ECONOMICS OF MERCHANDISING PULPWOOD IN WEST VIRGINIA

*Shawn T. Grushecky**

Assistant Director
E-mail: sgrushec@wvu.edu

Curt C. Hassler

Research Scientist
Appalachian Hardwood Center
Division of Forestry and Natural Resources
West Virginia University
Morgantown, WV 26506-6125
E-mail: curth@mail.wvnet.edu

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Abstract. There has been renewed interest in determining the feasibility of pulpwood merchandising yards in the Appalachian region. Intensive merchandising is a potential way to supply raw material to traditional markets as well as current and new weight-based pulp markets at a lower cost. The feasibility of developing a hardwood pulpwood sorting merchandising yard in West Virginia was investigated. More than 171,000 kg of pulpwood was procured for this project. The majority of the pulpwood purchased was red and white oak followed by black cherry and hickory. Results indicated that between 3.6 and 6.0 t of pulpwood was needed to saw 1 m^3 of lumber. The merchandising operation resulted in negative net revenues for all species studied. Handling cost was found to be one of the most important issues leading to this finding. However, it was found that merchandising low-quality sawlogs on the log-landing could be profitable. The cost and revenues reported in this study represent a complex blend of pricing and product yields that are dynamic with time. As weight-based markets, such as engineered products and bioenergy, expand and competition increases with traditional markets, inputs could be refined which would create a new set of merchandising options for roundwood.

Keywords: Concentration yard, roundwood markets, merchandising, pulpwood, low-grade sawlogs.

INTRODUCTION

West Virginia (WV) is the third most forested state in the nation (Widmann et al 2012). This resource base supports an extensive and diverse wood products industry. Although the current economic downturn has decreased the number of facilities, WV has supported more than 200 hardwood roundwood consumers (Alderman and Luppold 2005).

Several of these consumers focus their procurement on low-quality small-diameter material. These include markets for traditional pulp and paper production as well as for engineered wood products (EWP), plywood, and rustic fence plants. Of these, paper mills procuring small-diameter hardwoods in WV represent a significant market for roundwood pulpwood. EWP producers also procure high volumes of pulpwood; however, most of this procurement is limited to soft hardwood species. The addition of these markets in the mid-1990s increased timber consumption in WV, especially small-diameter and low-quality roundwood. Although markets exist for this material, there is still a large portion of low-quality roundwood that remains on the ground after harvest (Grushecky et al 2006). The lack of use may not be because of insufficient size; the average large- and small-end diameter of pieces measured was 23.4 and 12.5 cm, respectively, with an average length of 6.2 m (Grushecky et al 2006). These dimensions meet minimum product specifications for all current hardwood pulp markets in WV, therefore increased use of this resource may be possible.

* Corresponding author

One of the greatest barriers to increased extraction of this hardwood material is the cost (Grushecky et al 2007). One way to potentially increase the procurement of the remaining roundwood is to source it concurrently with higher-value products. Traditional sort yards have been gaining more attention as a potential means of generating profits for wood fiber producers (Anon 2009a; Ciolkosz et al 2010). Others have considered the storage of logging residues on landings as an integral part of models developed estimating delivered cost of biomass for bioenergy production in WV (Wu et al 2011).

Theoretically, a concentration yard approach could help provide lower-cost raw materials by sharing sorting costs as well as dynamically supplying higher-value markets with appropriate materials, especially if this can be done in conjunction with a current sawmilling operation. The underlying concept would function as described by Dramm et al (2004), except as new markets developed, the number of merchandising decisions would increase. The purchase of large-diameter, low-defect sawlogs at such an operation would not be feasible because competition for this resource is intense, thus making their procurement difficult. However, at $27-33/t, loggers have been supplying large amounts of pulpwood to paper and EWP in WV for many years. Because we know a portion of this roundwood easily meets low-grade sawlog specifications (Grushecky et al 2006), there may be an opportunity to purchase pulpwood at market prices and use the sawlogs that are merchandised to subsidize the cost of the remaining fiber. Such a system could also increase the use of logging residues by providing a framework for processing this resource into higher-value markets. Recently, a case study approach was used to evaluate the economics of processing small-diameter red oak in a sawmill and pallet-part mill setting (Perkins et al 2008). However, no investigation of enhanced pulpwood merchandising has been conducted in the region. The objective of this study was to determine if an opportunity exists to merchandise logs of value from pulpwood and market the remaining byproducts into weight-based markets.

METHODS

Production Components

Pulpwood was procured from several logging companies located in central WV. Six tractor trailer loads of hard hardwood pulp (red, black, white, and chestnut oak and hickory) as well as four tractor trailer loads of black cherry pulp were purchased directly from local loggers at prevailing market prices. This effectively diverted them from their original market destination (either EWP or pulping facilities). Although roundwood pulpwood specifications may vary somewhat with geographic region, the following specifications for pulpwood were used for this study: a minimum 10.2- to about 71-cm diameter and roughly 2.4-7.3 m long. These specifications were directly related to pulpwood markets available to the loggers used in this study as well as those sampled during logging residue field studies.

Once unloaded, pulpwood was merchandised using a high lift and mechanically bucked using a chainsaw. Crew members were trained and assisted in merchandising/bucking techniques by a primary processing facility owner with more than 30 yr log-buying experience. Each section of pulpwood was evaluated for potential to merchandise one or more sawlogs from that piece. Merchandising resulted in three product types: sawlogs, pulpwood, and firewood. Firewood included merchandised pieces that did not meet the minimum pulpwood specification. Minimum sawlog diameter was maintained for each species with oaks and hickory limited to a 20.3-cm minimum diameter and black cherry to a 15.2-cm minimum diameter. These diameter limits were developed based on interaction with local industry and our sawmill cooperator. All sawlogs were merchandised in standard lengths of 2.4, 3.7, 4.3, and 4.9 m but also included both 1.8- and 2.1-m logs in an attempt to take advantage of any Select lumber that might result. Each pulpwood piece was numbered with each merchandised piece designated with the piece number and a letter (A, B, C, or D). All pieces were weighed with diameters and length recorded for each piece. The position (butt or upper), number of clear sides, scaling defects (Rast et al 1973), and end condition (double heart, stain, shake, mineral, split, and interior/sector cull) were recorded for each sawlog merchandised.

The sawlogs were then transported to the sawmill for processing. The mill consisted of a circle headrig with a live deck, hydraulic log turner, and pneumatic dogs; an edger; and a chop saw for trimming. The circle saw configuration was chosen to represent a worst-case scenario with regard to saw kerf. Each log was sawn and the lumber and cant products recorded by species and log number. All lumber was graded according to standard National Hardwood Lumber Association lumber grading rules, and cants were sawn into 1.2-, 1.8-, 3.1-, or 3.7-m lengths and as either 139 × 152 mm or as 102 × 152 mm. Because of the large proportion of small-diameter sawlogs, tie and timber products were not included in the product mix.

Resulting data were standardized to a per cubic meter lumber and cant products basis. The following formula was the basis for determining profitability of the merchandising options:

$$NR = RL + RPW + RSR - CPW - CH - CS$$

where

NR = net revenue per 1 m^3 of lumber and cant products produced ($);
RL = lumber and cant revenue ($);
RPW = net residual pulpwood revenue, following merchandising ($);
RSR = net residual sawmill residue revenue, including bark, sawdust, and chips ($);
CPW = roundwood pulpwood cost ($);
CH = handling/merchandising cost ($); and
CS = sawing cost to produce lumber and cant products ($).

Lumber and cant revenue is based on lumber grade yields of the logs and selling price of the products sawn. Revenue from 1 m^3 of lumber and cants produced was determined by applying lumber grade yields to 1 m^3 of lumber and multiplying that yield by product prices.

The economic feasibility of merchandising pulpwood for sawlogs is highly dependent on prices received for the lumber and cant products produced. As prices change with time, the economic feasibility can change. Therefore, one logical approach is to select prices that are at or near their recent historic lows. Then, if economic feasibility can be achieved, one can be reasonably sure that merchandising remains a viable alternative. For the purposes of this study, pricing is based on Hardwood Market Report prices for December 2009 (Anon 2009b), which were at or near the bottom of hardwood pricing for the last decade (Table 1).

Roundwood pulpwood cost is determined from the total weight of pulpwood that must be purchased to generate 1 m^3 of lumber and cant products. This is based on the lumber and cants sawn from a ton of sawlogs and the weight of roundwood pulpwood required to generate this 1 m^3 lumber and cants. The relationship used to generate the tons of pulpwood needed to produce 1 m^3 of product takes the following form:

$$\text{Tons pulp to produce } 1\ \text{m}^3 = \frac{\text{Pulpwood WGT (kg)}}{\text{Lumber } (\text{m}^3) \times 1000\ \left(\frac{\text{kg}}{\text{ton}}\right)}$$

where Pulpwood WGT is the weight of pulpwood (kg) required to produce a given cubic meter of lumber.

The same formula can be used to calculate the weight of sawlogs needed to produce 1 m^3 of lumber by substituting sawlog weights for pulpwood weights. A base assumption of $27.55 per ton of pulpwood delivered to the merchandising site was made, which is compatible with base pulpwood pricing in the region of study. Likewise, this was the delivered price of pulpwood procured for this study. As distance from the receiving mill increases, this price could

Table 1. Lumber (4/4) and cant prices (\$/m^3) delivered to a receiving mill used in the analysis of merchandising pulpwood into sawlogs by species (Anon 2009b).

	Species			
Lumber grade[a]	Hickory	Red oak/ black oak	Black cherry	White oak/ chestnut oak
FAS	260.62	341.14	648.38	381.41
One face	256.38	336.90	644.14	377.16
Select	252.15	332.66	639.90	372.92
No. 1 com	211.89	237.31	264.86	228.84
No. 2a com	148.32	194.94	135.61	154.68
No. 2b com	63.57	63.57	63.57	63.57
No. 3a com	84.76	163.15	108.06	129.25
No. 3b com	63.57	63.57	63.57	63.57
Below grade	63.57	63.57	63.57	63.57
Cant	137.73	137.73	137.73	137.73

[a] Below-grade boards are assumed to be sold as pallet stock as are the No. 2b common and No. 3b common boards given that these two common grades are based on sound cuttings as opposed to clear cuttings.

increase by several dollars per ton to account for additional trucking cost. However, it was assumed that the merchandising yard is sufficiently distant from the fiber-receiving mill in that many suppliers working at any given time in the area of the merchandising yard will find it more cost-effective to deliver their pulpwood to the merchandising yard rather than incur additional trucking expenses in transporting it to the fiber-receiving mill. In large part, this is assumed to be a result of loggers taking advantage of the opportunity to gain at least one additional load per day (albeit at an equal or lower price) to the merchandising yard as opposed to trucking pulpwood to the more distant destination of the fiber-consuming mill. Of course, operators in other regions will certainly work under a different pricing structure for pulpwood, which should be considered when evaluating any merchandising opportunity.

Net residual pulpwood revenue (RPR) is the weight of residual pulpwood and firewood pieces following merchandising multiplied by delivered price per ton less the cost of trucking. A net delivered price of \$22.05 per ton was used for RPR based on the assumption that residual pulpwood being delivered to the fiber-consuming mill from the merchandising yard would be paid an additional premium for trucking distance but must incur a truck delivery charge. Estimating RPR is difficult because of the various trucking distance and pricing scenarios that could be encountered. It was also assumed that firewood-sized residuals would generate at least the value of roundwood pulpwood residuals.

Net residual sawmill residue revenue (RSR) is based on Massengale's (1971) study of residue weights, by scaling diameter, of mixed oak logs in the Missouri Ozarks. The 2.4- and 3.1-m log data, across the applicable range of diameters, was aggregated to estimate the percentage of log weight in bark, sawdust, and chips. On a percentage basis, bark, sawdust, and chips represent 12, 20, and 23%, respectively, of total sawlog weight. Selling price per ton of these residual products is assumed to be net of trucking cost (ie FOB sawmill) and is \$8.82, \$11.02, and \$11.02 per ton for sawdust, bark, and chips, respectively. These prices were obtained during the study period from forest products industry cooperators. With increasing demand from bioenergy markets in the Appalachian region, these prices should be considered a conservative estimate.

A \$5.50 per ton handling/merchandising cost was used to cover a knuckleboom loader, sawbuck, and front-end loader for merchandising and handling sawlogs. This value was generated through interaction with local mills and is comparable with handling costs found in the literature. Wang (2007) determined that loading and bucking costs averaged \$10.15/m^3, which is approximately \$5.50 per ton.

A sawing cost of \$84.76/m^3 was used for the mill tally of lumber and cants produced. This value included operating costs as well as the trucking cost to move products to market. Sawing cost used in this study was obtained from project cooperators; it was the same cost used for their business accounting purposes and charged to us contractually for their involvement in the study. The cost was lower than recently cited rates of \$102.1/m^3 (Perkins et al 2008). However, their estimates included raw material costs, which accounted for 72% of their total fixed and variable costs. Thus, our sawing cost, which does not include raw materials, is a conservative estimate of what it may cost a producer and should not lead to incorrect conclusions if price assumptions change.

Sawlog Profitability

The ultimate goal of such an operation is to merchandise as many profitable sawlogs as possible. Logistic regression was used to examine the attributes influencing the probability of sawlogs having sufficient value per ton to encourage merchandising. Using the lumber and weight information collected for each sawlog, value per ton can be calculated as

$$\frac{\left(\left(\sum_1^n (\mathrm{LLG} \times \mathrm{LGP})\right) - (\mathrm{TL} \times \mathrm{CS})\right) * 1000 \frac{\mathrm{kg}}{\mathrm{ton}}}{\mathrm{WGT}}$$

where

n = number of lumber grades sawn for each log;
LLG = lumber sawn for the n^{th} lumber grade (m^3);
LGP = market price for the n^{th} lumber grade ($/$m^3$);
TL = total lumber sawn for a log (m^3);
CS = sawing cost of lumber and cants ($84.76/$m^3$); and
WGT = sawlog weight (kg).

Again, a value of $84.76/$m^3$ was used to represent log-sawing costs. For the logistic analyses, the dichotomous outcome variable was selected based on a log value of $33.07/ton. Logs were considered profitable if their value/ton was greater than $33.07. This number was chosen based on the base pulp pricing structures common in the region; logs with values greater than $33.07/ton would be worth more in lumber than pulp markets. The probability to be profitable (p) was modeled as follows:

$$\ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \beta X_1 + \beta X_2 + \beta X_3 + \beta X_4 + \beta X_5 + \beta X_6$$

where

$\ln\left[\frac{P_i}{1-P_i}\right]$ = log of the odds ratio;

β_0 = intercept term;
βX_1 = coefficient and explanatory variable for species;
βX_2 = coefficient and explanatory variable for scaling diameter (cm);
βX_3 = coefficient and explanatory variable for sawlog position in tree (butt or upper);
βX_4 = coefficient and explanatory variable for clear sides (no. of clear log faces);
βX_5 = coefficient and explanatory variable for end (condition of log ends); and
βX_6 = coefficient and explanatory variable for scaling deduction (combination of cull, internal, sweep, and crook defects).

Forward selection was used to decrease the dimension of the original model using the likelihood ratio test to calculate significance levels (Freund and Littell 2000). Because variables not significant at $\alpha = 0.05$ could still be associated with the outcome after adjusting for the other variables, any factors with univariate results of $p < 0.25$ were considered eligible for entrance into the model. Each eligible factor was then tested against the decreased model. Only those factors significant at $p < 0.05$ were included in the final model.

Reclassifying Sawlogs

To further understand the impact of sawlog merchandising on overall profitability, iterative analyses were done to determine the influence of removing less profitable sawlogs and rerunning the overall profitability analyses. For each species, sawlogs were removed from the analyses and recoded as pulpwood based on their gross value per ton. Analyses were rerun, and impact on net revenue was evaluated. Sawlogs were separated based on values per ton less than $0-55.12 in $5.51/ton increments.

Table 2. Characteristics of pulpwood merchandised in West Virginia.

Species group[a]	No. full-length pieces	Weight of full-length pieces (kg)	No. sawlogs	Sawlog weight (kg)	No. residual pulpwood pieces	Weight of residual pulpwood (kg)	No. residual firewood pieces	Weight of residual firewood (kg)
Hickory	42	14,636.9	37	10,533.3	16	3267.2	7	836.4
Red oak	176	48,922.2	101	21,357.4	108	23,105.4	40	4459.2
Black cherry	258	38,428.4	211	17,790.4	144	15,356.7	113	5281.1
White oak	264	69,167.4	166	32,868.7	160	29,780.9	71	6517.6
Totals	740	171,154.9	515	82,549.7	428	71,510.3	231	17,094.5

[a] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

RESULTS

Production Components

A total of 740 pulpwood pieces were procured and merchandised, if possible, into sawlogs. This included more than 400 pieces of oak species and 258 pieces of black cherry (Table 2). Total weight of all roundwood pulpwood procured for this project was 171,154.9 kg. Of that total, 82,549.7 kg or 48.2% was merchandised into sawlogs. By species, 71.9% of hickory, 43.7% of red oak/black oak, 46.3% of black cherry, and 47.5% of white oak/chestnut oak were merchandised into sawlogs. Average scaling diameter was greatest for hickory species followed by oak species (Table 3).

Total output of lumber and cants sawn was 4.1 m^3 for hickory, 8.1 m^3 for red oak/black oak, 6.7 m^3 for black cherry, and 12.7 m^3 for white oak/chestnut oak. For hickory, about 8% of the resulting lumber met Select and better specifications (Table 4). The majority of the lumber produced was for industrial products.

Table 3. Characteristics of sawlogs of three common Appalachian species merchandised from roundwood pulpwood.

Species[a]	Converted to sawlogs (%)	Avg. log diam. (cm)	Avg. log length (m)	Avg. clear sides	Butt logs (%)
Hickory	71.7	28.4	3.1	1.8	23.3
Red oak	43.7	24.6	2.9	1.4	5.9
Black cherry	46.3	21.8	2.4	1.2	3.3
White oak	47.5	24.4	2.9	1.3	6.6

[a] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Required tonnage of pulpwood needed to produce 1 m^3 of lumber was lowest for hickory pulpwood. Red and white oaks, as well as black cherry, were fairly even in amount of pulpwood needed to produce 1 m^3 of lumber. Weight of sawlogs needed to produce 1 m^3 of lumber was similar for all species (Table 5).

Cost Components

Using these results, total costs for merchandising pulpwood were calculated. Total costs ranged from a high of almost \$283.77 per m^3 for red oak to a low of \$204.33 for hickory (Table 6). On average, the cost of procuring the pulpwood represented 57% and the sawing cost represented 33% of the total cost to produce 1 m^3 lumber. Sawing costs can be adjusted easily to refine the scenario for further investigation; for every \$1 per m^3 increase or decrease in sawing cost, gross revenue can be increased or decreased by an equivalent amount.

Table 4. Percentage lumber grade yields for sawlogs merchandised from pulpwood.

Lumber grade and overrun	Species[a] grade yield percentage			
	Hickory	Red oak	Black cherry	White oak
FAS	1.2	1.6	0.0	0.3
One face	6.6	2.3	0.3	1.1
Select	0.0	0.0	0.4	0.5
No. 1 com	18.0	8.7	6.3	3.5
No. 2a com	13.9	13.1	10.5	11.2
No. 2b com	1.0	0.3	0.0	0.5
No. 3a com	0.0	1.2	1.3	3.9
No. 3b com	0.0	0.1	0.0	1.7
Below grade	0.9	0.2	47.0	0.3
Cant	58.4	72.5	34.2	77.0

[a] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Table 5. Cubic meters sawn per ton of sawlogs, tonnages of sawlogs required to produce 1 m^3 of lumber and cants, and tonnages of pulpwood required to produce 1 m^3 of lumber and cants, by species.

	Species[a]			
	Hickory	Red oak	Black cherry	White oak
Cubic meter per ton sawlogs	0.4	0.4	0.4	0.4
Tons sawlogs needed for 1 m^3 lumber	2.6	2.6	2.7	2.6
Tons pulpwood needed for 1 m^3 lumber	3.6	6.0	5.8	5.4

[a] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Revenue Components

The RPR is more straightforward than the revenue portion of the merchandising equation. RPR is the difference between the total roundwood purchased and the sawlog weight multiplied by the net revenue received per ton of residual pulpwood. Red oak species had the highest RPR per cubic meter lumber production at \$74.75 followed by black cherry, white oak species, and hickory species at \$68.14, \$63.14, and \$22.35, respectively.

The next source of revenue is sawing byproducts (bark, dust, and chips), which represent the second largest component of nonsawlog revenue. Because the same yields per cubic meter and prices per ton were used for each species, the only variability in net revenue for sawing byproducts was caused by the weight needed to saw 1 m^3 lumber for each species (Table 7). Chips from slabs and edgings had the highest net revenue for sawing byproducts followed by sawdust and bark for each species, respectively.

The final component of revenue is the value associated with lumber and cants produced from the merchandised sawlogs (Table 8). Red oak sawlogs had the highest net revenue per cubic meter followed by hickory and white oak.

Table 6. Component costs for merchandising roundwood pulpwood into sawlogs and lumber and cant products.[a]

	Species[b]			
	Hickory	Red oak	Black cherry	White oak
Cost of roundwood pulpwood	\$107.27	\$165.84	\$158.60	\$150.44
Cost of merchandising	\$19.93	\$33.17	\$31.72	\$30.09
Sawing cost per cubic meter lumber and cants	\$84.76	\$84.76	\$84.76	\$84.76
Total cost to produce 1 m^3 of lumber and cants	\$204.33	\$283.77	\$275.07	\$265.28

[a] All costs in dollars per cubic meter.
[b] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Table 7. Revenue per cubic meter from sawmill residues, including bark, sawdust, and chips.[a]

	Species[b]			
	Hickory	Red oak	Black cherry	White oak
Bark				
Price per ton	\$8.82	\$8.82	\$8.82	\$8.82
Net revenue	\$7.17	\$7.23	\$7.33	\$7.14
Sawdust				
Price per ton	\$11.02	\$11.02	\$11.02	\$11.02
Net revenue	\$14.93	\$15.07	\$15.28	\$14.88
Chips				
Price per ton	\$11.02	\$11.02	\$11.02	\$11.02
Net revenue	\$17.16	\$17.33	\$17.57	\$17.12

[a] Net revenue was based on weight of sawlogs required to saw 1 m^3 lumber, percentage byproduct per ton, and price per ton for each sawing byproduct.
[b] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Table 8. Lumber and cant revenues per cubic meter for sawlogs merchandised from pulpwood in West Virginia.[a]

	Species[b]			
Lumber grade[c]	Hickory	Red oak/ black oak	Black cherry	White oak/ chestnut oak
FAS	\$3.13	\$5.46	—	\$1.14
One face	\$16.92	\$7.75	\$1.93	\$4.15
Select	—	—	\$2.56	\$1.86
No. 1 com	\$38.14	\$20.65	\$16.69	\$8.01
No. 2a com	\$20.62	\$25.54	\$14.24	\$17.32
No. 2b com	\$0.64	\$0.19	—	\$0.32
No. 3a com	—	\$1.96	\$1.41	\$5.04
No. 3b com	—	\$0.06	—	\$1.08
Below grade	\$0.57	\$0.13	\$29.88	\$0.19
Cant	\$80.43	\$99.85	\$47.10	\$106.05
Total revenue	\$160.45	\$161.59	\$113.81	\$145.17

[a] Missing values indicate lumber grades not sawn from merchandised logs.
[b] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.
[c] As specified by the National Hardwood Lumber Association (http://nhla.com).

Table 9. Net revenues generated by merchandising pulpwood into sawlogs in West Virginia.

	Species[a]			
	Hickory	Red oak/ black oak	Black cherry	White oak/ chestnut oak
Total cost to produce 1 m^3 lumber from roundwood pulpwood	\$204.33	\$283.77	\$275.07	\$265.28
Total revenue resulting from production of 1 m^3 lumber from roundwood pulpwood	\$197.89	\$251.57	\$197.39	\$223.36
Net revenue per cubic meter lumber	\$(6.44)	\$(32.19)	\$(77.68)	\$(41.92)

[a] Hickory includes all hickories (*Carya* spp.); red oak includes red (*Quercus rubra*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*) oaks; white oak includes white (*Quercus alba*) and chestnut (*Quercus prinus*) oaks.

Net revenues were negative for each species merchandised in this study. Hickory was the closest to breaking even followed by the red oak species group (Table 9). The red oak group had the highest total cost for producing a cubic meter of hardwood lumber at \$283.77; Hickory had the lowest total cost.

Sawlog Profitability

Total revenue on a per ton basis was greatest for red oak logs followed by hickory, white oak, and black cherry, respectively (Table 10). A total of 64 logs of all species were coded as profitable (value >\$30.00/ton) in the logistic analyses.

Because of its net revenue levels in the overall profit analyses, hickory was chosen as the reference for species comparisons. Univariate results indicated that an increased likelihood of log profitability was associated with species ($p = 0.0002$), scaling diameter ($p < 0.0001$), clear sides ($p < 0.0001$), and scaling deductions ($p = 0.0252$) because each significantly impacted the odds of a given sawlog being profitable. All were positive effects, except for scaling defects, which was negative (Table 10). These were the only factors that met the criteria ($p < 0.25$) for entering the forward selection process.

Of the variables assessed in the logistic analysis, the odds ratio for the comparison of red oak vs hickory was greatest at 3.21 (Table 11). This was followed by the association of profitability with number of clear sides and scaling diameter. Results from this analysis suggest that red oak logs with a larger scaling diameter and greater number of clear sides are the most profitable in terms of value generated per ton. Individually, for every centimeter increase in scaling diameter, the likelihood of being profitable increased by 1.8 times. Similarly, as number of clear sides increased, likelihood of profitability increased 1.9 times. Although significant, scaling deductions had little practical influence on profitability likelihood, only decreasing it by 0.008 times for each unit increase in deduction.

The breakeven log costs for the red oak species group was the highest at \$136.03/m^3. Both white oak and hickory species had similar breakeven log costs when merchandising variables were ignored and only log profitability was evaluated at \$108.33 and \$107.78, respectively. Breakeven log costs for black cherry were much lower at \$53.40/m^3. At a 10% profit level, white oak sawlogs would have to be purchased at \$85.04/m^3, hickory at \$87.01/m^3,

Table 10. Average value on a per ton basis for sawlogs merchandised from pulpwood.

Species group	No. logs	Value/ton (standard deviation)
Red oak	101	\$28.66 (±\$9.48)
Hickory	37	\$27.80 (±\$8.94)
White oak	166	\$23.17 (±\$8.12)
Black cherry	211	\$8.36 (±\$16.71)

Table 11. Proportional odds ratios for species effects and other predictor variables included in logistic regression model.

Effect	Point est.	95% Wald confidence limits
Black cherry vs hickory	1.22	0.37-3.97
Red oak vs hickory	3.21	1.13-9.13
White oak vs hickory	0.54	0.19-1.56
Scaling diameter	1.79	1.41-2.27
No. clear sides	1.89	1.46-2.43
Scaling deductions	0.008	0.001-0.37

red oak at \$110.10/m^3, and black cherry at \$37.89/m^3.

Reclassifying Sawlogs

Because of sample sizes, only red oak, white oak, and black cherry were used in reclassification iterations. Results obtained when sawlogs were classified based on their gross value/ton showed an almost exponential decline in net revenue for each species analyzed. White oak net revenue declined drastically after \$16.53/ton followed by black cherry at \$22.05/ton and red oak at \$27.56/ton (Fig 1). The main reason for the large decline in net revenue was the impact of handling. The greater the value of sawlogs an operator searches for becomes, the greater the number of pieces that need to be handled.

DISCUSSION

Log cost, use, supply, and markets are several of the factors that influence potential profitability of a roundwood sort yard in WV. Theoretically, sort yards could help provide a uniform log resource and ensure that roundwood is directed to the highest value markets (Dramm et al 2002). Likewise, development of new bioenergy markets will necessitate the movement of higher-value roundwood to obtain raw materials at lower price levels. Increased profitability of merchandising operations can be achieved through a combination of lowering costs and raising values of final products (Dramm et al 2004). Costs can be lowered through efficient yard layouts, minimized handling, and minimized effort in processing. Value increases can result from improved log markets, raw material product mixes, and log bucking practices (Dramm et al 2004).

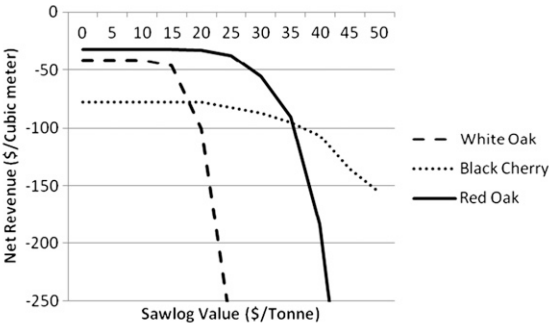

Figure 1. Results from iterative analyses in which sawlogs with given values per ton (x axis) were removed from analyses and recoded as pulpwood based on their gross value per ton. Analyses were rerun and the impact on net revenues (y axis) was evaluated. Sawlogs were separated based on values less than \$0-55/ton in \$5.50/ton increments.

Research investigating increased profitability from merchandising decisions in Appalachia primarily dealt with log-bucking decisions. Wang et al (2007) determined that stem dimension, species, bucker experience, and defects all impacted the merchandising of individual stems. In this study, the focus was less on individual stems and more on feasibility of merchandising low-quality roundwood in Appalachia. We found that delivering roundwood pulpwood to a yard (or sawmill) for the purposes of merchandising sawlogs from pulpwood was not an economically feasible alternative, at least under the prevailing hardwood market conditions during this study. Although there have been general increases in lumber prices compared with those used in this study, they are still not high enough to impact the feasibility of a sort yard system such as the one discussed in this study. To break even, revenues must increase or costs must decrease or a combination of both must occur. Revenue would have to increase 3% for hickory, 13% for red oak/black oak, 39% for black cherry, and 19% for white oak/chestnut oak to break even. Likewise, prices paid for pulp would have to decrease significantly. Red oak pulp cost would have to decline to \$15.32 and white oak to \$11.46/ton, and black cherry pulp would not be profitable to sort even if it had zero cost in procurement. In a study of the economics of processing small-diameter red oak logs on a new scragg mill designed for this purpose, Perkins et al (2008) determined that net present value and internal rate of return on such an operation were economically feasible at a log cost of \$38.58/ton. Although roundwood costs in this study were only \$27.56/ton, the additional costs of handling and the burden of nonsawlog roundwood severely impacted overall revenue in this operation.

Of the species merchandised in this study, hickory appeared to have the most potential. This is primarily because of its lack of popularity in the traditional hardwood lumber marketplace. Because of the lack of demand for hardwood dimension products, hickory logs that find their way into other fiber markets have larger-sized and higher-quality sawlog potential than other species. This is supported by the fact that on average, hickory sawlogs merchandised in this study had a larger log diameter, a higher number of clear sides, a higher proportion of butt logs, and a larger log volume than other species. If demand for hickory lumber were to increase and more hickory roundwood was diverted to sawlogs rather than pulpwood, the average size of potential sawlogs included in pulpwood loads would decrease as would quality, leading to poorer lumber grade yields and less net revenue. Likewise, it is probably not feasible for such an operation to purchase only hickory roundwood. Sorting burdens would be placed on loggers in such a scenario and would lead to lower amounts of available material.

As expected, the proportion of higher-grade lumber was minimal with the majority of volume being in cant products. However, in the case of black cherry, log quality was particularly poor, as evidenced by the significant volume of below-grade lumber. More than 48% of the cherry lumber produced during this study was No. 3A and below. This was mainly because of a large percentage of boards with numerous small knots that severely limited the number and size of clear cuttings. Production of high-grade/high-value lumber drives the profitability of any hardwood log merchandising system; these results reflect a potential hazard in any merchandising operation involving this species. Much of this was caused by the size of the cherry roundwood procured for this study, which was smaller than any of the other species sampled. This impacted profitability in two ways. First, the small size represented increased use by loggers from whom raw materials were purchased for this study. Loggers were merchandising cherry to a smaller size before putting it into pulpwood markets. Second, because of the smaller-diameter logs, the option of leaving the lower-grade boards in a cant product (not sawing as much lumber) was limited. During the time of this study, the market for black cherry lumber was excellent, and many mills were accepting cherry sawlogs with small minimum diameters and no clear sides.

One potential limitation of this study was the lumber yields obtained by our sawmill cooperator. Although the operator had >30 yr experience, all merchandised logs were sawn on a circular mill. Because of its increased saw kerf, lumber grade yields may not have been maximized. Band head rigs can increase lumber recovery factors up to 15% (Wade et al 1992), which can significantly increase yields on smaller-diameter logs.

Although hickory had the most potential to be profitable when all facets of merchandising were considered, when only merchandised sawlogs were considered, red oaks generated the greatest value per ton. As with species, log profitability was associated with physical characteristics of logs including number of clear sides, scaling diameter, and deductions. This indicates that by only merchandising those logs with a greater number of clear sides and larger scaling diameters as well as a minimum amount of scaling deductions, log profitability will be maximized. All these factors are known to increase yield of high-grade lumber (Hanks et al 1980) and should be assessed before identifying sawlogs from pulpwood. Although it would be expected that merchandising only those logs with the greatest potential for being profitable would increase the overall likelihood of profitability, the iterative revenue analyses did not support this conclusion. As the value/ton of logs classified as pulpwood increased, overall revenue of the merchandising operation decreased dramatically. This reflects that merchandising operations need to handle multiple pieces of pulpwood before a higher-value log is found to be merchandised. The greater the degree of handling, the greater the costs incurred (Dramm et al 2004). A scenario that could potentially lead to greater profitability would be to redirect the merchandising operation down the supply chain to the log-landing. Here, small sawlogs can be produced from pulpwood-sized material, and the remaining pulpwood can be sorted and transported directly to a fiber-consuming mill. This would decrease the amount of additional handling and trucking involved in merchandising sawlogs from pulpwood at a sawmill or satellite sort yard.

It is possible, using the data collected in this study, to determine the breakeven prices that a sawmill could offer for the size and quality of logs merchandised in this study. Breakeven sawlog costs can then be used to determine the potential for increased sorting on the log-landing, which could be more beneficial to the loggers and sawmill owners. Breakeven sawlog costs were developed based on the grade yield and overrun percentages for sawlogs merchandised in this study. Breakeven sawlog cost was determined by solving the log return equation:

$$\text{Log return} = \frac{\text{Gain from log} - \text{Sawing cost} - \text{Purchase cost}}{\text{Sawing cost} + \text{Purchase cost}}$$

where

Gain from log = gain calculated on a cubic meter basis by multiplying the calculated overrun resulting total lumber by the lumber grade yield percentages. Prices for each particular lumber grade are then used to determine total gain from an individual sawlog. Doyle overrun of the logs used in this study was determined as part of the analysis and was 42.5, 76.9, 38.4, and 74.4% for hickory, red oak, black cherry, and white oak, respectively. Doyle log scale was used to present results because it is the most commonly used log scale in WV (Lin et al 2011);

Sawing cost = price to saw logs ($\$/m^3$); a value of $\$84.75/m^3$ was used in this analyses; and

Purchase cost = price in $\$/m^3$ for purchasing sawlogs.

This equation can then be solved for purchase cost for any desired return:

$$\text{Purchase cost} = -\frac{\left(\begin{matrix}\text{Desired}\\ \text{return}\end{matrix} * \begin{matrix}\text{Sawing}\\ \text{cost}\end{matrix} - \begin{matrix}\text{Gain}\\ \text{from log}\end{matrix} + \begin{matrix}\text{Sawing}\\ \text{cost}\end{matrix}\right)}{(\text{Desired return} + 1)}$$

The breakeven log costs for the red oak species group was the highest at $\$321.15/m^3$. Both white oak and hickory species had similar breakeven log costs when merchandising variables were ignored and only log profitability was evaluated at $\$108.33/m^3$ and $\$107.78/m^3$, respectively. Breakeven log costs for black cherry were much lower at $\$53.40/m^3$. At a 10% profit level, white oak sawlogs would have needed to be purchased at $\$85.04/m^3$, hickory at $\$87.01/m^3$, and red oak at $\$110.10/m^3$. To achieve a 10% profit level for black cherry logs, they would have had to be purchased at $\$37.89/m^3$.

Based on breakeven log costs calculated, it may be feasible for loggers to do more sorting of low-grade sawlogs on the landing. Although exact prices for gatewood logs paid to loggers are not known, all breakeven sawlog costs determined in this study are within reason compared with current stumpage price estimates for the Appalachia region. For contract loggers, except for black cherry, the breakeven prices are more than enough to cover contract logging and trucking rates.

Generally, these small, low-grade logs are viewed negatively by traditional hardwood sawmills as evidenced by their well-recognized attempt to discourage their delivery by placing an artificially low delivered price on these logs. It is not uncommon to find pricing ranging down to $\$21/m^3$, therefore mills have significant room to increase prices and maintain a strong level of profit. Because this breakeven analysis does not include any residue (bark, sawdust, and chips) income, the profit margin is further enhanced.

This study was initiated to determine if revenue generated from merchandising valuable products from pulpwood was high enough to offset the increased handling costs and lower-value products produced from a sorting operation. Although our results were not encouraging, costs and revenues reported here represent a relatively complex blend of pricing that is dynamic with time. However, as new markets expand and competition increases with traditional markets, we can expect prices to increase, creating a new set of merchandising options for roundwood. Because of the way the revenue analyses were generated, the formula and conversion ratios presented in this study can be easily adapted to alternative yield and pricing assumptions, potentially leading to alternative conclusions as market changes occur. Likewise, as markets expand and log supplies begin to change, sawmills can maintain their supplies by purchasing lower-quality logs. Results indicated that sawmills could potentially pay loggers enough to cover their logging and trucking costs plus enough profit (or return on stumpage for independent loggers) to ensure that these types of logs are captured on the landing and not sent to the pulp pile as were those merchandised in this study.

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