Diversity of the Eastern Hardwood Resource and How This Diversity Influences Timber Utilization

William Luppold
Scott Pugh

Abstract

The eastern hardwood resource is often associated with high-quality sawtimber used in the production of grade products, but this segment of the resource accounts for approximately 20 percent of the cubic volume of all live trees. By contrast, 17 percent of the hardwood timber volume is classified as cull trees, and an additional 14 percent is low-quality sawlog-size growing stock. The remainder of the resource is midgrade sawtimber-size growing stock and smaller-diameter poletimber. This article first examines definitions and terms useful in understanding the structural component of the hardwood resource and then examines this resource and important hardwood roundwood markets on a regional basis. The quality of hardwood timber varies considerably by region. The East Central and Mid-Atlantic contain lower cull volume on a percentage basis in part because of large quantities of yellow-poplar. The Northern and East Central regions contain the greatest volume of high-quality sawtimber and produce relatively large quantities of hardwood lumber. The Southern region contains a large volume of hardwood timber, but much of this timber base is low quality or cull; still, this resource is highly utilized by a variety of industries, including grade hardwood sawmills. The West Central region can also be characterized as low quality but contains a third of the black walnut sawtimber in the United States. The Plains region contains the lowest volume of hardwood timber, and the widespread geographic distribution of this timber outside of Minnesota may make use of this material for most areas of this region uneconomical.

Since the early 1950s, the hardwood forests of the eastern United States have been expanding (Luppold and Miller 2014), and sawtimber volume on timberland was approaching 1.3 trillion board feet in 2013 (US Department of Agriculture Forest Service [USDA FS 2015]). Sawtimber volume has been an important measure of the timber resource because it is associated with the volume of trees traditionally used in the production of hardwood lumber and veneer. However, sawtimber is only 58 percent of the volume of live trees, and what can be termed as high-quality sawtimber (tree grades 1 and 2) is approximately 20 percent of total volume.[1] By contrast, 17 percent of the volume of the eastern timber base is classified as cull trees, and an additional 14 percent is low-quality sawlog-size growing stock (tree grades 4 and 5). This leads to three questions: (1) In addition to high-quality sawtimber, what are the other structural components of the hardwood resource? (2) What are the regional variations in these components? (3) What are the current and potential markets for these components?

In this article, we will first define the terms and concepts that can be used to evaluate the structural components of the hardwood resource using tools made available by the US Forest Service's Forest Inventory and Analysis (FIA) program (http://www.fia.fs.fed.us). We will then use this information to examine the hardwood resource on a regional

[1] The butt logs from hardwood trees graded 1 and 2 tend to be manufactured into grade lumber (lumber primarily used for appearance purposes) and numerous veneer products. The butt logs from trees graded 3 can go to a variety markets, depending on species and current lumber prices. Butt logs of lower-quality trees (tree grades 4 and 5) have normally been used in the production of industrial products, oriented strand board, or pulpwood. Additionally, tree grading can be a subjective process and until recently was more restrictive in the Southern region in the assignment of the hardwood tree grade 1 category. One of the benefits of combining trade grades 1 and 2 is reducing the impact of these past regional differences.

The authors are, respectively, Economist, USDA Forest Service, Northern Research Sta., Princeton, West Virginia (wluppold@fs.fed.us [corresponding author]); and Forester, USDA Forest Service, Northern Research Sta., Houghton, Michigan (spugh@fs.fed.us). This paper was received for publication in June 2014. Article no. 14-00054.

Forest Prod. J. 66(1/2):58–65.
doi:10.13073/FPJ-D-14-00054

level. The terms and concepts concerning forest inventory have been shortened to improve readability. Additional information regarding the development, access, and interpretation of inventory data is presented in the Appendix, but for precise definitions, the reader should consult Woudenberg et al. (2010) and USDA FS (2013a, 2013b).

Important Inventory Terms and Concepts

Inventory information is available for forest- and timberland land classifications. Forestland is a more inclusive measure and represents land with at least 10 percent cover by live trees of any size or land formerly having such cover and not currently developed for nonforest use. Timberland is forestland that is producing or is potentially capable of producing at least 20 ft^3/acre/yr of wood volume and excludes forestland withdrawn by laws prohibiting management for the production of wood products. Normally, timberland is the land type examined when evaluating timber markets and wood utilization issues.

The most comprehensive measurement of live timber volume is cubic volume of trees at least 5 inches in diameter at breast height (DBH). Cubic volume of all live trees is further subdivided into tree classes: growing stock, rough cull, and rotten cull. Rough cull trees represent 16 percent of all live tree volume of the eastern hardwood timber base, and rotten cull volume is 1 percent of total volume. As a comparison, the volume of eastern softwood cull trees is 5 percent (USDA FS 2015).

Growing stock are live trees of commercial species that meet minimum merchantability standards. Growing stock trees 11 inches DBH and larger are classified as sawtimber. Sawtimber trees must contain at least one 12-foot merchantable log or two noncontiguous 8-foot merchantable logs. Hardwood growing stock trees 5 to 10.9 inches DBH are classified as poletimber. Cull trees can be termed poletimber or sawtimber size, but when poletimber or sawtimber is not modified by the term size, it is in reference to growing stock. In the 2013 survey, 21 percent of the volume of poletimber-size and 13 percent of the volume of sawtimber-size trees in the eastern United States were cull (USDA FS 2015). However, these proportions vary widely by region and species group.

Tree grade is indicative of timber quality and is based on the sawlog portion of sawtimber trees. The sawlog portion of a sawtimber tree is the volume contained from 1 foot aboveground to a 9-inch top or to where the central stem breaks into limbs. The three most important characteristics that define tree grades 1, 2, 3, and 4 are the existence of a 16-foot or longer butt log, DBH requirements, and the clarity on the third-best log face. Tree grade 1 for most hardwood species must be at least 16 inches DBH and have an 83 percent yield on the third-best face. Tree grade 2 must be at least 13 inches DBH and have a 67 percent yield in the third-best face. Tree grade 3 trees have a minimum DBH of 11 inches and a 50 percent yield on the third-best face. A grade 4 tree contains a gradable 16-foot butt log that grades below 3. A tree grade 5 does not contain a 16-foot butt log but has at least two noncontiguous 8-foot logs or one 12-foot log. More information on tree grading can be found in USDA FS (2013a. 2013b).

In this study, we define high-grade sawtimber volume as the sawlog portions of tree grades 1 and 2, midgrade sawtimber volume as the sawlog portions of tree grade 3, and low-grade sawtimber volume as the sawlog portions of tree grades 4 and 5. The volume of high-grade, midgrade, and low-grade sawtimber, rough culls, and poletimber for the regions depicted in Figure 1 were developed from inventories reported on January 15, 2015.

Percent cull is defined as the percent of cull tree volume divided by total volume of all live trees 5 inches and larger. Average diameter of all trees is the volume-weighted diameter of all trees using the midpoint values of 19 reported diameter classes.[2] Similarly, average diameter of growing stock trees is the volume-weighted diameter of these trees. If the average diameter of all trees is substantially greater than the diameter of growing stock trees, then a disproportionate volume of cull trees are in larger-diameter classes (''wolf tree'') relative to growing stock trees. Similarly, if the diameter of all trees is substantially less than the diameter of growing stock trees, then a disproportionate volume of cull trees are in smaller-diameter classes. Percentage of poletimber growing stock is the percentage of volume in growing stock trees less than 11 inches in diameter per total volume of all growing stock.

Results and Discussion

The six eastern hardwood regions examined in this article are defined in Table 1. These regions are based on proportional volume of the most important species groups presented in Table 2. Major species groups with multiple species include select white oaks (primarily white oak [*Quercus alba*]); select red oaks (primarily northern red oak [*Q. rubra*] and cherry bark oak [*Q. pagoda*]); other red oaks (primarily black oak [*Q. velutina*], water oak [*Q. nigra*], southern red oak [*Q. falcata*], and scarlet oak [*Q. coccinea*]); other white oaks (primarily chestnut oak [*Q. prinus*] and post oak [*Q. stellate*]); hard maple (primarily sugar maple [*Acer saccharum*]); soft maple (primarily red maple [*A. rubrum*] and silver maple [*A. saccharinum*]); hickory (primarily pignut hickory [*Carya glabra*], mockernut hickory [*C. tomentosa*], shagbark hickory [*C. ovata*], bitternut hickory [*C. cordiformis*], and black hickory [*C. texana*]); tupelo/blackgum (blackgum [*Nyssa sylvatica*], swamp tupelo [*N. biflora*], and water tupelo [*N. aquatica*]); and cottonwood/aspen (primarily eastern cottonwood [*Populus deltoides*], quaking aspen [*P. tremuloides*], and bigtooth aspen [*P. grandidentata*]). Major species groups composed of a single species are yellow-poplar (*Liriodendron tulipifera*) and sweetgum (*Liquidambar styraciflua*). Proportion cubic volume of all live trees (at least 5 in. DBH) by hardwood species groups and region are shown in Table 2. The percentage of cull, average diameter of all trees, average diameter of growing stock trees, and percentage of poletimber growing stock are presented in Table 3.

The Southern region contains over 120 billion ft^3 of live hardwood trees, but 25 percent of this volume is in cull trees (Fig. 1; Table 3). Sixty-two percent of the region's tree volume is other red oak, sweetgum, other white oaks, blackgum/tupelo, and select white oak species groups

[2] The weights are the midpoints of diameter classes 5 to 6.9 inches to 39 to 40.9 inches. The percentage of trees greater than 40.9 inches is multiplied by 45. Because the development of a robust standard error for average diameter class is problematic, it is assumed that differences between average diameter class of all trees and diameter class of growing stock trees must exceed 0.3 inch to be considered significant.

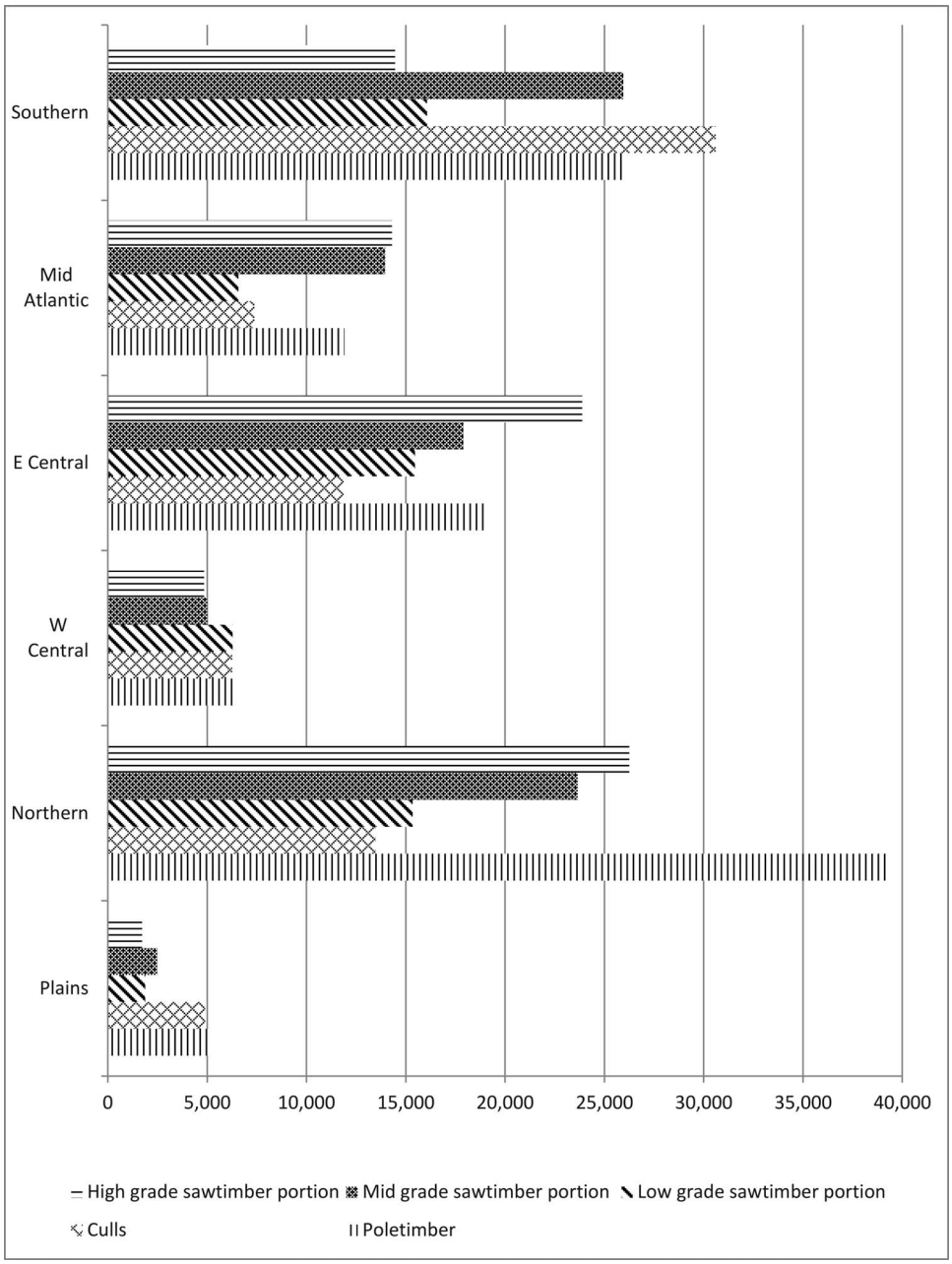

Figure 1.—Volume of live trees in high-grade sawtimber portion, midgrade sawtimber portion, low-grade sawtimber portion, rough culls, and poletimber (in million cubic feet). Source: US Department of Agriculture Forest Service 2015.

Table 1.—Eastern hardwood region.[a]

Region	States	Major species group
Southern	AL, AR, FL, GA, LA, MS, OK, SC, TX	Other red oaks, sweetgum, other white oak, tupelo/blackgum, select white oak
Mid-Atlantic	DE, MD, NJ, NC, VA	Yellow-poplar, other red oaks, select white oaks, soft maple
East Central	IN, KY, OH, TN, WV	Yellow-poplar, select white oaks, hickory, other red oaks
West Central	IL, IA, MO	Select white oaks, other red oaks
Northern	CT, ME, MA, MI, NH, NY, PA, RI, VT, WI	Hard maple, soft maple, selected red oaks, cottonwood/aspen
Plains	KS, MN, NE, ND, SD	Cottonwood/aspen, ash

[a] Source: US Department of Agriculture Forest Service (2015).

Table 2.—Proportion cubic volume of all live trees (at least 5 in. diameter at breast height) by hardwood species groups by region.[a]

Species group	Southern	Mid-Atlantic	West Central	East Central	Northern	Plains
Select white oaks	8.3	10.3	21.3	10.8	4.0	10.4
Select red oaks	4.4	5.5	5.9	5.6	9.9	5.7
Other white oaks	8.9	9.2	6.9	8.0	2.2	t
Other red oaks	22.7	10.7	17.1	8.7	4.1	1.4
Yellow birch	t	t	N	t	3.9	t
Hickory	6.3	4.9	10.0	9.2	2.0	1.0
Hard maple	t	1.3	2.4	7.0	15.5	4.0
Soft maple	3.9	10.6	5.6	8.5	21.9	4.7
Beech	t	2.0	t	3.4	4.0	N
Sweetgum	13.4	7.1	t	1.7	t	N
Tupelo/blackgum	8.4	4.2	t	1.3	t	N
Ash	3.2	2.7	3.5	4.8	2.0	11.6
Cottonwood/aspen	t	t	3.0	1.0	7.1	31.4
Basswood	t	t	1.2	1.5	2.5	5.1
Yellow-poplar	5.4	20.7	t	13.1	1.5	N
Black walnut	t	t	4.1	1.4	t	1.6
Other soft hardwoods	8.7	4.8	12.7	10.2	10.4	17.0
Other hard hardwoods	t	2.7	3.6	2.0	2.6	2.5
Noncommercial	3.7	1.8	1.2	1.6	t	1.9

[a] t = trace, less than 1 percent; N = none reported in this region. Source: US Department of Agriculture Forest Service (2015).

Table 3.—Major species groups, percentage of cull, average diameter of all trees and growing stock trees, and percentage of poletimber growing stock.[a]

Region	Species group	Cull (%)	Avg. diameter		Poletimber growing stock (%)
			All trees	Growing stock	
Southern	Other red oak	20.4	17.0	17.1	22.1
	Sweetgum	12.4	13.6	13.7	36.8
	Other white oak	33.8	16.3	15.4	28.1
	Tupelo/blackgum	22.2	13.5	13.7	34.1
	Select white oak	10.1	15.9	15.9	22.4
	Combined groups	25.0	15.2	15.6	28.3
Mid-Atlantic	Yellow-poplar	2.2	18.1	18.2	15.2
	Other red oak	7.2	16.8	16.8	19.6
	Select white oak	6.3	16.9	16.7	17.3
	Soft maple	25.2	13.5	13.7	37.1
	Other white oak	16.6	16.3	16.4	19.1
	Combined groups	12.4	15.9	16.2	22.8
East Central	Yellow-poplar	2.4	17.0	17.0	15.1
	Select white oak	6.8	16.8	16.5	16.2
	Hickory	5.3	14.1	14.0	26.9
	Other red oak	6.7	17.6	17.4	12.3
	Soft maple	17.1	14.2	14.1	34.4
	Other white oak	10.6	16.5	16.3	17.1
	Combined groups	12.1	15.8	15.9	21.9
West Central	Select white oak	16.2	17.0	16.2	20.2
	Other red oak	14.2	16.1	15.6	21.8
	Hickory	10.5	13.3	13.2	37.6
	Other white oak	22.0	13.5	12.7	39.7
	Combined groups	20.1	16.0	15.7	25.2
Northern	Hard maple	8.2	14.0	13.6	34.1
	Soft maple	11.3	13.0	12.9	40.0
	Select red oak	3.9	17.2	17.0	13.8
	Cottonwood/aspen	3.6	12.7	12.6	41.5
	Ash	7.5	13.5	13.4	37.2
	Combined groups	10.1	14.1	14.0	32.9
Plains	Cottonwood/aspen	13.1	16.3	14.5	43.8
	Ash	21.6	12.4	11.9	52.0
	Select white oak	42.2	16.8	15.6	26.8
	Combined groups	28.3	14.9	13.9	42.1

[a] Source: US Department of Agriculture Forest Service (2015).

(Table 2). Over 28 percent of the growing stock volume is poletimber, which appears adequate for future supplies of sawtimber-size growing stock. The average diameter for all trees in the Southern region versus growing stock trees is similar for the species groups listed in Table 3 except other white oak. In this region, over 66 percent of the timber volume of other white oak trees greater than 31 inches DBH is classified as rough cull. These ''wolf'' trees are often left uncut because they do not contain merchantable logs and/or are difficult to remove. Average diameter of all growing stock trees in the Southern region is greater than the average diameter of all trees because of several factors, including the volume of small-diameter noncommercial species.

Because of the high proportion of cull trees and low proportional volume of high-grade sawtimber trees, the Southern region timber base can be considered relatively low quality. Still, much of the sawtimber portion of this resource is highly utilized (Luppold and Miller 2014), and low-grade sound timber in all diameter classes is suitable for the paper industry (70% of total hardwood roundwood production in 2009 was pulpwood [Johnson et al. 2011]). There are also considerable quantities of higher-grade sawtimber needed to support hardwood grade mills (mills that primarily manufacture lumber for appearance purposes) within this region. Other major uses of hardwood roundwood in the Southern region include cross ties, pallet stock, container and structural veneer, timber mats, and board roads. The combined production of all hardwood sawmills (grade and industrial) in this region accounted for 21 percent of eastern production in 2008 (the last year that state estimates are available; US Department of Commerce [USDC] 2009).

Because of an apparent decline in demand, hardwood pulpwood production in this region declined by 15 percent between 2005 and 2011 (Johnson and Steppleton 2007, Bentley and Steppleton 2013). This decline may be offset by hardwood roundwood demand by large industrial fuel pellet facilities designed for the export market that have recently located in, or are being constructed in, this region (*Biomass Magazine* 2015). While the existence of these facilities has been noted in trade and newspaper articles, no reliable estimates of the volume of hardwood and softwood roundwood and residual material consumed by the fuel pellet industry have been developed as of early 2015.

Eighty-six percent of the volume of live timber in the Mid-Atlantic region is in Virginia and North Carolina, which have traditionally been considered southern states. The difference between the Southern and Mid-Atlantic regions is the higher volume of yellow-poplar and lower volumes of other red oaks, sweetgum, and tupelo/blackgum. Yellow-poplar has the lowest amount of cull timber volume of any of the species groups listed in Table 3, and the other red oak and select white oak in the Mid-Atlantic region also have relatively low cull rates compared with the Southern region. Yellow-poplar lumber exports have increased by 180 percent since 2005 (US Department of Agriculture, Foreign Agricultural Service 2015), so it could be expected that the production of this species in the port-accessible Mid-Atlantic region has also increased.

The only major species group in this region that has a high volume of cull and low-quality sawtimber is red maple (USDA FS 2015). There is very little difference between the average diameters of combined species groups of all trees versus growing stock trees, indicating that cull material is evenly spread through the diameter classes. While the Mid-Atlantic region had a large paper industry in 2009, regional sawlog and pulpwood production were nearly identical. The Mid-Atlantic region has also experienced declines in hardwood pulpwood production in recent years (Johnson and Steppleton 2007, Bentley and Steppleton 2013) and the establishment of fuel pellet facilities (*Biomass Magazine* 2015).

The hardwood resource in the East Central region can be characterized as high quality when examining the relative volume of grades 1 and 2 sawtimber and a relatively low volume of cull trees. This region contains two states associated with the South, Tennessee and Kentucky, which have a high proportional volume (87%) of hardwood trees when compared with the Southern region, which contains 48 percent softwoods. Tennessee and Kentucky also contain considerably more yellow-poplar and select white oak than states in the Southern region. The East Central region is similar to the Mid-Atlantic region in terms of percent cull, average diameters, and percentage of growing stock that is poletimber. The East Central region accounted for nearly 28 percent of the hardwood lumber produced in the eastern United States in 2008 but contains only 21 percent of the total hardwood timber base (USDA FS 2015). Several face veneer mills also are located in this region (Hardwood Plywood and Veneer Association 2015).

Nearly 40 percent of the sawlog portion of the growing stock in the West Central region is low grade (USDA FS 2015). In addition, nearly 20 percent of the sawtimber-size material in this region is in cull trees, and the cull tree volume of select white oaks, other red oaks, and other white oaks is concentrated in larger-diameter trees (Table 3). Pallet material can be produced from low-quality and cull timber, while cross ties can be processed from mid- and low-grade sawtimber as long as the tree has a contiguous 9-foot section that is sound. Pallets and cross ties have remained in relatively high demand over the past decade (Johnson 2014), and Missouri and Illinois have a large number of mills specializing in these industrial products (Tuttle et al. 2007, Illinois Forestry Development Council 2013). The white oak resource in this region also is used by the barrel stave industry, but the volume of material used by this industry has not been estimated in recent years. This relatively small region also contains a third of the black walnut sawtimber-size growing stock in the United States.

The Northern region had the largest volume of live timber and growing stock in 2013, but nearly a third of the growing stock volume was poletimber. One factor causing the higher percentage of growing-stock volume in poletimber in this region is that trees grow at slower rates than trees farther south (Smith et al. 2009), but this slow rate of growth causes a tighter ring count and has often translated to higher prices for lumber (Fig. 2). The quality of the sawlog portion of sawtimber trees in the Northern region is relatively high with over 75 percent being high grade and midgrade, and the volume of rough cull is lowest of all regions.

This region manufactured over 26 percent of lumber produced in the eastern United States in 2008 (USDC 2009), and because of the species distribution and quality of this

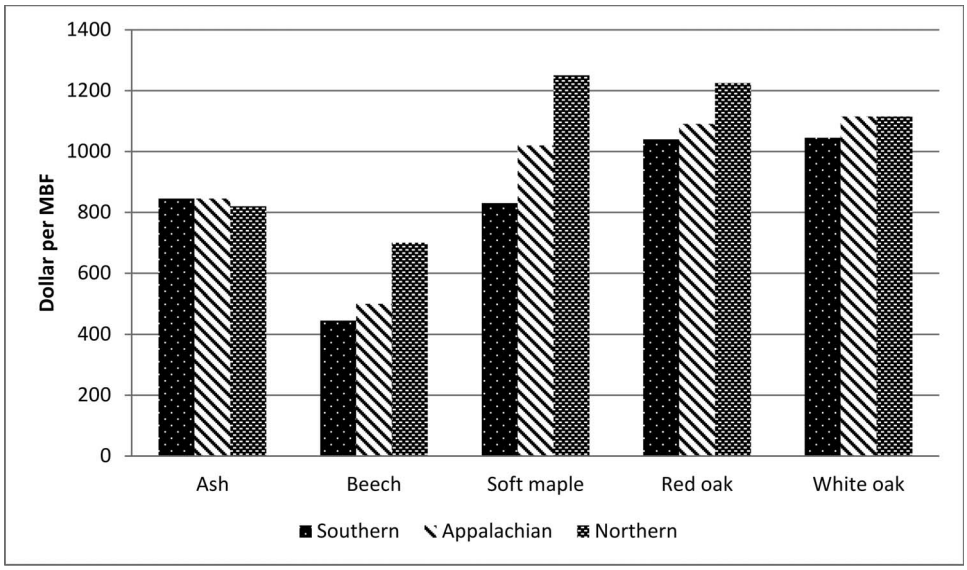

Figure 2.—Regional prices of first- and second-grade ash, beech, soft maple, red oak, and white oak green lumber. Soft maple prices are based on unselect color in the Northern and Appalachian regions and wormhole a defect (WHAD) in the Southern region. MBF = thousand board foot. Source: Hardwood Market Report *2013*.

timber base, the value of lumber produced in this region likely exceeds that of all other regions. This region also contains several veneer mills stretching from the states of Wisconsin to Pennsylvania. The apparent high quality of the timber inventory in the Northern region would initially seem to preclude the production of lower-value industrial, pulp, and panel products. However, the high volume of cull poletimber–size material (higher than any region other than the Southern) may be one of the reasons why high volumes of roundwood material are used by the pulp and panel industries in this region (Luppold and Sendak 2004, Piva and Witherspoon 2010, Haugen 2013).

Only 49 percent of the growing stock in the Plains region is in the sawlog portion, and over 28 percent of the live tree volume is cull. A disproportionate volume of cull material is in large-diameter trees for all major species groups and combined species groups. The most important species in this region are eastern cottonwood and quaking aspen. While 90 percent of the cottonwood growing stock volume is in sawlog portions, only 38 percent of quaking aspen growing stock exceeds 11 inches DBH. Quaking aspen is short lived and often cut for oriented strand board (OSB) or pulpwood prior to reaching sawtimber diameter (Haugen and Jacobson 2012). If quaking and other aspen species are not harvested once mature, they will often start to degrade or be succeeded by the more shade-tolerant species (Burns and Honkala 1990). Over 70 percent of the cull tree volume in the Plains states is sawtimber-size material; however, the widespread geographic distribution of the timber base in this region outside of Minnesota may make use of this cull material uneconomical. This region also has the largest proportion of poletimber in part because of the predominance of small-diameter aspen species.

Summary and Conclusions

The eastern hardwood timber base is composed of several structural components ranging from high-quality sawtimber-size growing stock to poletimber-size cull trees, and these components vary by region and species group. The Southern region contains over 120 billion ft^3 of live timber, but a high proportion of this resource is cull trees, and there is a low proportional volume of high-grade sawtimber trees. Still, much of the sawtimber portion of this resource is highly utilized, and the low-grade sound timber in all diameter classes is suitable for the paper industry in this region. There are also considerable quantities of higher-grade sawtimber needed to support the numerous very large hardwood-grade mills. While pulpwood production has been declining in this region in recent years, this decline may be offset by roundwood demand by industrial fuel pellet facilities designed for the export market.

The Mid-Atlantic and East Central regions have a low relative volume of cull timber in part because of the high volume of yellow-poplar in these regions. Of all species groups and regions examined in this study, yellow-poplar had the lowest proportion of cull material by a wide margin. By contrast, the soft maple resource in these regions has relatively high cull rates. Similar to the Southern region, the hardwood pulpwood production in the Mid-Atlantic region has declined in recent years, while fuel pellet production appears to be increasing. The East Central region also contains areas with relatively high rates of pulpwood production, but this region accounts for more lumber production than any other region.

Over 75 percent of the growing stock in the West Central region is in sawtimber portions, but 40 percent of all tree volume in this region is either low-grade sawtimber-size trees or cull. The sawmilling industry in this region is diverse, ranging from mills specializing in pallets and cross ties to white oak staves and black walnut lumber. Only 49 percent of the growing stock in the Plains region is in the sawlog portion, and over 28 percent of the live tree volume is cull. One of the most important species in this region is quaking aspen; it is short lived and often

cut for OSB or pulpwood prior to reaching sawtimber diameter. Both the West Central and the Plains regions contain relatively large quantities of large-diameter cull ''wolf'' trees, which continue to be left uncut because of low merchantability.

The Northern region contained the largest volume of live timber and sawtimber-size growing stock timber, but a third of this volume was poletimber growing stock. The quality of the sawlog portion of sawtimber trees in the Northern region is relatively high, and this region produced over 26 percent of the lumber manufactured in the eastern United States in 2008, but this region also contains pulp and panel industries. As markets change, the amount of the various structural hardwood timber components consumed will eventually change. Once the hardwood timber base is understood in a specific location, the methods and systems that will merchandise and use the various components of the resource have a higher chance of succeeding.

Appendix

Current estimates provided in this study are primarily from the 2013 inventories of each state examined. As of January 15, 2015, data for Texas were through 2011; for Kentucky and Tennessee, the data were through 2012. The exclusion of 2013 data for these states will not significantly change the results of this study because of the method by which inventory data are currently collected. Prior to 1999, the FIA conducted a periodic inventory at permanent field plots approximately every 10 years. Since 1999, FIA has implemented annual inventories in which a nominal 20 percent of plots are visited each year for most states (Smith 2002). After a nominal 5 years of data collection, an analysis and report are created based on the full set or ''cycle'' of plots. The exceptions to this time frame are Alabama, Louisiana, Mississippi, and North Carolina, which are currently on 7-year cycles. This creates a yearly moving window of 5- or 7-year cycles and reports. The last year of each full cycle is used to name the full set of plots. For example, the cycle of plots measured from 2009 through 2013 are collectively labeled the ''2013 inventory'' and are used to produce a 2013 report.

The data used in this article were derived using EVALIDator (USDA FS 2015). Sampling in the FIA program consists of a network of plots where standard forest inventory measurements are collected throughout the United States (Smith 2002; Bechtold and Patterson 2005; USDA FS 2013a, 2013b). To better understand the definitions of forestland, timberland, live timber, growing stock, and the sawlog portion of growing stock, refer to Woudenberg et al. (2010).

Minimum merchantability standards are met when at least one-third of the tree volume meets grade, soundness, and size requirements; otherwise, the tree is cull. A cull tree has form cull or a rotten section(s), but this cull material is deducted from the net volume. Twelve percent of cull trees (on a numeric but not volume basis) are noncommercial species, which are tree species of typically small size, poor form, or inferior quality and which normally do not develop into trees suitable for industrial wood products, hence the term ''noncommercial.'' In this article, noncommercial species are included only in cubic volume estimates of all live trees.

Two exceptions to the 16-inch minimum DBH for tree grade 1 are basswood (*Tilia* sp.) and ash (*Fraxinus* sp.), which can be 15 inches DBH. Because it is the length of the butt log and not the quality of that log defining grade 5 trees, grade 5 trees are sometimes more valuable than grade 4 trees when the butt log is relatively clear. More information on tree grading can be found in USDA FS (2013a, 2013b).

Literature Cited

Bechtold, W. A. and P. L. Patterson. 2005. The enhanced Forest Inventory and Analysis program—National sampling design and estimation procedures. General Technical Report SRS-80. USDA Forest Service, Southern Research Station, Asheville, North Carolina. 85 pp.

Bentley, J. W. and C. D. Steppleton. 2013. Southern pulpwood production, 2011. Resource Bulletin SRS-194. USDA Forest Service, Southern Research Station, Asheville, North Carolina. 38 pp.

Biomass Magazine. 2015. Pellet plants, online plant map. http://biomassmagazine.com/plants/listplants/pellet/US. Accessed February 7, 2015.

Burns, R. M. and B. H. Honkala. 1990. Silvics of North America. Agricultural Handbook 654. USDA Forest Service, Washington, D.C. 877 pp.

Hardwood Market Report. 2013. Weekly price report. *Hardwood Market Rep*. 91(43):2, 4, 10.

Hardwood Plywood and Veneer Association. 2015. Where to buy hardwood plywood veneer and engineered hardwood flooring. http://www.pageturnpro.com/Hardwood-Plywood-and-Veneer-Association/48714-2013-Where-to-Buy/index.html#1. Accessed February 18, 2015.

Haugen, D. E. 2013. Wisconsin timber industry: An assessment of timber product output and use, 2006. Resource Bulletin RRS-42. USDA Forest Service, Northern Research Station, Newtown Square, Pennsylvania. 66 pp.

Haugen, D. E. and K. Jacobson. 2012. Minnesota timber industry—An assessment of timber product output and use, 2008. Resource Bulletin NRS-78. USDA Forest Service, Northern Research Station, Newtown Square, Pennsylvania. 110 pp.

Illinois Forestry Development Council. 2013. 2013 Illinois sawmill directory. E. Holzmueller and N. Jensen (Comps.). Department of Forestry, Southern Illinois University, Carbondale. 31 pp.

Johnson, J. 2014. Estimates of hardwood lumber consumption 2013. Unpublished data. On file with *Hardwood Market Report*, Memphis, Tennessee.

Johnson, T. G., H. W. Bentley, and M. Howell. 2011. The South's timber industry, an assessment of timber product output, and use, 2009. Resource Bulletin SRS-182. USDA Forest Service, Southern Research Station, Asheville, North Carolina. 44 pp.

Johnson, T. G. and C. D. Steppleton. 2007. Southern pulpwood production, 2005. Resource Bulletin SRS-116. USDA Forest Service, Southern Research Station, Asheville, North Carolina. 42 pp.

Luppold, W. and G. Miller. 2014. Changes in eastern hardwood sawtimber growth and harvest. *Forest Prod. J.* 64(12):26–32.

Luppold, W. and P. E. Sendak. 2004. Analysis of the interaction between timber markets and the forest resources of Maine. *North. J. Appl. Forestry* 21(3):134–143.

Piva, R. J. and A. K. Witherspoon. 2010. Michigan timber industry: An assessment of timber products output and use, 2006. Resource Bulletin RRS-42. USDA Forest Service, Northern Research Station, Newtown Square, Pennsylvania. 66 pp.

Smith, W. B. 2002. Forest inventory and analysis: A national inventory and monitoring program. *Environ. Pollut*. 116(Suppl 1):S233–S242.

Smith, W. B., P. D. Miles, C. H. Perry, and S. A. Pugh. 2009. Forest resources of the United States, 2007. General Technical Report WO-78. USDA Forest Service, Washington, D.C. 336 pp.

Tuttle, J., T. Treiman, and J. Battson. 2007. Missouri forest industries 2007: Directory of primary wood processors. Missouri Department of Conservation, Forestry Division, Jefferson City. 36 pp.

US Department of Agriculture, Foreign Agricultural Service. 2015.

Global agricultural trade system. http://www.fas.usda.gov/gats/default.aspx. Accessed February 25, 2015.

US Department of Agriculture Forest Service (USDA FS). 2013a. Forest inventory and analysis national core field guide. Vol. 1. Field data collection procedures for phase 2 plots. Version 6.0.1. http://www.nrs.fs.fed.us/fia/data-collection. Accessed December 10, 2013.

US Department of Agriculture Forest Service (USDA FS). 2013b. Forest inventory and analysis national core field guide. Vol. 1. Field data collection procedures for phase 2 plots. Version 6.0.1 National Core Field Guide. http://www.srs.fs.usda.gov/fia/data_acquisition/field_guide/FieldGuide.htm. Accessed December 10, 2013.

US Department of Agriculture Forest Service (USDA FS). 2015. EVALIDator. http://apps.fs.fed.us/Evalidator/evalidator.jsp. Accessed January 1, 2015.

US Department of Commerce (USDC) Census Bureau. 2009. Lumber production and mill stocks—2008. MA321T(08)-1. USDC Census Bureau, Washington, D.C.

Woudenberg, S. W., B. L. Conkling, B. M. O'Connell, E. B. LaPoint, J. A. Turner, and K. L. Waddell. 2010. The Forest Inventory and Analysis database: Database description and user's manual version 4.0 for Phase 2. General Technical Report RMRS-GTR-245. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado. 336 pp.