Global interest in the use of renewable energy sources such as woody biomass continues to increase. In Minnesota, high fuel prices and energy policy have been major drivers for the growing interest in offsetting traditional nonrenewable with renewable energy sources. The latter mandates that 25% of the total energy produced in Minnesota will be derived from renewable energy sources (all forms) by the year 2025 (Minnesota Statutes 2008). In response, the state’s public utilities are seeking to substitute renewable for nonrenewable energy sources through wind energy, farm-grown closed-loop biomass (feedstock residues), and woody biomass production.

Timber harvesting residues, specifically the nonmerchantable tree tops and limbs associated with a commercial roundwood harvest, have the capacity to supply substantial feedstock for energy production. Forest site and stand conditions (including tree species composition, timber size class, wood quality, and soil properties), biomass collection and processing equipment, and stand management and regeneration objectives have been found to be important determinants of the amount of recoverable biomass volume available on a given commercial roundwood harvest site (Perlack et al. 2005).

The literature on woody biomass also addresses various environmental, ecological, economic, and logistical issues associated with harvesting and transporting woody biomass. This includes research on life-cycle analysis of the energy use and carbon emissions associated with biomass production relative to traditional fossil fuels (Magelli et al. 2009), sustainable levels of woody biomass removal (Thiffault 2009), the environmental impacts associated with woody biomass harvesting (Raulund-Rasmussen et al. 2008, Domke et al. 2008), supply chain characteristics and selection (Van Belle et al. 2003), chip size distribution (Spinelli et al. 2005), and harvesting productivity and costs (Asikainen and Pulkkinen 1998, Spinelli and Hartsough 2001, Suadicani 2003, Polagye et al. 2006, Spinelli and Visser 2009).

A review of the literature revealed only a few studies that identify or describe residual woody biomass harvesting practices in North America and the perspectives of biomass harvesters regarding these practices. To partially address this information gap, Minnesota logging business owners who collect and process nonmerchantable harvest residues (i.e., tree tops, branches, limbs) using a chipper or grinder were surveyed to characterize harvest practices used for gathering and processing this material; harvesters’ perspectives on the financial and environmental aspects of woody biomass harvesting; and the issues, opportunities, and concerns that are associated with harvesting and processing.

Survey Methods

A phone survey was conducted to obtain qualitative information from logging business owners who harvest biomass in Minnesota using a chipper or grinder. Logging businesses were identified by reviewing the equipment inventory of members of the Minnesota Logger Education Program (MLEP). As of December 2008, MLEP’s membership consisted of more than 400 large and small logging
businesses (MLEP 2008) and is considered the most comprehensive list of the state’s logging industry. Once an initial list of biomass harvesters was compiled, industrial, public agency, and consulting foresters, as well as logging equipment dealers and others (e.g., procurement managers at woody biomass energy facilities, researchers), were contacted to verify the completeness of this list.

The survey questions were developed and refined through researcher expertise and consultation with forestry and logging professionals in the state. The survey contained questions seeking qualitative information in several areas associated with biomass harvesting, including equipment, configuration of the harvesting operation, strategies used to retain woody material on-site, and constraints and opportunities.

Three weeks before the phone survey began, letters were sent to each business owner targeted in the survey to explain the general nature of the questions to be asked and that participation was entirely voluntary. Participants were also informed that all of the information they provide would be confidential: no attribution would be made to individual responses. All surveys were conducted directly with the logging business owner, whose responses were evaluated to quantify biomass harvest practices and identify emergent themes with regard to biomass harvesting in general. The phone interviews were conducted by one individual during July and August 2008. Each interview lasted approximately 20 minutes, with the interviewer transcribing participant responses. Twenty-six of the 28 Minnesota logging businesses identified as owning a chipper or grinder to process woody biomass participated in the survey. Numerous attempts were made to contact each of the two remaining business owners, but contact with them was never established.

Results and Discussion

All of the loggers who participated in the survey processed woody biomass with either a chipper or grinder. In-woods trailer-mounted chippers are typically large mechanized devices that reduce whole trees or portions of trees to chips of more or less uniform size using a knife blade. A grinder is also typically a large mechanized device that pounds the material it is fed into smaller pieces, which are a mulchlike product that is not uniform in dimension, through a combination of tensile, shear, and compressive forces. Because logging businesses tend to be different from one another due to factors such as firm size, equipment mix, operator skill, preferred species, landing size requirements, and market size and location, respondent opinions tended to vary. Where possible, explanations are provided to interpret why differences might occur.

Residual Biomass Harvest Timing

Minnesota’s woody biomass harvesters typically process residual biomass concurrent with a commercial roundwood harvest. A summary of the biomass processing equipment for the 26 respondents is presented in Table 1. According to the most recent (2003) statewide information about logging operations in Minnesota, approximately 85% of the wood volume was felled by a feller-buncher and transported to the landing with a grapple skidder (Powers 2004). Almost all of the remaining wood (14%) was felled with a cut-to-length harvester and transported to the landing using a forwarder. Based on the authors’ field observations, more than 90% of the biomass harvesters in Minnesota use a feller-buncher and grapple skid material whole-tree to a landing where a stroke delimber removes the residual biomass. A chipper or grinder then processes the residue while the roundwood is separately slashed into 100-in. products.

Seventeen responding business owners indicated that chipping or grinding of residual material is almost always conducted simultaneously with the roundwood harvest. Three additional business owners stated they operate their roundwood and biomass harvesting equipment concurrently on the same site between 60 and 90% of the time, and two businesses process roundwood and biomass simultaneously on 40–50% of their harvest sites. Two business owners stated they bring their biomass harvest equipment on the site only after the roundwood harvest operation is completed, and two were not able to quantify the extent to which biomass harvesting occurs concurrently with a commercial roundwood harvest.

The business owners that harvest biomass simultaneously with a roundwood harvest offered the following explanations.

- Chipping and grinding is more efficient when done simultaneously with a roundwood harvest.
- Landing sites with slashers (used to segment tree stems into roundwood products) are set up to transfer the wood directly to a chipper or grinder.
- Owning a small amount of harvesting equipment requires that all harvests be done simultaneously; equipment cannot occupy multiple sites at the same time.
- It is most efficient to have the same business harvest both the roundwood and the biomass. Harvesting is significantly slower when a second logging business removes biomass after a roundwood harvest has occurred.

For those logging businesses that harvest biomass after a roundwood harvest is completed through a reentry into the site, the following rationale was provided.

- Some markets pay more for chips or grindings with reduced moisture content; chipping or grinding after the roundwood harvest allows for additional drying time.
- Consumer-scale pricing on some state timber sales requires the chipping or grinding to be conducted after the roundwood harvest is complete. Because consumer-scale pricing is a pay-as-you-go method of paying for purchased stumpage in which the buyer is invoiced only for the material actually harvested, this policy was implemented by the state to ensure that loggers were not whole-tree chipping or grinding roundwood at biomass prices.
- Chipping or grinding must be done after the roundwood harvest is complete because of space limitations at the landing.
- Chipping and grinding are more efficient when they are conducted after the roundwood harvest.
- Because of inconsistent market demand, chipping or grinding cannot be done immediately on every harvest site.

### Table 1. Biomass processing equipment used by logging business owners participating in the survey according to roundwood harvesting equipment configuration.

<table>
<thead>
<tr>
<th>Biomass processing equipment</th>
<th>Number of logging business owners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut-to-length/forwarder</td>
<td>Feller buncher/skidder/slasher</td>
</tr>
<tr>
<td>Chipper</td>
<td>4</td>
</tr>
<tr>
<td>Grinder</td>
<td>1</td>
</tr>
<tr>
<td>Chipper and grinder</td>
<td>2</td>
</tr>
</tbody>
</table>

| Chipper                     | 16                                |
| Grinder                     | 2                                 |
| Chipper and grinder         | 6                                 |
A few business owners were unable to generalize the time during the roundwood harvest when biomass harvesting takes place because of the variability in their harvest operations. These owners indicated the size of the timber sale typically determines whether chipping or grinding is done concurrently with the harvesting of roundwood—larger timber sales are more prone to a simultaneous biomass harvest.

Preferred Tree Species
Ten chiper and six grinder respondents indicated that they have no preference for the tree species they process, yet the reasons cited by these owners varied depending on whether they operate a chiper or grinder. The grinder owners who stated that tree species does not matter reported that the reason was the ease at which grinders process any woody material. In contrast, businesses operating chippers and having no species preference indicated that the type of nonmerchantable material (e.g., tops, limbs, branches) left after a roundwood harvest, not the tree species or the energy market for woody biomass, determines what material would be chipped.

Those business owners who indicated a preference generally identified softwoods, noting that their chiper or grinder requires less maintenance than when hardwoods are processed. Many business owners who operate chippers have specific tree species they prefer because of the marginal increase in chip volume or the ease at which certain species’ tops and limbs can be processed. Several operators commented species desirability for chipping is a function of the straightness of the material, as straight tops are easier to pile and can be fed through a chipper more efficiently than those that are crooked. A few respondents indicated tree species preference is entirely dependent on the market and the types of chips or grindings they accept, whereas others noted that preference is based on moisture content rather than a particular species.

Tree Use
For purposes of this study, tops were defined as the upper portion of the main stem below the minimum diameter standard for commercial roundwood established by the landowner and/or the pur- chaser of the harvested product. Limbs and branches (the former being imprecisely defined as large branches) were defined as the nonmerchantable portions of the tree along the main stem not con- tained in the top.

For business owners operating chippers, tops (approximately 90% of respondents) and stems (approximately 67% of respondents) are the commonly used parts of the tree (Table 2). Although 12 business owners who chip biomass indicated they process limbs and branches, many respondents stated it is not economical to process them for the following reasons.
- Limbs and branches are too wiry to line up and efficiently process through a chipper.
- Limbs and branches are difficult to grab onto and do not chip well.
- Limbs and branches are not economically feasible to chip because of the time and the fuel requirements associated with piling and dragging them to the chipper.

Several owners who operate grinders have no strong preference on the parts of the tree used for grinding, commenting that grinders can easily process virtually any nonmerchantable part of the tree.

Deliming Location
Logging business owners were asked to identify where the majority of the delimbing occurs to remove tops, limbs, and branches. Eleven owners indicated that delimbing is performed adjacent to the chiper or grinder, typically the primary landing on the harvest site. These respondents cited economic efficiency and landowner preference (e.g., for aesthetic reasons) as primary reasons for processing biomass next to the deliming location.

Eight owners do not delimb where the chipper or the grinder is located, citing the following reasons for their change in location.
- The chiper or grinder is at the landing, and the deliming equipment works best in the woods (i.e., a grapple skidder brings whole-tree material to a stroke delimber located at an intermediate landing) or is part of the in-woods harvesting equipment (i.e., cut-to-length equipment where a forwarder transports material to the landing).
- The limbs and branches are not chipped; thus, it is easier to delimb in the woods and skid only the portions of the tree that will be processed back to the landing.
- Some state timber sales do not allow the delimer to be located at the landing.
- The landing space is not large enough for both a delimer and chipper or grinder to simultaneously operate; it becomes too congested.
- If the limbs and branches will be scattered in the woods, it is easier to delimb at the stump and leave the branches where they fall.

Three owners indicated that the location of the delimer and chipper or grinder depends on the size of the landing, with only large landing areas allowing for simultaneous deliming and processing.

Influence on Harvest Site Operations
Of the 26 businesses who completed the survey, 18 said that they do not alter their roundwood harvest or the location of their site infrastructure (e.g., landings, skid trails) if they collect and harvest the residual material. Owners that configure their roundwood harvest site infrastructure differently when harvesting biomass cited the following reasons:
- The slasher and chipper or grinder are located at the same landing.
- The limbs and branches from the roundwood harvest are piled neatly (as opposed to being scattered throughout the site) wherever chipping or grinding is to be conducted.

Table 2. Source of residual tree material processed for biomass energy by chippers and grinders in Minnesota during a roundwood harvest as stated by logging business owners who participated in the survey. Values are percentage of logging businesses by processing equipment type. Note that several respondents indicated multiple sources of residual tree material.

<table>
<thead>
<tr>
<th>Nonmerchantable tree portion</th>
<th>Chipper</th>
<th>Grinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stems</td>
<td>65</td>
<td>67</td>
</tr>
<tr>
<td>Tops</td>
<td>96</td>
<td>89</td>
</tr>
<tr>
<td>Limbs and branches</td>
<td>52</td>
<td>100</td>
</tr>
<tr>
<td>Othera</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

a Tops refers to the upper portion of the main stem below the usual diameter for producing roundwood.
b “Other” may include brush or all material included in a land-clearing site.
The landing is set up so that the chipper or grinder is nearby while slashing and delimbing.

Volume Removed

When asked about what influences the amount of residual woody biomass produced from a roundwood harvest site (as a percentage of the total roundwood harvest), owners cited differences among species (e.g., ease of processing material, amount of breakage during felling and skidding), timber sale regulations imposed by the forest landowner, stand age, season of harvest, and recoverable volume per acre. Several owners commented that mixed stands containing a high percentage of hardwoods relative to aspen often produce the greatest amount of recoverable material for chipping or grinding.

Residual Material Left On-Site

Several states have developed or are currently developing standards or guidelines for the amount of residual woody material that should be left on-site in conjunction with a biomass harvest. In 2008, Minnesota became the first state to develop guidelines (i.e., best management practices) for harvesting and processing logging residues that address nutrient retention, biological diversity, and wildlife habitat concerns. A core recommendation of Minnesota’s residual biomass harvest guidelines is to leave 33% of the residual tops and limbs at the harvest site after the biomass harvest is complete through intentional retention, as well as incidental breakage during skidding.

The logging business owners who participated in our survey were asked to identify the sources of woody material retained on-site. The majority (n = 22) of owners who leave woody material on-site indicated that this material is produced through incidental breakage (Figure 1). The remaining respondents stated that the residual biomass comes primarily from (in order of declining frequency) limbs and branches, nonmerchantable tops, and unharvested live trees.

For business owners indicating that incidental breakage is the source of woody material left on-site, a general consensus exists that 33% of residues were left postharvest, as recommended in Minnesota’s biomass harvest guidelines (Minnesota Forest Resources Council 2007). Their comments included the following.

- Incidental breakage occurring during felling and skidding accounts for more than 33%.
- The amount of incidental breakage that occurs depends on the season of harvest and the age of the trees in the stand.
- Most of the wood on state sales is over-mature; it would be impossible to take it all because it breaks when it hits the ground.
- More than 33% is left on-site through the process of harvesting (e.g., breakage, snags, and slash piles that are not used completely).

Site Restrictions

Nine business owners reported that they would harvest biomass from all harvest sites, regardless of physical or environmental constraints, but 17 owners said there are certain conditions or situations in which they would not harvest biomass. Some of these latter owners indicated that an operator’s ability to harvest biomass depends on the site prescription or landowner objectives, which may preclude biomass harvesting altogether. Several said they would not harvest biomass on sites with nutrient-poor or sandy soils. Some commented that they might still harvest biomass on these sites but would leave more woody material behind than normal to mitigate concerns over soil erosion and nutrient depletion. Other conditions cited where a residual biomass harvest might be limited include small harvest sites, sites that contain species yielding limited volumes of residual material (e.g., black spruce swamps, pure stands of aspen or jack pine), and sites where the residual biomass consists primarily of nonroundwood, brushy material.

Biomass Harvesting Constraints

Minnesota’s biomass harvesting business owners cited a number of factors that could constrain the ability to profitably harvest woody biomass in the future. These constraints include the following.

Insufficient Product Prices

Many owners noted that the combination of the low price paid for the delivered biomass, the limited number of facilities currently using biomass, and the instability of current biomass market prices make such harvesting economically challenging. Paraphrasing one respondent, “If you can’t operate this equipment for less than $30/ton, you’re not going to compete dollar for dollar with western coal.” As diesel prices were at a record high when the survey was conducted, another asked, “How do you harvest something that’s only worth the cost of trucking to get it to the mill?” Anecdotal evidence suggests that current market price for this material is $22–$27 per delivered green ton.

High Equipment and Diesel Fuel Costs

Some owners expressed concern over the difficulty of small logging businesses being able to enter the biomass harvesting market due to the large initial capital costs. It is not uncommon to have $300,000–$500,000 invested in one chipper or grinder, which also requires considerable diesel fuel and maintenance to operate. The following comments were offered by respondents.

- Markets are not paying enough for the investments that are made in biomass harvesting equipment.
- It is not economically feasible to harvest the logging slash with the current cost of diesel fuel.
- Transportation costs may be as much or more than the value of the woody biomass material.
• “In the past, we would leave all the residual wood in the forest. Now, it is worth something. But in a lot of stands, it is still not worth the time, effort, and equipment and energy costs to harvest that small additional amount of biomass material.”

• Biomass resources are generally not in proximity to processing facilities, thus increasing the haul distances and subsequently reducing profit margins.

Lack of Available Material
To make the industry profitable, many owners pointed to the need to increase the amount of available woody biomass that can be processed. For some owners, this concern was expressed as the ability to chip or grind whole trees instead of only residual materials left from a roundwood harvest. State law does not preclude whole-tree chipping or grinding, though this is typically regulated on public lands through timber sale regulations. For others, this relates to the number of timber sales where biomass harvesting is allowed. Comments pertaining to these concerns are presented below.

• There is not enough biomass material in just the tops and other nonmerchantable material.

• Some foresters can be overly protective with the increased removal of biomass. Consequently, there are sometimes sites where biomass harvesting is not allowed, but should be.

Environmental Regulations
Several owners identified concern over environmental regulations pertaining to biomass harvesting. These sentiments were expressed as follows.

• If there are too many regulations, the logging industry will not be sustainable.

• Few of the individuals involved in making the biomass harvesting policies understand the economics of harvesting a timber sale.

Biomass Harvesting Opportunities
In spite of the above constraints, when asked about the future of woody biomass harvesting in the state, business owners cited the following opportunities for biomass harvesting.

Markets
Many owners believe biomass harvesting will continue to grow as fuel costs remain high. They commented that the rising costs of fuel will create new opportunities to expand and diversify their markets, some noting the development and more recent need for wood pellets for thermal heating applications. Numerous owners also noted that in order for the bioenergy industry to expand, markets must become more consistent in their demand and their price paid. Some noted that, ironically, rising fossil fuel prices that generate additional biomass demand also increase the variable operating and transportation costs associated with biomass production. Given today’s poor economic climate and reduced diesel fuel prices, opinions regarding market outlook may have changed since the survey was administered.

Environmental Benefits
Some owners speculated the demand for burning woody biomass for energy will be a function of its environmental benefits compared with burning coal or other nonrenewable fuels. Others noted the positive effect biomass harvesting has on forest health through fuel hazard reduction and removal of invasive species or trees, which are more susceptible to insect infestation and disease.

Sustaining the Logging Industry
Like that of many parts of the United States, Minnesota’s forest products industry contracted dramatically in recent years because of the slumping economy. Between 2005 and 2008, Minnesota’s total roundwood harvest dropped from an estimated 3.6 million cords to under 3 million cords annually (Minnesota Department of Natural Resources 2008). Many respondents felt biomass markets can be a means of stabilizing and sustaining the logging industry.

New Business Opportunities
Some owners felt that the growth of biomass markets represents a new business opportunity for young and upcoming logging business owners. One respondent identified the potential financial benefits that young owners might receive from a business with a limited number of market participants, and another cited biomass harvesting as a way to improve the logging industry’s public image, stating: “Biomass harvesting makes the industry look a little cleaner.”

Conclusion
Previous studies of biomass harvesting focused primarily on the cost of biomass removal, independent of the range of logger practices and experiences. This study is unique in that we sought to inventory and seek information from logging business owners on biomass harvesting practices. In particular, we were interested in shedding light on the harvest practices they use, as well as the factors that influence these practices. For example, 18 of the 26 respondents do not make significant modifications to their commercial roundwood harvest operations to accommodate the removal of biomass. They also do not process all available residual biomass because of operational, economic, and practical constraints. Our study demonstrates the variability in biomass harvest practices that are applied in Minnesota, which has implications for the types of training provided by logger education programs. This variability in biomass collection and processing practices also suggests that research on the productivity of existing biomass harvesting systems, the types of biomass harvest equipment suitable for the upper Great Lakes region, and alternative equipment configurations may be warranted.

This study also provides insight into the willingness of loggers to participate in new biomass markets. Loggers recognize that it is important to sustain their industry in the currently depressed economy and view biomass harvesting as a way to expand their market opportunities and produce additional income or as a way to attract new business owners to the profession. They also identified a number of obstacles that could inhibit the growth of this industry. These include: an inconsistent demand for delivered wood chips and grindings, high fixed and variable operating costs, long distance from harvest site to markets, uncertainty about future resource supply, and possible restrictions on biomass harvesting to address environmental concerns. Unless prices for delivered biomass rise, few owners will be able to capitalize on this opportunity.

Literature Cited


MINNESOTA STATUTES. 2008. Chapter 41A. State of Minnesota, St. Paul, MN.


