65 percent No. 1 common and better.[2]

It is also generally — but not always — true that larger logs of the same grade yield a somewhat higher proportion of better grade lumber than smaller ones. However, differences in lumber quality due to increasing log size within a grade are less than differences between grades

Logs that fail to meet the minimum requirements of the factory lumber-log class may be placed in other categories, depending upon species and local markets. Two such classes are construction logs and local-use logs. Construction logs are sound logs that are suitable for high-quality ties and timbers but contain too many small sound knots to qualify as factory-lumber logs. Their value is generally less than that of high-grade factory logs; but for oak and certain other dense hardwoods, under some market conditions their value may be greater than that of grade-3 factory-lumber logs.

Local-use logs are those that fail to meet either factory or construction class specifications but still meet the minimum requirements that economically permit utilization — the *poorest log* concept. They contain unsound material or knots too large to qualify for construction logs and fail to meet the clear-cutting requirements of the grade-3 factory-lumber log.

Several publications have shown how log grades are applied in practice. Among the more complete of these reports are a

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[2]United States Forest Products Laboratory. HARDWOOD LOG GRADES FOR STANDARD LUMBER. U. S. Forest Prod. Lab. Rpt. D 1737, 66 pp., illus., 1953.

[3]Ash and basswood butt logs can in some cases be grade 1 logs at slightly smaller scaling diameters than other species. And special rules for grading black cherry logs, as yet unpublished, accept the presence of bud clusters and appreciable bark distortion without prescribing log degrade.

recent one by Ostrander *et al.*[1] and one by Lockard, Putnam, and Carpenter.[4]

This log-grading system for evaluating timber quality is gaining acceptance in the hardwood regions. Also, there is a greater recognition among forest managers that managing for quality is essential to profitable hardwood forestry.

As an illustration of the differences in stumpage value among log grades, we can compare the computed stumpage value of 18-inch sugar maple logs:[5]

Log grade	*Stumpage value per M bd. ft.*
1	$79
2	$40
3	$ 6

This provides a ratio among stumpage prices for grades 1, 2, and 3 of approximately 13:7:1, respectively. Although the ratio varies somewhat among species and by log sizes, the general trend holds for all situations.

Examples of the kinds of situations where quality should be considered are:

1. Judging the suitability of a stand of timber for the product that management wants.
2. Determining the tree size that denotes financial maturity.
3. Setting of rotation age.
4. Setting cutting diameters in diameter-limit operations.
5. Appraising stumpage value by buyer or seller. If tree diameter could be related in general to log grade, such a relationship would be extremely useful as an aid in making the above-mentioned decisions.

Work carried out by the Northeastern Forest Experiment Station in West Virginia in the past 12 years provides useful information about the relationships between tree d.b.h. and butt-log grade. The upper logs are not included in the relationships. Being smaller and containing more knots, these upper logs are generally of lower grade than the butt logs.[6] Thus the average

[4]Lockard, C. R., J. A. Putnam, and R. D. Carpenter. GRADE DEFECTS IN HARDWOOD TIMBER AND LOGS. U. S. Dept. Agr. Handbook 244, 39 pp., illus., 1963.

[5]From a Monongahela National Forest (West Virginia) stumpage appraisal made in 1962 and based on current lumber prices, current costs of production, and with appropriate allowance for profit and risk.

[6]Campbell, Robert A. TREE GRADES, YIELDS, AND VALUES FOR SOME APPALACHIAN HARDWOODS. U. S. Forest Serv. Southeast. Forest Expt. Sta., Sta. Paper 9, 26 pp., illus., 1951.

grade of all material in the sawlog portion of the tree is generally lower than the average grade of the butt log.

In the West Virginia data, species differences in d.b.h.-grade relationship are readily apparent. This inherent tendency for species to have different proportions of the various grades in logs of the same size is a familiar phenomenon to grade-conscious foresters who work with hardwoods. The results in this paper provide a quantitative evaluation of this tendency for six of the local species.

HARDWOOD STANDARD-LUMBER LOGS

Grade Factors*		*Specifications* Log grade 1			Log grade 2				Log grade 3
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Minimum diameter (inches)		[1] 13-15	16-19	20+	[2] 11	12+			8+
Minimum length (feet)		10+	10+	10+	10+	8-9	10-11	12+	8+
Clear** cuttings on each of the 3 best faces	Min. length (feet)	7	5	3	3	3	3	3	2
	Max. number	2	2	2	2	2	2	3	—
	Min. yield face length	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Max. sweep and crook allowance; % of gross vol.		15			30				50
Max. cull and sweep allowance; % of gross vol.		[3] 40			[4] 50				50

*End defects, although not visible in standing trees, are important in grading cut logs. Instructions for dealing with this factor are contained in U.S. Forest Prod. Lab. Rpt. D1737.

**A clear cutting is a portion of a face free of defects, extending the width of the face. A face is one-fourth the surface of the log as divided lengthwise.

[1] Ash and basswood butts can be 12 inches if otherwise meeting the requirements for small No. 1's.

[2] 10-inch logs of all species can be No. 2 if otherwise meeting the requirements for small No. 1's.

[3] Otherwise No. 1 logs with 41-50 percent cull can be No. 2.

[4] Otherwise No. 2 logs with 51-60 percent cull can be No. 3.

Figure 1.—Hardwood factory-lumber log-grade specifications.

STUDY PROCEDURE

The trees graded in this study were taken at random in uncut second-growth hardwood stands in West Virginia. Most of the samples came from the Fernow Experimental Forest near Parsons, where the grading was done primarily to make initial timber-quality estimates on areas selected for testing different timber-management systems. About 20 percent of all the sample trees in this grading study were from oak site study plots distributed around the State.

In grading the butt log, the best 12-foot section of the first 16-foot log was graded — a standard practice in this region. The grading face (1/4 of the circumference), or the face that determined the grade of the log, was the next-to-poorest face; this also is standard practice.

The work was done by a number of men over a period of 12 years. All of the graders were trained and experienced in log-grading. The same grading rules were used throughout the study. The work was facilitated by the use of a field guide for grading, a condensation of grading instructions used in card form (fig. 1). (For more detailed instructions refer to the paper by Ostrander *et al.*)

Four log grades were used in computing the d.b.h.-butt log grade relationship: factory grades 1, 2, and 3 and the construction-log grade. Cull butt logs, and butt logs classified as local-use logs because of extreme roughness and rot, were disregarded. It was felt that because these poorer grades usually resulted from incidents of past history, they were not representative of the inherent grade tendencies of the species. The use of such logs — although they are common in some stands — might have distorted the comparisons among species of d.b.h.-grade relationship.

RESULTS

Butt-log grades have been related to tree size for the following species:

	Trees graded (No.)
Sugar maple (*Acer saccharum* Marsh.)	223
Chestnut oak (*Quercus prinus* L.)	266
Red oak (*Quercus rubra* L.)	578
White oak (*Quercus alba* L.)	192
Yellow-poplar (*Liriodendron tulipifera* L.)	213
Beech (*Fagus grandifolia* Ehrh.)	195

All Factory-Log Grades

Although the definition of a minimum-size factory log is a log 8 feet long with a minimum diameter inside bark of 8 inches at the small end, many trees with logs of this size or larger will not produce a grade-3 (minimum grade) factory log because of imperfections.

The percentage of trees with factory-grade butt logs 1, 2, or 3 increases with tree size, although the rate of increase varies among species (fig. 2). For example, beech obviously contains a smaller proportion of factory-grade logs in most diameter classes than any other species, while most yellow-poplar butt logs are of factory grade even in the smallest sawtimber trees.

The final curves showing the relationships of butt-log grade to d.b.h. were constructed by first developing smooth curves for each species of the percentage of butt logs in each of the four log grades (1, 2, 3, and construction) over d.b.h. class. Then, the sheaf of curves for each species was adjusted so that the sum of the percentages for each d.b.h. class equalled 100 percent.

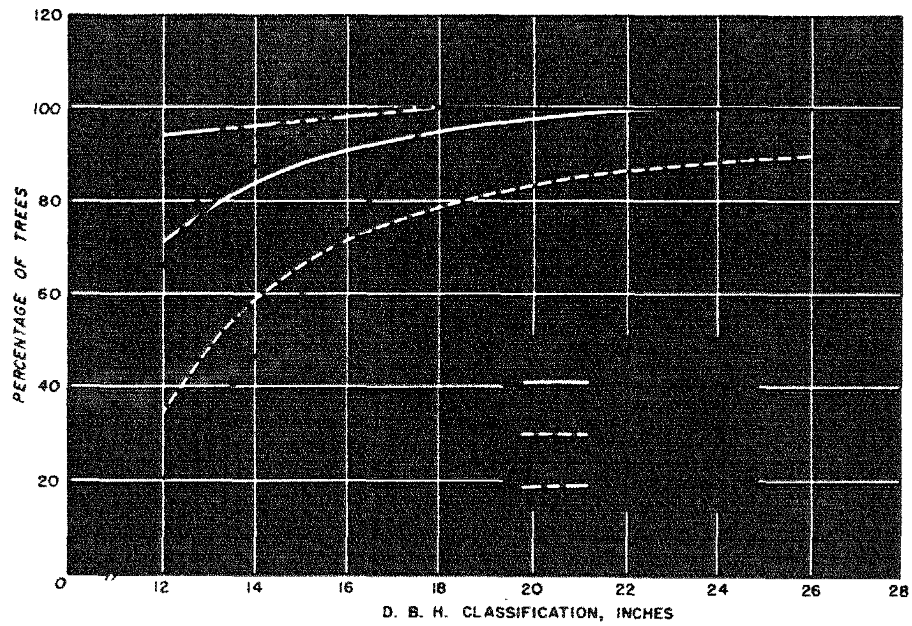
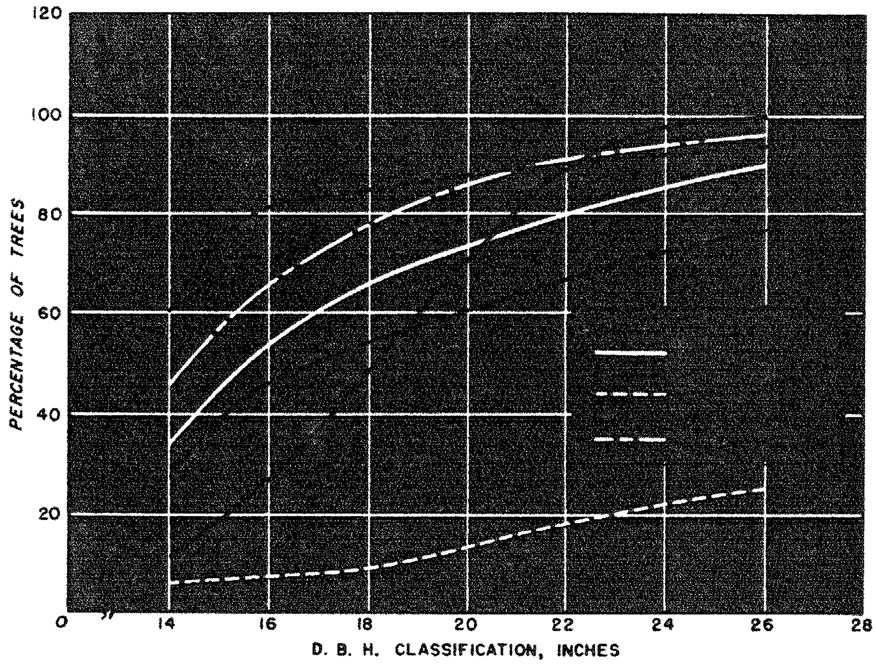


Figure 2.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grades 1, 2, or 3 over 2-inch d.b.h. class, for six hardwood species in West Virginia.

Figure 3.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grades 1 or 2 over 2-inch d.b.h. class, for six hardwood species in West Virginia.



Grade 1 and 2 Logs

The quality of lumber produced from grade-3 factory logs is generally low; and, except in the more valuable species, logging and milling these logs is often a marginal — sometimes a losing — business. For this reason, it is pertinent to look at the smoothed and adjusted curves of butt-log grade distribution over d.b.h. for factory grades 1 and 2 — the money-making grades. The percentage of trees with a grade 1 or 2 butt log is posively related to tree size (fig. 3).

Grade 1 Logs

Except for veneer logs, which were not considered in this study, the top grade is the grade-1 factory log. As shown previously, a grade-1 log of sugar maple has about twice the stumpage value of a grade-2 log. As with the trends for the preceding groups of log grades, results of the study reveal that the percentage of trees with a butt log grade of 1 increases with tree size (fig. 4).

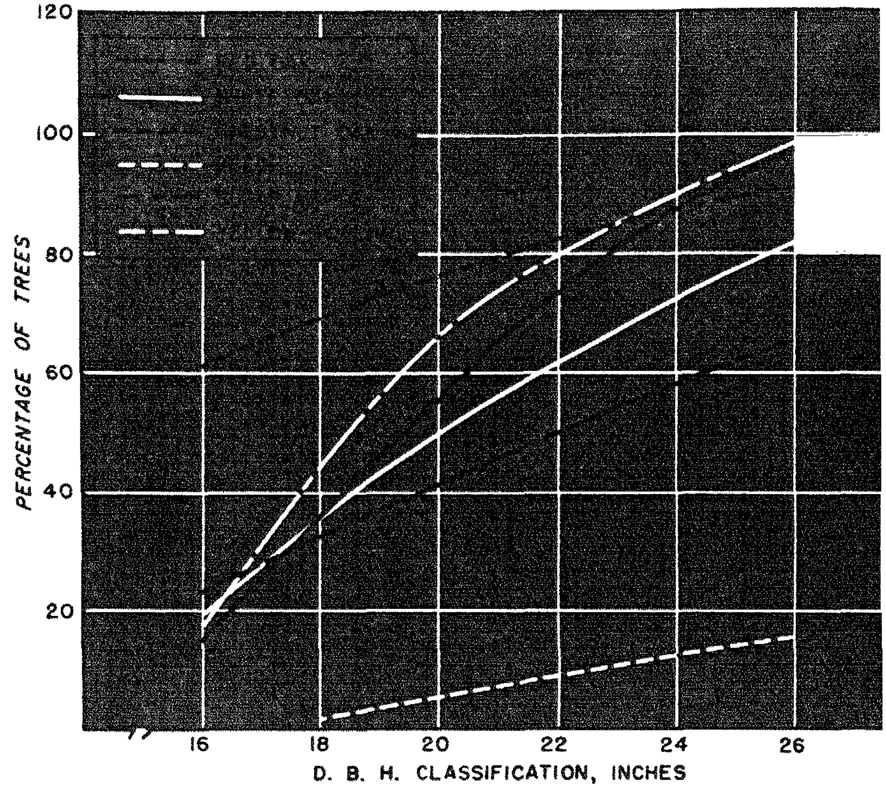


Figure 4.—Smoothed and adjusted curves of percentage of trees with butt logs in factory-lumber log grade 1 over 2-inch d.b.h. class, for six hardwood species in West Virginia.

ANALYSIS

Tests were made to detect significant differences between pairs of species in d.b.h.-grade relationship. Chi-square was used with the original or unadjusted data.

All Factory-Grade Logs

The first test involved the relationship between d.b.h. and the percentage of trees with factory-grade logs. The test was made for the range of d.b.h. classes where one of the two species being compared had less than 100 percent of the butt logs in factory grades. For example, yellow-poplar was compared to white oak in the 12-, 14-, 16-, and 18-inch d.b.h. classes and to chestnut oak in the 12-, 14-, and 16-inch d.b.h classes. As a result of testing, it was found that the following species differed significantly[7] from each other, except as noted, in the relationship of butt-log grade to d.b.h.:

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Sugar maple and chestnut oak
Red oak	—
Beech	—
White oak	Sugar maple
Chestnut oak	Sugar maple and yellow-poplar
Sugar maple	Chestnut oak, yellow-poplar, and white oak

Grade 1 and 2 Logs

The same type of chi-square testing was continued to determine which species differed in d.b.h.-grade relationship for log grades 1 and 2. A wider diameter range could be compared here than in the analysis for all factory grades because of the less frequent occurrence of 100-percent or 0-percent observations. For example, chestnut oak and sugar maple curves for all factory grades combined coincided (at 100 percent) from d.b.h. class 16 upward (fig. 1), while the corresponding curves for grades 1 and 2 combined were separate across the observed range of d.b.h. classes above 12 inches (fig. 2). It was found that the following species differed significantly from all other species, except as noted, in the relationship of butt-log grade to d.b.h.:

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Chestnut oak
Red oak	—
Beech	—
White oak	Sugar maple
Chestnut oak	Yellow-poplar
Sugar maple	White oak

Grade 1 Logs

The results of a comparable analysis of d.b.h.-grade relationships for grade-1 logs showed that each species differed significantly from all others, except as noted below, in relationship of butt-log grade to d.b.h. This analysis covered a slightly more

[7]A significant difference means that unless a 1-in-20 chance has occurred, there is a real difference between the species.

restricted range of d.b.h. than the analysis for grades 1 and 2 combined because of the absence of grade-1 logs in the small d.b.h. classes:

	Exception (species below show no significant difference from the one to the left)
Yellow-poplar	Red oak
Red oak	Yellow-poplar and white oak
Beech	—
White oak	Red oak and sugar maple
Chestnut oak	—
Sugar maple	White oak

DISCUSSION

A number of questions arise concerning the interpretation of the results of this study. Among the most important are: How valid are the data? What causes the differences among species? Exactly how can these results be applied in timber management?

How Valid Are the Data?

In judging the validity of the data, it is worthwhile to consider in detail how they were taken and to speculate about the nature and seriousness of possible sources of variation.

As mentioned previously, the data were taken over a restricted area, mostly on the Fernow Experimental Forest. The trees were in well-stocked stands on fair to excellent sites with site index 70 for oak probably most representative of the sample. Few trees from sites poorer than site index 55 for oak were included in the sample. The majority of the sampled forest stands were even-aged second growth containing scattered residuals left from the original cutting. The residuals represented species that were not in much demand when the virgin forests were cut. Of the six species in the study, yellow-poplar was represented by second-growth trees almost exclusively; red oak up to about 20 inches d.b.h. and chestnut oak up to about 18 inches d.b.h. were second growth; and white oak, beech, and sugar maple trees over 16 inches d.b.h. were mostly residuals from the original cuttings.

The stands sampled showed little or no evidence of past fire damage on the living trees. No cutting since the original harvest, except for the removal in some places of dead chestnut, was evident. There were no signs of current or past grazing by domestic stock.

The sampled trees were taken at random. The six species were sampled as they occurred in the stands. In many situations, the species grew in mixture. However, there was a correlation between site quality and relative frequency of occurrence of some species. For example, yellow-poplar was more common on the better sites and chestnut oak on the poorer sites.

The trees were graded by well-trained foresters who graded carefully with research standards in mind. The same grading rules were used throughout the period of study.

Surface indicators of degrading defects were relied upon because logs were graded in the standing tree and end defects could not be seen. It should be noted that, in areas where worm holes are prevalent in the chestnut and white oak — a common situation — the grade relationships as determined here are not valid for these two species unless the lumber is marketed under the terms, "worm holes no defect".

Within species and size classes, considerable variations in grade due to environmental differences among stands and to grader-judgment differences were possible: even well-trained men do not grade alike because they do not apply grading rules with the same judgment. However, conceivably the data used in this study are about as reliable as can be expected with a large sample embracing a range of species and d.b.h. classes. The consistency of the relationships and the results of the statistical analyses confirm to some extent the reliability of the data.

What Causes Differences Among Species?

The author believes that inherent differences in grade tendencies exist among species — primarily because of inherent differences in branching habit and frequency of dormant buds. It is readily acknowledged that degrading influences of the environment — such as fire, sapsuckers, logging injuries, and low site quality — may operate in many stands to distort inherited tendencies. However, considering the type of stands sampled, we think that most of these effects have probably been kept at a practicable minimum; any remaining variation due to environmental differences — and to grader-judgment differences also — may necessarily have to be accepted. An alternative might be to take a much smaller sample under even more uniform conditions. This might or might not give more usable results — if it could be done. It is also quite possible that more representative (and usable) results would have been obtained from a study that covered a wider range of conditions in the Appalachians.

It should be stressed that the grade characteristics of species as reflected by the study data are assumed to be independent of man's influence. A study like this cannot be made in stands under intensive management. For example, a number of areas under management on the Fernow Experimental Forest have been cut selectively once or twice. In these stands the present butt-log grades of the trees are much better for a given diameter class than is indicated by the relationships in this paper — because the trees of poorer grade (actual and potential) were cut in the managed areas. To illustrate, the few beech left in our managed stands after two cuts have average log grades far higher than those of the beech in the original stands. Some discussion of the more interesting grade relationships follows:

Chestnut oak.—The fact that this species grades relatively high may surprise many people. Two things should be kept in mind:

1. Chestnut oak usually yields relatively poorer lumber for a given log grade and diameter than most other species. One reason is that this species is particularly subject to worm attacks that degrade the lumber but usually do not leave detectable evidence of their presence on the log surface.
2. Chestnut oak from poor sites — dry ridges — was lightly represented in the sample. Because chestnut oak is such a prominent stand component on poor sites where most hardwood trees are of poor form and full of butt rot from past fires, this species is usually considered an undesirable tree. However, on fair sites or better, chestnut oak has good form and actually clears up faster than most other species.

Red oak.—The relatively low grade of this species at small diameters is due to the presence on the bark of numerous dormant buds. At least a portion of them are considered degrading imperfections. As the tree increases in d.b.h., the effect of these buds on log grade decreases, and large red oak grade up very well indeed.

The decreasing effect of buds on log grade as tree d.b.h. increases is due to several factors: (1) the grade rules call for classifying fewer buds as degraders in logs over 14 inches d.i.b. than in smaller logs; (2) as the log diameter increases, all defects become less important because shorter clear cuttings are permitted; and (3) apparently the actual number of buds may decrease with increasing tree size

Beech.—This tolerant, limby tree is notorious for its numerous surface imperfections and its low-grade logs. Well-formed, clean-stemmed beech trees are almost a rarity in the study area.

Yellow-poplar.—This intolerant species is well known for long clean stems, resulting from the early death and natural pruning of shaded branches. It frequently produces the maximum log grade for a given log size that is permitted by the grading rules. In the study area, one of the most frequently encountered grade defects was sapsucker damage.

APPLICATION OF RESULTS

The obvious general conclusion from the results of this study is that vigorous trees of high-grade potential should be reserved until they reach their peak of grade development — if the maximum production of quality lumber is desired.

Using figure 3 — the curves for log grades 1 and 2 — as a criterion, we see that until trees are 13 or 14 inches d.b.h. (or about 16 inches on the stump) they contain only small logs of marginal stumpage value. All species except beech show a rapid improvement in butt-log grade between 14 and 16 inches d.b.h. At about 16 inches d.b.h., chestnut oak grade improvement tapers off but the other species continue to improve rapidly in grade of the butt log until they are 18 inches d.b.h. or larger. This means that in an average or better stand of mixed Appalachian hardwoods, it probably would be extremely shortsighted to make a harvest cutting before the trees are 18 to 20 inches d.b.h. (about 22 to 25 inches on the stump). And when grade-1 logs (fig. 4) are considered, much can be gained by waiting until the trees are even larger.

A more precise interpretation of the meaning of these relationships will be possible when grade improvement of the upper logs is considered, when tree-growth rates are determined and applied, and when growth rates by tree-quality class are expressed as dollar values and interest rates. Employing these data, the forest manager will be working on a sounder basis for evaluating timber-management practices, setting rotations, discriminating among species, and marking trees to cut or leave. However, the current results on the relationship of butt-log grade to d.b.h. are still quite useful as guides to management and utilization, and several specific applications are given below:

Case 1

Question: A mill man is buying sugar maple stumpage to fill orders for high-quality lumber for furniture. He can sell only a small amount of low-grade lumber. He is offered a stand of timber that contains 100,000 board feet in trees 12 to 16 inches d.b.h. He must take all or none. Should he accept the offer?

Answer: *Definitely not. He needs grade-1 and grade-2 logs, particularly grade 1's. He will get relatively few grade-1 logs from this stand and, as a result, will saw out little high-grade material.*

Case 2

Question: A sawmill man has the chance to buy a stand of hardwood timber based on a diameter-limit cutting. He can sell all kinds of lumber but makes no money on grade-3 logs or poorer. He has a choice on this lot between cutting 5,000 board feet per acre to a 14-inch stump or 3,000 board feet per acre to an 18-inch stump. The price per 1,000 board feet is the same in each instance. Which cutting should he make?

Answer: *The latter. He probably would handle the extra 2,000 board feet at a loss if he took the first choice, unless he could buy the stumpage at a very low price.*

Case 3

Question: A man owns a stand of timber, which is on a good site and composed mostly of yellow-poplar, red oak, and sugar maple. There are 3,000 board feet per acre in old growth; and 8,000 board feet are in second growth between 11 and 18 inches d.b.h. and averaging 15 inches. How should the stand be marked?

Answer: *Mark the old residuals and those stems of second growth that are poor risks or have no grade-improvement potential. The owner cannot afford to sell good second growth at these sizes; few of the butt logs will be grade 1 — probably less than 15 percent (fig. 4). In another 10 years the trees will have grown an average of 2 to 3 inches in d.b.h., and probably about a third of them will have developed grade-1 butt logs.*

IMPLICATIONS FOR FUTURE RESEARCH

This study has produced information that can be used as a first step in determining average value growth rates for measuring economic maturity. To fulfill all the requirements, the following information is needed:

1. Upper-log grades by species, d.b.h. class, number of logs in the tree, and butt-log grade.
2. Diameter growth rates by species, d.b.h. class, site class, and a usable tree classification such as a dominance or vigor class.
3. Log values based on lumber values and costs of utilization.

Much of the needed field data have been obtained for West Virginia, and more are being collected. Within 1 to 2 years the necessary information should be available for the development of preliminary financial maturity guides.

Some other research needs in connection with the development of these guides are:

1. To increase the number of species for which data are being collected.
2. To study the effect of timber management on the relationship between log grade and tree characteristics.
3. To develop a method for predicting changes in tree grade or butt-log grade for individual trees.