Financial Assessment of Logging Residue Collection in the Southeast United States

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Abstract

Logging residue and nonmerchantable stems are an important component of present and future bioenergy resources. Integrated harvesting systems that chip or grind logging residues and nonmerchantable stems with the harvest of roundwood may be the most feasible technology and most likely to produce material at a competitive cost. We conducted simulated harvests on a wide range of southeastern US pine forests using a sample of Forest Inventory Analysis (FIA) inventory plots and Forest Vegetation Simulator (FVS) to model silvicultural treatments and intensities of pine management. In the simulation break-even marginal costs for biomass were typically present when residue volume exceeded 100 m^3 ha^{-1} or ratios of roundwood to biomass were less than 4:1. Increased roundwood harvesting productivity also increased the rate at which residue arrived at the landing for processing, which improved chipper utilization and lowered costs. In integrated systems some roundwood that meets pulpwood specifications may be merchandized as biomass because of the cost savings available from increasing chipper utilization. Cost savings from merchandizing all pulpwood as biomass could support stumpage payments that may be equivalent to pulpwood stumpage in areas with low pulpwood prices and low pulpwood demand.

The Billion-Ton Update (Downing et al. 2011) projected woody biomass availability for bioenergy and bioproducts from thinnings, collection of forest residue, and woody energy crop production. Forest residues will provide a majority of bioenergy supply for the foreseeable future. Both thinning and residue collection are conceptually simple because they involve conventional management systems and conventional harvesting systems in existing forests. However, the classification of logging residue is heavily dependent on markets, harvesting systems, and terrain. Logging residue is a by-product of the harvest of higher value material where the cost of manufacturing and transportation exceeds its value. Even in the last 30 years, changes in manufacturing and harvesting technology have altered the quality and quantity of forest residue, and these boundaries might continue to change even in the absence of bioenergy markets.

Collection of residue and nonmerchantable trees and roundwood (integrated systems) has the potential for lowering fixed and variable costs per unit volume from all products harvested. In full-tree harvesting systems the entire tree is felled and skidded to the landing. Processing roundwood results in only a portion of the wood used for products or accounted for in logging productivity. If a greater proportion of the tree is used, the production rate would increase, and fixed and variable costs per unit would decline for felling and skidding because the same work is required to produce more material. Cost analysis of integrated harvests measured by Baker et al. (2010) suggests that roundwood harvesting cost could increase or decrease as biomass products are added under different conditions. If lower costs can be achieved, the total harvesting revenue from current harvests or the land value from forest management would increase. Allocation of the net revenue to buyers, harvesters, or landowners will depend on whether the system is limited by biomass supply, demand, or harvesting effort. Biomass harvest opportunities will not be financially desirable unless the biomass and roundwood harvest produces higher total net revenue than roundwood production alone. Removal of logging residue for forest

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Table 1.—Forest types sampled in analysis and their frequency in the selected ecoregions.

Forest type	Description	Ecoregion (%)							
		223	231	232	234	255	1221	1223	1231
142	Slash pine			16.2					
161	Loblolly pine	1.4	60.3	60.6	16.5	22.8		1.9	26.1
162	Shortleaf pine							5.8	30.2
181	Eastern red-cedar	7.1							
402	Eastern red-cedar/hardwood	8.2							
404	Shortleaf pine/oak							5.8	13.3
406	Loblolly pine/hardwood	0.6	12.2	10.5					3.4
501	Post oak/blackjack oak	6.9				45.2		7.9	5.9
502	Chestnut oak						22.5		
503	White oak/northern red oak/hickory	57.6	14.5				30.6	63.3	16.4
504	White oak							10.5	
506	Yellow poplar/white oak/northern red oak						16.4		
515	Chestnut oak/black oak/scarlet oak						18.3		
520	Mixed upland hardwood	12.2	13.0	12.8	8.1	18.8	12.2	4.7	4.7
602	Sweetgum/Nutall oak/willow oak				19.9	8.0			
605	Overcup oak/hickory				12.8				
705	Sycamore/pecan/American elm				9.1				
706	Sugarberry/hackberry/elm/green ash	6.0			33.7	5.2			

management objectives might also be possible if the landowner shares in the cost with a fee for that service or lower stumpage prices.

Productivity and cost for residue and nonmerchantable harvest systems have been explored with different systems. Single pass, integrated systems are generally viewed as the most efficient for southern full-tree harvest systems (Stokes et al. 1984, Miller et al. 1987). The rate of biomass harvest in integrated systems often results in low chipper or grinder utilization at 20 to 30 percent of scheduled time (Westbrook et al. 2007, Baker et al. 2010) and high fixed cost per unit. The second challenge for integrated harvesting systems is managing system time to ensure that net revenue rather than biomass production is maximized. Higher biomass volumes may result in tradeoffs between roundwood and biomass harvest where the producer may opt for the product generating the higher marginal return (Westbrook et al. 2007, Baker et al. 2010). Previous marginal cost analysis found that logging residue costs from full-tree systems ranged from \$2.27 to \$6.88 per green tonne (gt) in situations where residue volume equaled 15 to 57 percent of the total harvest (Puttock 1995). More recently, costs of fuel chips ranged from \$8.04 to \$14.44 gt^{-1} with biomass harvests ranging from 5 to 50 percent of total volume (Baker et al. 2010). In modeling an integrated system with fuel reduction as a major goal, Han et al. (2004) reported biomass costs that included only grinding of \$8.14 m^{-3}, while total cost of all material equaled \$14.95 m^{-3}. Bolding et al. (2009) attributed costs to the merchantable and biomass components and estimated stump-to-truck costs of \$36.21 gt^{-1} for all material and just \$10.96 gt^{-1} for merchantable material even though biomass was 39 percent of total volume. A cut-to-length (CTL) system had integrated harvesting costs of \$27.50 gt^{-1} for biomass chips compared with \$9.37 gt^{-1} for roundwood (Bolding and Lanford 2005). CTL systems may be less efficient as integrated systems because more machine activity is required to fell, collect, and transport biomass from nonmerchantable trees and logging residues. While these analyses provide precise cost, they describe only a limited number of harvest scenarios and stand conditions that might be encountered.

In this study we developed a simulation model for analyzing the roundwood and woody biomass production under a range of management regimes. The objective was to compare the expected marginal costs of biomass chips from logging residue and nonmerchantable stems in pine clear-cuts using a set of stand conditions and harvest production models. The pine clear-cuts encompass a range of silvicultural treatments and intensities. The forest type samples were selected to represent initial stand conditions and site productivity across ecoregions in the US South. The biomass removal alternatives included the range of likely scenarios from no collection to marketing of pulpwood as biomass chips. Pine management was the focus because the modeled range of silvicultural treatment and harvest intensity are likely to occur on the landscape, and increased biomass production from southern forests is more likely to come from managed pine forests.

Methods

Growth models

Samples were selected randomly from Forest Inventory Analysis (FIA) plots identified through a frequency distribution of forest type by ecoregion (Table 1). Four to eight of the most frequent forest types were selected to represent each ecoregion. In the selection of samples for modeling, we controlled for site class, extreme slope, and wetland conditions. The ecoregions sampled across the region included central interior broadleaf forest (223), southeastern mixed forest (231), outer coastal plain mixed forest (232), lower Mississippi riverine forest (234), prairie parkland (255), central Appalachian broadleaf forest (1221), Ozark broadleaf forest (1223), and Ouachita mixed forest (1231).

To simulate growth and yield of the samples we used the Forest Vegetation Simulator (FVS; Dixon 2008). The FVS is a model for predicting forest stand dynamics developed and maintained by the US Department of Agriculture Forest Service. It is commonly used to summarize current stand conditions and to predict future stand conditions under different forest management regimes. The basic FVS model structure is calibrated to unique geographic areas called FVS variants. For this study we used the southern or SN variant. FVS predicted stand conditions for 5-year cycles until the end of the rotation (final harvest). Management activities were simulated using FVS ''keywords.'' Each keyword simulated a specific action. Fertilization was simulated using the keyword ''BAIMULT,'' which is a multiplier that increases diameter and height growth. A multiplier was calculated for each stand based on the mean annual increment for the stand rotation length simulated without any intervention. The fertilization multiplier chosen reflected a general effect of fertilization (Fox et al. 2007).

Management regimes were developed for pine even-aged management. Pine management included replanting to the same pine species indicated by the forest type. Hardwood forest types were all regenerated with loblolly pine (*Pinus taeda*). Pine management regimes were distinguished by management intensity (low, medium, and high). The low regime involved an initial site preparation burn, planting, and thinning. For the medium regime, vegetation control with herbicide at establishment and at age 5 years was added to the low regime. For the high regime, a fertilizer application after thinning was added to the medium regime. The regimes affected time to final harvest with low at 40 years, medium at 35 years, and high at 30 years.

Harvesting scenarios

We considered that the plots could be harvested using four alternative scenarios. Scenario A is the harvest of the merchantable volume estimated by FVS. Scenario B is the harvest of the merchantable volume and the biomass from the tops and limbs. Scenario C is the harvest of the merchantable volume, biomass from the tops and limbs, and small nonmerchantable stems. Scenario D includes all the previous biomass harvest and redirects the pulpwood to biomass chips. The biomass available for Scenario B was calculated using a ratio of total tree volume and merchantable volume in different diameter ranges for pine and hardwood using equations (Clark and Saucier 1990), and we assumed that only 65 percent would be collectible (Dykstra et al. 2009). While 65 percent is frequently used in this context, there little evidence to support it. In general, the Scenario B methods estimated that biomass for tops and limbs accounted for 20 percent of the total tree volume. For nonmerchantable tree biomass (Scenarios C and D), we applied a stem volume equation for understory tree volume using average height and diameter at breast height (Phillips 1980). Scenario C generated biomass for tops, limbs, and nonmerchantable volume that accounted for 30 percent of the total volume. For Scenario D, biomass chips were made from all the pulpwood stems and the top wood pulpwood from sawtimber stems (estimated to be 15% and 29% for pine and hardwood, respectively; Porterfield and von Segen 1976).

Harvest cost and revenue

To harvest the merchantable volume and biomass chips, we modeled conventional full-tree logging operations suitable for gently sloping upland terrain (0% to $<30\%$ slope) and strongly sloping terrain ($\geq 30\%$). Typical system costs were estimated as before tax cost, using a cash flow method on systems with in-woods equipment that ranged from new to near the end of their projected machine life. The system modeled for gently sloping terrain was a typical three-machine system ($500,000 capital value) capable of producing between 20 and 30 gt per productive machine hour (pmh) depending on forest conditions. The second system for strongly sloping terrain had six laborers, two dozers, and a grapple skidder for primary transport and a tracked feller-buncher and manual felling and limbing. The system could produce between 15 and 25 gt pmh^{-1} and had a capital value of about $500,000. For biomass production we assumed that the loader of both operations would feed a 400-kW drum chipper with a current capital cost of $250,000. We chose a chipper capable of high production rates (80 gt pmh^{-1}), even though a smaller chipper might satisfy production needs. The higher capacity chipper avoided cost transfers to the trucking operation in the form of excessive loading delays or set-out trailer systems.

The production rates (cubic meters per productive machine hour) for loading, processing, and felling were calculated using regression equations for loading (Lanford et al. 1990), processing (Miller and Greene 1992), and felling on terrain with slopes less than 30 percent (Visser and Stampfer 2003) and greater than or equal to 30 percent (Gingras 1988). The production rates for skidding were determined by plotting the results from seven estimates of skidding productivity for modern skidders (Lanford and Stokes 1996, Kluender et al. 1997, Klepac and Rummer 2000, Visser and Stampfer 2003, Wang et al. 2004, Pan et al. 2008). The production rate for skidding decreased with slope: 45.3 m^3 pmh^{-1} for less than 20 percent, 39.6 m^3 pmh^{-1} for 20 to 29 percent, and 22.6 m^3 pmh^{-1} for slopes 30 percent or more. Skidding production rates were influenced by skidding distance because increased slope required longer skid distances to offset increases in road building costs and accommodate fewer opportunities for good landing locations. The average skidding distances used for the slopes were 150, 240, and 450 m, respectively. We assumed that the loader could sort and feed biomass into the chipper at the same rate that it loaded roundwood, 36.6 m^3 pmh^{-1}, and the chipper operated 110 percent of the time the loader was engaged in feeding the chipper. Total scheduled time needed to cut 1 acre of the plot was estimated as the maximum productive machine hours needed among all processing phases divided by the maximum utilization rate (80%).

Plots with higher slopes had higher fixed costs to accommodate road building costs and equipment transportation for the high slope system. The fixed cost of the harvest was based on an assumption of a 20-hectare treatment area and equaled $148, $198, and $247 ha^{-1} for slopes 0 to 9 percent, 10 to 29 percent, and equal to or greater than 30 percent, respectively. Per-hectare costs represent machine move-in costs of about $500 per machine and landing and road preparation costs of $1,500, $2,500 and $2,500 for the slope classes 0 to 9 percent, 10 to 19 percent, and 30 percent or more, respectively. Fixed, variable, and labor and overhead costs are presented in Table 2. Estimates were generated by building logging firms with a mix of older and newer equipment that would likely harvest the low slope ($<30\%$) and high slope ($\geq 30\%$) harvests. Fixed costs (depreciation, interest, and insurance) were estimated using cash flow methods for the current year of operation. Variable costs were estimated with rules of thumb from Brinker et al. (2002) and the Caterpillar

Table 2.—Harvesting cost in dollars per scheduled machine hour (smh) and productive machine hour (pmh) for low slope and high slope systems.

Component	Low slope (<30%)		High slope (≥30%)	
	Fixed cost ($ smh^{-1})	Variable cost ($ pmh^{-1})	Fixed cost ($ smh^{-1})	Variable cost ($ pmh^{-1})
Felling	26.51	39.42	31.13	44.69
Skidding and bunching	17.39	39.42	28.43	109.83
Loading and processing	28.08	48.84	15.11	27.11
Labor and overhead	91.37		154.23	
Chipper	43.25	62.65	43.25	62.65
Labor and overhead with chipper	118.78		200.50	

Performance Handbook (Caterpillar, Inc. 1996). The technique is described by Smidt et al. (2009).

Costs for each treatment were derived by summing the total scheduled and productive hours needed to harvest and process all of the material designated by each scenario and multiplying by appropriate fixed or variable costs. Harvest fixed costs were allocated by dividing the fixed cost per hectare by the harvested volume. We subtracted the total cost of Scenario A (roundwood only) from the total cost of Scenario B or C and divided that by biomass harvested in that scenario to arrive at marginal cost (dollars per cubic meter). Estimated harvesting costs are ''stump to truck'' and exclude trucking cost.

Results

Stand parameters for harvests averaged by regime and site class are given in Table 3. Volumes are given in cubic meters, but conversion of plantation loblolly pine volume to mass would be 890 kg (green mass) m^{-3} or 0.98 English tons m^{-3} (Newbold et al. 2001). Trends in merchantable volume by regime reflect that density was lowered through thinning and herbicide treatments in the high and medium regimes. The lower stand volume was countered by a greater proportion of higher value products. Height changes reflect the shorter rotation length for the high and medium regimes and higher productivity with respect to site class. They also reflect the fact that fertilization was modeled as a basal area multiplier that minimally affected height growth, so volume growth from more intensive regimes might be conservative. Sites with greater productivity tend to have greater hardwood volumes, and regime effects on hardwood volume are complicated by interactions between site productivity and competition. Collectible top and limb biomass (65% of total) averages ranged from 9 to 13 percent of total volume, and nonmerchantable stem volume added another 1 to 5 percent.

The residual value is the wood value to roadside minus wood cost to roadside and would likely encompass revenue needed for procurement cost, profit, and stumpage (Fig. 1). Revenues were estimated as southern average delivered prices from Fourth Quarter 2010 for Timber Mart-South (Timber Mart-South 2011). Logging residue chips were priced as in-woods whole-tree pine chips. In the region, nearly all of this product type is used for cogeneration at pulp and paper facilities. Delivered prices were converted to freight on board (FOB) roadside by subtracting trucking cost of \$6.92 m^{-3}. The dominant factor in residual value is volume per hectare. High site productivity and intensive stand treatments result in larger trees, which have lower per unit harvesting costs and higher value. Not all the management prescriptions were suitable for the sites, and six plots with less than 60 m^3 ha^{-1} had negative net revenue. Additionally, sites that had residual value less than \$5 m^{-3} did not have enough residual value to accommodate profit and a nominal stumpage payment. Nine plots with less than 90 m^3 ha^{-1} were excluded from further analysis.

Across all scenarios and sites, the cost for biomass production was related strongly to the biomass available (Fig. 2). The values for Scenarios B and C overlap considerably, since nonmerchantable volume was a small contributor to total biomass in these managed stands. At a value for in-woods whole-tree chips of \$18.86 m^{-3}, only a few harvests of residue or nonmerchantable material plus residue would return stumpage or profit. Generally, biomass harvests that exceeded 100 m^3 ha^{-1} would generate net revenue available for stumpage or profit. The profitability of marketing pulpwood as biomass would depend on the price of each product, haul distance to each location, and stumpage price expectations. The productivity of the

Table 3.—Harvested stand parameter averages for regime and site class combinations, both merchantable (merch.) and total volumes (merchanatable, nonmerchantable, and residue).

Regime	Site class	Height (m)	QMD (cm)[a]	Merch. mean (m^3 ha^{-1})	Merch. pine (%)	Merch. pulpwood (%)	Total mean (m^3 ha^{-1})	Total tops and limbs (%)	Total nonmerch. (%)
High	4	21	30	270	97	34	316	13	1
	5	20	31	254	99	30	298	13	2
	6	17	27	195	100	57	224	9	4
Low	4	24	24	341	88	45	401	12	3
	5	23	23	336	89	46	390	12	2
	6	19	22	228	93	70	265	9	5
Medium	4	23	27	295	91	49	342	12	2
	5	21	26	264	95	50	306	11	2
	6	18	23	210	98	81	240	9	4

[a] QMD = quadratic mean diameter.

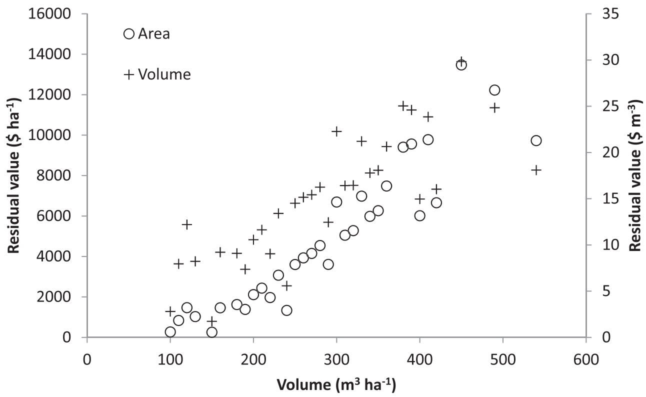

Figure 1.—Residual stand value for merchantable harvest volume on a volume and per-acre basis using revenue estimates (dollars per cubic meter, freight on board): $23.83, pine pulpwood; $25.23, hardwood pulpwood; $32.12, pine Chip and Saw; $44.20, pine sawtimber; $25.32, small hardwood sawtimber; and $42.93, large hardwood sawtimber.

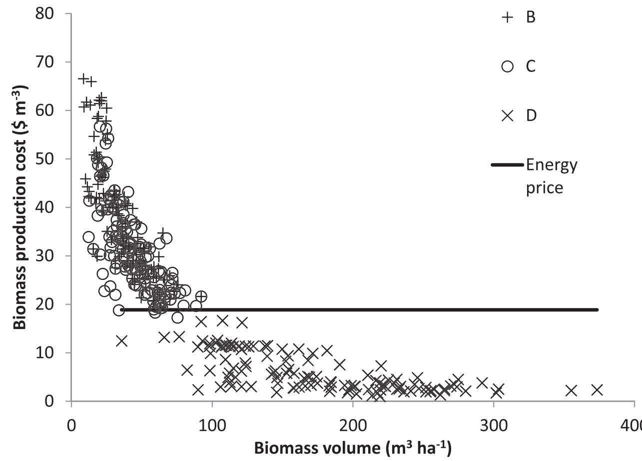

Figure 2.—Biomass production costs to roadside versus the biomass volume per hectare for scenarios B, C, and D. Energy price is $18.86 m^{-3} (freight on board).

roundwood logging operation was an important factor in marginal biomass costs. Loader roundwood productivity was highly correlated with marginal costs for Scenario B (–0.65). The correlation declined (–0.352) for Scenario C because felling and skidding costs for nonmerchantable trees were added to marginal cost. The correlation is reversed for Scenario D (0.74) because high productivity means reduced pulpwood volumes.

Chipping the pulpwood resulted in considerably lower costs for biomass and roundwood due to better utilization of the chipper. Chipping pulpwood also reduced the roundwood processing time. Biomass chipping lowered

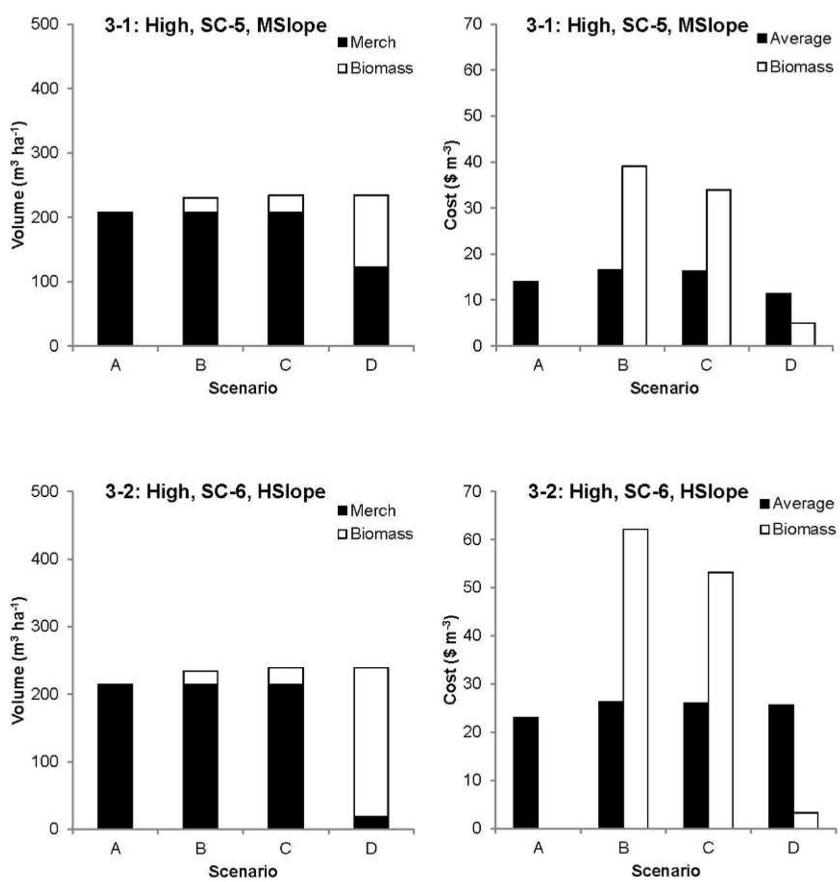

Figure 3.—Volumes of merchantable and biomass harvest for the four scenarios and average cost of all harvested material and the cost of biomass harvest for the four scenarios. (3-1) High regime, site class 5, with moderate slopes. (3-2) High regime, site class 6, with high slopes.

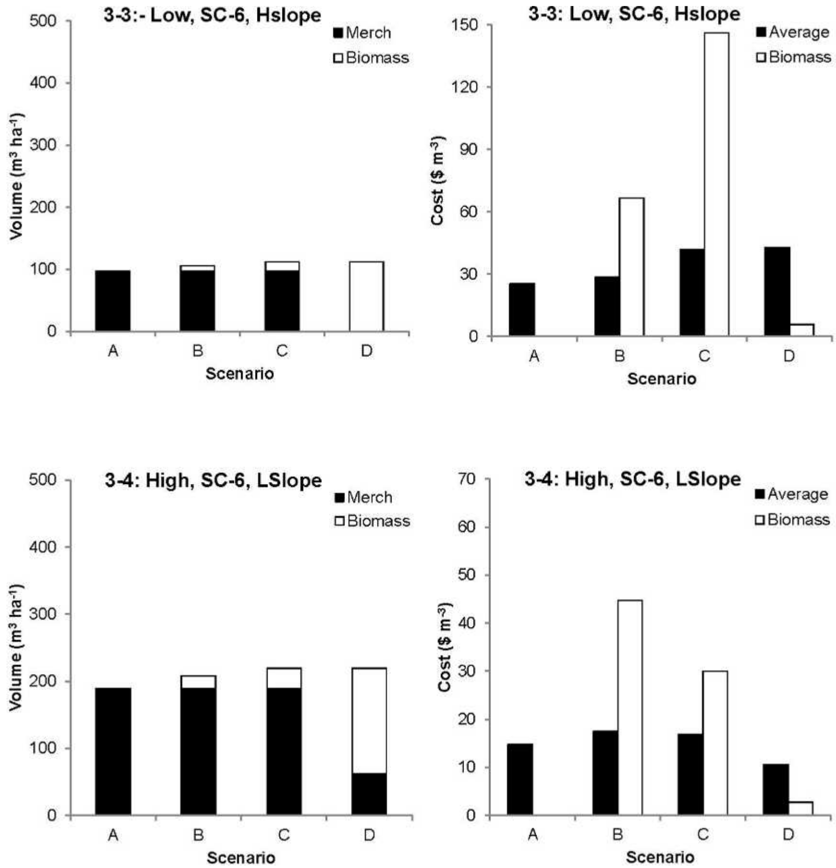

Figure 3 (Continued).—Volumes of merchantable and biomass harvest for the four scenarios and average cost of all harvested material and the cost of biomass harvest for the four scenarios. (3-3) Low regime, site class 6, with high slopes. (3-4) High regime, site class 6, with low slopes.

the fixed cost per unit volume on the rest of the logging system and variable cost per unit volume on some processes. At very high biomass volume per hectare, the marginal cost of the biomass is lower than the cost of just chipping because the cost per unit of the whole operation may be reduced.

We selected some cases to show the range of effect on both volume harvest and average and marginal cost (Fig. 3). In samples 3-1 and 3-2, the incremental biomass volume was small for Scenarios B and C and pulpwood was about one-third of the merchantable volume. The small biomass volumes in B and C resulted in very high marginal costs for biomass, while the average cost is minimally affected. Scenario D has lower average cost and lower marginal biomass cost because chipping removed the production constraint at the loader and lowered fixed costs. These examples represent a majority of the samples. In 3-2, the effect of higher slope ($\geq$30%) is evident in both average and biomass harvest costs. Sites with low harvest volumes like 3-3 also had increased harvest cost due mainly to lower stem volume and higher fixed costs per unit. Sample 3-4 was also on higher slopes, but the higher volume and larger tree size (due to more intensive silviculture) mitigated harvesting costs. Samples 3-5 and 3-6 represent relatively high volume harvests in low slope harvesting conditions. The effects of regime and site class can be seen in the larger pulpwood volume in sample 3-5. The effect of larger tree size can be seen in the lower harvest costs for 3-6.

Discussion

Using a set of stand variables, production equations, and harvesting costs, we can compare the marginal costs of biomass harvesting across a broad range of scenarios. Published biomass harvesting costs for residue harvest were frequently lower than those simulated here (Westbrook et al. 2007, Baker et al. 2010). Baker et al. (2010) recorded roundwood harvest costs in clear-cuts between \$9.00 and \$10.50 m^{-3} (converted at 0.98 gt m^{-3}). For similar stands (150 to 200 m^3 ha^{-1}), this simulation yielded costs from \$12 to \$14 m^{-3}. This may be related to more conservative harvesting production rates from the models than from observed harvest data or simply differences in system costs. Marginal biomass production costs in those same stands ranged from \$14 to \$16 m^{-3}, while Baker et al. (2010) recorded a range from \$10 to \$16 m^{-3}. Differences in biomass production cost begin with calculation methods (joint production vs. marginal cost) and may also be affected by the lower cost and lower productivity chippers. Operationally more material may be chipped than was estimated in the simulation because it could be less desirable (broken, too short, or too crooked). Westbrook et al. (2007) projected a linear relationship between the ratio of roundwood to biomass and biomass cost and indicated ratios of less than 10:1 would yield profitable biomass

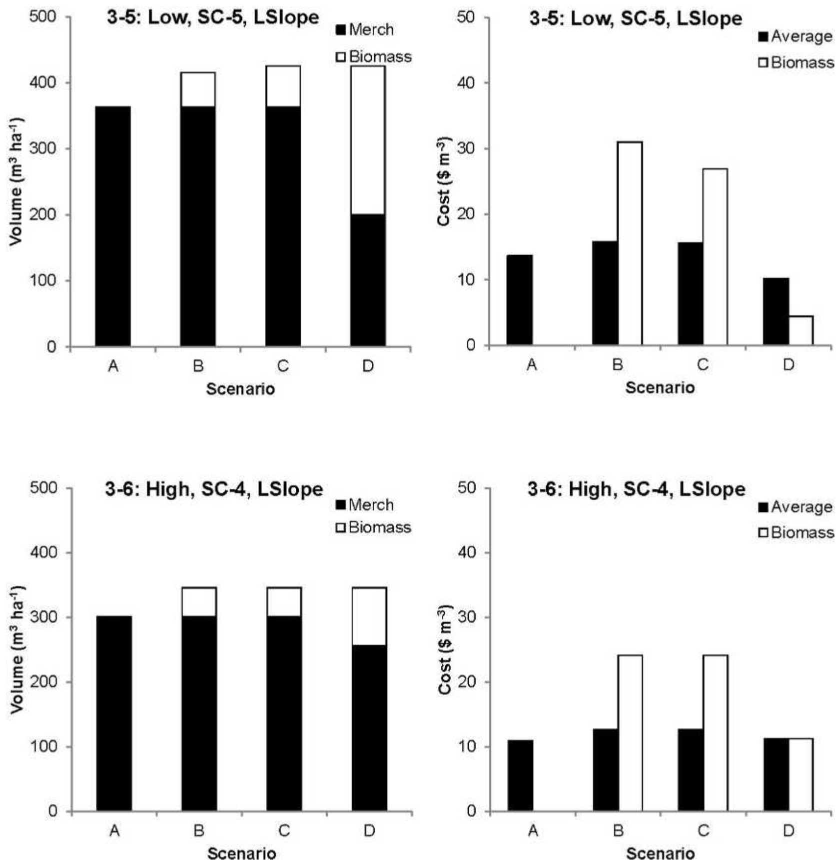

Figure 3 (Continued).—Volumes of merchantable and biomass harvest for the four scenarios and average cost of all harvested material and the cost of biomass harvest for the four scenarios. (3-5) Low regime, site class 5, with low slopes. (3-6) High regime, site class 4, with low slopes.

harvesting. In these simulations, similar costs did not occur until the ratio was much smaller (3:1 to 4:1). The difference could be related to the modeled harvest production versus observed data and the application of a larger, more expensive chipper in this simulation.

Stands with less than 100 m^3 ha^{-1} of biomass available had harvesting costs that were generally above current values for wood supplied to cogeneration facilities. Since loggers have limited control over site selection, firms equipped to produce residual chips may harvest sites where chip production costs are greater than income. In some cases the losses may be rationalized by strategic advantages in harvesting the residue (more markets or cleaner harvest sites) or paid for by reduced stumpage. Harvest analyses to determine logging residue harvest profitability are often lacking.

It is appropriate to question the chipper size we chose. A smaller chipper would have lowered fixed chipping costs and shifted the curve in Figure 3 downward, resulting in break-even costs at a greater range in biomass volume. We argue that the larger chipper is a likely choice because excess production capacity often rewards contractors by giving them the ability to produce more material when market and weather conditions are favorable. Additionally, the number of available owned and contracted trucks is one of the constraints in harvesting productivity (Greene et al. 2004), which could push contractors to choose the most productive chipper affordable to minimize in-woods waiting time. The behavior of loggers engaged in these activities will likely shift product separation, so chipping costs can be reduced by merchandizing a portion of the pulpwood through the chipper. The reduction in marginal cost by increased chipper utilization is likely to offset the marginal return of roundwood pulpwood. The same relationship was apparent in the merchandizing of logs from in-woods clean-chipping operations (Shrestha and Lanford 2002). The biomass available as residue chips will increase as loggers try to support residue collection with the chipping of roundwood that minimally meets roundwood pulpwood specifications across a range of sites that vary in suitability (lower production rates and residue volume). The assumption that 65 percent of residues are recoverable has an effect on estimated supply and cost. Considering the relationships in Figure 3, the average cost of residue chips could be lowered if collecting and chipping some of the remaining 35 percent could be accomplished for less than the marginal cost. Indeed, changes in the assumption would affect the financial feasibility of four of the six samples shown.

The discussion of how much biomass volume is produced per hour of roundwood production is the most critical question in determining whether logger and landowner net revenue can be increased by harvesting logging residue and nonmerchantable trees. The production equations used in this analysis seemed adequate and produced sensible results, but some harvesting conditions were outside of the conditions for which they were built.

Widespread adoption of logging residue collection will affect market prices for bioenergy and pulpwood. Analyses of supply and costs should consider how efforts to increase biomass production from logging residue will affect pulpwood volume from harvests. We have not only estimated the marginal costs, but also provided information regarding the biomass supply, which would be useful in regions with limited history of biomass supply and market data.

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