Examination of Roundwood Utilization Rates in West Virginia

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Abstract

Forest harvesting is an integral part of the West Virginia forest economy. This component of the supply chain supports a diverse array of primary and secondary processors. A key metric used to describe the efficiency of the roundwood extraction process is the logging utilization factor (LUF). The LUF is one way managers can discern the overall use of harvested roundwood. To update LUF in West Virginia, roundwood utilization during harvesting operations was investigated on 30 active sites in 2008. Approximately 3.6 markets were used by the loggers sampled. The average utilization rate at the time of felling and bucking in the woods was 87.8 percent for trees sampled during this study. Over 97 percent of the roundwood that was processed on the landing was utilized. No relationship was found between the number of markets and utilization rates. Results from this study provide estimates on the overall efficiency of harvest operations as well as the characteristics and quantity of material being left after harvest. This information is important to those involved in the management of the hardwood resource as well as those making investments in wood processing industries.

During the last two decades, major changes have impacted Appalachian forest products markets. Probably the most notable has been the dramatic decline in domestic furniture production. US manufacturers have not been able to compete with furniture imports, most of which have been driven by increased globalization, as well as lower labor and environmental costs in other parts of the world (Schuler et al. 2001). Traditional roundwood using manufacturers also have seen shifts in wood fiber value streams including increases in consumption by engineered product producers as well as increased attention by energy producers (Grushecky et al. 2007).

Thus, both global competition and shifts in domestic markets have increased the importance of optimizing the recovery of roundwood volume and value in forest operations. Production efficiency and recovery rates must be measured and understood before they can be optimized throughout the forest-to-markets supply chain. Understanding manufacturing efficiencies from harvesting through the primary production stage will help increase the productive capacity of our forest products sector. This ultimately will benefit the standing forest resource by giving landowners and foresters insights that can guide them in specifying harvest constraints to help ensure that the residual stand meets expectations.

The US Department of Agriculture (USDA) Forest Service has been the primary source for information regarding the utilization of hardwoods in the Appalachian region. The Timber Products Output group (TPO) within the Forest Service's Forest Inventory and Analysis (FIA) group tracks resource removals and their impacts on the forest and economies of the United States. This includes three components: (1) roundwood use surveys of both industrial and nonindustrial primary (roundwood) timber products users as well as residue types and amounts generated and sold by primary processing industry sectors, (2) determination of logging utilization rates, and (3) combining logging utilization information with TPO information to obtain resource removals. Two utilization factors are calculated during this process: a logging utilization factor (LUF) and a sawmill utilization factor (SUF). By definition, the LUF represents the ratio of harvested roundwood volume that is left in the woods versus that brought to market. The SUF helps us understand the conversion efficiency during

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primary processing. It is constructed by comparing the amount of residues (bark, chips, and dust) produced versus the amount of product produced. Of these components, logging utilization research gives us the most information regarding the waste associated with the harvest of timber. The LUF can be used to determine removals by applying it to the volume of wood reportedly processed by facilities in any given state (Blyth and Smith 1979).

Other methods, such as line intersect sampling, have been used to estimate the volume of logging residues remaining after harvest in West Virginia (Grushecky et al. 1998, 2006). In an earlier study, no relationships were found between the amount of logging residue measured at sites and the number and distance to different roundwood markets (Grushecky et al. 2007). While these studies help to develop a better understanding of waste wood availability, they do not identify the reason for the wood being available in the first place. Because these surveys are conducted after harvest, there is no information available on the influence of site conditions and markets on overall utilization. Combining the assessments of the harvested resource and the available markets at the time of harvest can increase our understanding of roundwood utilization.

Logging studies that simultaneously address environmental/market factors and material recovery rates, such as those performed by the USDA Forest Service (Bentley and Johnson 2006, 2009), provide better utilization information than do postharvest residue studies. However, the intensity of these studies comes at a cost. In the northeastern United States, which includes West Virginia, a single set of LUFs have been in use, despite wide variation in forests, species, and markets. Another issue with the current LUFs being used in the northeastern United States is the fact that they are at least two decades old (E. Wharton, retired, USDA Forest Service Northern Research Station, personal communication, 2009). Because of the changes in technology and available markets, LUFs should be updated on a more consistent basis. Even with these challenges, LUFs are an important tool for determining the availability of larger dimension components of wood fiber in a region (but not smaller branchwood components). They are used by many to assess regional timber supply-and-demand scenarios for locating new wood products facilities. Likewise, increased importance has been placed on TPO information because of a renewed emphasis on biofuel production. Because of their availability and perceived low cost, wood by-products are often the first raw material sourced when developers are interested in locating a new bioenergy facility.

Individual operational factors such as logger type and forester involvement could also impact utilization. Timber harvests in West Virginia can be conducted by several types of logging firms including contract, independent, and company. Contract loggers (contracted by the organization that bought the stumpage—usually a primary processor) and independent loggers (logging operators that bought the stumpage) tend to be most prevalent. Company crews, crews that are owned and managed by a primary wood processing operation, are less common. While forester involvement has been shown to affect harvest planning in West Virginia (Provencher et al. 2007), the influence on roundwood utilization has not been investigated.

The primary objective of this research project was to investigate roundwood utilization rates on timber harvests in West Virginia. A secondary objective was to determine the impact of harvest site and logger characteristics on overall utilization rates.

Methods

To investigate roundwood utilization in West Virginia, 30 active timber harvests were sampled during the summer and early fall of 2008. The population of harvest sites was obtained from West Virginia Division of Forestry (DOF) logging notification forms. In West Virginia, timber harvesting notification is mandated under the 1992 Logging Sediment Control Act (Grushecky et al. 2006). To obtain a reasonable representation of LUF for the entire state of West Virginia such that variability owing to differences in species composition, harvest type, market proximity, and terrain was captured, harvests were stratified based on the three USDA Forest Service FIA units (Alderman and Luppold 2005) in West Virginia. Approximately 20 active harvests in each of the FIA units (northeastern, southern, and northwestern) were randomly selected from the state's listing of current harvest operations. More potential sites were identified (20) than were actually sampled because of the timing of harvest completions, denial of access by some landowners/loggers, and size constraints (sites needed to be at least 15 acres) that limited the feasibility of completing sampling on some of the harvest sites. Ultimately, 10 unique harvest sites were evaluated in each of the FIA units. The sampling methodologies used at each site were patterned after the techniques used by the USDA Forest Service Southern Research Station (Bentley and Johnson 2009). The goal for each site was to sample 30 felled trees for utilization. Utilization information was collected when the tree was felled and subsequently merchandised in the woods as well as when the tree was bucked and prepared for market at the landing. The landing utilization data were not collected by Bentley and Johnson (2009), adding a unique perspective to our study.

In-woods utilization

Once an active harvest site was chosen, the field crews met with the logging supervisor before fieldwork commenced. A survey was used to collect general harvest information including the following:

1. Global positioning system coordinates of landing
2. Type and log size and quality specifications of all product markets
3. Number of loggers on logging crew
4. Average number of truckloads leaving site each day
5. Location of all product markets
6. Type of logging operation (contract, independent, company owned)
7. Degree of mechanization (fully mechanized having mechanical harvester, grapple skidder, and sawbuck vs. not fully mechanized)

The field crew then noted the current location of harvesting within the tract and the general direction of harvest progression. With this information, field crew members were positioned a safe distance from harvesting while the logging crew felled several trees in a given area. Once the trees were felled and topped, the field crew collected the following information for each tree:

1. Species
2. Stump height

3. Stump diameter
4. Diameter at 12-inch stump
5. Diameter at breast height (DBH)
6. Diameter at 16-foot log
7. Diameter and distance to topping point in woods
8. Diameter and distance to 9-inch top of main stem (limit of hardwood sawlog portion as per USDA Forest Service FIA definition)
9. Diameter and distance to 4-inch top of main stem (limit of growing-stock portion as per USDA Forest Service FIA definition)
10. Large and small end diameters for each portion of the felled tree remaining as long as they met a 4-inch diameter and 8-foot length minimum
11. Utilization (binary) of each measured piece

Details of the measurement points and adjustments that were made for branched trees and trees with other types of form abnormalities are available in Bentley and Johnson (2006, 2009). All diameters were based on outside-bark measurements taken with calipers.

Landing utilization

The felled trees were sequentially numbered by painting on the large and small ends of the log sections that were bucked out in the woods. In some cases these sections were essentially tree-length logs while at other logging operations these sections were the final log products (depending on whether the logging operation was running a sawbuck at the landing or manually bucking). The logs were then skidded to the landing by the logging crews. Once the tree stem portions arrived at the log landing, another field crew member recorded the following information for each bucked stem:

1. Tree number (from the woods)
2. Large and small end diameter
3. Total log length
4. Product category for each log (based on specification provided in conversation with harvest supervisor)
5. Large and small end diameter for any unutilized piece

Analyses

Upon returning from field visits, data were entered into the computer. Since this project produced a tremendous amount of data, significant attention was given to data checking and resolving discrepancies before analyses could proceed. All markets were geospatially identified, and the over-the-road travel distance from each landing to each product market was determined using a Web-based travel network algorithm.

With these data, a number of useful metrics were calculated. These included growing- and nongrowing-stock volume as well as percent underutilization and percent overutilization. Growing-stock volume, as defined by FIA merchantability standards, is the volume in the main stem of a tree from a 1-foot stump to a 4-inch top. Volume merchandised outside of these parameters is considered nongrowing-stock volume. All volume in the 1-foot stump, the tree stem above the 4-inch top to the growing tip of the tree, and in all limbs 4 inches and larger and at least 5 feet long are considered nongrowing stock according to FIA protocol.

Most of the time trees are not cut exactly at a 1-foot stump, nor are they cut off at exactly 4 inches. Trees cut above a 1-foot stump and below 4 inches would be considered underutilized, and that volume not utilized would be considered growing-stock residue. On the other hand, by FIA standards, trees cut below a 1-foot stump and above a 4-inch top are considered 100 percent utilized, and those portions below and above are considered overutilization. A myriad of combinations actually occur on active harvest operations. The aggregated volume from measured trees has provided overutilization and underutilization factors that can be applied to statewide inventory results for an estimate of growing-stock and nongrowing-stock logging residues (Bentley and Johnson 2009). The tops of the sawtimber portion of each stem (7 in. in softwoods and 9 in. in hardwoods) also were recorded so that both sawtimber and poletimber portions of the growing-stock section could be determined.

Landing utilization was calculated for each numbered tree that was skidded to the landing. A few numbered trees were not measured on the landing because they were (1) not skidded from the field, (2) dropped by the skidder along the way, or (3) had illegible tags/numbering as a result of environmental conditions. The information collected on these trees was used for calculating in-woods utilization rate but not landing utilization rate.

An overall utilization rate was calculated by dividing the cubic-foot volume of all products produced at the landing by the total cubic-foot volume for each measured tree. The overall utilization is roughly equivalent to the product of in-woods total tree utilization and landing utilization. Differences are due to minor differences in measurements and the fact that some stem sections were included in the in-woods calculation but not in the landing calculation because of tracking issues.

The influence of market distance on utilization rates was investigated using Pearson correlation. Actual distances to current markets as well as calculated distances to all major pulpwood and oriented strandboard (OSB) markets in West Virginia and surrounding states (even if they were not being used) were developed for each site. The relationship between overall utilization rate and other site factors including forester involvement, type of logger (contract, independent, and company), number of product markets, mechanization (fully or nonfully mechanized), and number of employees (full-time equivalent) was tested using analysis of variance (ANOVA) with $\alpha = 0.05$. The following general model was used for all tests:

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

where Y_{ij} is the overall utilization rate over all 30 sites, μ is the overall mean, α_i is the effect of the ith treatment, and ε_{ij} is the unexplained variability. The Tukey Studentized Range Test was used for multiple comparison testing. For both number of product markets and number of employees, data were recoded into two categories—''high'' and ''low.'' High represented measurements equal to or greater than the mean response for that particular indicator. Low represented all other measurements. Rounding was performed to the nearest integer value.

To meet assumptions of the parametric statistical tests used in the overall analysis, the total utilization rate was tested for normality. The Shapiro-Wilk hypothesis that total utilization was normally distributed was accepted ($P <$

0.06). Therefore, we assumed that the calculated utilization rate was representative of a normal distribution.

Results

Sites

Presampling harvest characteristics based on West Virginia DOF notification data for each of the three West Virginia DOF regions is shown in Table 1 along with harvest site information for the sample sites. A total of 10 harvests from each of the three West Virginia DOF regions were sampled during the summer and fall of 2008. Region 2, which encompasses the southern portion and central mountain counties, had the highest level of active harvests during the sampling period. Region 3, the northwestern portion of the state, had the largest average harvest size on record for the sites scheduled for harvest during 2008 (99 acres per site). As it turned out, the 10 sites sampled in Region 1 in the northeastern part of the state were, on average, larger than the sites in the other two regions (Table 1).

Logging crew characteristics

The majority of the loggers sampled were contract or independent loggers (logging operators that bought the stumpage). Company crews composed only 13 percent of the sample (Table 2). Twenty percent of the loggers used a mechanical felling machine, and 27 percent used a grapple skidder. On the landing, 70 percent of the loggers sampled used a mechanical bucking loader/saw (sawbuck). Of the 30 harvests sampled, 5 (17%) used a mechanical harvester, grapple skidder, and sawbuck, and thus could be considered fully mechanized (Table 2). The majority of the harvest operations that we sampled were on private land (93%) and had a professional forester involved in the harvest (73%). All of the fully mechanized harvests had professional forester involvement. On average, contract loggers had forester involvement on 78 percent of the harvests sampled, followed by 75 percent for company crews, and 67 percent for independents.

The number of employees working on each site ranged from two to nine. The mean number of employees for all 30 harvests was 4.4. Mechanized harvests averaged more employees than nonmechanized harvests (6.0 vs. 4.0). Contract loggers averaged 4.9 employees, independents averaged 3.6, and company crews averaged 4.8 employees on site. Four of the five fully mechanized harvests were contract logging crews.

The reported number of product truckloads produced per day ranged from one to nine. The mean number of daily truckloads was 3.3. Fully mechanized harvests produced 5.2 loads per day compared with an average of 3.0 for nonmechanized crews. Contract loggers produced the greatest number of loads per day (3.6), followed by company crews (3.2), and independents (3.0). While a variety of truck types and configurations were used, the average truck payload ranged from 20 to 25 tons per load.

Table 2.—Characteristics of loggers and logging sites sampled during a 2008 roundwood utilization study of 30 active timber harvests in West Virginia.

Harvest site characteristics	No. of sites (total $n = 30$)	Percent
Contract logger	14	47
Independent logger	12	40
Company crew	4	13
Mechanical harvester[a]	6	20
Grapple skidder[a]	8	27
Sawbuck[a,b]	21	70
Private land	28	93
Forester involvement	22	73

[a] Five of the 30 logging operations ran a mechanical harvester, grapple skidder, and sawbuck and thus are classified as ''fully mechanized.''

[b] A sawbuck, in this context, is a metal-framed stand associated with a circular cutoff saw onto which a tree-length piece of roundwood is loaded using a knuckle-boom at the landing. The piece of roundwood is placed, cut, indexed forward, cut again, etc.—thus, this is part of a mechanized (but not optimized) bucking system.

Markets

Seven primary markets were identified during the sampling of the 30 harvest operations (Table 3), as well as one additional output that was termed ''waste.'' As expected, each of the harvest sites produced sawlogs (Table 3). Following sawlogs, the next most common market was OSB pulp and pulpwood for paper production and yellow poplar (*Liriodendron tulipifera*) peeler materials (Table 3). Each of the harvests visited left waste material on the landing that was not merchandised.

The number of markets used ranged from one to six and averaged 3.6 across the 30 sample sites. Markets used by contract, independent, and company loggers did not differ greatly, with calculated means of 3.5, 3.7, and 3.5 markets, respectively. Harvests that had a forester averaged 3.8 product markets, and those without averaged 3.0.

Forty-seven percent of the sites delivered to sawlog as well as pulpwood and OSB pulp markets. Fifty percent of sites with a forester delivered to both sawlog and OSB and pulp markets, whereas 38 percent of sites without a forester used these markets. Half of both contract and company crews delivered to both sawlog and OSB and pulp markets, whereas 42 percent of independents did the same.

When looking at all major sawlog, pulp, and peeler markets, 33 percent of the loggers sampled delivered to each. Again, half of company loggers delivered to sawlog, peeler, and pulpwood markets, followed by 36 percent of contract loggers, and 25 percent of independents. Forester involvement also affected delivery to major sawlog, peeler,

Table 1.—Presampling data collected from West Virginia Division of Forestry Harvest Notification forms for each region sampled during a 2008 roundwood utilization study in West Virginia.

West Virginia Division of Forestry region	Total no. of acres scheduled for harvest in 2008	Total no. of harvests	Avg. harvest size (acres)	No. of sampling sites	Avg. harvest size of sample sites
1. Northeast	10,541	188	56	10	114
2. Southern	21,909	276	79	10	71
3. Northwest	17,435	175	99	10	67

Table 3.—Percentage of sites and trees producing different roundwood products and the percentage of total volume merchandised by product class at the landings of 30 active timber harvests in West Virginia during 2008.

Product	% of sites producing product	% of trees yielding product	% of total volume on landing
Sawlog	100	66.8	58.0
Peeler (yellow poplar)	57	13.2	8.1
Pulpwood (oriented strandboard and paper pulp)	60	56.3	20.2
Fence post	10	1.4	5.8
Fence rail	30	8.8	1.1
Scragg	17	8.9	1.1
Firewood	20	4.0	3.3
Waste	100	25.4	2.4

and pulp markets. Thirty-six percent of harvests with a forester delivered to all of these markets compared with 25 percent of those without a forester. Distances between individual markets ranged from 23.3 miles for those that delivered to scragg markets to 138.7 miles for a high-quality sawlog market (Fig. 1).

Sawlog market transport distance averaged 38 miles (standard deviation [SD] = 27.7). Distances to pulpwood, peeler, and OSB pulp were relatively consistent, averaging 68.1, 71.3, and 71.8 miles, respectively. The average distance to the closest pulpwood and OSB pulp facilities for those sites that did not include them as markets averaged 85.2 and 84.3 miles, respectively. The minimum distance to a wood products facility that was not delivered to was 34.4 miles for pulpwood and 44 miles for OSB pulp.

In-woods utilization

A total of 816 felled trees were sampled during this study, 84 less than our goal of 900 trees. A sample size of 900 was not achieved as a result of loggers finishing work before all trees were measured or the harvest being completed before sampling was finished. Twenty-three unique species were represented by the samples taken on the 30 harvests. Yellow poplar had the highest frequency of occurrence, followed by red maple (*Acer rubrum*), black oak (*Quercus velutina*), and red oak (*Quercus rubra*).

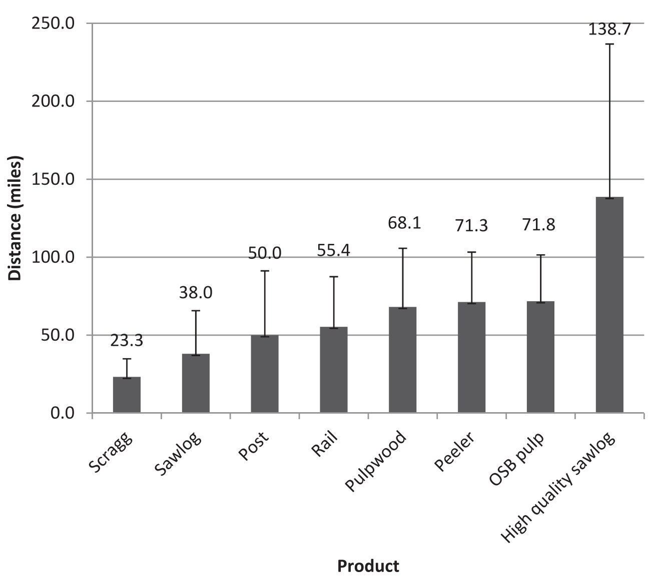

Figure 1.—Average (standard deviation represented by error bar) distance between log landing and markets for 30 harvests sampled in West Virginia.

When species were grouped by specific physical and market characteristics, the yellow poplar group was the most prevalent (Table 4). This was followed by the white oak (white and chestnut oak [*Quercus alba* and *Quercus prinus*]), soft maple (red maple), and red oak (red and black oak) groups.

The average DBH for the 816 trees measured was 16.9 inches (SD = 4.5 in.), the average stump height was 9.8 inches (SD = 7 in.), and the average stump diameter was 20.6 inches (SD = 5.6 in.; Table 5). The soft maple species group had the smallest DBH and stump diameter. The red oak species group had the largest DBH and stump diameter, followed by the hard maple (*Acer saccharum*) and black cherry (*Prunus serotina*) species groups. Hickory species and pine species had the lowest average stump heights. White oak and hard maple had the highest average stump heights, although both were below 12 inches (the assumed stump height used in TPO utilization studies in the eastern United States).

The mean tree bole length to a 9-inch merchantable top was 49.8 feet (SD = 24.2 ft). Not all stems had a merchantable height that was exactly 9 inches due to branching and other stem form inconsistencies. The mean diameter at the 9-inch merchantability point was 9.3 inches (SD = 0.8 in.) for all stems measured. The average bole length to at least a 4-inch merchantable top was 69.4 feet (SD = 4.5 ft). Again, not all stems had a merchantable

Table 4.—Number of sample trees in each of 10 species groups measured on 30 active timber harvests in West Virginia during 2008.[a]

Species group[b]	No.	% of total
Yellow poplar	208	25.5
White oak	149	18.3
Soft maple	114	14.0
Red oak	78	9.6
Mixed hardwood	74	9.1
Softwood species	58	7.1
Hard maple	52	6.4
Hickory spp.	39	4.8
Cherry	28	3.4
Soft hardwood	16	2.0

[a] Table is sorted by descending number of occurrences.

[b] Yellow poplar includes only yellow poplar (*Liriodendron tulipifera*). White oak includes white (*Quercus alba*) and chestnut oak (*Quercus prinus*). Soft maple includes only red maple (*Acer rubrum*). Red oak includes red (*Quercus rubra*) and black (*Quercus velutina*) oaks. Mixed hardwoods includes American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), black birch (*Betula lenta*), black locust (*Robinia pseudoacacia*), black gum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), paper birch (*Betula papyrifera*), and black walnut (*Juglans nigra*). Softwood species includes members of the *Pinus* spp. and eastern hemlock (*Tsuga canadensis*). Hard maple includes only sugar maple (*Acer saccharum*). Hickory spp. includes all hickories (*Carya* spp.). Cherry includes only black cherry (*Prunus serotina*). Soft hardwood includes cucumber (*Magnolia acuminata*), American basswood (*Tilia americana*), and bigtooth aspen (*Populus grandidentata*).

Table 5.—Mean diameter at breast height (DBH), stump height, and stump diameter of trees in each of 10 species groups measured on 30 active timber harvests in West Virginia during 2008.[a]

Species group	DBH (in.)	Stump height (in.)	Stump diam. (in.)
Red oak	18.9 (4.1)	9.8 (7.3)	24.7 (5.8)
Hard maple	18.3 (4.5)	10.7 (5.0)	21.8 (6.3)
Cherry	18.1 (2.9)	9.7 (2.2)	20.9 (4.7)
White oak	17.7 (5.0)	11.0 (10.1)	22.0 (4.8)
Yellow poplar	17.5 (4.2)	10.0 (7.6)	20.8 (5.5)
Soft hardwood	16.7 (3.3)	10.6 (5.1)	19.5 (4.8)
Hickory spp.	15.6 (3.0)	7.3 (5.7)	20.8 (4.1)
Mixed hardwood	15.4 (3.5)	10.4 (5.5)	18.4 (4.1)
Pine spp.	15.1 (5.5)	7.3 (4.5)	18.8 (7.0)
Soft maple	14.8 (4.1)	9.1 (3.3)	17.4 (4.9)
All species combined	16.9 (4.5)	9.8 (7.0)	20.6 (5.6)

[a] Standard deviations are reported in parentheses. Table is ordered by descending DBH.

Table 6.—Mean bole lengths to a 9- and 4-inch merchantable top and mean end of utilization (top) diameter of harvested stems for each of 10 species groups from data collected on 30 active timber harvests in West Virginia during 2008.[a]

Species group	Bole length to 9 in. from top (ft)	Bole length to 4 in. from top (ft)	Diam. of stem at point where utilization ends (in.)
Cherry	49.7 (11.2)	65.9 (11.4)	9.4 (3.2)
Hard maple	48.8 (15.3)	68.2 (13.6)	11.3 (4.6)
Hickory spp.	46.2 (13.6)	69.1 (10.6)	9.4 (3.3)
Mixed hardwood	37.6 (15.9)	57.3 (15.1)	8.7 (3.3)
Pine spp.	41.4 (27.3)	64.6 (21.1)	5.9 (3.3)
Red oak	53.7 (15.5)	74.4 (13.8)	11.5 (3.9)
Soft hardwood	50.9 (16.2)	69.4 (13.8)	10.7 (2.6)
Soft maple	38.7 (15.4)	58.6 (13.9)	8.3 (3.4)
White oak	51.8 (39.8)	68.7 (12.3)	10.2 (4.3)
Yellow poplar	60.3 (16.0)	80.3 (15.1)	9.4 (3.6)
All species combined	49.8 (24.2)	69.4 (4.5)	9.3 (0.8)

[a] Standard deviations are reported in parentheses.

height that was exactly 4 inches. The average diameter at the 4-inch merchantability point was 4.3 inches (SD = 0.6 in.). Yellow poplar stems had the largest bole length to a 9- and 4-inch top at 60.3 and 80.3 feet, respectively. The mixed-hardwood species group had the shortest length to a 9- and 4-inch top (Table 6).

The mean in-woods bucking diameter or end of utilization along the main stem for all trees sampled was 9.4 inches (SD = 3.9 in.). This represents the diameter at which the loggers bucked the main stem in the woods. The red oak species group had the largest diameter at the end of utilization at 11.5 inches, followed by hard maple at 11.3 inches (Table 6). The pine group and soft maple had the smallest diameter at the end of utilization point of 5.9 and 8.3 inches, respectively.

A total of 74,972 ft^3 of harvested trees were sampled during the 30 site visits. Total tree utilization ranged from 75.4 to 99.1 percent. Average whole-tree utilization was 87.8 percent (Table 7). Sawlog-sized material measured totaled 65,823 ft^3 and had a mean utilization rate of 94.1 percent. Sawlog utilization ranged from 82.1 to 99.9 percent. More than 9,000 ft^3 of pulp-sized material was measured, of which 42.5 percent was utilized. Pulp utilization ranged from 0 to 95 percent on the 30 sites.

The pine species group had the highest overall in-woods utilization rate (96.3%), followed by the yellow poplar and black cherry groups (Table 8). The soft-hardwood group had the lowest in-woods utilization rate (79.0%), followed by the hard maple and mixed-hardwood groups. Sawlog utilization among species groups followed similar patterns as total tree utilization—the pine species group (98.7%) had the highest sawlog percentage and the soft-hardwood group had the lowest (88.1%).

Landing utilization

A total of 796 trees were measured on the landing during this study. This is less than the 816 trees measured in the woods because several trees were lost between the woods and the landing. These trees do not represent unutilized stems, rather they were not skidded to the landing during the study period or the numbers written on the logs had become illegible during transport and thus were not used in the calculations for landing utilization rate.

The mean utilization rate found on the landings sampled was 97.9 percent (SD = 5.6%). Variation among species groups was not pronounced, ranging from 96.3 percent for soft hardwoods to 99.4 percent for the hard maple species group (Table 8).

Approximately 66.8 percent of all trees had a sawlog merchandised from them on the landing (Table 3). Pulpwood was merchandised from 56.3 percent of the stems. Of those trees from which a sawlog was merchandised, 50.6 percent also contained pulp material, but only 8.7 percent produced a peeler log. Furthermore, of those stems where a sawlog was not merchandised, peelers made up 22.4 percent and pulpwood 67.8 percent of the products, respectively.

In terms of tree volume utilization, 58 percent of the total tree volume that was measured on the landing was merchandised as a sawlog (Table 3). Pulpwood was the next highest product category produced on the landing, with 20 percent of the total volume. The least merchandised product on the landing was rail and scragg material at 1 percent.

The interaction between product merchandising and species showed that on average the red oak species group had the highest proportion of its volume being merchandised as sawlogs (79.8%, Table 9). This was followed by black cherry (74.1%) and white oak (71.6%). Only 45.6 percent of the yellow poplar group was merchandised as sawlogs; however, an additional 26.2 percent was devoted to peeler markets.

Overall utilization

When the in-woods and landing utilization rates are combined, an overall utilization rate can be calculated for the harvests sampled. The overall utilization rate for the 30 harvest sites was 86.9 percent (SD = 11.8%). Again, the soft-hardwood species group had the lowest overall utilization rate followed by white oak (Table 8). The pine group had the highest overall utilization rate and yellow poplar had the second highest.

Pearson correlation test results found no relationship between the distance to individual markets and overall utilization on harvested sites. Similarly, no relationship was

Table 7.—Total volume and in-woods utilization percentage for trees harvested on 30 active harvest sites in West Virginia during 2008.

Total volume (ft^3)						In-woods utilization (%)		
Sawlog		Pulpwood		Tree				
Used	Not used	Used	Not used	Used	Not used	Sawlog	Pulp	Total tree
61,932.6	3,890.5	3,887.2	5,261.6	65,819.9	9,125.1	94.1	42.5	87.8

Table 8.—Average overall utilization rate for species groups sampled on 30 timber harvests in West Virginia during 2008.[a]

Species group	Utilization (%) In-woods	Landing	Total
Pine spp.	96.3	98.0	94.1
Yellow poplar	91.0	97.6	89.3
Cherry	90.3	97.7	88.4
Soft maple	87.7	98.0	87.5
Hickory spp.	87.0	97.7	85.9
Mixed hardwood	84.1	98.8	85.8
Hard maple	83.8	99.4	84.6
Red oak	85.6	97.8	84.5
White oak	84.7	97.4	83.9
Soft hardwood	79.0	96.3	76.9
All species combined	87.8	97.9	86.9

[a] Table is sorted in descending order of total utilization.

detected between distance to pulpwood market and overall utilization for those cases in which a proximally located pulpwood market was not exploited.

Utilization rates on sites that had a forester involved versus those sites that did not were not significantly different ($P = 0.5850$). Sites with a forester involved averaged 86.6 percent utilization versus 88.2 percent on sites without. There was a significant difference in utilization rate among logger types ($P = 0.0112$). Both independent (88.5%) and contract (88.3%) loggers had higher average utilization rates than company loggers (77.5%).

The utilization rate for companies that were fully mechanized versus those that were not did not differ ($P = 0.1789$). Likewise, no difference in overall utilization was found for those loggers with a high number of markets ($P = 0.6320$) or a high number of employees (0.9412) compared with those with a lower number.

Discussion

As public interest in sustainability has increased, so has the importance of documenting the efficient use of our hardwood resources. This information is used to not only forecast the use of this resource but also to determine the amount, sizes, and types of materials that are available for both existing and new product markets and the overall efficiency of our industry.

In West Virginia, like other central Appalachian states, timber is harvested by loggers under contract with the timber owner, those who work directly for hardwood sawmills, and those who work independently. As in past studies (Alderman and Luppold 2005, Wang et al. 2007), we found that contract loggers were most prevalent in West Virginia, followed by company crews, and independent loggers. Typically, contract loggers supply higher value sawlogs on a per thousand board feet basis to the contracting mill, and many times rely on markets for low-grade material to supplement their revenue. Company crews are normally on the payroll of hardwood sawmills, and their main role is to supply the sawmill with raw materials. Independent loggers function alone, with products moving to those facilities that will pay the highest prices while meeting the minimum price expectations of the logger.

Those harvesting timber in West Virginia have access to a wide variety of markets. During the period of data collection, a wide number of markets, both inside and outside the state, were available to those producing roundwood products. These include hardwood-grade and scragg mills; pulpwood facilities; two OSB facilities that were both centrally located in the state; a plywood veneer mill (also centrally located); an engineered wood product structural product veneer mill; several rustic fence markets; as well as a number of concentration yards for hard-hardwood pulp, sawlog, and hardwood veneer markets. The overall distribution and frequency of roundwood markets can vary according to a number of factors. Roundwood

Table 9.—Product class–based breakdown of merchandised volume for each species group based on a 2008 harvest utilization study in West Virginia.

Species group	Merchandised volume (%) Sawlog	Peeler	Pulp	Fence rail	Fence post	Firewood	Scragg	Waste
Cherry	74.1	0.0	22.2	0.0	0.0	1.1	0.3	2.2
Hickory spp.	52.2	0.0	45.4	0.0	0.0	0.0	0.0	2.3
Hard maple	71.2	0.0	17.3	0.0	0.0	2.2	8.4	0.8
Mixed hardwood	48.3	0.0	37.4	0.0	1.8	0.0	10.6	1.8
Pine spp.	37.3	0.0	8.7	35.7	14.9	0.5	0.0	2.9
Red oak	79.8	0.0	13.3	0.0	0.0	1.9	2.2	2.8
Soft hardwood	38.3	14.4	31.8	0.0	0.0	0.0	12.0	3.6
Soft maple	54.2	0.0	37.3	0.0	0.0	0.0	6.7	1.7
White oak	71.6	0.0	17.9	1.5	0.0	3.5	2.7	2.8
Yellow poplar	45.6	26.2	13.8	10.6	0.0	0.0	1.1	2.6

markets typically develop based on the local species mixes as well as quality characteristics of the resource (Luppold and Bumgardner 2004). Other factors such as transportation efficiencies, companion industries, and governmental support can influence the development of markets over time. West Virginia has historically been a heavily forested state with a large variation in species composition as well as bole quality. In 2007, the top 10 tree species (based on volume) represented 71 percent of the total volume of live trees on forest land and the majority of the private forestlands were composed of trees in the largest stand size classes (Widmann et al. 2010).

At this time there are approximately 200 companies that purchase and/or process roundwood materials in West Virginia. An even greater number exist outside West Virginia but within economically feasible trucking distances. Historically, the most important of these has been hardwood grade mills. This trend is still evident today. Although we identified seven different markets, only sawmills were supplied by every contractor surveyed in this study. While we did not differentiate among different types of sawmills, veneer mills, or pulpwood mills as in Luppold and Bumgardner (2004), all of the product markets that were identified had little overlap. Our results are comparable to those of Alderman and Luppold (2005), who identified approximately 10 West Virginia roundwood markets, Wang et al. (2007) who identified 9 markets in a 2006 study, and Wang et al. (2009) who identified 7 markets. The average number of markets used per harvest site was slightly lower in this study than the Alderman and Luppold (2005) project (3.6 vs. 4.0). This is probably due to the contraction in the overall West Virginia forest products industry that continued through 2009. This also can be seen in the lower number of employees per crew and truckloads per day recorded in this project versus Wang et al. (2007). Likewise, the Alderman and Luppold (2005) study did not differentiate between those harvests with and without foresters. Our survey found that those sites with foresters averaged a higher number of markets than those without. It is possible that the harvests surveyed in the earlier article had more forester involvement. While evidence does not exist linking foresters to a higher number of markets, research has shown that landowners who involved foresters in the timber sale process were more satisfied with the outcomes of the harvest operation (Egan 1999).

Theoretically, the number of markets used by a logger could influence the manner in which the resource is harvested. As the number of available markets increases, we would expect the utilization rate to increase. This would be especially true if all markets were complementary and not competing. We found that less than half of the loggers surveyed delivered to each of the three markets that were cited most frequently by loggers in this study: sawlogs, OSB pulp, and pulpwood. The additional oversight by a forester only brought this ratio up to 50 percent. When the next major market is considered (peelers), only 33 percent of those sampled delivered to each of these top four markets.

Alderman and Luppold (2005) postulated that the type of logging crew explained much of the variation in product markets. They felt that independent loggers should have access to more markets than contract and company loggers. However, they found similar results to this study. Independent loggers actually delivered to fewer product markets than contract and company loggers. Alderman and Luppold (2005) reasoned that this was due to both the broad categorization of their product markets and terrain. West Virginia is characterized by steep slopes that can limit the size of log landings and thus limit the room for product merchandising. While these are both true, in a randomly designed study the effects of these factors should be the same for all harvests visited. This is especially true for the product category breakdowns, since the same categories were used for each harvest sampled. One possible explanation for this incongruity is that independent loggers might have access to fewer markets because they may not benefit from scale efficiencies that some contract loggers enjoy. Forest products companies that hire contract loggers typically have several contractors working for them at any given time. Thus the amount of roundwood these companies can move allows them access to more markets. Each of the loggers under contract would benefit from these circumstances.

Contrary to transportation economic theory as cited by Alderman and Luppold (2005), the highest value markets were also the closest markets in this study. The average haul distance to sawmills was less than for all other markets. Estimates from this project are similar to those of Alderman and Luppold (2005), the average distance to sawmills only increased by 4 miles over their findings. The average distance to OSB pulp markets was also similar to the results of Alderman and Luppold (2005); however, we found that the distance to the *other pulpwood markets* was approximately 20 miles greater in this study. The fact that the average distance to pulpwood markets was greater for loggers not delivering pulpwood than for those serving this market suggests that operators may have refrained from hauling to these markets as the distance increased beyond 70 miles. Typically, pulpwood buyers pay a premium for distance traveled, especially when wood inventories are low. It is possible that pulpwood inventories were high during the time of this study and loggers working at greater distances from these facilities were not encouraged to make roundwood deliveries.

There are few studies that have reported overall utilization of roundwood during harvest operations in the Appalachians. Probably the most extensive work has been conducted in Virginia and North Carolina by the USDA Forest Service's Southern Research Station. The in-woods utilization rate found for hardwoods in North Carolina was 79 percent (Bentley and Johnson 2006). In a similar study in Virginia, overall hardwood utilization was reported as 75 percent (Bentley and Johnson 2009). The lower level of utilization in these states could be the result of many factors; however, it does not appear to be market related because there are many hardwood markets available despite the abundance of softwood volumes in these states (Bentley and Johnson 2009). Other utilization studies have shown even lower levels. Wang et al. (2009) measured whole stem utilization on 300 trees in West Virginia. On a length basis, the utilization rate averaged 58.7 percent. This is mainly due to the measurement of tree utilization with total tree height as the denominator, as well as the fact that it is on a length basis. Volumetric measures of utilization are much better than length-based measures because they give a better estimate of the actual material being used and left in the woods.

As expected, utilization rates on the landing were much higher than those found in the woods. Every piece of stem not used on the landing represents wasted time, fuel, and ultimately profitability for the logger. In West Virginia, the majority of stems are bucked for grade/value on the landing. Therefore, those sections not used on the landing were likely discarded because they reduced the value of the piece in question. Bucking productivity is also highly dependent on stem size and length (Wang 2007), two variables that can also affect landing utilization rates.

In this project, oak species had lower in-woods utilization rates than species with a more excurrent branching pattern, such as pine species and yellow poplar. Species-specific utilization is also heavily dependent on the buck-off point in the woods. Both the pine species group and yellow poplar had much smaller diameters at buck-off than the oaks. While markets also influence the utilization of these species, we did not find any direct relationships between distance to market and species-specific utilization. Likewise, no relationship between overall utilization and markets was revealed, which is similar to the results from previous studies where logging residue accumulations were investigated (Grushecky et al. 2007). Utilization rates were found to be even higher in this study when product category was considered. Sawlog-sized material had an overall utilization rate of 94 percent in this project, which is the same as the North Carolina (Bentley and Johnson 2006) and lower than the Virginia (Bentley and Johnson 2009) studies, which reported 94.1 and 96.0 percent utilization rates, respectively. The main reason the in-woods utilization rates were lower in the Virginia and North Carolina studies is the pulpwood utilization rates. In Virginia, pulpwood utilization averaged 32 percent, and in North Carolina it averaged 18.5 percent. These were both much lower than the 42.5 percent pulpwood utilization rate found in this project. This is likely due to the prevalence of hardwood pulp and other nonsawlog markets in West Virginia. This evidence is strengthened by the fact that over 80 percent of tree stems on the landing that did not have a sawlog removed were merchandised into three main secondary markets: pulpwood, peeler, and rail material.

Results from this project help us understand current hardwood tree utilization on sites in West Virginia. Not only does this information provide estimates on the overall efficiency of harvest operations, but it also allows us to determine the characteristics and quantity of material being left after harvest. This information is important not only to those involved in the management of the hardwood resource, because it may help them recognize underutilization risks associated with different sites and harvest plans, but also to those who are making investments in wood processing industries, because it gives insight on residue amounts and characteristics. While the influence of markets and site characteristics did not explain a significant amount of the variation in overall utilization, we can assume from data collected in other states that the presence of nonsawlog markets can increase the utilization rate of pulpwood-sized material. Further research on utilization rates in other hardwood producing states in the region would help strengthen the relationship between utilization and site characteristics. Likewise, similar data from other states would strengthen the prediction equation and allow those using it to have a better understanding of its predictive capacity.

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