Quality Indexes for Oak Sawlogs Based on Green Lumber Grade Yields

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Abstract

Quality Indexes for red oak (*Quercus rubra*) and white oak (*Quercus alba*) logs were established using multivariate regression models developed by the US Department of Agriculture (USDA) Forest Service that predicted green 4/4 lumber grade yields from hardwood sawlogs. Past Quality Indexes were based on air-dried lumber grade yields, but these yields can be affected by mill-specific factors. Considering green lumber as the finished product isolated the drying process and any subsequent changes in lumber product value from the analysis. Lumber grades were consistent with National Hardwood Lumber Association specifications, while log grades were based on the USDA Forest Service grading rules. Input data into the models included log scaling diameter, log length, and percent scaling defect. Green lumber grade yields were then used along with price relatives developed from 5-year lumber grade price averages (nominal) to develop Quality Indexes for each species. Two applications of the Quality Index are illustrated.

The Quality Index is a timber measure that dates to Herrick (1946) at Purdue University. It is a single number that expresses the relative value of a hardwood sawlog as determined by the value of different National Hardwood Lumber Association (NHLA) grades of 4/4 lumber that can be sawn from it. A great deal of research and outreach by the US Department of Agriculture (USDA) Forest Service in the 1960s and 1970s built upon Herrick's (1946, 1956) efforts to improve the utilization of eastern hardwood species (e.g., Mendel and Smith 1970). Much of this occurred in the Appalachian hardwood region of the eastern United States.

A Quality Index has several applications in the valuation of timber products. One is its ability to place an objective value on a factory grade hardwood log based on its predicted lumber grade yields. Another is that when used in conjunction with Tree Value Conversion Standards (DeBald and Dale 1991), a conversion return for hardwood sawtimber can be realized. Ultimately, a Quality Index can be applied as part of a financial maturity assessment of individual hardwood trees or stands (Goodman and Mendel 1978). Unfortunately, the indexes have not been revised since Debald and Dale's (1991) work over two decades ago.

Hardwood timber products in some sections of the country, like the southern United States, are of overall lesser scale and quality as related to a log's ability to produce appearance grade hardwood lumber. Weight scaling has since become more prevalent in these regions. Stick scaling became a less efficient means of evaluating individual sawlogs as their average size decreased over the 20th century, and weight scaling was implemented by the lumber industry to save both time and money (Daniels 2001). The prompt delivery of fresh hardwood logs that are high in moisture, and thus weight, benefits the landowner, but the mill also gains by receiving raw material free from stain or degradation. The increasing recognition of weight scaling as a means of transaction in the southern United States encouraged efforts to develop volume-to-weight (or weight-to-volume) conversions for hardwood sawtimber in that region (e.g. Doruska et al. 2006).

Scaling and grading individual hardwood logs is still the more common practice in the Appalachian region of the eastern United States, where the production of appearance grade hardwood lumber is a quality-driven sector. Sawlogs must be of appropriate diameter, length, and straightness, with defects along the length and at the log ends kept to a minimum. Together, these factors ultimately determine a log's ability to yield the wide, long, and clear cuttings required by the higher NHLA lumber grades (Rast et al. 1973). Appearance grade hardwood lumber and factory log prices can therefore vary widely between species and between grades within a species.

Luppold and Bumgardner (2006) described the 1961 to 2005 hardwood lumber price trends as erratic overall. From 1961 to 1985, real FAS and No. 1 Common oak prices were increasing significantly, while the opposite trends were occurring in the No. 2 Common grade for the species. Beginning in 1986, prices for No. 2 Common red oak

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(*Quercus rubra*) and white oak (*Quercus alba*) lumber significantly increased, while FAS and No.1 Common prices were not significantly different from zero. Inflation-adjusted prices for Ohio No. 2 and better red oak sawlogs remained unchanged from 1960 to 2011, but No. 2 and Better white oak log prices were increasing significantly (Duval et al. 2014). With the higher grade lumber prices declining and log prices holding steady or improving, operating margins for sawmills had narrowed considerably by the mid-2000s (Hoover 2013b).

The 2007 to 2009 Recession that followed was unlike any the hardwood industry had faced since World War II (Luppold et al. 2014). Surviving sawmills focused specifically on log supply chains as the industry emerged from the low point of its most recent business cycle (Hoover 2013a). Hassegawa et al. (2013) questioned the validity of Quebec's sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*) lumber merchantable value models developed earlier by Petro and Calvert (1976). They concluded an update was necessary, in part because of the Petro and Calvert model's consistent underestimating of the species' log Quality Indexes.

Providing new Quality Indexes for oak sawlogs was the objective of this study, but using a different approach than that taken previously in the United States (DeBald and Dale 1991). Here, green lumber board foot yields were considered, whereas previously, lumber yields were expressed on a dry basis (Mendel and Smith 1970, DeBald and Dale 1991). Today, many hardwood sawmills still sell their lumber green, and factors affecting degradation in the air-drying yard are often mill specific (Howard and Yaussy 1986). By considering green 4/4 lumber as the finished product, the drying process and any subsequent changes in lumber product value were isolated from the analysis. Two multivariate regression models permitted simulating a range of conditions over a large number of replications (Yaussy and Brisbin 1983, Yaussy 1986).

The Quality Index

Quality Index tables are based on NHLA lumber grade yields from hardwood sawlogs of varying sizes. Previous work by the USDA Forest Service used air-dried lumber grade yields from hardwood sawlogs (Mendel and Smith 1970, DeBald and Dale 1991). Logs were assessed based on scale and quality criteria, with a grade of F1, F2, and F3 (Rast et al. 1973).

The data needed to develop the index are species, log scaling diameter, lumber grade yield by log grade, and 4/4 hardwood lumber prices by grade. Equation 1 describes the calculation[1]:

$$\begin{aligned} QI = (P_{FAS} \times PR_{FAS}) + (P_{1C} \times PR_{1C}) \\ + (P_{2C} \times PR_{2C}) + (P_{3C} \times PR_{3C}) \end{aligned} \tag{1}$$

where QI is the Quality Index measure for a log of particular size and grade. The percentage of each lumber grade (P_{FAS}) is the volume of lumber that would meet that grade relative to the total volume of lumber that could be sawn from the log. The price relative (PR_{FAS}) is the ratio of each lumber grade's price as it relates to the price of No. 1 Common lumber. Prices are collected over a 5-year period to account for a business cycle. The PR_{1C} always equals 1.00, the PR_{FAS} is always greater than 1.00, and the PR_{2C} and PR_{3C} are always less than 1.00.

Oak Quality Indexes based on green lumber yields

Updated Quality Indexes for northern red oak and white oak were created by simulating green lumber board foot yields from a range of logs, which varied by diameter, length, and scaling defect. Multivariate regression models developed by Yaussy and Brisbin (1983) and Yaussy (1986) were used to calculate lumber yields for red and white oak green, respectively (Tables 1 and 2). The study areas in both cases were the Appalachian hardwood region. Grading criteria followed the USDA Forest Service's log grading rules (Rast et al. 1973).

One thousand logs of each species were simulated, with the assumption that all were sawn entirely into 4/4 lumber. Minimum scaling diameter limits corresponded to the USDA Forest Service log grading standard. Maximum diameter limits were imposed because the number of logs sampled by diameter class was stated by neither Yaussy and Brisbin (1983) nor Yaussy (1986) when their respective models were developed. Mendel and Smith (1970) discussed the erratic nature of their log data in the higher diameter classes when developing earlier Quality Indexes. Hanks et al. (1980) provided information on setting reasonable upper scaling diameter limits.

Red and white oak lumber prices were obtained from Hardwood Review (Charlotte, North Carolina) for the period from January 2011 to December 2015. Red oak prices corresponded to Hardwood Review's southern Appalachian lumber market region, while white oak prices were for the Appalachian region as a whole. The 5-year averages were determined from monthly data and then indexed to the average price of No. 1 Common to develop price relatives for each species (Table 3).

Table 3 also highlights changes in the price relatives for FAS and No. 2 Common in 2015 compared with 1984, where the 1984 price relatives were based on 1980 to 1984 prices (DeBald and Dale 1991). The 2015 price relatives were greater for both grades in each species versus those from 1984. This means FAS prices for the 2015 period had moved further away from No. 1 Common compared with the 1984 period. On the other hand, the price spreads between No. 1 Common and No. 2 Common had lessened. The largest overall increase between periods for the price relatives was for No. 2 Common red oak at 0.37, while the price relative for FAS red oak increased the least at 0.17. The changes in price relatives for white oak were similar, 0.22 for FAS and 0.23 for No. 2 Common.

Equation 1 was then applied for each species–log grade–log diameter combination to derive log Quality Indexes (Tables 4 and 5). Because green board foot yields were used in this update of the oak Quality Indexes, the results in Table 4 and Table 5 are not directly comparable to past updates of hardwood log Quality Indexes (Mendel and Peirsol 1977, DeBald and Dale 1991).

Using the Quality Index

Two methods of evaluating log value can be accomplished using the Quality Index. One is to predict lumber

[1] Here, F1F was combined with FAS; Selects with 1C; 2A and 2B into 2C; and 3A and 3B into 3C per Yaussy (1986) and NHLA (2014).

*Table 1.—Percent lumber yields by National Hardwood Lumber Association lumber grade for red oak (*Quercus rubra*) logs.*[a]

Log grade	Lumber grade	% lumber yield at a scaling diam. (in.) of:																
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
F1	FAS	—	—	—	—	—	35.6	37.2	39.5	41.8	44.9	45.6	46.7	47.4	50.6	50.4	50.3	52.7
	1C	—	—	—	—	—	31.0	31.3	30.9	30.6	29.6	30.4	30.7	31.0	29.9	30.9	31.8	31.0
	2C	—	—	—	—	—	22.3	20.9	19.7	18.3	17.1	15.7	14.6	13.7	12.6	11.5	10.6	9.67
	3C	—	—	—	—	—	11.1	10.6	9.92	9.28	8.31	8.27	8.04	7.94	6.96	7.17	7.37	6.6
F2	FAS	—	—	—	9.34	12.4	13.5	15.9	17.8	19.0	20.1	22.2	22.1	23.8	24.9	25.8	26.5	—
	1C	—	—	—	28.2	30.4	31.4	33.5	35.3	36.6	38.0	39.9	40.5	42.1	43.2	44.5	45.4	—
	2C	—	—	—	33.9	31.9	30.8	28.8	27.0	25.6	24.1	22.3	21.4	19.8	18.6	17.3	16.3	—
	3C	—	—	—	28.6	25.2	24.3	21.7	19.9	18.8	17.8	15.6	15.9	14.2	13.2	12.4	11.8	—
F3	FAS	0.00	0.27	1.07	2.25	3.27	4.40	5.42	6.44	7.34	—	—	—	—	—	—	—	—
	1C	10.4	12.4	14.5	17.3	19.5	21.9	24.0	26.1	27.9	—	—	—	—	—	—	—	—
	2C	28.1	32.7	34.8	35.4	35.3	34.7	33.8	32.8	31.7	—	—	—	—	—	—	—	—
	3C	61.8	54.6	49.6	45.1	41.9	39.0	36.8	34.7	33.1	—	—	—	—	—	—	—	—

[a] Values were obtained by applying a multivariate green lumber grade yield regression model developed by Yaussy and Brisbin (1983).

*Table 2.—Percent lumber yields by National Hardwood Lumber Association lumber grade for white oak (*Quercus alba*) logs.*[a]

Log grade	Lumber grade	% lumber yield at a scaling diam. (in.) of:																
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
F1	FAS	—	—	—	—	—	17.8	17.9	21.5	20.6	23.2	24.0	26.1	26.9	26.2	28.5	27.7	30.0
	1C	—	—	—	—	—	31.6	31.3	31.6	32.0	32.6	33.2	33.9	34.7	35.5	36.2	37.0	37.6
	2C	—	—	—	—	—	26.9	27.2	26.5	26.4	25.5	25.5	23.9	23.1	22.5	21.5	20.9	20.0
	3C	—	—	—	—	—	23.8	23.5	20.4	21.0	18.7	18.7	16.1	15.3	15.8	13.8	20.0	12.4
F2	FAS	—	—	—	15.6	15.8	16.5	16.9	17.1	17.7	18.1	18.7	19.1	19.4	20.1	19.9	—	—
	1C	—	—	—	10.9	14.6	16.9	20.6	24.3	26.7	29.8	32.1	34.6	36.8	38.8	41.4	—	—
	2C	—	—	—	34.1	34.6	33.7	32.9	32.5	31.0	29.9	28.6	27.5	26.5	24.7	24.9	—	—
	3C	—	—	—	39.4	35.0	33.0	29.6	26.2	24.5	22.1	20.6	18.8	17.3	16.4	13.9	—	—
F3	FAS	2.06	1.09	1.13	1.61	2.25	2.88	3.69	4.36	5.01	5.79	6.55	6.85	7.36	—	—	—	—
	1C	0.00	0.00	0.00	0.00	0.00	3.42	6.75	11.3	14.9	17.7	20.3	24.7	27.6	—	—	—	—
	2C	0.00	17.9	27.0	32.7	36.1	38.8	39.4	40.1	40.3	39.7	39.0	39.4	39.0	—	—	—	—
	3C	97.9	95.6	83.4	73.4	64.5	54.9	50.1	44.3	39.8	36.9	34.1	29.1	26.0	—	—	—	—

[a] Values were obtained by applying a multivariate green lumber grade yield regression model developed by Yaussy (1986).

product value on a thousand board foot basis (MBF) using Tables 4 and 5 along with the current prices for No. 1 Common red and white oak lumber. Table 6 illustrates an example for red oak, while Table 7 does so for white oak. The lumber prices given in Tables 6 and 7 were from January 2016. Multiplication of the Quality Index by the No. 1 Common price provides the lumber product value per MBF for each log grade by scaling diameter of each species. For example, the predicted value of 1 MBF of lumber obtained from F1 red oak logs with a scaling diameter of 16 inches is US$694 (Table 6). For white oak, the predicted value of 1 MBF of lumber obtained from F1 logs with a scaling diameter of 16 inches is US$757 (Table 7).

*Table 3.—Red oak (*Quercus rubra*) and white oak (*Quercus alba*) average lumber prices (nominal) from January 2011 to December 2015 and 2015 price relatives.*[a]

	FAS	1C	2C	3C
Red oak lumber				
5-yr average price (US$)	1,012	672	561	492
2015 price relative	1.51	1.00	0.83	0.73
1984 price relative	1.34		0.46	
White oak lumber				
5-yr average price (US$)	1,212	710	531	473
2015 price relative	1.71	1.00	0.75	0.67
1984 price relative	1.49		0.52	

[a] Price relatives for FAS and 2C from DeBald and Dale (1991) for 1984 are provided for comparison.

A second way to apply the Quality Index is to estimate the lumber product value within a single log. Once the log's grade is determined and the lumber yield predicted, the Quality Index can be applied knowing the current price of No. 1 Common lumber:

$$\text{Lumber product value} = \text{Log volume} \times \text{QI} \times \frac{\text{Current price of } 4/4 \text{ 1C}}{1,000} \qquad (2)$$

Lumber yield can be estimated using local log rules and/or proprietary information.

Assume two logs, one red oak and one white oak, are harvested in southern Appalachia and delivered to a local mill. Their scaling diameters are 16 inches. They are 12 feet in length, excluding trim. Five percent defect is present in each. Applying the USDA Forest Service's factory log grading specifications, the logs grade as F1. According to Yaussy and Brisbin's (1983) model, the red oak log contains 135 board feet of lumber, while Yaussy's (1986) model predicts the white oak log contains 130 board feet of

*Table 4.—Red oak (*Quercus rubra*) Quality Index, southern Appalachian region.*

Scaling diam. (in.)	Quality Index		
	F1	F2	F3
8	—	—	0.79
9	—	—	0.80
10	—	—	0.82
11	—	0.91	0.83
12	—	0.94	0.85
13	1.11	0.95	0.86
14	1.13	0.97	0.87
15	1.14	0.99	0.89
16	1.16	1.00	0.90
17	1.18	1.01	—
18	1.18	1.03	—
19	1.19	1.03	—
20	1.20	1.05	—
21	1.22	1.06	—
22	1.22	1.07	—
23	1.22	1.08	—
24	1.23	—	—

lumber. By comparison, two commonly used log rules in the eastern United States, the International ¼-Inch and Doyle log rules, produce estimates that the logs contain 130 and 108 board feet, respectively, but these rules do not take into account the percent defect present (Avery and Burkhart 1994).

The lumber product value of each log can now be determined. Summary information is provided in Table 8. Given the parameters above for the two logs, the values of No. 3 Common and Better lumber obtainable from the F1 logs are calculated to be US$94 for the red oak log and US$98 for the white oak log. If logs of similar scale were to grade as F2, the lumber contained within those logs would have estimated values of US$81 and US$94, respectively; for F3 logs, the respective values would be US$73 and US$78. Note this is the value of the lumber in the logs, not the value of the logs (Table 8).

*Table 5.—White oak (*Quercus alba*) Quality Index, Appalachian region.*

Scaling diam. (in.)	Quality Index		
	F1	F2	F3
8	—	—	0.63
9	—	—	0.64
10	—	—	0.66
11	—	0.89	0.68
12	—	0.91	0.71
13	0.98	0.92	0.74
14	0.98	0.94	0.76
15	1.02	0.95	0.78
16	1.01	0.97	0.80
17	1.04	0.98	0.82
18	1.05	0.99	0.83
19	1.07	1.00	0.85
20	1.08	1.01	0.87
21	1.08	1.03	—
22	1.10	1.03	—
23	1.10	—	—
24	1.12	—	—

*Table 6.—Red oak (*Quercus rubra*) Quality Index applied to the price of No.1 Common for January 2016.*[a]

Scaling diam. (in.)	Quality Index			1C lumber price (US$/MBF)	Lumber product value (US$)		
	F1	F2	F3		F1	F2	F3
8	—	—	0.79	600	—	—	472
9	—	—	0.80	600	—	—	481
10	—	—	0.82	600	—	—	489
11	—	0.91	0.83	600	—	549	499
12	—	0.94	0.85	600	—	566	508
13	1.11	0.95	0.86	600	668	571	516
14	1.13	0.97	0.87	600	675	585	524
15	1.14	0.99	0.89	600	684	595	531
16	1.16	1.00	0.90	600	694	602	538
17	1.18	1.01	—	600	706	608	—
18	1.18	1.03	—	600	710	620	—
19	1.19	1.03	—	600	714	620	—
20	1.20	1.05	—	600	717	630	—
21	1.22	1.06	—	600	730	636	—
22	1.22	1.07	—	600	730	641	—
23	1.22	1.08	—	600	730	645	—
24	1.23	—	—	600	740	—	—

[a] MBF = thousand board feet.

Summary

The Quality Index is a practical and easy-to-use tool to evaluate the lumber product value of oak logs. All the data needed to make business-specific Quality Indexes are often contained in a mill's records: log scale and quality data, lumber grade yield for each log grade, and the lumber's selling price. Should air-dry yields be desired, volume and grade change conversion factors can be applied as well. Based on final product value, and allowing for individual

*Table 7.—White oak (*Quercus alba*) Quality Index applied to the price of No.1 Common for January 2016.*[a]

Scaling diam. (in.)	Quality Index			1C lumber price (US$/MBF)	Lumber product value (US$)		
	F1	F2	F3		F1	F2	F3
8	—	—	0.63	750	—	—	472
9	—	—	0.64	750	—	—	483
10	—	—	0.66	750	—	—	496
11	—	0.89	0.68	750	—	670	513
12	—	0.91	0.71	750	—	681	533
13	0.98	0.92	0.74	750	734	691	555
14	0.98	0.94	0.76	750	735	704	570
15	1.02	0.95	0.78	750	763	714	587
16	1.01	0.97	0.80	750	757	724	601
17	1.04	0.98	0.82	750	778	735	614
18	1.05	0.99	0.83	750	786	744	626
19	1.07	1.00	0.85	750	803	752	639
20	1.08	1.01	0.87	750	811	760	651
21	1.08	1.03	—	750	807	769	—
22	1.10	1.03	—	750	826	774	—
23	1.10	—	—	750	822	—	—
24	1.12	—	—	750	840	—	—

[a] MBF = thousand board feet.

Table 8.—*Predicted lumber product value obtainable from 16-inch, 12-foot red oak (*Quercus rubra*) and white oak (*Quercus alba*) logs with 5 percent defect across three log grades.*[a]

	Log grade	Log volume (BF)	Quality Index	1C lumber price (US$/BF)	Lumber product value (US$)
Red oak	F1	135	1.16	0.60	94
	F2	135	1.00	0.60	81
	F3	135	0.90	0.60	73
White oak	F1	130	1.01	0.75	98
	F2	130	0.97	0.75	94
	F3	130	0.80	0.75	78

[a] BF = board feet.

costs, risk, and profit, one can determine a fair price to pay for a log.

Use of the Quality Index should consider several factors. Lumber price relatives are 5-year averages, indexed to No. 1 Common. As prices for various grades change over time, so may the price relatives, particularly should price spreads between grades change. This was noted here for FAS and No. 2 Common. Users should take note when newly published price trend analyses are made available, particularly regarding price movements over the most recent 5 years.

Also, the Quality Indexes are based on lumber yields obtained from bandmills in the southern Appalachian region, with all of the sawn lumber assumed as 4/4 thickness. This was done because 4/4 lumber is a common product across commercial hardwood species. It is not the industry norm, however, and future work will explore a better representation of the products obtainable from hardwood sawlogs. While it is not an exact depiction of many mills' product mixes, the Quality Index can provide a benchmark against which to gauge a mill's wood inputs and outputs.

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