ARE OBSERVED TRENDS IN HARDWOOD TREE GRADE DUE TO RESOURCE CHANGES OR DATA ANOMALIES?

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Abstract—Preliminary analyses show decreasing amounts of higher grade tree volumes in the east-central United States, suggesting degradation in the hardwood saw-log resource. While there were indications of trend, the quality and repeatability of the tree grade data themselves has been questioned, questions that Quality Control data could not answer. While the quantification of tree grade on Forest Inventory and Analysis plots has potential value, subjectivity and inconsistency limits the variable's usefulness.

The temperate broadleaf and mixed broadleaf/conifer forests of the east-central United States are an important ecological and economic resource. Preliminary analyses and anecdotal evidence have shown decreasing prevalence of higher quality trees as defined by their tree grade, suggesting degradation in the hardwood saw-log resource. If true, such trends could indicate forest management shortcomings or large-scale demographic changes. The indepth analysis of volume across tree grades required to assess this situation, however, also requires careful scrutiny and understanding of the methods used to grade a tree. Tree grading is one of the most subjective evaluations made on a Forest Inventory and Analysis (FIA) plot and requires that field crews have considerable training and experience before accuracy and repeatability is achieved.

We investigated trends in the proportion of volume in each tree grade from 2001 to 2013 in Kentucky (KY) and Tennessee (TN) for a selection of high-value timber species. Additionally, we examined the Quality Assurance/Quality Control (QA/QC) data collected during this period.

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METHODS

Forest Inventory and Tree Grading Procedures

Volume of the saw-log portion (FIA variable VOLCSNET) (Woudenberg and others 2010, Oswalt and Conner 2011) of the tree is estimated for sawtimber-sized trees that meet certain minimum requirements. Trees that meet sawtimber size requirements are graded for tree quality. Tree grades 1 through 4 are in descending order of quality. A tree grade 1 tree is larger, with a minimum diameter at breast height (d.b.h.) of 16 inches, and has more clear wood free of defects within the saw log. Grades 2, 3, and 4 are of smaller d.b.h. or have less clear wood in the saw log. Tree grade 5 is different. These trees do not meet the requirements of tree grades 1-4 but have a saw log located somewhere in the tree other than the butt portion, e.g., upper stem or branch, or have at least two noncontiguous 8-foot long logs.

Data Queried from the FIA Database

We queried the FIA Database (FIADB) to extract data on selected sawtimber-size hardwood trees measured in KY and TN from 2001 to 2013. Both States are on 5-year remeasurement cycles. The response variable chosen was the proportion volume in each tree grade on each plot. Values of zero were generated so that each tree grade had a value on every plot. Comparisons were made among the proportions of volume in each tree grade to evaluate whether there were changes over time. Several hardwood species were chosen for

inclusion in the query based on expert knowledge of the resource and demand by forest industry. We also queried the database for older data from the periodic forest inventories by tree grade, filtering on the same hardwood species. Percentages of volume by tree grade were calculated by dividing the volume in each tree grade by the total volume for that inventory. Blind and cold-check QA/QC data for tree grade were extracted for these same States. Field data collection in both KY and TN was done by Forest Service, U.S. Department of Agriculture personnel during the periodic inventories. However, with the implementation of annualized inventories starting in 2001, State natural resource agency personnel have collected the data.

Statistical Methods

We tested for differences between individual years of data, not between the averages of multiple years. For example, we compared 2001 to 2002, 2002 to 2003, etc., but not the average for the cycle ending 2004 to the average for the cycle ending 2009. This was done for two reasons. First, we are interested in differences in tree data from specific measurement years. Second, we treat individual years of data as independent from one another except when comparing one year to its remeasured value five years later, e.g., comparing 2002 to 2007. Comparing averages for a full cycle of panels or remeasured years would violate the assumption of sample independence, and other methods must then be used to assess statistical differences (Westfall and others 2013). Estimates and standard errors were computed for each tree grade and year using a ratio of means estimator, then compared using the overlapping confidence interval method.

The accuracy and repeatability of tree grade by the field crew and QA/QC foresters were assessed using matrices of frequency distributions. It was assumed that the more experienced, highly trained QA/QC foresters provided a truer assessment of tree grade against which the field crew calls were judged. While variation around the relatively subjective tree grade assessment is to be expected, we focused our examination on whether field crews showed any consistent bias toward over- or under-estimating the tree grade.

RESULTS

The numbers of trees extracted from FIADB ranged from a high of 591 trees in TN in 2013 to a low of 353 trees in KY in 2002. In an average year for TN and KY combined, there were 40.1 grade 1, 107.8 grade 2, 178.7 grade 3, 99.7 grade 4 and 23.7 grade 5 trees.

In KY, the mean plot volume percentage in tree grade 1 reached a high value in 2002 then decreased significantly to 2004 (Fig. 1). In TN, mean tree-grade-1 plot volume percentage was stable until 2005, when it decreased significantly from 2006 and then began increasing until 2013 (Fig. 2). For tree grade 2, the percentages in KY held relatively stable with some fluctuations across the study period. In TN, however, tree grade 2 decreased from 2005 to 2006, recovered, and then decreased again. Volume percentages in tree grades 3 and 5 remained relatively stable in both States, while tree grade 4 percentages behaved erratically.

Periodic inventory results for KY show that percentages of volume remained relatively stable except for tree grade 1. Tree grade 1 in KY was 13.4 percent of the volume in 1988, while in 2004 (moving average of annualized data from 2001 to 2004) it was 24.2 percent (Table 1). Tree grade 1 also showed volatility in TN (Table 1). Tree grade 4 in TN displayed a decrease from 1989 to 1999, low values through 2004, then an increase that continued through 2009 and 2012. In KY, tree grade 2 values from 1998 were comparable to those found in the KY 2004 annualized moving average.

QA/QC Results

Of the field plots that were revisited by QA/QC foresters to conduct blind checks on field crew measurements, a total of 440 trees were assessed during both visits in Kentucky from 2001 to 2013 (Table 2). On average across all years, there was a 66.0-percent agreement on the tree's grade. In Tennessee there were 224 trees graded with 64.6-percent agreement. Notable in the QA/QC data were the small number of trees that were blind-checked in some years and how variable the numbers of checked trees were from year to year. Extremes ranged from only 7 trees blind-checked in TN in 2002 and 2012 to 104 trees in KY in 2005.

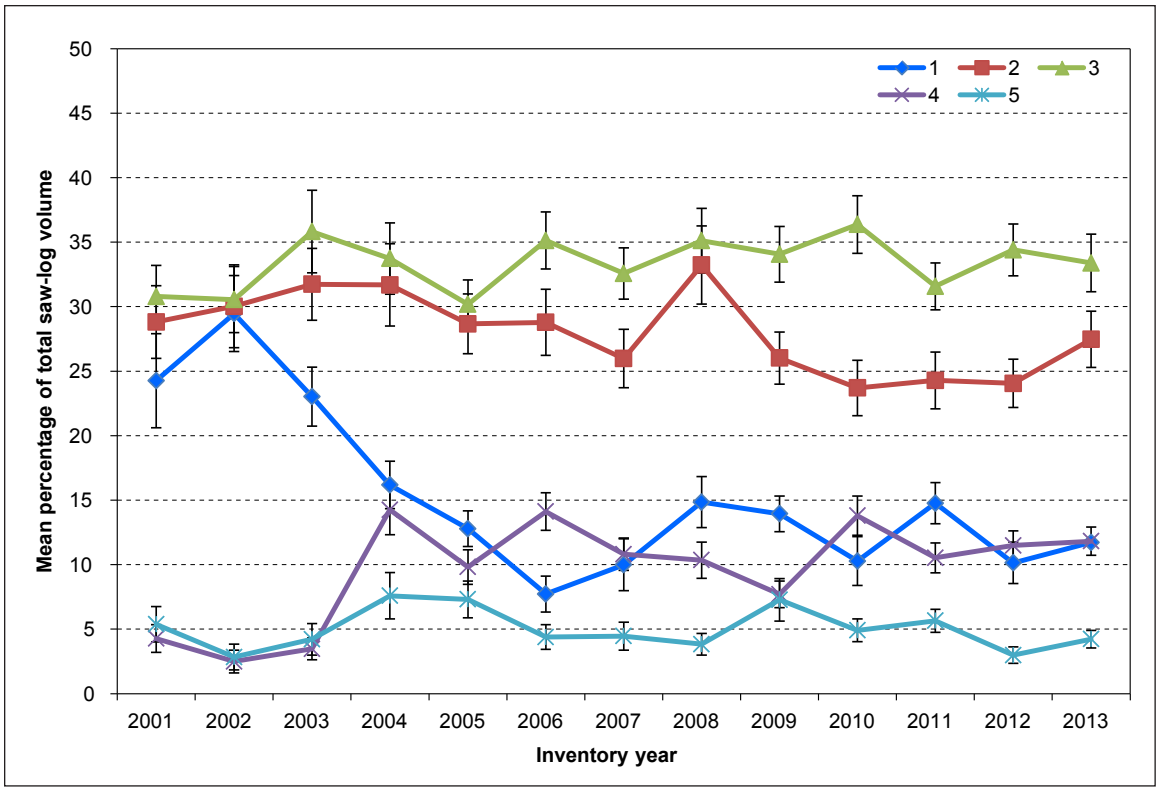

Figure 1—Mean percentage of plot net saw-log volume per plot by tree grade with standard errors of the mean, Kentucky, 2001-2013.

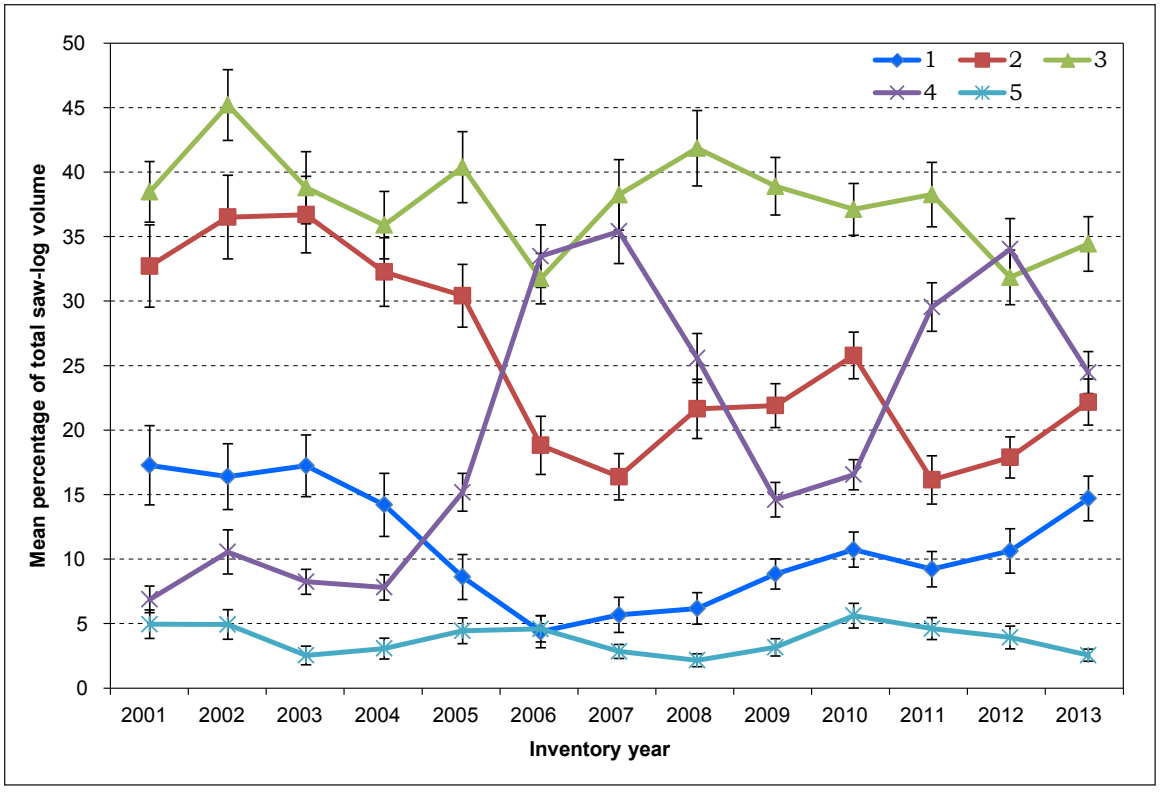

Figure 2—Mean percentage of plot net saw-log volume per plot by tree grade with standard errors of the mean, Tennessee, 2001-2013.

Table 1—Percentage of net volume (cubic feet) of saw-log portion of sawtimber trees on timberland by hardwood tree grade for Kentucky and Tennessee for periodic inventories (KY 1988, TN 1989, TN 1999) and annualized moving averages (2004, 2009, 2012).

	Inventory year—Kentucky				Inventory year—Tennessee				
Grade	1988	2004	2009	2012	1989	1999	2004	2009	2012
1	13.4	24.2	13.0	13.8	8.6	22.7	16.2	6.9	9.5
2	30.4	31.5	31.2	29.3	20.6	29.7	33.5	23.3	21.7
3	37.3	33.2	37.9	39.0	46.6	35.6	38.2	40.2	39.0
4	11.4	5.6	11.5	12.2	18.9	7.2	8.0	25.6	25.2
5	7.4	5.4	6.4	5.7	5.4	4.7	4.1	4.0	4.6

Table 2—Numbers of trees graded on plots visited by both field crew and Quality Assurance/Quality Control foresters with numbers and percentage of tree grade agreements for Kentucky and Tennessee, 2002 to 2013.

	Kentucky				Tennessee			
Measurement year	Total trees graded by either field or QA/QC	Total trees with both field and QA/QC grades	Number with matching grades	Percent trees with matching grades	Total trees graded by either field or QA/QC	Total trees with both field and QA/QC grades	Number with matching grades	Percent trees with matching grades
2002	9	8	7	87.5	7	7	4	57.1
2003	36	33	23	69.7	9	8	4	50.0
2004	39	38	26	68.4	11	9	5	55.6
2005	104	98	61	62.2	68	61	35	57.4
2006	34	33	18	54.5	28	25	20	80.0
2007	19	19	8	42.1	13	11	4	36.4
2008	15	15	12	80.0	0	0	-	-
2009	11	11	7	63.6	28	28	24	85.7
2010	54	54	33	61.1	10	10	7	70.0
2011	24	24	17	70.8	10	10	8	80.0
2012	25	25	17	68.0	7	7	4	57.1
2013	70	70	45	64.3	33	33	27	81.8
Total	440	428	274	66.0	224	209	142	64.6

Frequency distributions of tree grade agreement and disagreement were examined. All possible combinations of field crew and QA/QC tree grade calls were put in matrices by State and year. Based on a visual examination of these sparse data, there may have been a slight trend toward field crews calling tree grades higher than QA/QC foresters when they were in disagreement. Overall, however, this possible trend was weak and based on too few instances to judge adequately.

DISCUSSION

While there were indications of trend over time from 2001 to 2013, the quality and repeatability of the tree grade data themselves has been called into question. Zarnoch and Turner (2005) questioned the validity of the 2001 tree grade data from KY based on values observed in the preceding periodic forest inventories. They cited amounts of tree grade 1 volume that were twice as great in 2001 as they were in the periodic inventory of 1988 (Zarnoch and Turner 2005). They postulated that changes in the training of KY field crews on tree grading resulted in assigning too many trees to tree grade 1 when compared to past inventories. However, there has been no documentation or studies to indicate the possibility of a similar bias in the TN data, where a decrease in tree grade 1 volume was also observed. The TN field crews operated and were trained independently of the KY field crews.

While we can postulate management or biological reasons for steady decreases or increases in certain grades of volume over time, it is harder to do so for the seemingly abrupt changes seen in tree grade 4. There, we must consider that observed trends might be due to training inconsistencies or field crew turnover. The QA/QC data did not provide satisfactory answers to these questions, primarily due to the paucity of data for specific grades during any given year. Perhaps with a larger QA/QC sample, patterns would have emerged. While the quantification of tree grade on FIA plots has potential value, the subjectivity and inconsistency of the variable limits its usefulness in TN and KY.

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