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To the Graduate Council:

I am submitting herewith a thesis written by Hollis R. Large entitled "Hardwood Flooring Yields from Appalachian Red Oak Lumber." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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Major Professor

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HARDWOOD FLOORING YIELDS FROM APPALACHIAN RED OAK LUMBER

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Hollis R. Large

March 1971

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ABSTRACT

The purpose of this study was to determine the effect of the size and grade of red oak lumber on the quantity and quality of hardwood flooring yield. The data were to provide information which may be used by flooring producers in determining the optimum input lumber mix under varying market conditions.

Three grades of kiln-dried red oak lumber, 1, 2, and 3A common, were selected for study. Each of the three grades were subdivided into four size classes based on lumber width and length. The size classes consisted of lumber less than eight inches wide and less than eight feet long, greater than eight inches wide and less than eight feet long, less than eight inches wide and greater than eight feet long, and greater than eight inches wide and greater than eight feet long. The lumber was converted to 25/32 x 2 1/4 inch strip flooring and graded into 2 common, 1 common, select, or clear flooring grades.

Analysis of the data showed that lumber grade had a significant effect on both percent yield and the grade distribution of flooring. One common lumber had an overall yield of 75.5 percent followed by 2C and 3AC with yields of 68.5 and 62.7 percent, respectively. With respect to flooring grade distribution, the majority of flooring from 1C lumber was in the clear and select flooring grades, while the majority of flooring from 3AC lumber was concentrated in the 2C and 1C flooring grades. Flooring yield from 2C lumber was more evenly distributed among the four flooring grades.

Percent yield of flooring varied considerably with board width. Wide lumber had an average yield of 75.2 percent, while narrow lumber had an average yield of only 62.6 percent. Lumber length had little effect on flooring yield.

Simulation methods were employed to show the amount of waste in the manufacture of flooring could possibly be reduced from 31.11 to 27.80 percent by converting two inch strips of waste lumber into 25/32 x 1 1/2 inch flooring.

Recommendation for further study dealing with several aspects of hardwood flooring production were suggested.

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CHAPTER I

INTRODUCTION

Tennessee produces more strip hardwood flooring than any other state in the hardwood producing area of the United States. In 1969, twenty plants throughout Tennessee operated approximately 30 of the 150 production units, or about 20 percent of the productive capacity of the entire industry. An efficient production unit is capable of producing approximately five million board feet of flooring annually. Thus the productive capacity of machinery in place in the state may be estimated to be about 150 million board feet of flooring per year. Today many of the existing units are idle because the demand for hardwood flooring has not justified mills running at full capacity.[1]

Historically, the hardwood flooring industry has been production-oriented; that is, all grades of flooring produced were marketed without specific planning concerning consumer preferences. However with increasing competition from other flooring materials, the industry is beginning to recognize consumer tastes and change to market-oriented production. Many market analysts agree that if flooring producers are to remain in business, they must tailor production to meet consumer preferences (7).

The flooring industry has traditionally been a highly competitive and low-profit margin operation. Characteristics of the business

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[1]Personal communication with Henry H. Willins, Executive Vice President, National Oak Flooring Manufacturers' Association, dated January 28, 1969.

have been high volume production with corresponding low net value per unit output and relative "ease of entry" during peak demand periods. In addition, the industry has been plagued with shifting markets and changes in consumer tastes. In such a business, plant managers must have a thorough understanding of available alternatives of production processes and raw materials utilized. Basic to this understanding is a knowledge of the quantity and quality of flooring obtained from a specific grade and size of lumber. Generally plant managers know the size and grade distribution of lumber that is used in the production of flooring, and the majority know the approximate length and grade distribution of the finished product. However very few managers know, with any degree of certainty, the expected changes in yield of flooring by grade and length if lumber input mixes are changed to take advantage of potential "savings" in either the acquisition of particular grades of lumber or expected increases in sales of particular flooring grades.

The objective of this study was to obtain lumber input-flooring output data to be used in conjunction with current market prices in determining the optimum input mix of lumber grades and sizes. Hopefully this information will help place hardwood flooring at a higher competitive level by defining the potential savings to be derived from more flexible production schedules.

The study was conducted by the University of Tennessee Forestry Department in cooperation with the U. S. Forest Service Forest Products Marketing Laboratory, Princeton, West Virginia, as part of a more comprehensive flooring research project being conducted at the Forest Products Marketing Laboratory. A flooring mill in East Tennessee cooperated in collecting the data.

CHAPTER II

ANALYSIS OF SUPPLY AND DEMAND OF HARDWOOD FLOORING

I. DEMAND

As late as 1955, hardwood flooring was installed on 68 percent of the floor area in new residential construction (4). At that time the hardwood flooring industry was relatively free of competition from other flooring materials, and for the most part, operated under semi-stable market conditions. By 1963, however, the amount of floor area being covered by hardwood had declined to 34 percent, a decrease of 50 percent over an eight-year period (4).

Several factors have contributed to the decline in demand for hardwood flooring. The factor which seemingly had the most pronounced effect was the availability and price of competing flooring materials, the most significant of which was carpeting. Recent technological advances, resulting in more efficient production of synthetic fibers, allowed carpets to become very competitive in terms of price. In addition, consumer tastes and preferences have been swayed in favor of carpets by costly and effective advertising campaigns. Most carpeting materials are produced by large corporations financially capable of such promotional efforts, whereas the smaller hardwood flooring firms lack the financial resources necessary to match these efforts (1).

Two financial factors, aside from those pertaining to individual consumers (such as personal income), have indirectly decreased the demand for hardwood flooring. The first was a sharp decline in

residential home construction in the late 1960's. The National Forest Products Association (2) reported that the number of one-family housing starts in 1969 decreased 25.2 percent below the 1968 level. Credit shortages coupled with high interest rates due to inflationary conditions in the nation's economy were major factors contributing to the decline of housing construction.

Accompanying this decline in one-family housing construction was a trend toward increased construction of multi-unit dwellings. Buildings of this type usually contain plywood or concrete slab floors finished with such materials as vinyl and asbestos tile, linoleum, and carpets, all of which are important competitors of hardwood flooring.

A second financial factor which has drastically affected the demand for hardwood flooring came as the result of a change in the building code of government-financed homes. In 1967, the Federal Housing Administration (FHA) approved carpeting over plywood as a finished floor for loan value purposes.[1] This change posed an immediate threat to the hardwood flooring industry.

II. SUPPLY

In the wake of decreasing demands for hardwood flooring, market forces caused a corresponding decrease in supply (production). This was evidenced by many of the less efficient firms leaving the industry and several of the larger multi-unit firms decreasing production.

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[1]Conference with Mr. Henry H. Willins, Executive Vice President, National Oak Flooring Manufacturers' Association, March 20, 1970, in Memphis, Tennessee.

The price of flooring increased an average of 4.7 percent per year from 1965 through 1969 as shown in Table 18 in the Appendix. There are two probable reasons for this increase in price. First and probably the most significant is inflation, which approximately equaled the price increase over the same time period. The second reason stems from a characteristic of small competitive firms, that of increasing unit price as volume sales decrease in an effort to maintain revenue levels. Apparently many small flooring producers unsuccessfully raised prices in an attempt to maintain previous levels of revenue and defray rising production costs.

Problems of Acquisition Supply

Increased market emphasis in the production of hardwood flooring suggests the need of an engineered raw material which can be converted to the desired type of flooring at minimum cost. Sarles (7) reported that approximately 75 percent of oak flooring manufacturers indicated a desire to purchase lumber in stock widths of three inches or multiples of three. At the present time, however, precut lumber of this nature is unavailable to most flooring producers. Presently, most flooring mills in the Appalachian area use a mixture of 2 common (2C) and 3A common (3AC) lumber grades in the production of flooring. However, mill-run lumber, which includes grades above and below 2C and 3AC, is used in some plants. Other mills purchase mill-run lumber and sort out the 2C and 3AC grades to be converted to flooring; the remaining grades are used in the manufacture of specialty products such as cabinets, trim, plank, and parquet flooring or sold to other companies, primarily furniture and pallet manufacturers.

The acquisition supply problem could be alleviated, in part, by horizontal integration of flooring, furniture, and pallet firms. In general all three of the above firms use a different grade of lumber in the manufacture of their respective products, but in many instances are forced to buy mill-run lumber. Horizontal integration, on the other hand, is often difficult to achieve due to the small size and family ownership characteristics of firms in all three industries. As the situation now stands, the best alternative open to hardwood flooring producers is to raise their level of efficiency as high as possible with the materials available. This endeavor again requires the basic input-output data which was an objective of this study.

III. FACTORS AFFECTING CONSUMER PREFERENCES

The Appalachian area, with its abundance of low-grade hardwood timber used in appreciable amounts for hardwood flooring, was one region severely affected by the decline in markets. Because the hardwood flooring industry is so important to the economy of the Appalachian area, the U. S. Forest Service Forest Products Marketing Laboratory, Princeton, West Virginia, has undertaken a program of research directed toward finding ways to help wood regain a larger share of the flooring market (5). Laboratory personnel recognized the need to assess consumer preferences and to compare installation costs of the major types of flooring as a first step in this endeavor.

Tenant Cost and Ease of Maintenance

From preliminary data obtained in a nine-city survey, Martens (5) reported that 82 randomly selected Boston housewives living in

apartment dwellings indicated about a fourth less time spent for care of hardwood strip flooring than for an equal area of wall-to-wall carpeting. These Boston housewives considered the "ease of maintenance" of hardwood flooring and carpeting to be comparable. However, when data from all nine cities were analyzed, the housewives indicated that about 5 1/2 hours less time per year was required to maintain carpets than wood floors, and they rated wall-to-wall carpeting three times easier to maintain.

Respondents were asked what type of flooring would be preferable in the living room if they were building a new home. The housewives' preferences were closely associated with the type of flooring material of the dwelling in which they had been living. Approximately 65 percent of the respondents who had hardwood floors said they would prefer hardwood flooring; the rest preferred wall-to-wall carpeting. Of the respondents who had wall-to-wall carpets, about 67 percent said they wanted carpet, with the remaining 33 percent desiring hardwood flooring. The Boston housewives indicated the function of the room affected flooring preference with 55 percent of the total respondents preferring hardwood flooring in the bedrooms and 50 percent preferring hardwood flooring in the living room.

Owner's Installation and Maintenance Cost

The importance of installation costs cannot be underestimated in influencing the ultimate flooring selection by the consumer. The second phase of Marten's study (4) was to interview apartment owners about initial installation cost and subsequent maintenance costs.

The lowest installation cost was for composition tile--$35 per 100 square feet, with an average life of 17 years. Hardwood flooring was the most expensive to install--$60 per 100 square feet, but had a wear life of over 50 years. The wear life of carpeting averaged 7 1/2 years, with an installation cost of $58.61 per 100 square feet. In annual cost for maintenance per 100 square feet, hardwood floors had a definite economic advantage, while composition tile and wall-to-wall carpets were two and three times more expensive, respectively. Hardwood floors were least expensive and wall-to-wall carpets most expensive for long-term floor cost for the home owners.

CHAPTER III

PROCEDURE

I. SPECIES SELECTION

Hardwoods most commonly used for flooring include species groups of oak, maple, beech, birch, and pecan. Oak, the most plentiful, is by far the most extensively used. Nine species of white oak and 11 species of red oak are processed into flooring (8). The majority of flooring, however, is produced from red oak lumber. Three species of red oak are used for flooring in appreciable amounts in Tennessee, namely: southern red oak (Quercus falcata Michx.); black oak (Quercus velutina Lam.); and northern red oak (Quercus rubra L.). All three species produce acceptable flooring, but most authorities agree that northern red oak flooring is slightly higher in quality and more closely resembles the general category known in the flooring trade as Appalachian red oak flooring. For these reasons northern red oak flooring was selected for study.

II. SAMPLING DESIGN

The lumber selected for study consisted of a stratified random sample with sub-samples. Three grades of kiln-dried lumber, 1 common, 2 common, and 3A common, made up each stratum. Each grade contained four sub-strata, hereafter referred to as size classes. The four size classes were NS, NL, WS, and WL, where W = width more than eight inches; N = width less than eight inches; L = length more than eight feet; and

S = length less than eight feet. Each of the 12 grade-size class combinations was replicated once, resulting in 24 separate sub-samples. The volume of lumber in each of the sub-samples was drawn in approximately equal proportions and not according to the volume distribution used in daily production at the cooperating mill.

The four size classes were established on the basis of yield from simulated flooring cuttings from 2C red oak boards in preliminary studies conducted by Koenick (3). Plotted yield data indicated a distinct increase in flooring yield from boards wider than eight inches and longer than eight feet, thus determining the eight-inch and eight-feet break in board width and length, respectively.

Due to the lack of specific data on red oak lumber, the distribution of boards within each size class was based on a study of the board size distribution of Appalachian hard maple lumber as shown in Tables 14, 15, and 16 in the Appendix. The tables show lumber volume by length and width expressed as a percent of the total volume. It was assumed that the board size distributions of northern red oak and Appalachian hard maple lumber of the same grade were approximately the same.

Using simulation methods similar to those employed in establishing the size classes, Koenick found the minimum sample size per sub-sample to be 200 board feet (3). This amount appeared to be the minimum volume necessary to adequately represent the distribution of boards within one size class.

Since 200 board feet of lumber were needed in each size class, the original percentage values in the maple distribution tables were

converted to percentages of the desired 200 board feet per size class. The latter percentage values were then converted to board feet, again based on 200 board feet per size class. These board feet values served as the basis for determining the number of sample boards for each width-length combination within the size classes.

In calculating the required number of boards, mathematically rounding up to the next whole board created an excess volume above the desired 200 board feet per size class. As a means of reducing this excess, adjacent volume values within each of the size class distributions and representing boards of the same length were frequently combined to reduce the number of fractional boards. The actual board foot volume per size class in each replication is shown in Table 1.

Samples were drawn from kiln-dried lumber during a one-week time period, which limited the selection of specific board sizes. When this occurred, available boards within the same grade of the next closest size were substituted. The final board distribution pattern is shown for each size class in Tables 2, 3, and 4. In a few instances, for specific board dimensions, the two replications did not have the same number of boards.

Sorting sheds were provided by the cooperating flooring mill for storage and breakdown of lumber samples. Approximately 40 man-days were spent assembling the lumber samples.

III. CONVERSION PROCESS

After the samples were assembled and properly marked, the lumber was transferred from the sorting sheds to the flooring machine where it

TABLE 1

ACTUAL BOARD FOOT VOLUME PER SIZE CLASS IN RED OAK LUMBER SAMPLE

Grade-Size Class Combination[a]	Replication 1	Replication 2
	board feet	
1CNS	188.25	188.25
1CNL	188.00	177.33
1CWS	230.75	230.75
1CWL	232.67	222.67
2CNS	226.83	228.17
2CNL	218.17	218.17
2CWS	217.00	217.67
2CWL	224.67	224.67
3ACNS	221.33	220.67
3ACNL	222.50	222.50
3ACWS	181.17	181.17
3ACWL	185.58	185.58
Total	2536.92	2517.60

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 2

BOARD DISTRIBUTION FREQUENCY OF 4/4 1 COMMON RED OAK LUMBER

Length[a] in Feet	Width[b] in Inches											
	3	4	5	6	7	8	9	10	11	12	13	14
4		1		2	3			1				
5					2		1	1				
6	NS			3	2	1	3	2	2	1		WS
7					1	1	5		1	1		
8		1	7	9	9	7	9	4		5		2
9				1								
10				3	4	2		3	1	2		
11				1								
12			1	5	10			(1)(0)[c]				
13	NL											WL
14							2	3		2	1	
15												
16						(2)(1)[d]	1	2	1	1		

[a] S = Short lumber less than eight feet long
L = Long lumber greater than eight feet long.

[b] N = Narrow lumber less than eight inches wide
W = Wide lumber greater than eight inches wide.

[c] n = 1 and 0 boards for replication 1 and 2, respectively.

[d] n = 2 and 1 boards for replication 1 and 2, respectively.

TABLE 3

BOARD DISTRIBUTION FREQUENCY OF 4/4 2 COMMON RED OAK LUMBER

Length[a] in Feet		Width[b] in Inches											
		3	4	5	6	7	8	9	10	11	12	13	14
4			1		2		2		2		2		1
5			2		4		2	2			1		
6	NS		1	3	5		5	3	2	3	1	WS	
7					2		1		1				
8			(3)(2)[c]	5	(8)(9)[d]	11	6	8	7	3	1	(1)(0)[e]	(0)(1)[f]
9					1					1			
10			1	2	3		5	2	3			1	
11					1			1					
12	NL			2	5		2	3	2	1	1	WL	
13					1								
14				1	2	3		1	4	1			
15													
16				1	3		1					1	

[a] S = Short lumber less than eight feet long
L = Long lumber greater than eight feet long.

[b] N = Narrow lumber less than eight inches wide
W = Wide lumber greater than eight inches wide.

[c] n = 3 and 2 boards for replication 1 and 2, respectively.

[d] n = 8 and 9 boards for replication 1 and 2, respectively.

[e] n = 1 and 0 boards for replication 1 and 2, respectively.

[f] n = 0 and 1 boards for replication 1 and 2, respectively.

TABLE 4

BOARD DISTRIBUTION FREQUENCY OF 4/4 3A COMMON RED OAK LUMBER

Length[a] in Feet	Width in Inches[b]											
	3	4	5	6	7	8	9	10	11	12	13	14
4				3		2				1		
5				5			2	2				
6	NS	2	2	3	3	2	3	2		3		WS
7				2		2	2					
8			(3)(4)[c]	(9)(8)[d]	12	8	10	4	2	1		
9					1							
10			1	2	3	3	3	2	1			
11						1	1					
12				3	3	2	3	3	1			
13	NL											WL
14				2	3	2	1		3			
15												
16				2	2	1	1					

[a] S = Short lumber less than eight feet long
L = Long lumber greater than eight feet long.

[b] N = Narrow lumber less than eight inches wide
W = Wide lumber greater than eight inches wide.

[c] n = 2 and 4 boards for replication 1 and 2, respectively.
n = 9 and 8 boards for replication 1 and 2, respectively.

was converted into flooring. The lumber was processed into strip flooring 25/32 inches thick by 2 1/4 inches wide. Although several sizes of oak flooring are available, 25/32 x 2 1/4 inch flooring represents approximately 90 percent of all oak strip flooring produced. The final step in the production process was to grade the flooring into 2 common, 1 common, select, or clear flooring grades based on the following National Oak Flooring Manufacturers' Association standards (5):

> Two Common - May contain sound natural variations of the forest product and manufacturing imperfections. The purpose of this grade is to furnish an economical floor suitable for homes, general utility use, or where character marks and contrasting appearance are desired. Bundles to be 1 1/4 foot and up. Average length 2 1/2 feet.
>
> One Common - Shall be of such nature that will lay a good residential floor and may contain varying wood characteristics, such as flags, heavy streaks and checks, worm holes, knots and minor imperfections in working. Bundles to be 2 foot and up. Average length 3 feet.
>
> Select - The face may contain sap, small streaks, pin worm holes, burls, slight imperfections in working, and small tight knots which do not average more than one to every 3 feet. Bundles to be 2 foot and up. Average length 3 3/4 feet.
>
> Clear - The face shall be practically clear, admitting an average of 3/8 of an inch of bright sap. The question of color shall not be considered. Bundles to be 2 foot and up. Average length 4 1/4 feet.

Each piece of flooring was then measured and tallied by length and grade. Yield, in board feet, of each piece of flooring was computed by the relationship 0.020833 X length in inches, where 0.020833 is the board foot volume of a piece of flooring three inches wide by one inch long by one inch thick.

Mill personnel were used in all phases of the conversion and grading processes.

IV. STATISTICAL DESIGN

An analysis of variance was used to assess the yield ratios (flooring out/lumber in) of the grades, size classes, interaction of grades and size classes, and replications. An analysis of variance was also used to evaluate the yield ratios of the three lumber grades within each of the four size classes.

The chi-square statistical test was employed to compare flooring yield grade distributions with respect to both board-foot volume and number of pieces of all possible combinations of input lumber grades. Comparison of the flooring yield distribution of each size class by grade with the yield distribution of all size classes within the same grade was made using the chi-square test. Chi-square tests were also used to compare the flooring yield distribution with respect to volume and number of pieces of all possible size class combinations within the same grade. Included in the latter analysis was a comparison of the grouped "narrow" size classes and the grouped "wide" size classes. Similar treatment was given the "long" and "short" size classes.

Since the various grades of flooring have specified minimum lengths, attention was given to this aspect of flooring yield. Each grade of flooring from all grade and size class combinations of lumber was sorted into one-foot length intervals. The flooring ranged from 9 to 104 inches in length. The Kolmogorov-Smirnov two-sample test (8) was used to compare board foot volume and number of pieces in each length interval for all possible size class combinations within each of the three lumber grades. The total flooring (combined volume and

combined number of pieces within each size class) was compared in the same manner.

Services of the University of Tennessee Computing Center were used in all of the statistical analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Due to the slight differences in input lumber volume, an analysis of variance was performed on the mean yield ratios of the two replications. Mean yield ratio was defined as $\frac{\frac{\text{output}}{\text{input}}}{n}$ where n is the number of observations. The test results in Table 5 show no significant differences in the mean yield ratios of the two replications.[1] Differences in yield did occur, however, when the input lumber was sorted into the various grades and size classes.

I. FLOORING YIELD BY LUMBER GRADE

Results of the analysis of the data shown in Table 6 indicated highly significant differences in the mean yield ratios of the three lumber grades. One common lumber had the highest percent yield of 75.5 followed by 2C and 3AC lumber with yields of 68.5 and 62.7 percent, respectively. Percent yield is the mean yield ratio multiplied by 100. These data are in general agreement with the 66 percent yield reported by most flooring producers using a mixture of 2C and 3AC lumber.

II. FLOORING YIELD BY SIZE CLASS

The mean yield ratios of all four size classes, regardless of grade were compared. The analysis indicated the significant difference

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[1] Non-significant refers to $(P > 0.05)$;
Significant refers to $(0.01 < P \leq 0.05)$; and
Highly significant refers to $(P \leq 0.01)$.

TABLE 5

MEAN INPUT AND OUTPUT AND CORRESPONDING MEAN YIELD RATIOS OF TWO REPLICATIONS

Replication	Number of Observations[a]	Mean Input	Mean Output	Mean Yield Ratio[b]
		board feet		
1	12	211.410	145.870	0.688
2	12	209.855	144.778	0.690

[a]Includes all grade-size class combinations in each replication.

[b]Differences between mean yield ratios are non-significant at 0.05 level of probability.

TABLE 6

MEAN INPUT AND OUTPUT AND CORRESPONDING MEAN YIELD RATIOS OF THREE LUMBER GRADES

Lumber Grade[a]	Number of Observations	Mean Input	Mean Output	Mean Yield Ratio[b]
		board feet		
1C	8	207.334	157.639	0.755
2C	8	221.919	152.164	0.685
3AC	8	202.645	126.170	0.627

[a]1C, 2C, 3AC - Common lumber grades.

[b]Differences among mean yield ratios are significant at 0.01 level of probability.

in flooring yield was due to lumber width rather than length. As shown in Table 7, the WS and WL size classes had mean yields of 75.8 and 74.7 percent, respectively, while NS and NL yielded only 63.5 and 61.7 percent, respectively. A higher usable wood/waste ratio explains the greater yield from the wide boards.

When interaction between grades and size classes was analyzed, no significant difference among the grade and size class combinations was evident. However, as shown in Table 8, greater mean yield ratios were observed in combinations containing the 1C grade and wide lumber. These observations support the separate analyses for both grade and size class stratifications. The analysis showed that 1C wide boards produced the greatest yield, but due to relative cost, few producers, if any, use an appreciable amount of 1C lumber for flooring.

III. FLOORING GRADE DISTRIBUTION ANALYSIS

Chi-square tests indicated that board length had a significant effect on the yield distribution of the board foot volume and number of pieces of flooring. In all comparisons involving the combined "short" and the combined "long" size classes within each of the three lumber grades, highly significant differences were noted. The "short" lumber produced consistently higher flooring yield (both volume and number of pieces) in the 1C and select grades (Table 9). The "long" lumber yielded similarly higher yields in the 2C and clear flooring grades.

In Table 10, highly significant differences occurred when the flooring yield distributions of all possible combinations of input

TABLE 7

MEAN INPUT AND OUTPUT AND CORRESPONDING MEAN YIELD RATIOS OF FOUR SIZE CLASSES

Size Class[a]	Number of Observations	Mean Input	Mean Output	Mean Yield[b] Ratio
		board feet		
NS	6	212.360	134.368	0.635
NL	6	207.778	127.108	0.617
WS	6	209.752	160.287	0.758
WL	6	212.640	159.533	0.747

[a]N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

[b]Differences among mean yield ratios are significant at 0.05 level of probability.

TABLE 8

MEAN INPUT AND OUTPUT AND CORRESPONDING MEAN YIELD RATIOS OF ALL GRADE-SIZE CLASS INTERACTIONS

Grade Size Class Interaction[a]	Number of Observations	Mean Input	Mean Output	Mean Yield Ratio[b]
		board feet		
1CNS	2	188.250	126.800	0.675
1CNL	2	182.665	128.675	0.705
1CWS	2	230.750	189.195	0.820
1CWL	2	227.670	185.885	0.820
2CNS	2	227.500	146.735	0.645
2CNL	2	218.170	126.880	0.580
2CWS	2	217.335	166.480	0.765
2CWL	2	224.670	168.560	0.750
3ACNS	2	221.330	129.570	0.585
3ACNL	2	222.500	125.770	0.565
3ACWS	2	181.170	125.185	0.690
3ACWL	2	185.580	124.155	0.670

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

[b] Differences among mean yield ratios are non-significant at 0.05 level of probability.

TABLE 9

FLOORING YIELD[a] BY GRADE FROM SHORT AND LONG LUMBER

Lumber Grade[b]	Board Length[c]	Flooring Grade			
		2C	1C	Select	Clear
		board feet			
1C	Short	24	170	203	169
	Long	35	113	182	214
2C	Short	60	288	264	42
	Long	79	252	216	75
3AC	Short	119	373	160	17
	Long	170	287	136	34
		number of pieces			
1C	Short	11	142	238	241
	Long	20	105	213	290
2C	Short	38	264	280	46
	Long	51	220	238	83
3AC	Short	34	288	126	12
	Long	115	231	121	33

[a]Broken lines indicate the consistently higher yield in 2C and clear flooring grades from long lumber and the corresponding higher yield in 1C and select flooring grades from short lumber.

[b]1C, 2C, 3AC - Common lumber grades.

[c]Short - Lumber less than eight feet long
Long - Lumber greater than eight feet long.

TABLE 10

LUMBER INPUT AND FLOORING YIELD OF THREE LUMBER GRADES

Lumber Grade[a]	Lumber Input Volume	Flooring Grade				Total Yield
		2C	1C	Select	Clear	
		board feet				percent
1C	1658.67	31	247	451	531	75.9
2C	1775.35	89	484	518	129	68.7
3AC	1620.50	199	519	247	45	62.3

[a]1C, 2C, 3AC - Common lumber grades.

lumber (1C-2C, 1C-3AC, 2C-3AC) were compared using the chi-square test. The 1C-3AC comparison (comparing two non-adjacent grades) showed extreme variation in the two distributions. One common lumber yielded only 31 board feet of 2C flooring while 3AC yielded 199 board feet of the same grade. In contrast, 1C lumber yielded 531 board feet of clear flooring as compared to 129 board feet from 3AC. The two adjacent grade comparisons showed considerably less variation. All results indicated that the majority of flooring from the 1C lumber grade was in clear and select flooring grades, while the majority of flooring from the 3AC lumber was in the 2C and 1C flooring grades.

The chi-square test was further employed to compare flooring yield distributions of each separate size class with the weighted flooring yield distribution of all combined size classes within the same lumber grades. Flooring volumes were weighted to compensate for unequal percentages in each size class (relating to the hard maple distribution) and unequal amounts of lumber in the four size classes. Twelve comparisons were made, two of which showed significant differences. The 2CWS and the 3ACNS flooring distributions were significantly different from their respective adjusted distributions. Both size classes had relatively low amounts of flooring in the clear grade.

IV. FLOORING YIELD BY LENGTH

A total of 240 Kolmogorov-Smirnov tests were conducted comparing the flooring yield distributions with respect to flooring length. Both board foot volume and number of pieces per length interval were examined. Eight length intervals were employed: 9-17 inches, 18-29 inches, 30-41

inches, 42-53 inches, 54-65 inches, 66-77 inches, 78-89 inches, 90-104 inches. Of the 120 volume comparisons made, only 16 showed significant differences, assuming no Type II error was made. Thirteen of these 16 involved "narrow" versus "wide" size class comparisons. Narrow lumber yielded noticeably more flooring in the first four length intervals, while wide lumber yielded more flooring in the last four length intervals (Table 11).

V. WASTE ANALYSIS

The amount of waste resulting from the manufacture of flooring varied considerably. Waste percentages from the 12 grade-size class combinations ranged from 18.02 percent (1CWS) to 43.38 percent (3ACNL). The average percent actual waste shown in Table 12 for 1C, 2C, and 3AC was 24.66, 31.45, and 37.23 percent, respectively. The "narrow" lumber averaged 37.41 percent waste while the percent waste from "wide" lumber averaged only 24.81.

The first step in the flooring manufacture process is to rip the lumber into three inch strips. Consequently, the 5, 8, 11, and 14 inch boards will result in a two inch strip of waste lumber. Attempts were made to find ways of utilizing these strips and, in turn, reduce the amount of waste. One possible alternative considered in this study was to convert these strips to 25/32 x 1 1/2 inch flooring.

Since the width of the lumber used in this study was tallied to the nearest inch, it was assumed that alternate boards, 5, 8, 11, and 14 inches in width, would be of sufficient width to produce a 1 1/2 inch wide strip of flooring. By adding this simulated yield to the

TABLE 11

MEAN VOLUME OF FLOORING FROM THIRTEEN COMPARISONS INVOLVING NARROW VS. WIDE SIZE CLASSES

Lumber[a] Description	Flooring Length	
	Shorter than 53 inches	Longer than 53 inches
	board feet	
Narrow	95.8	51.3
Wide	77.5	83.0

[a] Narrow - Lumber less than eight inches wide
Wide - Lumber greater than eight inches wide.

TABLE 12

ACTUAL PERCENT WASTE, ADJUSTED PERCENT WASTE, AND CALCULATED PERCENT OF WASTE REDUCTION IN MANUFACTURE OF 1 1/2 INCH WIDE FLOORING FROM 2 INCH WIDE STRIPS OF WASTE LUMBER

Grade-Size Class Combination[a]	Actual Waste	Adjusted Waste	Waste Reduction
1CNS	32.66	27.20	5.46
1CNL	29.58	26.64	2.94
1CWS	18.02	16.75	1.27
1CWL	18.39	17.62	0.77
2CNS	35.52	29.59	5.93
2CNL	41.86	35.72	6.14
2CWS	23.43	21.33	2.10
2CWL	24.99	23.68	1.31
3ACNS	41.40	36.01	5.39
3ACWS	30.93	30.17	0.76
3ACWL	33.11	30.22	2.89
3ACNL	43.48	38.67	4.81
Average	31.11	27.80	3.31

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

actual yield and adjusting the percent waste values accordingly, the overall average waste could be reduced from 31.11 to 27.80 percent. Comparative percent waste values are shown in Table 12.

VI. COST-VALUE RELATIONSHIPS

Yield values represent only an intermediate step in determining the most profitable grade or size or combinations of each to be used in the production of flooring. Prices of both the lumber and the flooring must be considered in the final analysis.

The flooring industry is characterized by unstable prices because it is composed of many small firms and lacks recognized industry leaders. Fluctuating prices tend to complicate the optimal selection of lumber to be used in the manufacture of flooring. This is especially true when the fluctuation of the price of lumber is not in proportion to the corresponding change in the price of flooring.

A cost and return analysis was included in this study to demonstrate the effect of price changes on gross returns from the sale of hardwood flooring. The analysis was conducted on the basis of 1000 board feet of lumber in each of the three grades. The volume of lumber allotted to each size class was based on the total percentage in each size class of the original hard maple distribution. The actual flooring yield was adjusted so that given volumes are in proportion to the actual lumber input volume. Mean annual prices of lumber were obtained from a hardwood flooring mill in the Appalachian area for the period 1965 through March, 1970. Corresponding data for flooring were obtained from H. H. Willins, Executive Vice President of the National Oak

Flooring Manufacturers' Association. The price listings are included in Tables 17 and 18 in the Appendix. Total dollar value, value added (net of lumber costs only), and percent return (value added divided by lumber cost) were computed and compiled as shown in Tables 19-24 in the Appendix.

Percent return values (Table 13) show that 3AC lumber resulted in the highest average percent return, 68.25 percent, during the 1965 through March, 1970, time period. Two common ranked second with 61.8 percent return, while 1C had the lowest of 35.15 percent.

The width of the board had a noticeable effect on percent return. Average return on wide lumber was 70.43 percent compared to the 44.28 percent return on narrow lumber. This effect can be attributed to the high amount of waste associated with narrow lumber. Lumber length had very slight effect on percent return. Short lumber was higher with an average of 59.96 percent as compared to long lumber which had an average percent return of 54.73.

Based on this cost-return analysis, price conditions were such that during the years of 1965, 1967, and 1968, 3AC lumber was the most profitable grade to be used for flooring. In 1966, 1969, and through March, 1970, periods during which the price of both lumber and flooring increased considerably, 2C lumber proved to be the most profitable. One possible explanation for this occurrence is the fact that as prices increase, the percentage increase in the price of flooring is greater than that of lumber. Also when 2C replaces 3AC in the manufacture of flooring, higher proportions of the better grades of flooring will result.

TABLE 13

GROSS RETURN[a] FROM THE MANUFACTURE AND SALE OF HARDWOOD FLOORING FOR THE 1965-MARCH, 1970, TIME PERIOD

Grade-Size Class Combination[b]	Year					
	1965	1966	1967	1968	1969	March, 1970
	percent return					
1CNS	26.06	36.68	15.54	23.78	14.09	8.89
1CNL	32.48	44.04	21.46	31.13	20.17	14.34
1CWS	52.80	65.71	40.05	50.40	38.49	32.25
1CWL	51.62	64.74	39.14	50.03	37.93	31.54
Average	40.74	52.79	29.04	38.83	27.67	21.75
2CNS	63.06	69.67	60.52	57.58	64.54	52.93
2CNL	43.68	49.80	41.78	40.31	46.39	36.26
2CWS	87.67	94.75	85.10	80.87	90.52	78.28
2CWL	85.29	92.81	82.85	79.66	88.36	75.60
Average	48.86	76.75	67.56	64.60	72.45	60.76
3ACNS	63.55	68.63	63.51	63.53	59.56	50.51
3ACNL	51.34	57.11	52.01	56.00	50.91	42.36
3ACWS	83.60	89.72	84.46	86.58	82.50	72.98
3ACWL	76.33	82.47	77.30	80.35	76.04	66.87
Average	68.70	74.48	69.32	71.61	67.25	58.18

[a]Net of lumber input cost only.

[b]1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

CHAPTER V

SUMMARY

I. SCOPE OF THE STUDY

The primary objective of this study was to determine the quantity and quality of hardwood flooring yield from specific grades and sizes of red oak lumber. Secondary objectives included an analysis of waste lumber resulting from the manufacture of hardwood flooring and the effect of changing lumber and flooring prices on gross return from the sale of hardwood flooring.

Three grades of lumber (1C, 2C, 3AC) each subdivided into four size classes (NS, NL, WS, WL) were selected for analysis. Each of the 12 grade-size class combinations contained approximately 200 board feet of lumber with one replication of each. All lumber was converted to 25 x 2 1/4 inch strip flooring and graded by personnel at the cooperating flooring mill. Flooring yield data were recorded and evaluated objectively through statistical analysis.

II. PRINCIPAL FINDINGS

One common lumber had a total flooring yield of 75.5 percent, the highest of the three grades studied. Two common and 3AC yielded 68.5 and 62.7 percent, respectively.

An analysis of flooring yield from the various size classes indicated that wide lumber produced significantly higher yields than narrow lumber. Size classes containing wide lumber had an average

percent yield of 75.2 while the size classes containing narrow lumber had an average percent yield of only 62.6. Lumber length had little effect on percent yield of flooring.

Lumber length, however, noticeably affected the flooring grade distribution. Long lumber produced consistently higher flooring yields in the two extreme flooring grades, 2C and clear. Short lumber produced similarly higher yields in the two middle flooring grades, 1C and select.

The amount of waste resulting from the manufacture of flooring varied considerably among the 12 grade-size class combinations. Waste percentages ranged from 18.02 (1CWS) to 43.48 (3ACNL) percent. The average percent waste from 1C, 2C, and 3AC lumber was 24.66, 31.45, and 37.23 percent, respectively. Wide lumber averaged 24.81 percent waste while narrow lumber averaged 37.41 percent.

Simulation methods were employed to show that the overall average waste resulting from the production of hardwood flooring could be reduced from 31.11 to 27.80 percent by converting two-inch strips of waste lumber to 25/32 x 1 1/2 inch flooring.

A cost-return analysis, based on lumber and flooring prices from 1965 through March, 1970, indicated that during periods of relatively stable prices, 3AC was the most profitably lumber grade used in flooring production. In 1966 and 1969, periods during which the price of lumber and flooring increased considerably, 2C lumber appeared to be the most profitable.

III. CONCLUSIONS

Lumber grade and size had a noticeable effect on the quantity and quality of flooring yield. In general, the better grades and the wide lumber resulted in a higher quantity and quality of flooring. However this type of raw material would be more expensive for the producer to procure. The opposite cost-price relationship existed for lower grades and narrow lumber. This situation, in turn, leads to a series of cost trade-offs, which each flooring producer must consider in determining the optimum input lumber mix. In addition, flooring producers should evaluate their present operation with regard to (1) the grade-mix, cost and general size characteristics of the lumber they are presently using, (2) alternative sources of lumber suitable for flooring, (3) feasibility of horizontal integration with other wood-using firms, and (4) the flooring demand characteristics within their present market area.

IV. RECOMMENDATIONS FOR FURTHER STUDY

Although this study has provided additional insight into the flooring yield characteristics of red oak lumber, more comprehensive and precise information is needed if hardwood is to regain and maintain a satisfactory share of the flooring market. To date very few studies have been conducted with this objective in mind.

Listed below are recommendations for further research which should be beneficial to the hardwood flooring industry. Recommendations are based on information that would have been helpful in the planning

of this research, in interpreting these data, and/or in conducting additional studies of a similar nature. These recommendations include:

1. a study of the feasibility of making pre-cut lumber three inches in width (or multiples of three inches in width) available to flooring producers;

2. research showing the long-range advantages of horizontally integrating firms in the furniture, pallet, and hardwood flooring industries;

3. production studies to determine differences in production costs when processing different grades of lumber;

4. development of a model, possibly through linear programming, which would integrate lumber and production costs, flooring yield data, and current flooring prices in such a manner as to determine the optimum lumber input mix under varying market conditions; and

5. economic studies dealing with the supply and demand aspects of hardwood flooring.

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APPENDIX

TABLE 14

PERCENT OF 4/4 1 COMMON HARD MAPLE LUMBER VOLUME BY LENGTH AND WIDTH

Length (feet)	Width (inches)																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
4		.05	.07	.16	.14	.09	.04	.03		.01							.62
5		.07	.13	.28	.16	.13	.10	.07	.02								1.00
6	.01	.23	.30	.74	.83	.44	.46	.40	.32	.05	.11						3.92
7		.03	.10	.12	.21	.12	.09		.05	.12							.88
8	.01	.40	1.15	2.36	2.78	2.22	1.66	.89	.49	.75	.27	.12	.04		.05	.05	13.31
9		.04	.25	.42	.28	.18	.18	.03		.04							1.44
10		.58	1.52	3.02	4.02	3.29	2.11	1.64	1.10	1.03	.48	.20	.11	.05	.06		19.29
11		.09	.16	.12	.14	.19	.23		.04								1.00
12	.01	.60	1.54	3.22	3.79	3.04	2.38	2.33	.83	1.23	.58	.12	.13	.14	.07		20.10
13		.01	.07	.11	.13	.07	.08	.04	.05								.61
14	.06	.48	1.15	3.57	3.92	2.93	2.44	2.66	1.32	.31	.54	.21	.15	.08			19.88
15		.02	.11	.16	.11	.13	.05	.11									.71
16		.31	1.04	2.65	2.55	2.77	2.58	2.03	1.97	.93	.23						17.18
Total[a]	.10	2.96	7.65	16.99	19.13	15.67	12.45	10.27	6.23	4.50	2.23	.68	.53	.28	.19	.05	99.91

Source: Prepared from information furnished by the Northeastern Forest Experiment Station, Forest Products Marketing Laboratory, Princeton, West Virginia.

[a]Line and column totals are slightly high due to rounding error.

TABLE 15

PERCENT OF 4/4 2 COMMON HARD MAPLE LUMBER VOLUME BY LENGTH AND WIDTH

Length (feet)	Width (inches)																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
4		.10	.18	.14	.24	.21	.11	.12	.03	.13		.04					1.34
5		.21	.28	.24	.27	.17	.14	.07		.02		.02					1.46
6	.01	.32	.43	1.18	.77	.83	.44	.23	.10	.31	.18	.06	.03	.03			4.98
7		.04	.12	.19	.19	.13	.04	.16	.03	.06							1.00
8	.02	.64	1.20	2.45	4.11	2.43	1.52	1.22	.79	.71	.24	.04					15.44
9		.21	.10	.31	.17	.14	.09	.07	.11	.08			.05				1.37
10	.04	.75	1.56	3.34	4.53	3.39	2.40	1.53	.99	.14	.20			.12	.06		19.12
11		.03	.10	.25	.21	.34	.38	.08	.04		.05	.06					1.59
12		.67	1.25	3.25	4.12	2.79	3.31	1.22	.93	.79	.30						18.67
13		.02	.05	.15	.17	.32	.22	.15									1.11
14		.28	.82	2.70	3.50	2.33	2.17	1.65	.96	.52	.07			.08			15.14
15			.02	.10	.33	.09		.11									.67
16		.15	1.35	3.47	2.81	2.60	3.11	2.26	1.03	1.05	.16						18.03
Total[a]	.10	3.46	7.53	17.84	21.48	15.82	14.00	8.93	5.06	3.85	1.23	.24	.08	.25	.06		99.92

Source: Prepared from information furnished by the Northeastern Forest Experiment Station, Forest Products Marketing Laboratory, Princeton, West Virginia.

[a]Line and column totals are slightly high due to rounding error.

TABLE 16

PERCENT OF 4/4 3A COMMON HARD MAPLE LUMBER VOLUME BY LENGTH AND WIDTH

Length (feet)	Width (inches)																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
4		.07	.19	.20	.16	.13	.13	.12	.07	.07	.02	.17					1.38
5	.01	.09	.13	.23	.11	.17	.19		.02			.03					1.02
6	.02	.24	.28	.57	.62	.38	.40	.22	.17	.19	.08			.05			3.27
7		.04	.16	.11	.20	.20	.23	.11		.26							1.35
8	.01	.25	.70	2.14	3.58	2.75	2.10	.98	.37	.76	.44	.11					14.25
9		.03	.07	.31	.23	.61	.25	.04	.05								1.63
10	.04	.36	.69	2.39	3.42	3.92	2.39	1.91	1.28	.19	.13	.07	.07				16.93
11		.04	.05	.21	.08	.51	.72	.05	.19								1.88
12	.05	.25	.63	3.37	4.51	3.73	3.04	1.85	.70	.61	.24						19.04
13				.12	.09	.22	.12	.06									.63
14		.14	.59	2.81	4.90	3.15	2.14	1.34	2.21	.98							18.32
15				.23	.27	.06		.07									.66
16	.02	.10	.46	3.83	3.51	2.72	2.30	2.64	2.71	1.12	.11						19.57
Total[a]	.18	1.67	4.01	16.59	21.76	18.61	14.07	9.45	7.81	4.21	1.05	.41	.07	.05			99.93

Source: Prepared from information furnished by the Northeastern Forest Experiment Station, Forest Products Marketing Laboratory, Princeton, West Virginia.

[a]Line and column totals are slightly high due to rounding error.

TABLE 17

YEARLY AVERAGE F.O.B. MILL PRICE PER 1000 BOARD FEET OF GREEN APPALACHIAN RED OAK LUMBER[a]

Year	Grade		
	3AC	2C	1C
1965	$62.87	$74.20	$103.95
1966	72.11	84.60	114.25
1967	59.64	71.10	106.98
1968	62.00	75.59	104.62
1969	81.52	91.45	142.22
March, 1970	80.00	90.00	135.00

[a]Personal communication with personnel at the cooperating flooring mill, dated March 26, 1970.

TABLE 18

YEARLY AVERAGE MANUFACTURER'S SELLING PRICE OF FLOORING PER 1000 BOARD FEET[a]

Year	Grade			
	2C	1C	Select	Clear
1965	$ 99.50	$179.50	$197.50	$203.50
1966	124.00	210.00	235.00	245.00
1967	101.00	170.00	185.00	192.50
1968	131.00	169.00	196.00	204.50
1969	165.00	222.50	242.50	252.50
March, 1970	160.00	207.00	220.00	225.00

[a]Personal communication with Henry H. Willins, National Oak Flooring Manufacturers' Association, dated March 20, 1970.

TABLE 19

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON 1965 LUMBER AND FLOORING PRICES

Grade-Size Class Combination[a]	Bd.Ft./ 1000	Cost	2C		1C		Select		Clear		Waste Bd.Ft.	Total Value	Value Added	Percent Return
			Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value				
1CNS	133.4	$13.87	1.0	$0.10	21.3	$ 3.82	31.9	$ 6.31	35.7	$ 7.26	43.5	$ 17.48	$ 3.61	26.06
1CNL	488.5	50.78	8.4	0.83	47.2	8.48	124.6	24.61	163.9	33.35	144.4	67.27	16.49	32.48
1CWS	61.9	6.43	1.1	0.11	11.0	1.98	19.8	3.91	18.8	3.83	11.1	9.83	3.40	52.80
1CWL	309.7	32.19	9.8	0.97	47.4	8.51	81.9	16.17	113.8	23.15	56.8	48.81	16.62	51.62
Total	993.5	$103.27	20.2	$2.01	126.9	$22.78	258.3	$51.01	332.2	$67.60	255.9	$143.39	$40.12	
2CNS	171.0	$ 12.69	4.9	$0.48	39.0	$ 7.00	52.4	$10.35	14.0	$ 2.85	60.7	$ 20.69	$ 8.00	63.06
2CNL	488.1	36.22	26.7	2.66	92.1	16.54	123.6	24.41	41.4	8.43	204.2	52.04	15.82	43.68
2CWS	68.7	5.10	3.9	0.39	25.2	4.53	22.1	4.36	1.4	0.29	16.1	9.57	4.47	87.67
2CWL	265.4	19.69	15.7	1.56	81.3	14.59	75.2	14.85	27.0	5.49	66.3	36.49	16.80	85.29
Total	993.2	$ 73.70	51.1	$5.09	237.7	$42.66	273.3	$53.97	83.9	$17.07	347.3	$118.78	$45.09	
3ACNS	137.4	$ 8.64	9.9	$0.99	45.3	$ 8.14	23.9	$ 4.72	1.4	$ 0.29	56.8	$ 14.13	$ 5.49	63.55
3ACNL	487.3	30.64	63.6	6.32	109.2	19.59	76.7	15.15	26.0	5.30	211.8	46.36	15.73	51.34
3ACWS	72.9	4.58	10.5	1.05	28.5	5.11	9.9	1.96	1.5	0.30	22.5	8.41	3.83	83.60
3ACWL	305.8	19.23	47.0	4.68	107.8	19.35	42.4	8.38	7.3	1.49	101.2	33.90	14.68	76.33
Total	1003.4	$ 63.08	131.0	$13.04	290.8	$52.19	152.9	$30.20	36.2	$ 7.37	392.4	$102.81	$39.72	

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 20

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON 1966 LUMBER AND FLOORING PRICES

Grade-Size Class Combination[a]	Bd.Ft./ 1000	Cost	2C		1C		Select		Clear		Waste Bd.Ft.	Total Value	Value Added	Percent Return
			Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value				
1CNS	133.4	$15.24	1.0	$0.12	21.3	$ 4.46	31.9	$ 7.51	35.7	$ 8.74	43.5	$20.83	$ 5.59	36.68
1CNL	488.5	55.81	8.4	1.04	47.2	9.92	124.6	29.29	163.9	40.15	144.4	80.39	24.58	44.04
1CWS	61.9	7.07	1.1	0.13	11.0	2.31	19.8	4.66	18.8	4.62	11.1	11.72	4.65	65.71
1CWL	309.7	35.38	9.8	1.21	47.4	9.96	81.9	19.24	113.8	27.88	56.8	58.29	22.91	64.74
Total	993.5	$113.51	20.2	$2.51	126.9	$26.65	258.3	$60.69	332.2	$81.38	255.9	$171.23	$57.72	
2CNS	171.0	$ 14.47	4.9	$0.60	39.0	$ 8.19	52.4	$12.32	14.0	$ 3.43	60.7	$ 24.55	$10.08	69.67
2CNL	488.1	41.29	26.7	3.31	92.1	19.35	123.6	29.05	41.4	10.15	204.2	61.86	20.56	49.80
2CWS	68.7	5.81	3.9	0.48	25.2	5.30	22.1	5.18	1.4	0.35	16.1	11.32	5.51	94.75
2CWL	265.4	22.45	15.7	1.95	81.3	17.07	75.2	17.67	27.0	6.61	66.3	43.29	20.84	92.81
Total	993.2	$ 84.02	51.1	$6.34	237.7	$49.91	273.3	$64.22	83.9	$20.55	347.3	$141.01	$56.99	
3ACNS	137.4	$ 9.91	9.9	$1.23	45.3	$ 9.52	23.9	$ 5.61	1.4	$ 0.35	56.8	$ 16.71	$ 6.80	68.63
3ACNL	487.3	35.14	63.6	7.88	109.2	22.92	76.7	18.03	26.0	6.38	211.8	55.21	20.07	57.11
3ACWS	72.9	5.26	10.5	1.30	28.5	5.98	9.9	2.33	1.5	0.36	22.5	9.97	4.72	89.72
3ACWL	305.8	22.05	47.0	5.83	107.8	22.64	42.4	9.97	7.3	1.80	101.2	40.24	18.18	82.47
Total	1003.4	$ 72.36	131.0	$16.25	290.8	$61.06	152.9	$35.94	36.2	$ 8.88	392.4	$122.13	$49.77	

[a]1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 21

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON 1967 LUMBER AND FLOORING PRICES

Grade-Size Class Combination[a]	Bd.Ft./ 1000	Cost	2C		1C		Select		Clear		Waste Bd.Ft.	Total Value	Value Added	Percent Return
			Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value				
1CNS	133.4	$14.27	1.0	$ 0.10	21.3	$ 3.61	31.9	$ 5.91	35.7	$ 6.86	43.5	$16.49	$ 2.22	15.54
1CNL	488.5	52.26	8.4	0.85	47.2	8.03	124.6	23.06	163.9	31.55	144.4	63.48	11.22	21.46
1CWS	61.9	6.62	1.1	0.11	11.0	1.87	19.8	3.66	18.8	3.63	11.1	9.27	2.65	40.05
1CWL	309.7	33.13	9.8	0.99	47.4	8.06	81.9	15.15	113.8	21.90	56.8	46.10	12.97	39.14
Total	993.5	$106.28	20.2	$ 2.04	126.9	$21.57	258.3	$47.78	332.2	$63.94	255.9	$135.34	$29.05	
2CNS	171.0	$ 12.16	4.9	$ 0.49	39.0	$ 6.63	52.4	$ 9.70	14.0	$ 2.70	60.7	$19.52	$ 7.36	60.52
2CNL	488.1	34.70	26.7	2.70	92.1	15.66	123.6	22.87	41.4	7.98	204.2	49.20	14.50	41.78
2CWS	68.7	4.88	3.9	0.39	25.2	4.29	22.1	4.08	1.4	0.28	16.1	9.04	4.16	85.10
2CWL	265.4	18.87	15.7	1.58	81.3	13.82	75.2	13.91	27.0	5.19	66.3	34.50	15.63	82.85
Total	993.2	$ 70.62	51.1	$ 5.17	237.7	$40.40	273.3	$50.55	83.9	$16.14	347.3	$112.26	$41.65	
3ACNS	137.4	$ 8.19	9.9	$ 1.00	45.3	$ 7.71	23.9	$ 4.42	1.4	$ 0.27	56.8	$13.40	$ 5.20	63.51
3ACNL	487.3	29.06	63.6	6.42	109.2	18.56	76.7	14.19	26.0	5.01	211.8	44.18	15.11	52.01
3ACWS	72.9	4.35	10.5	1.06	28.5	4.84	9.9	1.84	1.5	0.28	22.5	8.02	3.67	84.46
3ACWL	305.8	18.24	47.0	4.75	107.8	18.33	42.4	7.85	7.3	1.41	101.2	32.34	14.10	77.30
Total	1003.4	$ 59.84	131.0	$13.24	290.8	$49.43	152.9	$28.29	36.2	$ 6.97	392.4	$97.93	$38.09	

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 22

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON 1968 LUMBER AND FLOORING PRICES

Grade-Size Class Combination[a]	Bd. Ft./ 1000	Cost	2C		1C		Select		Clear		Bd. Ft.	Total Value	Value Added	Percent Return
			Bd. Ft.	Value	Bd. Ft.	Value	Bd. Ft.	Value	Bd. Ft.	Value				
1CNS	133.4	$13.96	1.0	$ 0.13	21.3	$ 3.59	31.9	$ 6.26	35.7	$ 7.29	43.5	$17.28	$ 3.32	23.79
1CNL	488.5	51.11	8.4	1.10	47.2	7.98	124.6	24.43	163.9	33.51	144.4	67.02	15.91	31.13
1CWS	61.9	6.48	1.1	0.14	11.0	1.86	19.8	3.88	18.8	3.85	11.1	9.74	3.26	50.40
1CWL	309.7	32.40	9.8	1.28	47.4	8.01	81.9	16.05	113.8	23.27	56.8	48.61	16.21	50.03
Total	993.5	$103.94	20.2	$ 2.65	126.9	$21.45	258.3	$50.62	332.2	$67.93	255.9	$142.64	$38.70	
2CNS	171.0	$ 12.93	4.9	$ 0.64	39.0	$ 6.59	52.4	$10.28	14.0	$ 2.87	60.7	$ 20.37	7.44	57.58
2CNL	488.1	36.90	26.7	3.50	92.1	15.57	123.6	24.23	41.4	8.47	204.2	51.77	14.87	40.31
2CWS	68.7	5.19	3.9	0.51	25.2	4.27	22.1	4.32	1.4	0.29	16.1	9.39	4.20	80.87
2CWL	265.4	20.06	15.7	2.06	81.3	13.74	75.2	14.73	27.0	5.52	66.3	36.04	15.98	79.66
Total	993.2	$ 75.08	51.1	$ 6.70	237.7	$40.16	273.3	$53.56	83.9	$17.15	347.3	$117.57	$42.50	
3ACNS	137.4	$ 8.52	9.9	$ 1.30	45.3	$ 7.66	23.9	$ 4.68	1.4	$ 0.29	56.8	$ 13.93	$ 5.41	63.53
3ACNL	487.3	30.21	63.6	8.33	109.2	18.45	76.7	15.03	26.0	5.32	211.8	47.13	16.92	56.00
3ACWS	72.9	4.52	10.5	1.38	28.5	4.81	9.9	1.94	1.5	0.30	22.5	8.43	3.91	86.58
3ACWL	305.8	18.96	47.0	6.16	107.8	18.22	42.4	8.31	7.3	1.50	101.2	34.19	15.23	80.35
Total	1003.4	$ 62.21	131.0	$17.17	290.8	$49.14	152.9	$29.97	36.2	$ 7.41	392.4	$103.69	$41.48	

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 23

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON 1969 LUMBER AND FLOORING PRICES

Grade-Size Class Combination[a]	Bd.Ft./ 1000	Cost	2C		1C		Select		Clear		Waste Bd.Ft.	Total Value	Value Added	Percent Return
			Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value				
1CNS	133.4	$18.97	1.0	$ 0.16	21.3	$ 4.73	31.9	$ 7.75	35.7	$ 9.00	43.5	$21.64	$ 2.67	14.09
1CNL	488.5	69.47	8.4	1.38	47.2	10.51	124.6	30.22	163.9	41.38	144.4	83.49	14.01	20.17
1CWS	61.9	8.80	1.1	0.18	11.0	2.45	19.8	4.80	18.8	4.76	11.1	12.19	3.39	38.49
1CWL	309.7	44.05	9.8	1.61	47.4	10.55	81.9	19.86	113.8	28.73	56.8	60.75	16.70	37.93
Total	993.5	$141.30	20.2	$ 3.34	126.9	$28.24	258.3	$62.63	332.2	$83.87	255.9	$178.08	$36.78	
2CNS	171.0	$ 15.64	4.9	$ 0.80	39.0	$ 8.68	52.4	$12.71	14.0	3.54	60.7	$ 25.73	$10.09	64.54
2CNL	488.1	44.64	26.7	4.41	92.1	20.50	123.6	29.97	41.4	10.46	204.2	65.34	20.70	46.39
2CWS	68.7	6.28	3.9	0.64	25.2	5.62	22.1	5.35	1.4	0.36	16.1	11.97	5.69	90.52
2CWL	265.4	24.27	15.7	2.59	81.3	18.09	75.2	18.23	27.0	6.81	66.3	45.72	21.44	88.36
Total	993.2	$ 90.83	51.1	$ 8.44	237.7	$52.88	273.3	$66.26	83.9	$21.18	347.3	$148.76	$57.93	
3ACNS	137.4	$ 11.20	9.9	$ 1.64	45.3	$10.09	23.9	$ 5.79	1.4	$ 0.36	56.8	$ 17.87	$ 6.67	59.56
3ACNL	487.3	39.72	63.6	10.49	109.2	24.29	76.7	18.60	26.0	6.57	211.8	59.95	20.22	50.91
3ACWS	72.9	5.94	10.5	1.73	28.5	6.34	9.9	2.41	1.5	0.37	22.5	10.85	4.90	82.50
3ACWL	305.8	24.93	47.0	7.76	107.8	23.99	42.4	10.29	7.3	1.85	101.2	43.89	18.96	76.04
Total	1003.4	$ 81.80	131.0	$21.62	290.8	$64.70	152.9	$37.08	36.2	$ 9.15	392.4	$132.55	$50.75	

[a] 1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 24

SIMULATED FLOORING YIELD BY GRADE FROM TWELVE GRADE-SIZE CLASS COMBINATIONS OF LUMBER SHOWING DOLLAR VALUE, WASTE, VALUE ADDED, AND GROSS PERCENT RETURN BASED ON LUMBER AND FLOORING PRICES THROUGH MARCH, 1970

Grade-Size Class Combination[a]	Bd.Ft./ 1000	Cost	2C		1C		Select		Clear		Waste Bd.Ft.	Total Value	Value Added	Percent Return
			Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value	Bd.Ft.	Value				
1CNS	133.4	$18.01	1.0	$ 0.16	21.3	$ 4.40	31.9	$ 7.03	35.7	$ 8.02	43.5	$19.61	$ 1.60	8.89
1CNL	488.5	65.95	8.4	1.34	47.2	9.77	124.6	27.42	163.9	36.87	144.4	75.40	9.46	14.34
1CWS	61.9	8.36	1.1	0.17	11.0	2.28	19.8	4.36	18.8	4.24	11.1	11.05	2.70	32.25
1CWL	309.7	41.81	9.8	1.56	47.4	9.81	81.9	18.01	113.8	25.60	56.8	54.99	13.19	31.54
Total	993.5	$134.12	20.2	$ 3.24	126.9	$26.27	258.3	$56.82	332.2	$74.74	255.9	$161.06	$26.94	
2CNS	171.0	$ 15.39	4.9	$ 0.78	39.0	$ 8.07	52.4	$11.53	14.0	$ 3.15	60.7	$ 23.54	$ 8.15	52.93
2CNL	488.1	43.93	26.7	4.27	92.1	19.07	123.6	27.19	41.4	9.32	204.2	59.86	15.93	36.26
2CWS	68.7	6.18	3.9	0.62	25.2	5.23	22.1	4.85	1.4	0.32	16.1	11.02	4.84	78.28
2CWL	265.4	23.89	15.7	2.51	81.3	16.83	75.2	16.54	27.0	6.07	66.3	41.94	18.06	75.60
Total	993.2	$ 89.39	51.1	$ 8.18	237.7	$49.20	273.3	$60.12	83.9	$18.87	347.3	$136.36	$46.98	
3ACNS	137.4	$ 10.99	9.9	$ 1.59	45.3	$ 9.38	23.9	$ 5.25	1.4	$ 0.32	56.8	$ 16.54	$ 5.55	50.51
3ACNL	487.3	38.98	63.6	10.17	109.2	22.60	76.7	16.88	26.0	5.86	211.8	55.50	16.51	42.36
3ACWS	72.9	5.83	10.5	1.68	28.5	5.90	9.9	2.18	1.5	0.33	22.5	10.09	4.26	72.98
3ACWL	305.8	24.46	47.0	7.53	107.8	22.32	42.4	9.33	7.3	1.65	101.2	40.82	16.36	66.87
Total	1003.4	$ 80.27	131.0	$20.97	290.8	$60.19	152.9	$33.64	36.2	$ 8.15	392.4	$122.95	$42.68	

[a]1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less then eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

TABLE 25

HARDWOOD FLOORING YIELD STUDY, INPUT-OUTPUT SUMMARY

Grade-Size Class Combination[a]	Replication	Flooring Out				Total Flooring Out	Total Lumber In	Out/In	Waste
		1C	2C	Select	Clear				
		board feet						percent	
1CNS	1	32.67	1.18	46.81	49.15	130.17	188.25	69.15	30.85
	2	27.33	1.25	43.35	51.50	123.43	188.25	65.57	34.43
2CNS	1	48.67	6.69	69.83	20.37	145.56	226.83	64.17	35.83
	2	55.08	6.25	69.67	16.92	147.92	228.17	64.83	35.17
3ACNS	1	82.98	12.29	37.15	0.00	132.42	221.33	59.83	40.17
	2	62.83	19.71	39.65	4.54	136.73	220.67	61.96	38.04
1CNL	1	23.37	5.94	52.08	48.54	129.93	188.00	69.11	30.89
	2	11.94	0.33	41.12	74.02	127.41	177.33	71.85	28.15
2CNL	1	42.69	12.06	55.67	18.50	128.92	218.17	59.09	40.91
	2	39.67	11.81	54.83	18.54	124.85	218.17	57.23	42.77
3ACNL	1	52.10	32.69	34.40	5.90	125.09	222.50	56.22	43.78
	2	47.58	25.35	35.65	17.87	126.45	222.50	56.83	43.17
1CWS	1	45.94	5.15	70.27	73.81	195.17	230.75	84.58	15.42
	2	36.21	2.96	77.42	66.64	183.23	230.75	79.41	20.59
2CWS	1	83.56	11.92	66.71	7.54	169.73	217.00	78.22	21.78
	2	76.17	12.67	72.81	1.58	163.23	217.67	74.99	25.01

TABLE 25 (Continued)

Grade-Size Class Combination[a]	Replication	Flooring Out				Total Flooring Out	Total Lumber In	Out/In	Waste
		1C	2C	Select	Clear				
				board feet				percent	
3ACWS	1	58.39	26.92	31.31	3.00	119.62	181.17	66.03	33.97
	2	83.21	25.31	18.00	4.23	130.75	181.17	72.17	27.83
1CWL	1	39.77	3.96	60.97	73.75	178.27	232.67	76.62	23.38
	2	29.94	10.42	59.60	93.54	193.50	222.67	86.90	13.10
2CWL	1	68.42	12.19	69.04	21.90	171.55	224.67	76.36	23.64
	2	69.21	14.37	58.23	23.77	165.58	224.67	73.70	26.30
3ACWL	1	66.48	29.92	20.92	6.75	124.07	185.58	66.85	33.15
	2	64.37	27.17	30.56	2.15	124.25	185.58	66.95	33.05

[a]1C, 2C, 3AC - Common lumber grades;
N - Narrow lumber less than eight inches wide;
S - Short lumber less than eight feet long;
W - Wide lumber greater than eight inches wide; and
L - Long lumber greater than eight feet long.

VITA

Hollis R. Large was born in Tazewell, Tennessee, on February 23, 1943. He attended elementary school in Claiborne County and was graduated from Claiborne County High School in 1961. After four years in the U. S. Navy, he entered The University of Tennessee, Martin, in 1965, transferred to The University of Tennessee, Knoxville, in 1967, and received a Bachelor of Science Degree in Forestry in 1969.

In the summer of 1969, he accepted a research assistantship at The University of Tennessee, Knoxville, and began study toward a Master of Science Degree in Forestry, which he received March, 1971. He is a member of the Society of American Foresters.

He is married to the former Nancy Fugate of Tazewell, Tennessee.