RELATIONSHIP BETWEEN LOGGING RESIDUE ACCUMULATIONS AND SITE CHARACTERISTICS IN SOUTHERN WEST VIRGINIA

Shawn T. Grushecky, David W. McGill, Stephen M. Perkins, and R. Bruce Anderson[†]

ABSTRACT.—In West Virginia, substantial volumes of logging byproducts, in the form of unwanted logs, limbwood, and treetops, remain on the ground following timber-harvesting operations. While these residues are ecologically important, their recovery and utilization following harvesting may have tremendous economic potential. We investigated logging residue accumulations after timber harvesting in fire-prone southern West Virginia using line-intersect methodologies. Seventy timber harvests that occurred during 2000-2001 were sampled for logging residue accumulations. The average diameter measured at the intersection with sampling transects for all residue was 7.3 inches. The average overall weight of wood residue left after timber harvest in the 14-county region was 10.4 tons/acre. Oak species had the highest residue accumulations followed by mixed hardwoods and maple species. We found little relationship between distance to landing, distance to market, and average slope with residue accumulations. Relationships between distance to markets and residue accumulations were analyzed for a number of potential residue buyers in the region. Because of their ecological importance, we do not recommend complete use of this resource. However, when left in the woods, logging residues are not converted into useable products, and ultimately, more jobs for the Appalachian region. More emphasis needs to be placed on the further utilization of this resource in West Virginia.

Introduction

Large amounts of logging residues or "slash", in the form of unwanted logs, limbwood, and treetops, are abundant after timber harvesting in West Virginia (Grushecky et al. 1997). Logging residues contribute to the diversity and cover resources of a logged site (McComb 2003), whereas factors such as piece orientation, size, decay state, species and abundance of coarse woody debris dictate its importance to wildlife (Harmon et al. 1986). Logging residue, or course woody debris, is an important component of the habitat requirements for birds (Lohr et al. 2002), amphibians (Butts and McComb 2000), and small mammals (Loeb 1999). Future site productivity can also be impacted by the additions or removals of logging residues. Appalachian forest floor mass has been found to be greater immediately following cutting, and then falls to pre-cut levels within several years (Johnson et al. 1985, Mattson and Swank 1989). Johnson et al. (1985) determined that soil solution concentrations of NH_4^+ -N, NO_3^- -N and K were higher in cut areas harvested with a whole-tree system in Appalachia. In the southern Appalachians, long-term soil cation concentrations were not impacted by commercial sawlog harvests (Knoepp and Swank 1997).

Environmental impacts of logging residue removals must be balanced with economic benefits of their recovery. The utilization of logging residues may have tremendous economic potential in a state that relies heavily on its wood products industry. In 1997, the wood products industry accounted for over $1 billion of the states total manufacturing output (U.S. Census Bureau 1997). This represents approximately 6 percent of the total manufacturing output in West Virginia, and does not include logging and forest management activities, both large components of the primary manufacturing industry. Within the past decade, several large wood products firms have established manufacturing facilities in West Virginia that use low-grade wood in their composite, or engineered wood products (Luppold et al. 1998). Before this, the market for low-quality roundwood in West Virginia was very limited. Currently, wood contained in logging residues is suitable for use in many engineered wood products, and potentially, for other value-added products in future markets. Efficient recovery of this material is imperative, especially since skidding and trucking have been identified as potential barriers against increased hardwood production in the area (Luppold et al. 1998).

[†]Assistant Director (STG), Appalachian Hardwood Center; Associate Professor (DWM) and Silviculture Extension Specialist, Graduate Research Assistant (SMP), and Assistant Professor of Wood Science (RBA), West Virginia University Division of Forestry, PO Box 6125, Morgantown, WV 26506-6125. STG is corresponding author: to contact, call (304) 293-2941 x2413 or email at sgrushec@wvu.edu

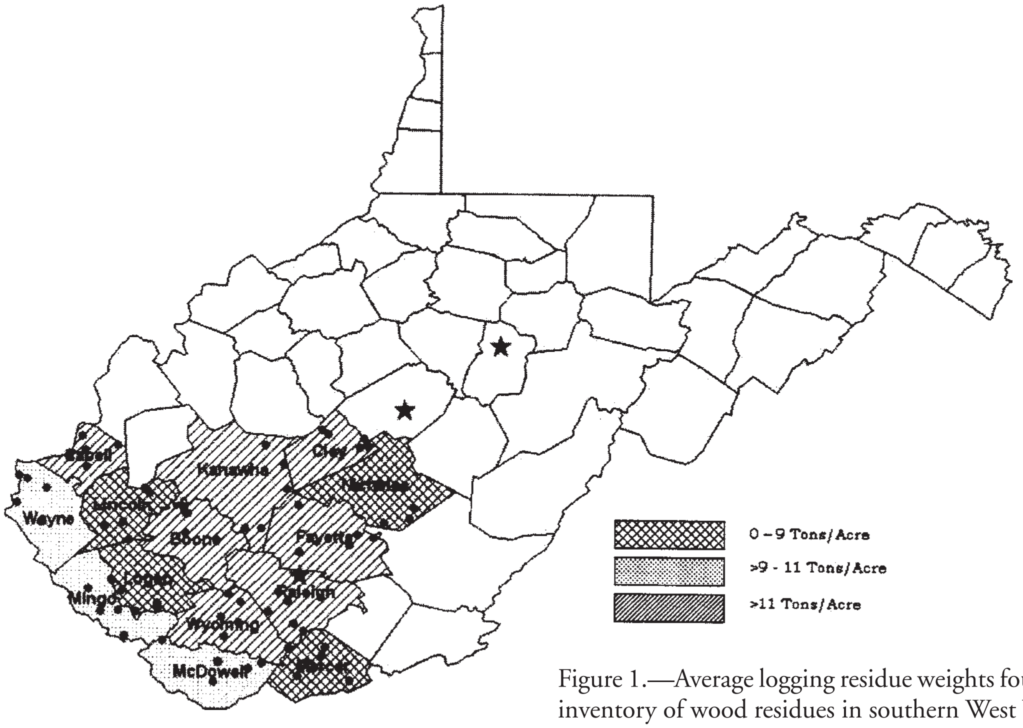

Figure 1.—Average logging residue weights found during a 2002 inventory of wood residues in southern West Virginia. Dots represent logged areas sampled for woody residues. Stars represent locations of engineered wood products facilities in West Virginia.

As part of a larger research project funded by the USDA Forest Service to investigate forest fire fuel wood loadings, we sampled logging residues in southern West Virginia. The objectives of this study were to investigate the impacts of harvest site characteristics, including slope, terrain, and distance to markets, on the amount of logging residues remaining after harvest.

METHODS

Logging Residue Estimation

Line intersect sampling was used to sample logging residues in southern West Virginia. A total of 5 harvested sites were sampled in each of 14 southern West Virginia counties during the summer of 2002 (fig. 1). Harvest blocks were at least 20 acres in size to eliminate any edge bias. Each harvested site was selected randomly from a list of all harvests conducted during 2000-2001 in the focus counties. Harvest sites were located using West Virginia Division of Forestry logging notification forms, which are mandated under the 1992 Logging Sediment Control Act. Under this act, all loggers are required to submit a harvest plan before timber operations commence.

At each logging site, woody residues were sampled using a logged area analysis methodology (Warren and Olsen 1964, Van Wagner 1968, Bailey 1970, Martin 1976, Van Wagner 1982, Hazard and Pickford 1986). Starting from the main log landing, sampling points were randomly located within the harvest boundaries; all sample points were 198 ft. (3 chains) apart. Locations for residue points were found by selecting a random azimuth and distance from enumerated skid trails. From each point, two 100-ft-long transects were established. The first was located by selecting a random azimuth. The second transect was set at a right angle to the first, so each transect began at a common point. The UTM coordinates for each sample point on every harvested site were recorded using a Trimble GeoExplorer 3 global positioning system (GPS). All spatial data were geo-referenced after collection in the field.

Field technicians measured the wood residue as they walked along transects, recording the diameter and species of each residue piece at the point where it intersected the transect. All residue pieces were at least 4 in. in diameter at the small end and 4 ft. long. Fifteen sample plots (each made up of two

100 ft. transects) were located in each harvest for a total of 3000 ft. of transect per logged site. One of every four transects was sampled intensively to provide information related to residue characteristics. On intensive lines, measurements included the species and diameter at the transect intersection, as well as the small end diameter (to a minimum of 4 inches), large end diameter, piece length, and potential product (pulpwood versus sawtimber).

To calculate volumes and weights of logging residues, we used equations first developed by Warren and Olsen (1964) and modified by Van Wagner (1968). Van Wagner (1968) gave the following weight equation:

$$W = \frac{11.65S\sum d^2}{L}$$

where W is the weight of logging residue in tons/acre, S is the specific gravity of the logging residue, d is the diameter of logging residue at intersection with transects, and L is the length of the sampling transect. Van Wagner (1968, 1982) describes the development of logging residue equations in eloquent detail.

Average Slope of Harvested Site

Harvest boundaries for each of the 70 sites were obtained from the West Virginia State Division of Forestry notification records. Boundaries were digitized and converted into geo-referenced layers in a geographic information system (GIS) using ArcView 8.3 (ESRI, 380 New York Street Redlands, CA 92373-8100). Likewise, digital elevation models (DEM), in the form of an elevation grid, were incorporated into the GIS for each of the harvest sites. The ArcView 8.3 Spatial Analyst extension was used to calculate the mean slope percentage for each of the harvested tracts based on the clipped DEM for each harvest location, thus limiting slope estimations to the harvested areas.

Distance between Sample Point and Landing

Distances from residue sampling points to log landings were measured to determine the effect of skid distances on material recovery. Layers consisting of UTM coordinates for each residue sample point and landing locations were developed in the project GIS. A coordinate extension available for ArcView 8.3 was used to calculate the distance between each residue sampling point and the log landings. Distances calculated represent a straight line between the residue sampling locations and landings. This measurement represents skid turn distance well because in most cases, as the straight line distance between the landing and sample point locations increases, so does actual skidding distance.

Distance Between Harvest Sites and Engineered Wood Products Markets

Using the GIS, we calculated the total distance between the main log landing on each harvested site to three main users of woody residues in West Virginia; the Weyerhaeuser oriented strandboard (OSB) plant in Heaters, WV, the Georgia Pacific OSB facility in Mt. Hope, WV, and the TrusJoist Parallel Strand Lumber and Laminated Strand Lumber facility in Buckhannon, WV. We chose these facilities because they are an end market for the majority of low quality roundwood produced during timber harvests in West Virginia. For each harvested site, we attempted to calculate 2 alternative routes to each market. Routes were chosen based on the shortest distance suitable for tractor-trailers hauling residue. Routes were measured by digitizing roads between landings and markets using a distance-measuring tool in the GIS.

Results

We sampled 2100 transects in southern West Virginia during the summer of 2002 and measured a total of 5796 pieces of logging residue. This represents approximately 40 miles of logging residue transects. The most prevalent species of logging residue was yellow-poplar (*Liriodendron tulipifera*), representing 14.5 percent of the residue crossed by transects. Yellow-poplar was followed by red oak (*Quercus rubra*) and white oak (*Quercus alba*), which accounted for 13.3 percent and 10.2 percent of the number of residue pieces, respectively.

Table 1.—Average diameter of species at intersection with residue transects. Listed along with the average diameters and their respective standard deviations (in parentheses) are the average weight, average small end diameter, average large end diameter, and average length of logging residue sampled in southern West Virginia.

Species[a]	Mean Diameter	Weight (Tons/ac)	Small End Diameter	Large End Diameter	Length
Cherry	6.4 (2.7)	0.1 (0.2)	5.3 (2.4)	8.1 (3.1)	19.1 (11.9)
Maple	6.4 (2.6)	1.2 (1.0)	4.5 (1.3)	7.4 (2.7)	20.0 (11.9)
Misc. Hardwoods	7.3 (3.5)	2.5 (2.0)	5.0 (2.3)	9.3 (4.4)	21.1 (12.0)
Oak	7.7 (3.6)	5.0 (3.1)	4.8 (2.0)	9.6 (3.9)	20.1 (10.6)
Soft hardwoods	7.9 (3.7)	0.2 (0.4)	4.4 (1.2)	8.6 (3.4)	19.0 (10.0)
Softwoods	7.2 (3.1)	0.1 (0.3)	4.8 (1.5)	9.1 (3.8)	21.5 (14.2)
Yellow-poplar	7.2 (3.0)	1.2 (1.0)	5.2 (2.0)	9.1 (3.0)	20.3 (12.1)

[a]Cherry - black cherry (*Prunus serotina*); Maple - red maple (*Acer rubrum*), sugar maple (*Acer saccharum*); Oak - red oak (*Quercus rubra*), black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), American chestnut (*Castanea dentata*); Soft Hardwood - aspen (*Populus spp*.), basswood (*Tilia americana*), cucumber (*Magnolia acuminata*), sycamore (*Platanus occidentalis*), tree-of-heaven (*Ailanthus altissima*); Softwood - eastern hemlock (*Tsuga canadensis*), pine (*Pinus spp*.); Yellow-poplar - yellow-poplar (*Liriodendron tulipifera*); Miscellaneous Hardwoods - American elm (*Ulmus americana*), black birch (*Betula lenta*), American beech (*Fagus grandifolia*), black gum (*Nyssa sylvatica*), black locust (*Robinia pseudoacacia*), yellow buckeye (*Aesculus octandra*), American dogwood (*Cornus florida*), fraser magnolia (*Magnolia fraseri*), hickory spp. (*Carya spp*.), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), yellow-birch (*Betula alleghaniensis*).

The average diameter measured at the intersection with sampling transects for all residue was 7.3 inches. The corresponding maximum diameter was 34 inches. To facilitate result interpretations, residue was broken down into 7 groups based on species attributes and marketability (table 1). The soft hardwood species group had the largest diameters at intersection (7.9 inches), but the second lowest frequency (77 pieces measured). Oak species had the second largest diameter at intersection (7.7 inches) and the largest frequency (2117 pieces measured) (table 1). The average overall weight of wood residue left after harvest in the 14-county region was 10.4 tons/acre. The minimum tonnage found among the 70 harvest sites visited was 2.3 tons/acre and the maximum was 20.3 tons/acre. The highest residue volumes were found in the central portion of our study area (fig. 1).

Oak was the most prevalent species group by weight, averaging 5.0 tons/acre over the study area (table 1). Miscellaneous hardwoods and maple species followed the oaks with 2.5 and 1.2 tons/acre respectively. Black cherry had the lowest average weight over the study area at 0.1 tons/acre remaining after harvest. The maximum amount of residue left of any one species was 15.1 tons/acre for oaks. Oaks, followed by miscellaneous hardwoods, had the largest accumulations of residue in the study area. The dominance of oak as logging residue in the study area is further emphasized when compared to the next three highest species in terms of total weight, miscellaneous hardwoods, maple species, and yellow-poplar (fig. 2).

On intensive transect lines; large and small-end diameters and total lengths were recorded so that residue piece size could be characterized. A total of 1305 pieces of logging residue were measured on intensive lines. The average large-end and small-end diameter of the pieces measured on intensive lines was 9.2 and 4.9 inches, respectively. The average length of all logging residue was 20.4 feet.

Oak species had the largest average large-end diameter of 9.6 inches. Miscellaneous hardwoods followed oak with an average large-end diameter of 9.3 inches. Yellow-poplar followed oaks and miscellaneous hardwoods with an average large-end diameter of 9.1 inches. Overall lengths were similar by species (table 1). Softwoods and miscellaneous hardwoods had the longest average lengths of 21.5 and 21.1 feet, respectively. These were followed by yellow-poplar residue that had an average length of 20.3 feet.

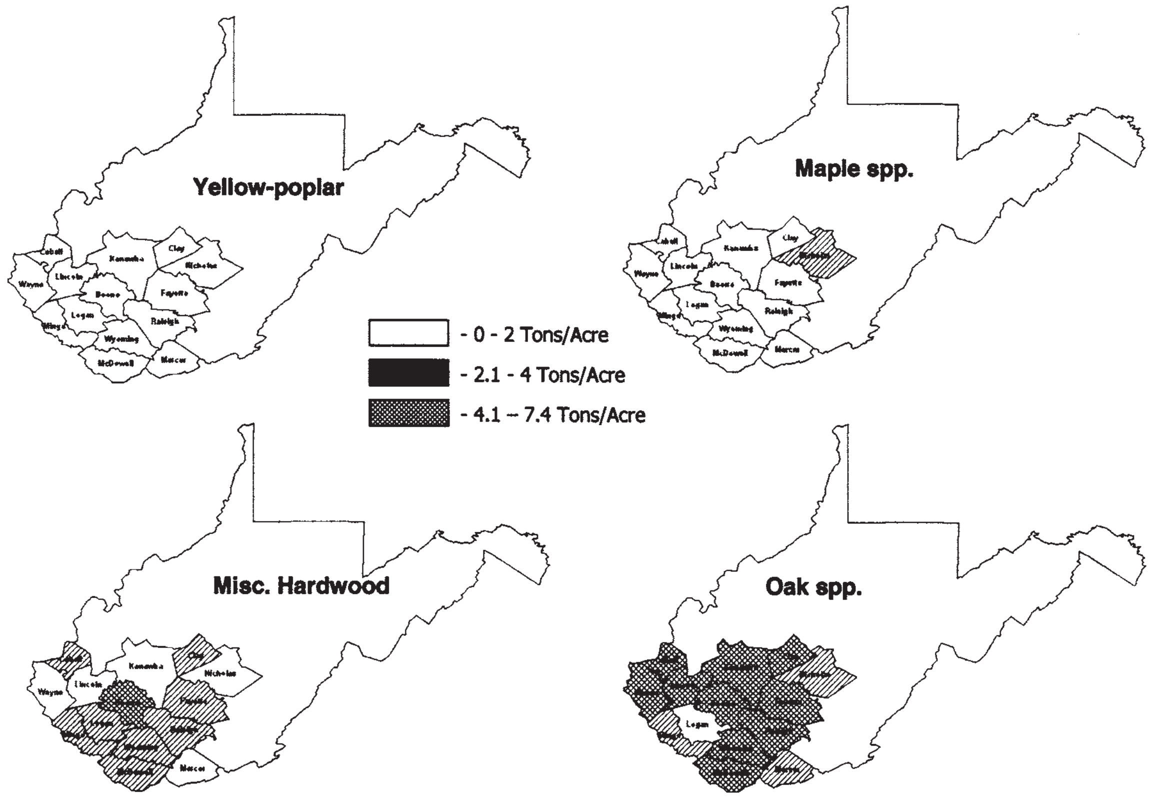

Figure 2.—Average logging residue weights for the top 4 species groups found during a 2002 inventory of wood residues in southern West Virginia.

Logging residue piece size was used to calculate the total amount of "marketable" residue available in the study area. This was based on determining the total volume of residue that met a 12-foot length criterion, which is a common specification in the engineered wood products industry in West Virginia. Once volume was calculated that met length specifications, total residue available was determined by multiplying the total weight available per acre by the average acres harvested in each county per year. Harvest data were obtained from notification forms supplied by the West Virginia State Division of Forestry. A total of 810,584 tons of residue were available during the study period in the 14-county region (table 2). When the residue loads were further broken down by species acceptable for the engineered wood products industries in West Virginia (Weyerhaeuser, Georgia Pacific, TrusJoist), approximately 332,649 tons of logging residue were available during the sampling period in the 14-county area.

The average slope of harvested areas sampled in southern West Virginia was 30.8 percent (± 9.3 percent). We did not find any evidence that slope had any influence on total residue accumulations remaining after harvest (r=-0.09, P=0.43). The average distance between residue sampling points and the log landings of harvests measured in southern West Virginia was 979.8 feet (±490.5 feet). We did not find a relationship among distances from landings to the location of our sample points (r=-0.13, P=0.28).

The average distance to an engineered wood product facility from the harvest locations sampled in southern West Virginia was 108.9 miles (± 42.5 miles). The Truss Joist facility was farthest, on average, from the logged sites sampled at 153.2 miles (± 60.8 miles). The Georgia Pacific Oriented Strand Board plant was the closest, on average, to the logged sites sampled at 68.5 miles (± 31 miles). The Weyerhaeuser Oriented Strand Board plant averaged 105.2 miles (± 35.9 miles) from the logged areas sampled. We found no significant correlations among the distances from harvest landings on those sites sampled and the Engineered Wood Products facilities in West Virginia.

Table 2.—Total residue weight (tons/acre) found remaining after harvest in each of 14 counties sampled in southern West Virginia. Total residue available was calculated using the percentage of the total volume that met a 12 foot length specification. Acres harvested are average of years 1992-2001, obtained from West Virginia State Division of Forestry Logging Notification Forms.

County	Total Weight (Tons/Acre)	Percent Length Specification	Total Avail/Acre (Tons/Acre)	Acres Harvested	Total Tons/Year
Boone	12.7	0.87	11.0	9342	102,762
Cabell	11.7	0.75	8.8	1965	17,292
Clay	11	0.9	9.9	6447	63,825
Fayette	11	0.79	8.7	9169	79,770
Kanawha	11.3	0.84	9.5	13712	130,264
Lincoln	9	0.71	6.4	3220	20,608
Logan	7.1	0.7	5.0	6860	34,300
McDowell	10.8	0.89	9.6	9223	88,541
Mercer	7.8	0.83	6.5	2606	16,939
Mingo	10.1	0.88	8.9	4101	36,499
Nicholas	8.2	0.53	4.3	9363	40,261
Raleigh	11.7	0.83	9.7	9755	94,624
Wayne	10.5	0.78	8.2	2057	16,867
Wyoming	12	0.82	9.8	6942	68,032
Totals	144.9	11.12	116.3	94762	810,584

Discussion

The quantity of logging residues remaining after timber harvesting likely varies according to the intensity of the harvest operation and the available markets. There continues to be a substantial amount of woody residue remaining on site after timber harvesting in West Virginia. In southern West Virginia, Grushecky et al. (1997) found from 6.2 to 15 tons/acre of logging residues remaining after harvests that occurred in 1993-1994. With this research project, we found a similar amount of residue at 10.4 tons/acre in southern West Virginia. By species, logging residue breakdowns also were similar. In the 1993-1994 period, oaks were the prevalent residue, followed by mixed hardwoods and yellow-poplar (Grushecky et al. 1997).

Economic factors are likely the main determinant of the composition of logging residues remaining after harvest. The lower the value of the logging residues, the more likely it will be left on site. Efficient recovery of logging residues must occur at the time of harvest to remain profitable. Many of the factors that cause useable residue pieces to be left in the woods interact with one another. For example, skidding efficiency, site visibility, potential markets, and material quality all work together to generate the residue levels observed following timber harvesting in the region. Skidding and trucking have been cited as barriers to loggers wanting to increase production, especially in southern West Virginia (Luppold et al. 1998). We found little evidence that distance to markets, skid distances, and/or the average slope of harvested sites affected residue concentrations. Because of the high degree of variability in harvesting, markets, and site characteristics, there is a correspondingly high variation associated with residue weight estimates. Therefore, variation in residue loads hindered our efforts at discovering relationships among site characteristics and logging residue volumes. However, since harvests were chosen randomly for this project, we assume that the residue loads reported are a representative sample of all harvests in southern West Virginia.

Although no relationship was found among site factors and logging residue levels, the logging residue resource characteristics found through this study are important. If all species of logging residues are considered, there was enough logging residue to run a engineered wood production facility a total of 406 days, assuming the use of 2000 tons per day. Thus, this region alone could support an additional engineered wood products facility or a biomass conversion refinery, if they could make use of all residue species. This is especially true if the ring porous hardwoods such as oaks (*Quercus* spp.) could be better utilized. Oak is highly sought after for dimensional lumber, yet most engineered wood products facilities in West Virginia prefer only small quantities of oak because of its undesirable physical properties for composite manufacturing. From a utilization standpoint, this is unfortunate as there is about 2.4 times the amount of residue at least 12 feet long when oak is included in average residue loading calculations. More emphasis needs to be placed on the use of lower quality, smaller oak in the form of topwood, pulpwood and unwanted logs. The feasibility of using this unwanted oak residue for value added products such as flooring, or components for the furniture and cabinet manufacturing industry, was addressed in the late 1970s and early 1980s (Reynolds and Gatchell 1979, Reynolds et al. 1983, Hansen and Araman 1985). These approaches or new technologies that allow for the co-firing of power plants or bio-refineries that use wood biomass need to be evaluated under current market conditions, especially since recent policies propose decreasing the United States dependence on foreign fuels.

When left in the woods, logging residues are not converted into useable products, and ultimately, jobs for West Virginians. However, logging residues remain an important component of Appalachian forest ecosystem. For this reason, we do not recommend complete utilization, but we should strive to use a greater portion of this valuable resource. While we typically think of the larger firms as creating the main demand for wood residue, other opportunities may exist for composite or solid fuel products and should be considered when developing marketing plans for these residues.

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