VISUAL TREE GRADING SYSTEMS FOR ESTIMATING LUMBERYIELDS IN YOUNG ANDMATURESOUTHERNPINE

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ABSTRACT

New visual tree grading systems for mature southern pine ≥ 35 years old and young pine < 35 years old based on number and size ofbranches in the lower bole are described. A series of lumber grade yield studies was conducted to test the new grading rules. A total of 2 14 natural loblolly pine (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill) trees 9 to 20 inches diameter at breast height (DBH) were harvested from 37-, 39-, 42-, 56- and 73-year-old stands and 152 loblolly pine trees 9 to 18 inches DBH were harvested from 22-, 25-, 27-, 34- and 39-year-old planted stands in the Georgia Piedmont. The study trees were graded using the new rules and processed into lumber. Results show the new grading rules separated trees into three significantly different stumpage value classes based on lumber grade yield. Average stumpage value per hundred cubic feet (CCF) of sawlog was 16 percent higher for grade 1 trees compared to grade 2 trees, and that for grade 2 trees was 27 percent higher than for grade 3 trees using the rules for trees ≥ 35 years old. Average stumpage value per CCF of sawlog was 13 percent higher for grade 1 trees compared to grade 2 trees; that for grade 2 trees was 19 percent higher than for grade 3 trees using the rules for trees < 35 years old. Regression equations are presented for estimating lumber grade yield based on tree grade, dimensions, and age. The grading systems were developed with the cooperative effort of state and federal agencies and industry. [1]

Timber buyers and sellers need to know as much as possible about a southem pine tree's potential to produce lumber. The current tree grades for southern pine (8) that are based on older natural trees do not work well in younger stands, are time consuming to use, and have not been readily adopted. This paper describes two new, user-friendly, tree grading systems: one for mature pines ≥ 35 years old and one for young pines < 35 years old.

National Forests in the South are managed using the ecosystem approach to multiple use, sustained yield. Under ecosystem management, naturally regenerated southern pines grown at long rotations using single-tree or group selection can show superior wood properties. An easy-to-apply, user-friendly grading system that evaluates a pine tree's potential for producing quality products could help the Southern Region of the USDA Forest Service base timber appraisals on lumber quality potential.

Because the softwood harvest from National Forest lands has decreased considerably, while the demand for softwood lumber has increased, timber harvests from private lands in the South will increase. Private landowners are using intensive plantation management and short rotations to meet this demand and improve their economic return. A pine tree grading system developed for young southern pine could help timber buyers and sellers estimate potential lumber grade yields from young planted southem pine.

USDA Forest Service and industry researchers have been developing grading systems for southern pine logs since the 1930s (2,3,6). In 1953, the USDA Forest Service developed interim log grades for southern pine (10). After additional testing, the interim grades proposed in 1953 were adopted as the standard southern pine log grades for the USDA Forest Service (1). These USDA Forest Service log grades were based on the aggregate number and size of various knots relative to log-scaling diameter. Under these rules, the number of overgrown knots plus the sum of diameters of sound knots plus twice the sum of diameters of unsound knots were related to log-scaling diameter.

[1] Cooperators include: Federal Paper Board Co., Inc., Regelwood, N.C.; Mead Coated Board, Inc., Phenix City, AL; Trus Joist MacMillan, Colbert, Ga.; Georgia-Pacific Corp., Atlanta, Ga.; Timber Products Inspection, Conyers, Ga.; Southern Pine Inspection Bureau, Pensacola, Fla.; Georgia Forestry Commision, Macon, Ga.; Southern Region, USDA Forest Serv., Atlanta, Ga.; Cooperative Forestry, USDA Forest Serv., Atlanta, Ga.; and Forest Prod. Lab., USDA Forest Serv., Madison, Wis.

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Before the late 1960s, no grading systems were developed for southern pine trees. Trees were graded by using personal judgment or by applying log grades on a log-by-log basis to standing trees. In 1968, tree grades for southern pines were developed (8). These tree grades base tree evaluation on the number of clear faces in the butt 16-foot log. A face is one-fourth the circumference of the butt 16-foot log and extends the length of the log. Clear faces are those free from knots measuring more than 1/2 inch in diameter, overgrown knots of any size, and holes more than 1/4 inch in diameter. This tree grading system works well when applied to older mature trees. However, because the grader must examine a tree closely for overgrown knots or knots as small as 1/2 inch, the system is time consuming to use.

Under the standard lumber grading rules for southern pine (9), the size and location of knots in relation to board width are the key to grading dimension lumber. Thus, the new pine tree grading systems described in this paper are based on the presence and size of live and dead branches in the lower bole. These grading systems also use other quality indicators that are seen and evaluated easily, such as cankers, seams, sweep, and crook. The new rules do not include overgrown knots or bark distortions or branches ≤ 0.5 inches in diameter outside bark (d.o.b.), which are difficult to see on standing trees.

This paper describes the development and testing of the new grading systems. The ability of the new grading systems to separate trees into stumpage value classes was examined based on tree lumber grade yield studies. This paper also presents equations for predicting tree lumber yields by lumber grade based on tree grade, tree diameter at breast height (DBH), and height for trees ≥ 35 years old and trees < 35 years old.

TABLE 1. — Tree grading rules for southern pine ≥ 35 years old.

Characteristics[a]	Grade 1 Above average	Grade 2 Average	Grade 3 Below average
DBH	≥ 11 .o in.	≥ 9.0 in.	≥ 9.0 in.
Sawlog merchantable ht.	≥ 33 ft.	≥ 17 ft.	≥ 17 ft.
Live branches ≤ 3 in. d.o.b.[b,c]	None in butt 33 ft.	No limit in butt 33 ft.	No limit in butt 33 ft.
Dead branches ≤ 2 in. d.o.b.	4 or less in butt 33 ft.	No limit	No limit
Live or dead branches > 3 and < 4 in. d.o.b.	None in butt 33 ft.	None in trees ≤ 13.0 in. DBH; no limit in trees ≥ 13 in.	No limit
Live or dead branches ≥ 4 in. d.o.b.	None in butt 33 ft.	2 or less in each log of trees ≥ 13.0 in. DBH; none in trees < 13.0 in. DBH	No limit
Straightness	Able to buck 10 ft. min. log with ≤ 1 in. sweep per log (2 cuts)	Able to buck 8 ft. min. log with ≤ 3 in. sweep per log	Able to buck 8 ft. min. log with < 5 in. sweep per log
Seams and cankers	None in butt33 ft.	1, ≤ 3 in. wide in butt 33 ft.	> 1, or > 3 in. wide in butt 33 ft.
Decay or rot	None	None	Permitted

[a] Grade butt 33 feet or to sawlog merchantable top if less than 33 feet; sawlog merchantable height is: 1) height to local minimum d.o.b. top; or 2) where a whorl of three or more branches, whose diameters are equal to or greater than the diameter of the stem occurs within a 1 -foot section if there is not a minimum of 8 feet of clear stem above the whorl.
[b] Disregard branches 0.5 inches d.o.b.
[c] Measure branch d.o.b. across grain.

TABLE 2. — Tree grading rules for southern pine < 35 years old.

Characteristics[a]	Grade 1 Above average	Grade 2 Average	Grade 3 Below average
DBH	≥ 9.0 in.	≥ 9.0 in.	≥ 9.0 in.
Sawlog merchantable ht.	≥ 17 ft.	≥ 17 ft.	≥ 17 ft.
Live branches ≤ 3 in. d.o.b.[b,c]	None in butt 17 ft.	No limit in butt 17 ft.	No limit in butt 17 ft.
Dead branches ≤ 2 in. d.o.b.	1 or less in butt17 ft.	No limit	No limit
Live or dead branches > 3 and < 4 in. d.o.b.	None in butt 17 ft.	None in trees ≤ 13.0 in. DBH; no limit in tree ≥ 13 in.	No limit
Live or dead branches ≥ 4 in. d.o.b.	None in butt 17 ft.	2 or less in butt log of trees ≥ 13.0 in. DBH; none in trees < 13.0 in. DBH	No limit
Straightness	≤ 1 in. sweep in butt 17 ft.	≤ 3 in. in butt 17 ft.	< 5 in. log in butt 17 ft.
Seams and cankers	None in butt 33 ft.	1, ≤ 3 in. wide in butt 33 ft.	> 1, or > 3 in. wide in butt 33 ft.
Decay or rot	None	None	Permitted

[a] Grade butt 17 feet; sawlog merchantable height is: 1) height to local minimum d.o.b. top; or 2) where a whorl of three or more branches, whose diameters are equal to or greater than the diameter of the stem occurs within a l-foot section if there is not a minimum of 8 feet of clear stem above the whorl.
[b] Disregard branches 0.5 inches d.o.b.
[c] Measure branch d.o.b. across grain.

PROCEDURES

TREE GRADING RULES

After reviewing current tree grading systems and consulting with timber markers, an initial tree grading system was developed based on visual quality indicators that are easily seen and evaluated. This system placed a tree into one of three grades: grade 1, trees of high quality that will yield above-average proportions of No. 1 & Btr. lumber; grade 2, trees of average quality that will yield average proportions of No. 1 & Btr. lumber; and grade 3, trees of below-average quality that will yield below-average proportions of No. 1 & Btr. lumber. The initial grading system was based on presence and size of live and dead branches, seams, cankers, sweep, and crook in the first two 16-foot sawlogs. By placing trees into

TABLE 3. —*Average tree recovery data by 1968 tree grades for southern pine in the Georgia Piedmont ≥ 35 and < 35 years old.*

Tree grade	Study trees	DBH	Tree lumber yield[a]	Proportion of lumber in No. 1 & Btr.	No. 2	No. 3 & 4	Lumber recovery facto?	Lumber value"	Stumpage value
	(no.)	(in.)	(BF)	- - - - - - - - - - - - - -	(%)	- - - - - - - - - - - - - -		($/MBF)	($/CCF[d])
Trees ≥ 35 years									
1	48	14.1	263	49	42	9	6.5	346	141
2	43	14.2	230	33	53	14	6.8	337	140
3	123	14.2	197	17	60	23	6.3	314	116
Total	214								
Trees < 35 years									
1	0		--	--	—		--		--
2	16	13.0	217	31	57	12	6.8	339	141
3	136	12.9	155	16	65	19	6.3	317	118
Total	152								

[a] Mill tally.
[b] Board feet of lumber produced per cubic foot of sawlog.
[c] Wholesale lumber value, *Random Lengths* prices, Nov., 1995 (5).
[d] CCF = 100 cubic feet of sawlog.

potential grades without examining for overgrown knots or bark distortions, a tree can be graded without closely examining average- or below-average trees. This grading system assumed a tree with no live or dead branches in the butt 33 feet that has naturally pruned early and therefore contains a large volume of clear wood.

Based on the initial grading rules, a grade 1 tree could have no live branches in the butt 33 feet, but was allowed up to four dead branches ≤ 2 inches d.o.b., ≤ 1 inch of sweep or crook, and no cankers or seams in the butt 33 feet. A grade 2 tree could have unlimited live and dead branches, but no more than four live or dead branches ≥ 4 inches d.o.b., sweep ≤ 3 inches, and only one canker or seam ≤ 3 inches wide in the butt 33 feet. A grade 3 tree was any tree with more than two live or dead branches ≥ 4 inches d.o.b., a canker or seam > 3 inches wide, or sweep > 3 and < 5 inches in the butt 33 feet.

When applied to trees of various ages, this system based on grading the butt 33 feet would not work for young planted trees. When grading trees based on the butt 33 feet, no grade 1 loblolly or shortleaf pine trees were found in stands < 35 years old because live and dead branches were always observed below 33 feet. The initial grading system was retained for grading mature trees older than 35 years. A second grading system based on grading the first 16-foot sawlog or butt 17 feet and using the same grading principles was developed for young trees < 35 years old. **Table 1** lists the rules for grading mature southern pine ≥ 35 years old. **Table 2** lists the rules for grading young southern pine < 35 years old. Under the young tree rules, the timber grader examines only the butt 17-foot log for presence and size of branches but examines the butt 33-foot log for cankers and seams.

STUDY TREES

A series of lumber grade yield studies tested the new southern pine tree grading rules as they were applied to trees of various ages and DBH classes. A stratified random sample of three trees per tree grade per 2-inch DBH class from 9 to 20 inches DBH was harvested when present from five natural and five planted stands in the Georgia Piedmont. The average ages of the five natural loblolly pine (*Pinus taeda* L.) and shortleaf pine (*P. echinata* Mill) stands harvested were 37, 39, 42, 56, and 73 years. The five planted loblolly pine stands harvested had ages of 22, 25, 27, 34, and 39 years. The 22- and 25-year plantations were unthinned; the 27-, 34-, and 39-year plantations were thinned.

Each study tree was graded standing using the new young or mature grading rules and the 1968 Forest Service grading rules (8). The DBH and total height of each tree was also recorded and the trees were felled. Before skidding, the location and size of all visual defect indicators (bark distortions, overgrown knots, dead knots, live knots, seams, cankers, sweep, and crook) on each sawlog were recorded. The study trees produced 1,038 sawlogs 8 to 16 feet in length. Sawlogs were bucked to minimize sweep and crook and maximize log length.

SAWING AND LUMBER GRADING

Study logs were processed into lumber in two sawmills. The sawlogs harvested from the 27-, 34-, and 39-year planted stands and 37-, 42-, 56-, and 73-year natural stands were processed into lumber in a mill equipped with a band head-saw and vertical-gang resaw. Logs were sawn to produce maximum width 8/4 lumber and a minimum of 4/4 boards. As each board was sawn from a log, it was identified by tree and log source.

The sawlogs harvested from the 22- and 25-year planted stands and 39-year natural stands were processed into lumber in the second sawmill. The logs ≥ 10 inches diameter inside bark (d.i.b.) small end (scaling diameter) were sawn on a band head-saw and vertical-gang resaw and logs 10 inches d.i.b. small end were processed on a chipping head saw. The logs sawn in the second mill were processed into 4/4 boards, 8/4 dimension, 5/4 decking, 3- by 4- and 4- by 4-inch dimension, and 6- by 6-inch timbers. As each board was produced, it was identified by tree and log source.

The lumber was graded green by certified southern pine lumber graders. The graders pencil-trimmed each board and assigned the grade (9) to the board as they felt it would grade dry and surfaced. The green lumber tally was reduced 5 percent to account for downfall during drying and surfacing. The following lumber grades were identified: DSS, No.

TABLE 4. — Average **tree recovery** *data* **by new tree** *grades* **and DBH class for** *loblolly* **and** *shortleaf pine* **≥ 35** *years* **old in the Georgia Piedmont.**

DBH class	Study trees	Sawlog merchantable height	Tree lumber yield[a]	Proportion of lumber in No. 1 & Btr.	No. 2	No. 3&4	Lumber recovery factor[b]	Lumber value per MBF[c]	Stumpage value per Ton	CCF[d]	MBF Scribner
(in.)	(no.)	(ft.)	(BP)	(%)				($)			
Grade 1 trees											
12	14	52	150	49	41	10	6.8	341	42	141	336
14	9	60	246	48	47	5	6.6	349	43	144	307
16	9	62	337	56	32	12	6.9	350	45	150	285
18	9	71	517	38	50	12	7.6	354	50	165	314
20	3	67	604	62	31	6	7.5	375	54	179	291
All	44	60	314	49	41	10	7.0	349	45	151	312
Grade 2 trees											
10	27	38	71	26	61	13	5.1	329	35	116	296
12	18	45	134	28	62	10	6.5	328	38	128	273
14	25	52	206	30	58	11	6.7	336	41	137	262
16	22	53	266	26	60	14	6.9	328	40	135	222
18	11	58	350	18	57	25	7.0	332	42	138	199
20	8	50	383	13	63	24	6.6	333	40	133	179
All	111	48	203	26	60	14	6.5	331	39	130	252
Grade 3 trees											
10	10	33	58	13	43	44	5.3	261	22	72	163
12	11	42	115	19	59	22	5.9	310	32	107	243
14	13	49	167	10	59	31	6.0	297	31	102	193
16	14	48	218	24	46	30	6.1	307	33	110	178
18	7	58	285	5	60	35	6.4	297	32	107	120
20	4	49	335	6	67	27	6.3	326	40	124	145
All	59	46	177	15	54	31	5.9	298	31	102	182

[a] Mill tally.
[b] Board feet of lumber produced per cubic foot of sawlog.
[c] Wholesale lumber value, ***Random*** *Lengths* prices, Nov., 1995 (5).
[d] CCF = 100 cubic feet of wood.

1D, No. 1N, No. 2D, No. 2N, No. 3, and No. 4 for 8/4 lumber; C, D, No. 2, No. 3, and No. 4 for 4/4 boards; premium, standard, No. 3, and No. 4 for 5/4 decking; and No. 1, No. 2, No. 3, and No. 4 for 3- by 4- and 4- by 4-inch dimension, and 6- by 6-inch timbers.

Analysis

The wholesale value of lumber produced from each tree was determined based on November 1995 prices (5). The value of each board was calculated based on its size, length, and lumber grade. However, to duplicate a common practice in the Piedmont, dense and nondense lumber was not priced separately for No. 1 and No. 2 grades. After the value of each piece was determined, the lumber grades were merged into No. 1 & Btr., No. 2, and No. 3 & 4 grade groups.

Regression equations were developed using the SAS General Linear Model procedure (7) to predict tree sawlog stemwood cubic volume, total lumber volume (mill tally), green lumber cubic volume, and proportion of lumber produced that graded No. 1 & Btr., No. 2, and No. 3 & 4 for trees ≥ 35 years and trees < 35 years old. The following linear model was used to predict sawlog stemwood cubic volume and total lumber volume for each tree grade:

$$Y = a + b\,(D^2H) \qquad [1]$$

where:

Y = sawlog stemwood volume (ft.^{3})
or
Y = green lumber cubic volume (ft.^{3})
or
Y = total lumber volume, mill tally (board feet (BF))
D = tree DBH (in.)
H = tree total height (ft.) or tree sawlog merchantable height (ft.)
a, b = regression coefficients

The following linear model was developed using tree grade as a class variable to predict the proportion of total lumber volume (in BF) that graded No. 1 & Btr., No. 2, and No. 3 & 4, by tree grade:

$$Y = a + b\,(D^2H) + c\,(AGE) \qquad [2]$$

where:

Y = proportion of lumber graded No. 1 & Btr. (%)
or
Y = proportion of lumber graded No. 2 (%)
or
Y = proportion of lumber graded No. 3 & 4 (%)
AGE = tree age (yr.)
a, b, c = regression coefficients

The value of lumber, wood chips, sawdust and bark per ton, per 100 cubic feet of wood (CCF), and per 1,000 BF (MBF) Scribner was calculated for each tree to examine whether the grading systems can separate trees into stumpage value classes. Sawlog volume inside bark was calculated using Smalian's formula. Volume of butt logs was calculated based on two sections: the butt 4 feet and the remainder of the log. The volume of upper sawlogs was calculated based on one section. The weight with bark of the tree-length logs harvested from 22- and 25-year planted stands and 39-year natural

TABLE 5. — Average tree recovery data by new tree grades and DBH class for loblolly pine < 35 years old in the Georgia Piedmont.

DBH class	Study trees	Sawlog merchantable height	Tree lumber yield[a]	Proportion of lumber in			Lumber recovery factor[b]	Lumber value per MBF[c]	Stumpage value per		
				No. 1 & Btr.	No. 2	No. 3&4			Ton	CCF[d]	MBF Scribner
(in.)	(no.)	(ft.)	(BF)	(%)				($)			
Grade 1 trees											
10	10	39	82	37	50	13	6.5	335	39	131	360
12	13	48	143	26	68	6	6.7	344	42	142	305
14	11	60	257	27	60	13	1.3	330	42	142	282
16	8	65	340	27	59	14	1.2	338	44	146	278
All	42	52	196	29	60	11	6.9	337	42	140	307
Grade 2 trees											
10	12	41	77	21	73	6	5.8	342	37	126	311
12	14	43	117	12	73	15	6.1	319	35	117	235
14	15	47	177	18	66	16	6.5	321	37	124	230
16	7	51	254	12	72	16	7.0	330	41	137	226
18	3	62	328	12	67	21	6.8	320	38	128	153
All	51	46	157	16	70	14	6.3	327	37	124	246
Grade 3 trees											
10	16	37	65	13	60	27	5.3	304	28	96	238
12	16	45	124	16	58	26	6.2	303	32	108	233
14	16	45	162	7	63	30	6.4	297	32	107	180
16	8	49	212	6	65	29	6.1	296	31	104	157
18	3	66	313	5	66	29	6.1	302	32	107	160
All	59	44	140	11	61	28	6.0	301	31	104	206

[a] Mill tally.
[b] Board feet of lumber produced per cubic foot of sawlog.
[c] Wholesale lumber value, *Random Lengths* prices, Nov., 1995 (5).
[d] CCF = 100 cubic feet of wood.

stands was recorded in the field. The weight of logs from the remaining stands was calculated based on log volume, assuming 67 pounds of wood and bark per cubic foot of wood. The value of bark residue, sawdust, and wood chips per tree-length log to a 5.5-inch d.i.b. top or the sawlog merchantable top was calculated using the following assumptions:

Bark residue = 10 percent of sawlog weight with bark (4);

Value of bark residue = $1 5/ton;

Sawdust from band and vertical-gang saw = 10% of sawlog wood volume (4);

Sawdust from chipping saw = 8% of sawlog wood volume;

Value of sawdust = $1 5/ton;

Value of clean wood chips = $28/ton.

The weight of wood chips per sawlog was calculated using the following formula:

$$Y = (LOGVOL - LUMGNVOL - SAWDUSTV) \times (LOGWDCF) \quad [3]$$

where:

Y = green weight of wood chips from a log (lb.)
LOGVOL = log wood volume ($ft.^3$)
LUMGNVOL = volume of green lumber produced from a log ($ft.^3$)
SAWDUSTV = volume of sawdust ($ft.^3$)
LOG WDCF = log wood weight per cubic foot (pcf)

The weight of sawdust per sawlog was calculated using the following formula:

$$Y = (SAWDUSTV) \times (LOG WDCF) \quad [4]$$

where:

Y = green weight of sawdust from a log (lb.)

A cost of $100 per MBF mill tally to saw, trim, dry and surface the lumber and an internal rate of return on capital of 18 percent before tax were assumed. Cut-and-haul costs of $14 per ton were also assumed. Stumpage value per tree was calculated by subtracting mill manufacturing costs, cut-and-haul costs, and cost of capital from the value of all products (lumber, chips, sawdust, and bark) produced from a tree.

Results and discussion

The 366 study trees (214 ≥ 35 years and 152 < 35 years) produced 7 1,294 BF of lumber: 7 percent was 4/4 boards; 2 percent was 5/4 decking; 8 1 percent was 814 lumber; and 10 percent was 3- by 4-inch or 4- by 4-inch dimension or 6- by 6-inch timbers. The 8/4 lumber sawn from the trees ≥ 35 years yielded 16 percent DSS, 17 percent No. 1, 50 percent No. 2, 13 percent No. 3, and 4 percent No. 4 lumber. The 8/4 lumber sawn from the trees < 35 years yielded 3 percent DSS, 16 percent No. 1, 62 percent No. 2, 15 percent No. 3 and 4 percent No. 4. When the lumber for all trees was merged, 23 percent was No. 1 and Btr., 59 percent No. 2, and 18 percent No. 3 and 4 lumber. The average lumber recovery factor (LRF)[2] for all study trees was 6.4.

The 1968 grading rules (8) did a good job identifying the trees ≥ 35 years old that yielded an above-average, average, and below-average proportion of No. 1 and Btr. lumber based on tree grade (**Table 3**). These rules also did a good job identifying the trees ≥ 35 years that yielded an above-average proportion of No. 3 and 4 lumber. However, under the 1968 rules, 58 percent of the study trees

[2] LRF is the BF of lumber produced per cubic foot of sawlog.

TABLE 6. — Regression coefficients for loblolly and shortleaf pine ≥ 35 years old in the Georgia Piedmont based on DBH, total height, and tree age.

Dependent variable	Model[a]	Repression coefficients A	B	C	Standard error of estimate (Sy·x)	Coefficient of determination (r^2)	Coefficient of variation
Grade 1 trees							
Sawlog stem volume (ft.‘)	1	-1.8674 (.1190)[b]	0.00216 (.0001)		4.1	.95	12.7
Total lumber volume (BF)[c]	1	-42.419 (.0859)	0.01683 (.0001)		38.3	.92	17.9
Green lumber volume (ft.‘)	1	-2.96124 (.3235)	0.00122 (.0001)		2.8	.92	18.0
Proportion of No. 1 & Btr. lumber (%)	2	0.36133 (.0137)	-0.00000239 (.4909)	0.00325 (.0702)	.19	.33	69.9
Proportion of No. 2 lumber (%)	2	0.51919 (.5955)	0.00000198 (.5635)	-0.00268 (.1278)	.19	.21	34.0
Proportion of No. 3 & 4 lumber (%)	2	0.11948 (.0121)	0.00000042 (.8765)	-0.000562 (.6849)	.15	.31	78.8
Grade 2 trees							
Sawlog stem volume ($ft.^3$)	1	-0.64701 (.2066)	0.00191 (.0001)		4.1	.95	12.7
Total lumber volume (BF)	1	-21.481 (.4232)	0.01391 (.0001)		38.3	.92	17.9
Green lumber volume (ft.‘)	1	-1.54261 (.0124)	0.00102 (.0001)		2.8	.92	18.0
Proportion of No. 1 & Btr. lumber (%)	2	0.13968 (.3637)	-0.00000355 (.0931)	0.00335 (.0033)	.19	.33	69.9
Proportion of No. 2 lumber (%)	2	0.77302 (.0817)	0.00000058 (.9777)	-0.00340 (.0025)	.19	.21	34.0
Proportion of No. 3 & 4 lumber (%)	2	0.0873 (.0008)	0.0000035 (.0334)	0.000045 (.9587)	.15	.31	78.8
Grade 3 trees							
Sawlog stem volume (ft.‘)	1	1.2233 (.3250)	0.00177 (.0001)		4.1	.95	12.7
Total lumber volume (BF)	1	-10.31882 (.3781)	0.01183 (.0001)		38.3	.92	17.9
Green lumber volume (ft.‘)	1	-0.85002 (.4990)	0.00088 (.0001)		2.8	.92	18.0
Proportion of No. 1 & Btr. lumber (%)	2	0.04117 (.6362)	-0.00000386 (.2801)	0.00361 (.0566)	.19	.33	69.9
Proportion of No. 2 lumber (%)	2	0.58662 (.0001)	0.00000985 (.0054)	-0.00473 (.0115)	.19	.21	34.0
Proportion of No. 3 & 4 lumber (%)	2	0.3722 1 (.0001)	-0.00000599 (.03 10)	0.00112 (.4444)	.15	.31	78.8

[a] Model 1, $Y = a + b\,(D^2TH)$
where:
D = tree DBH (in.)
TH = tree total height (ft.)
a,b = regression coefficients

Model 2, $Y = a + b\,(D^2TH) + c\,(AGE)$
where:
AGE= (yr.)
a,b,c = regression coefficients

[b] The t-test for p-values for regression coefficients
[c] Mill tally (BF).

≥ 35 years old were grade 3 because the 1968 rules consider overgrown knots as a defect within a face in the butt log. The average value of lumber produced by mature grade 1 trees was only 3 percent higher than that produced by grade 2 trees. Grade 2 trees, in turn, produced an average value of lumber only 7 percent higher than that produced by grade 3 trees. Because the difference in lumber value between grade 1 and grade 2 trees was so small and the LRF for grade 1 trees was below that for grade 2 trees, the stumpage value per CCF was not significant between grade 1 and grade 2 trees ≥ 35 years old **(Table 3).** The lower LRF of grade 1 trees occurred because some grade 1 trees had cankers or sweep in the second log. These defects, which reduce lumber yield, are not noted in the second log under the 1968 rules.

Under the 1968 rules, no trees < 35 years were grade 1, only 10 percent were grade 2, and 90 percent were grade 3

TABLE 7. — *Regression coefficients for loblolly pine < 35 years old in the Georgia Piedmont based on DBH, total height, and tree age.*

Dependent variable	Model[a]	Regression coefficients A	B	C	Standard error of estimate (Sy·x)	Coefficient of determination (r^2)	Coefficient of variation
Grade 1 trees							
Sawlog stem volume (ft.³)	1	*-4.38386*	0.00233		3.0	.94	12.9
		(.1276)[b]	(.0001)				
Total lumber volume (BF)[c]		*-45.8259*	0.01748		24.5	.93	16.1
		(.0581)	(.0001)				
Green lumber volume (ft.³)		*-3.36923*	0.00129		1.8	.93	16.7
		(.0059)	(.0001)				
Proportion of No. 1 & Btr. lumber (%)		*0.39698*	-0.000005 12	-0.00110	.16	.20	90.9
		(.3059)	(.3050)	(.7962)			
Proportion of No. 2 lumber (%)	2	*0.53544*	0.00000282	0.000714	.19	.15	29.4
		(.2386)	(.6328)	(.8867)			
Proportion of No. 3 & 4 lumber (%)		*0.06758*	0.0000023 1	0.000382	.15	.29	83.0
		(.6965)	(.6258)	(.9245)			
Grade 2 trees							
Sawlog stem volume (ft.³)		*-1.68183*	0.00201		3.0	.94	12.9
		(.8029)	(.0001)				
Total lumber volume (BF)	1	*-26.6605*	0.01432		24.5	.93	16.1
		(.6391)	(.0001)				
Green lumber volume (ft.³)	1	-1.77842	0.00104		1.8	.93	16.1
		(.0507)	(.0001)				
Proportion of No. 1 & Btr. lumber (%)		0.19769	0.000000046	-0.00167	.16	.20	90.9
		(.8105)	(.9918)	(.7078)			
Proportion of No. 2 lumber (%)	2	0.80608	-0.00000646	-0.00019	.19	.15	29.4
		(.7850)	(.2230)	(.9709)			
Proportion of No. 3 & 4 lumber (%)		-0.00377	0.00000641	0.00187	.15	.29	83.2
		(.9306)	(.1323)	(.6595)			
Grade 3 trees							
Sawlog stem volume (ft.³)		-2.00242	0.00200		3.0	.94	12.9
		(.0303)	(.0001)				
Total lumber volume (BF)		-21.7801	0.01297		24.5	.93	16.1
		(.0038)	(.0001)				
Green lumber volume (ft.³)	1	-1.53372	0.00094		1.8	.93	16.1
		(.7506)	(.0001)				
Proportion of No. 1 & Btr. lumber (%)		0.23237	-0.00000792	-0.000568	.16	.20	90.9
		(.0205)	(.0888)	(.8870)			
Proportion of No. 2 lumber (%)	2	0.75945	0.0000137	-0.01094	.19	.15	29.4
		(.0001)	(.0132)	(.0215)			
Proportion of No. 3 & 4 lumber (%)		0.00818	-0.00000579	0.01151	.15	.29	83.0
		(.9309)	(.1889)	(.0028)			

[a] Model 1, $Y = a + b\,(D^2TH)$
where:
D = tree DBH (in.)
TH = tree total height (ft.)
a,b = regression coefficients

Model 2, $Y = a + b\,(D^2TH) + c\,(AGE)$
where:
AGE= (yr.)
a,b,c = regression coefficients

[b] The t-test for p-values for regression coefficients.
[c] Mill tally (BF).

(Table 3). The 1968 rules did not separate the young trees well because the bark of young trees has num[illegible] [illegible]vn knots in the butt log, therefore, almost all young-planted trees were grade 3.

The new rules for grading trees ≥ 35 years old did a good job separating the study trees based on lumber grade yield **(Table 4). The** proportion of lumber produced in each lumber grade did not change considerably with increasing DBH class for grade 1, 2, or 3 trees. The LRF generally increased with increasing DBH class for all three tree grades **(Table 4).** The average LRF was highest for grade 1 trees and lowest for grade 3 trees.

The average value of lumber per MBF mill tally was 5 percent higher for grade 1 trees compared to grade 2 trees and 11 percent higher for grade 2 trees compared to grade 3 trees **(Table 4).** The value of lumber per MBF increased with increasing DBH class for grade 1 trees but did not change consistently with increasing DBH class for grade 2 or grade 3 trees.

The new tree grading system for southem pine ≥ 35 years old did a good job separating trees into stumpage value classes **(Table 4).** Average stumpage value per ton of sawlog was 16 percent higher for grade 1 trees compared to grade 2 trees, and was 27 percent higher for grade 2 trees compared to grade 3 trees. Stumpage values differed significantly ($p >$ .OOOl) among the three tree grades because the higher quality trees produced higher value lumber and a higher yield of lumber per volume of sawlog than the lower quality trees.

The new rules for grading trees < 35 years did a good job separating trees based on lumber grade yield **(Table 5).** The proportion of No. 2 lumber produced from the young planted trees did not vary consistently with tree grade. The proportion of No. 3 & 4 lumber produced increased with decreasing tree quality. The average LRF for the young trees was highest for grade 1 trees and lowest for grade 3 trees. The average value of lumber per MBF mill tally for the young planted trees was only 3 percent higher for grade 1 trees compared to grade 2 trees and 9 percent higher for grade 2 trees compared to grade 3 trees **(Table 5).**

The new tree grading system for pine < 35 years old separated the study trees into three significantly different ($p >$,001) stumpage value classes. The average stumpage value per CCF of sawlog was 13 percent higher for grade 1 trees compared to grade 2 trees, and was 19 percent higher for grade 2 trees compared to grade 3 trees. Stumpage value differed significantly with tree grade because higher grade trees had a higher LRF and produced higher value lumber.

Regression equations predict tree sawlog stemwood volume, total lumber volume mill tally (BF), lumber green volume (ft.‘), and proportion of lumber graded **No.** 1 & Btr., No. 2, and No. 3 & 4 by tree grade for loblolly and shortleaf pine ≥ 35 years old **(Table 6)** and planted loblolly pine < 35 years old **(Table 7).** A set of prediction equations was developed for trees ≥ 35 years old and trees < 35 years old using the following as independent variables: tree DBH, total height (TH), and age; or DBH, sawlog merchantable height (MH), and age. The models and coeffkients based on DBH and total height are presented in **Tables 6** and 7 and the models and coefficients based on DBH and sawlog merchantable height are available from the authors. Sawlog stem volume and total lumber volume by tree grade are predicted using DBH and TH or DBH and MH as independent variables. When DBH and height were used as independent variables (Model [**1**]), age was not a significant variable for estimating stemwood volume or total lumber volume ($p = 0.1355$ for trees ≥ 35 years old; $p = 0.6153$ for trees < 35 years old). However, when predicting the proportion of lumber produced by lumber grade using Model [**2**], age was a significant variable for some lumber grades (**Tables 6** and 7).

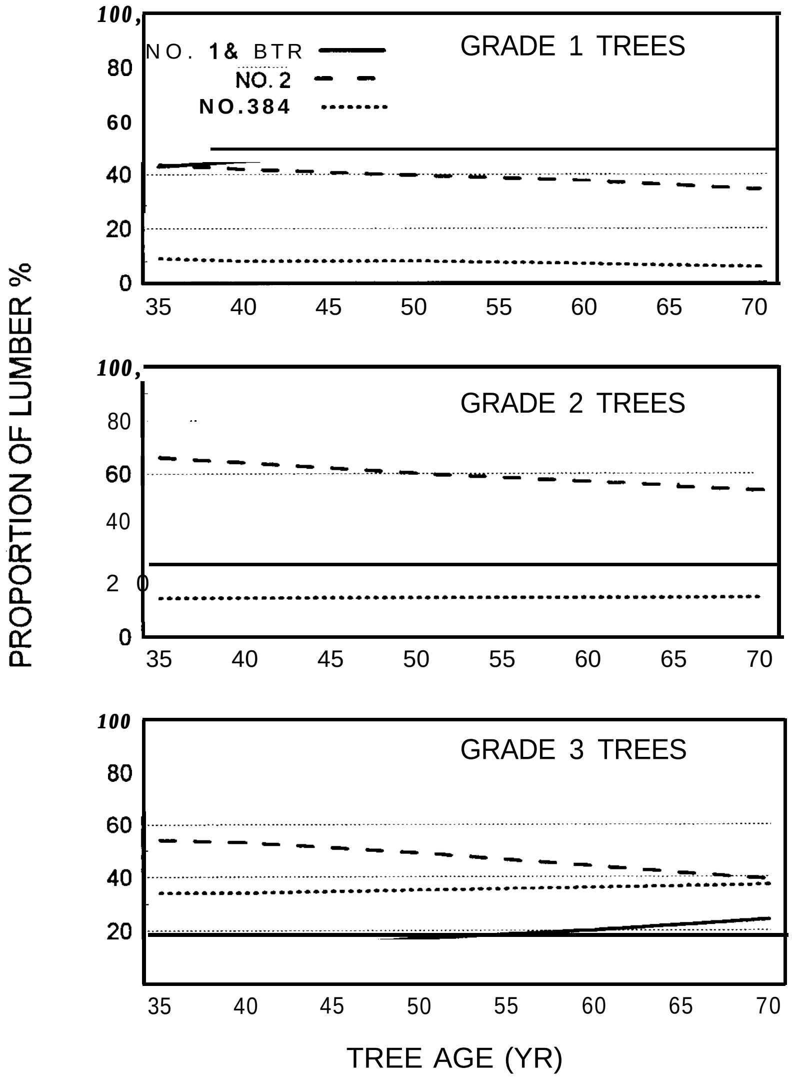

Figure 1. — Effect of increasing tree age on estimated proportion of No. 1 & Btr., No. 2, and No. 3 & 4 lumber produced from a 14-inch-DBH, 70-foot, 35-year-old southern pine in the Georgia Piedmont by tree grade.

Using the coefficients from **Tables 6** and 7 and Model [**2**], **Figures 1** and 2 show how the proportion of lumber by lumber grade changes with age in a 14-inch-DBH, 70-foot-tall, 35-year-old southern pine and 20-year-planted loblolly pine, respectively. The proportion of lumber graded No. 1 & Btr. increased 12 percent, the proportion graded No. 2 decreased 9 percent, and the proportion graded No. 3 & 4 decreased 3 percent when tree age increased from 35 to 70 years for grade 1 trees **(Fig. 1).** For grade 2 trees, the proportion of lumber graded No. 1 & Btr. increased 12 percent, the proportion graded No. 2 decreased 12 percent, and the proportion graded No. 3 & 4 did not change with increasing tree

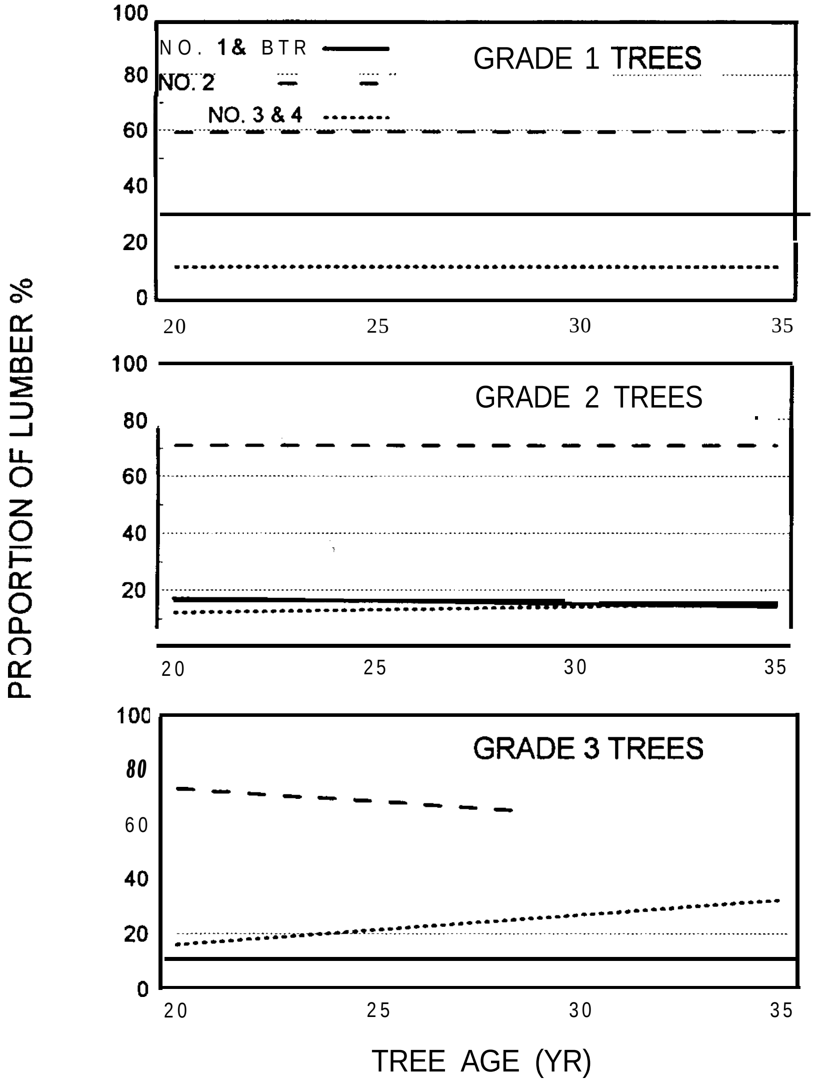

Figure 2. — Effect of tree age on estimated proportion of No. 1 & Btr., No. 2, and No. 3 & 4 lumber produced from a 14-inch-DBH, 70-foot, 20-year-old loblolly pine in the Georgia Piedmont by tree grade.

age. For grade 3 trees, the proportion of No. 1 & Btr. increased 13 percent, the proportion of No. 2 decreased 17 percent, and the proportion of No. 3 & 4 increased 4 percent with increasing tree age. The proportion of No. 1 & Btr., No. 2, or No. 3 & 4 lumber did not vary considerably with tree age for grade 1 or 2 young trees **(Fig. 2).** However, in grade 3 young trees, the proportion of No. 2 lumber decreased 17 percent and the proportion of No. 3 & 4 lumber increased 17 percent with increasing tree age **(Fig. 2** and **Table 7).** This change in proportion, caused by the increase in canker size with tree age in grade 3 trees, illustrates why trees with cankers should be harvested during the first thinning.

Conclusions

The new tree grading rules for southern pine ≥ 35 years old and those for pine < 35 years old easily and effectively separate trees into three tree value classes based on visual quality indicators. The new grading systems, based on presence and size of live and dead branches, identify a tree's potential to produce a high proportion of No. 1& Btr. lumber or a high proportion of low value No. 3 & 4 lumber. When grading trees ≥ 35 years, trees must be graded based on size and number of branches in the butt 33 feet. When grading trees < 35 years, the trees must be graded based on branches in the butt 17 feet. However, when evaluating a tree for cankers or seams, the timber marker must examine the butt 33 feet of the bole in both young and mature trees.

The new tree grading rules for mature and young pine separated study trees into three significantly different stumpage value classes. The average stumpage value per CCF of sawlog was higher for grade 1 trees than for grade 2 trees, and that for grade 2 trees was higher than for grade 3 trees when using the new grading rules for both mature pine and young planted loblolly pine.

Regression equations were developed to estimate tree sawlog stemwood volume, total lumber volume, and proportion of lumber graded No. 1 & Btr., No. 2, or No. 3 & 4 based on tree grade, tree dimensions, and age. When estimating stemwood and lumber volume, tree grade, DBH, and height were the significant independent variables. However, when estimating proportion of lumber by lumber grade, tree age was a significant variable for estimating some lumber grades.

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