Perceptions of Debarking Small-Diameter Stems in the Wood Products Community

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Abstract

Sufficiently valuing small-diameter-stem (diameter < 9 in.) woody material in Pennsylvania forest product markets may incentivize increased utilization of that material, a resource opportunity that would provide economic and ecological benefits to the state's forests and forest products community. Debarking is one primary process that could enhance the value of these small-diameter-stem materials for secondary markets. The wood products community in Pennsylvania was surveyed as to their perceptions of the status and value of economical small-diameter-stem debarking. The largest perceived current market for debarked, small-diameter-stem material identified by respondents is for chips for pulp and paper, and anticipated future demand is expected to be highest for chips for pulp and paper, chips for energy, and small-dimension lumber. Respondents who currently supply a given market tend to be more optimistic about that market than respondents who do not serve that particular market. Shredded wood/hog fuel and mulch are the two markets with the lowest overall scores for anticipated benefit of additional processing by debarking. Seventy-six percent of all respondents indicated that economical small-diameter-stem debarking would benefit their operation.

From a commercial wood products perspective, the value of an individual tree or community of similar trees is dependent on a number of factors, including size, species, quality, maturity, operational availability, ease of processing, and supply chain economics. This complex set of factors leads to a differentiation in value or utility among a diverse community of trees. The term ''low-use wood'' is often used to denote trees that are of poor form, quality, size, and value, which tend to be underutilized in existing wood products markets. Improved processing and utilization technologies (debarking among them) seek to improve the economics of harvesting and using such material. While most harvest operations recover primary value from higher-quality sawtimber stems, low-use wood is abundant in Pennsylvania forests. A 2004 inventory of Pennsylvania's forest resource across all ownerships found that 57 percent of total biomass (657.8 million tons) is classified as low-use wood, with nearly three-fourths of that material on privately owned land, where a legacy of high grading is more common (McWilliams et al. 2007). In the most recent 10-year update to that comprehensive inventory, disparity between measures of the growth of sound wood volume and growing stock volume (considering cull deductions and noncommercial species) indicates that the stock of low-value wood has increased faster than higher-quality timber in Pennsylvania forests (Albright et al. 2017).

The underutilization of low-use wood is a market resource opportunity but also an underrealization of opportunities to improve stand outcomes ecologically. Failure to harvest or otherwise intentionally manage the low-use wood resource has a lasting impact in this region's forests. Repeated removal of higher-value stems with retention of low-use stems at the end of a stand rotation can hinder the potential and success of forest regeneration, degrade the diversity and quality of genetic stock in a community of trees, and alter species composition and structure in the stand. In addition to harvest scenarios, proactive management earlier in stand rotation progress enhances both the health and the value of a maturing stand

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through intermediate silvicultural treatments that concentrate and co-opt inevitable stand mortality in undesirable stems that are not economically mature but that occupy space, light, water, and nutrient resources in competition with future high-value stems or that must be salvaged due to forest health issues (often designated ''timber stand improvement'' activities). Despite the demonstrated value of these management activities, the small size of the harvested stems they involve results in intermediate management techniques being infrequently attempted, especially on private land, and being precommercial when they are attempted. In either case, with end-rotation or mid-rotation activities, improved market opportunities for low-use wood would incentivize more beneficial management interventions. An assessment of bioenergy potential from forestry for 2050 shows that forests can be a major source of bioenergy without endangering the supply of industrial roundwood and wood fuel without further deforestation (Smeets and Faaji 2006).

Efforts regarding the underutilization of low-use wood material from harvesting and intermediate silvicultural practices in Pennsylvania forests have focused on slash residues from sawtimber stems, poor-quality stems, noncommercial or undesirable sawtimber species, and small-diameter material. Regarding slash, conventional harvesting of mature stands recovers only about 60 percent of the tree wood, leaving residual material that includes small-diameter logs, tops, and limbs that correspond to about 20 percent of the tree biomass (Ghaffariyan 2010, Ghaffariyan et al. 2017). The collection of forest residues is usually unprofitable because such material has low market value in current conditions, and removal logistics/transportation of this low-value material contributes to additional expenses (Wolfsmayr and Rauch 2014). Therefore, enhancing the value of this material may incentivize fuller use of the slash resource; however, the value of retention of this material for nutrient cycling, protection of regeneration from herbivory, and other services often make slash a less desirable candidate for increased utilization and removal from the forest. As a result, increasing the value and utilization of small-diameter stems may be a more desirable focus for enhancing and expanding utilization and value-added processing technologies, such as debarking.

The value and market utility of small-diameter-stem woody biomass is limited in part by differences in the physical and chemical properties of wood versus bark (Han and Shin 2014, Fabio and Smart 2020). For example, high-quality pellet production requires a low-ash feedstock that can be realized only when the high-ash bark fraction is removed from wood. Moreover, debarked wood tends to dry faster, affecting the logistics associated with the handling process. The delivery cost of woody biomass can be decreased by 50 percent if the moisture content changes from 50 to 30 percent (Johnson et al. 2012, Greene et al. 2014). Debarked wood is more homogeneous, increasing its acceptability for the pulp and paper industry and its efficient biomass conversion into biofuels and bioproducts (Nurmi and Lehtimäki 2011, Jacob et al. 2013, Chahal and Ciolkosz 2019). Bark itself has a place in by-product markets, such as fiber, tannins, gums, resins, flavorings, antibiotics, mulch, building material, and/or medicinal products (Harkin and Rowe 1971, Kain et al. 2012, Marron 2015, Shara and Stohs 2015). Therefore, managing and dealing with wood and bark material of small-diameter woody material separately has commercial relevance both to enhance the value of wood and to create additional products from bark. The process of ''debarking'' for separating wood and bark can be influenced by several factors, such as harvest season, wood type, and moisture content (Chahal et al. 2020b). Limited research has been conducted on debarking systems and tends to focus on larger-stem logs (Kharrat et al. 2020). There is a need for additional work to further improve the efficiency of debarking systems (Chahal and Ciolkosz 2019). Techno-economic analysis of debarking for small-diameter-stem short-rotation woody crops suggests that overall supply chain economics can be improved by including a debarking step (Chahal et al. 2020a). This in turn suggests that small-diameter-stem debarking of forest wood may create similar economic advantages.

Pennsylvania contains abundant forestland, with over 6.75 million ha (16.75 million acres) that cover over 58 percent of area of the state. These forests support clean water, clean air, recreational opportunities, habitats for thousands of plants and animals, and numerous wood products. The net volume of live trees continues to increase (5.6% from 2012 to 2017) and constituted about 38,960.4 million ft^3 in 2017, up from 36,881.7 million ft^3 in 2012 (Albright 2018). Timber is also very important for Pennsylvania's economy; the forest products industry employs around 100,000 people and has an economic impact of nearly $20 billion annually. In addition, an estimated $10 billion to $12 billion is contributed by the recreational and other value of the forest (Finley et al. 2019).

The objective of this article is to analyze the status of small-diameter woody material and attitudes about future markets, especially with respect to debarked small-diameter-stem wood. This information will be valuable for informing techno-economic analysis and product development for debarking systems and strategies.

Methodology

Survey design

The objectives of the survey used in this study were to determine the prevalence of small-diameter-stem woody material used in various markets in Pennsylvania and to assess the perceived value of economical small-diameter-stem debarking for those markets. To achieve those objectives, a multimode (online and paper survey) static display was used. A survey instrument was designed utilizing a limited question set to target the varied technological comfort levels of the population and reduce the likelihood of participant dropout during the survey process (Cooper and Lamias, 2001). The survey instrument included a total of seven questions to measure the current usage of small-diameter woody material (stem diameter less than 9 in. diameter to breast height) and attitudes about current and future markets, especially with respect to debarked small-diameter-stem wood. Additional factors, such as wood species and geographic region, were not specified in the survey. The term ''economical debarking'' was not strictly defined in the survey, allowing respondents to apply their individual understanding of the forestry economy to their responses. Four occupations were defined for the forest products sector: (1) harvester/logger, (2) buyer/processor, (3) consultant, and (4) other. Eight markets were identified as potential end uses of small-diameter-stem wood: (1) chips for energy, (2) chips for pulp/paper, (3) chips for composite wood products, (4) chips for other use, (5) shredded wood /hog fuel (6) mulch (7) small-dimension lumber, and (8) other. The survey was limited to seven questions, and respondents were permitted to skip any questions they did not wish to complete. In brief, the questions asked were the following:

1. What type of wood products professional are you (harvester/logger, buyer/processor, consultant, or other)?
2. What percentage of your current product comes from small-diameter woody material?
3. What products do you currently produce from small-diameter woody material?
4. What percentage of your small-diameter woody material goes to each market?
5. How much demand do you expect for different products (from small- or large-stem material) in the next 10 to 20 years (5-point Likert scale from ''no demand'' to ''high demand'')?
6. Would economical debarking of small-diameter woody material increase its value for any products (5-point Likert scale from ''no increase'' to ''very high increase'')?
7. To what degree would your operation benefit from economical small-diameter-stem debarking (5-point Likert scale from ''no benefit'' to ''extremely beneficial'')?

A purposive sampling technique was used for the identification and selection of information-rich cases related to the phenomenon of interest. Purposive sampling is a nonprobabilistic sampling technique where the researcher relies on his or her own judgment to select individuals or groups of individuals who are especially knowledgeable about or experienced with a phenomenon of interest (Palinkas et al. 2015). Three organizations were targeted for the survey: the Pennsylvania Forest Products Association, the Pennsylvania Sustainable Forestry Initiative, and the Pennsylvania Fuels for Schools and Communities working group, which were judged to exhibit the desired knowledge of forest products in Pennsylvania that is required for the research. Although the purposive sample is not randomly selected, individual respondents from within that sample can be selected at random to achieve an approximate effect (Attewell and Rule 1991), but the relatively small sample size of the population precluded such an approach, similar to many studies of the forestry sector (Aguilar and Garrett 2009, Tyndall et al. 2011, Wade and Moseley 2011). The distribution of occupations of the respondents was compared to that of the Pennsylvania Forest Products Association as a whole to assess whether poststratification weighting would be appropriate for the survey results (Best and Harrison 2013). The survey was conducted over a 3-month period during the late winter of 2020. Each question also gave respondents the opportunity to add comments if desired. While the primary survey medium was online (Qualtrics XM), paper surveys were made available to all who preferred to not use the online system. Requests to complete the survey were circulated to members of the Pennsylvania Forest Products Association, the Pennsylvania Sustainable Forestry Initiative, and the Pennsylvania Fuels for Schools and Communities working group.

Data analysis

Data analysis was carried out using software data analysis tools (Excel, Microsoft Corp., R Statistical Computing Software, Foundation for Statistical Computing). Almost all of the questions were closed ended with the option to add comments. Two questions solicited quantitative responses, while the others are of a categorical nature (both nominal and ordinal). The frequency of the categorical responses was calculated and converted to percentages. The individual responses from Question 4, where respondents were asked to estimate the percentage of small-diameter woody material that goes to each market, were used as weighting factors to increase the relative impact of responses to Questions 5 and 6 from those who currently serve the given market for those products. To do this, the weighted score of an individual response was calculated using the following equation:

$$S_W = F_i \times Y \tag{1}$$

where S_w = the weighted score of an individual response, F_i = the weighting factor of a particular response equal to the fraction of respondent's small-diameter woody material that goes to that product's market, and $Y = 1$ if a respondent has chosen a particular level of response and 0 otherwise. The total weighted score of a level of response was calculated by summing the weighted scores of all the individual responses for a particular level of response as follows:

$$S_{WT} = \Sigma S_W \tag{2}$$

where S_{WT} = the total weighted score for a level of response. The Freeman theta value was calculated to characterize the strength of association between nominal responses (Question 1) and ordinal responses/Likert-scaled responses (Questions 2, 5, 6, and 7). The Spearman rank correlation coefficient (SRCC) was calculated to find the strength of association among ordinal responses/Likert-scaled responses (among responses of Questions 2, 5, 6, and 7). In case of Questions 5 and 6, perceptions regarding only the top three products (based on the responses to Question 4) were paired with other responses and the values of the Freeman theta and SRCC calculated. After calculating respective values of the Freeman theta and SRCC, these metrics were evaluated on the basis of following criteria (Fowler et al. 2013):

- .00 to .19 = very weak association
- .19 to .39 = weak association
- .40 to .59 = moderate association
- .60 to .79 = strong association
- .80 to 1.0 = very strong association

P values are also calculated and reported along with SRCC values for each pair.

Results and Discussion

Respondents to the survey self-identified as 16 percent harvester/logger, 47 percent buyer/processor, 6 percent consultant, and 31 percent other ($N = 32$). While the relatively small size of the population surveyed precludes probabilistic sampling, the breakdown of respondent categories shows similarity to that of the Pennsylvania Forest Products Association membership (17% harvester/logger, 49% buyer/processor, 3% consultant, and 28% other; $N = 260$); the organization was established to represent the forest products community as a whole. Thus, poststratification weighting was not applied to the results.

However, additional bias (i.e., of those willing to complete a survey vs. those not willing) may exist in the data set, and results should be interpreted accordingly. The category ‘‘other’’ includes, for example, pellet manufacturer, forest program manager, and timber investment management organization forester.

Current use of small-diameter material

The percent of material handled by the respondents that is small diameter is displayed in Figure 1 and ranges from 0 to 100 percent, with an average of 30.5 percent (coefficient of variation = 1.1). Most (56%) respondents' material supply includes a small percentage (<20%) of small-diameter wood, and 22 percent of respondents do not utilize any small-diameter wood.

When broken down by occupation, the average amount of small-diameter material handled ranges from an average of 21.5 percent for buyers/processors to 56 percent for harvesters/loggers. This suggests that small-diameter woody material occupies a variety of niches in the Pennsylvania wood products sector, ranging from a small component of a person's business to being the primary product handled.

When analyzed according to market, the most common small-diameter product reported in the survey is chips for pulp and paper, with 84 percent of respondents identifying that as one of their markets (Table 1). (Note that markets specified under ‘‘other’’ included ‘‘wood pellets,’’ ‘‘pole wood,’’ and ‘‘firewood.’’ Respondents typically serve multiple markets; thus, the sum total of percentages is greater than 100.)

Hog fuel was the least common product, with only 21 percent of respondents noting that as a product they handle. Pulp and paper is also the largest portion of the small-diameter woody material market for respondents, with an average market size of 38.5 percent, which is more than twice as high as composite wood products, the next highest value (Table 1). Shredded hog fuel is the smallest market among respondents, with an average of 0.4 percent of material going to that use. This suggests that pulp and paper suppliers are less diversified in their market, whereas those who service other uses are more likely to supply multiple markets. The number of markets served by a respondent ranges from one to six, with an average of 2.7. The market size (in percent) versus number of markets served follows a pattern consistent with the following centroid of possible values:

$$S_i = (1/n) \times S_{i=1}^{n}(1/i) \quad (3)$$

where S_i = the centroid of possible sizes of the ith market (percent) in the sorted list of market sizes (from largest to smallest) and n = the number of markets served.

The mean absolute error of the centroid equation is 6.7 percent (Fig. 2). This suggests that market allocations in the industry are grouped around the centroid of possible percentages rather than, for example, a top-heavy distribution of market share in which the largest market receives nearly all of a company's product or an even distribution of market share in which each market receives an equal amount of product. It could be argued that this represents an unbiased market allocation scenario that could be used as a basis for modeling the market allocation behavior of forest products companies.

Future market perception

Respondents' views of future markets for small-diameter wood are shown in Table 2. Chips for pulp and paper is the product for which all respondents are optimistic regarding future demand; none of the respondents predicted lack of demand for it in the future. Shredded hog fuel is the product with the highest percentage of respondents (38%) who are pessimistic regarding future demand. The weighted responses for future product demand are presented in Table 2. Weighted responses are overwhelmingly more optimistic. This suggests that, except for shredded hog fuel, people who already serve the market for a particular product are more optimistic than the overall average of all respondents regarding the future demand of those products. This ‘‘self-optimism’’ could be due to greater insight into opportunities for each sector or perhaps due to innate optimism in the wood products community about one's chosen work. The implication is that future growth and innovation are more likely to occur in businesses that are already serving a given market sector.

Perception on "usefulness of debarking"

Table 3 shows a summary of responses about the perception of how much value debarking can add to different products from small-diameter woody material.

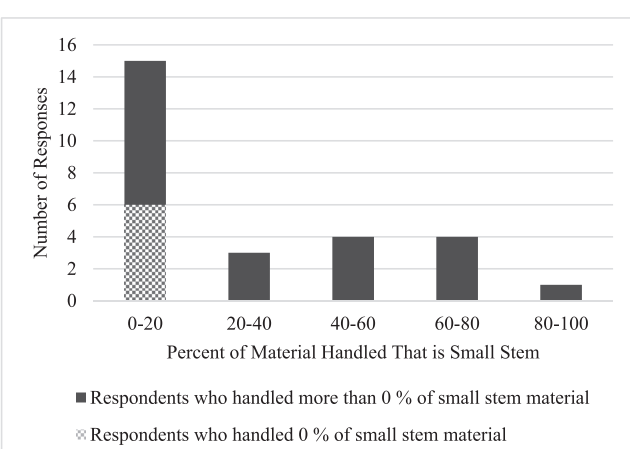

Figure 1.—Percentage of small-diameter-stem material handled.

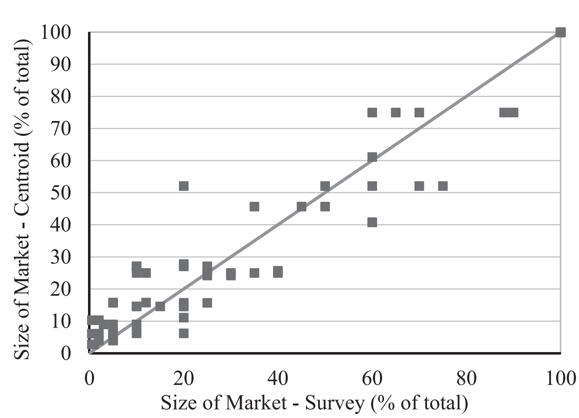

Figure 2.—Scatterplot of market size given by respondents versus centroid of possible market sizes.

Table 1.—Breakdown of markets served with small-diameter woody material.

Market	Respondents who service that market (% of respondents)	Average sales to that market (% component of company sale portfolio)			
		Min	Mean	Max	Standard error
Chips for energy	42	1	37.8	100	40.1
Chips for pulp/paper	84	10	54.3	100	30.8
Chips for composite wood products	47	10	38.0	100	33.8
Chips for other use	58	1	14.5	40	12.5
Shredded wood/hog fuel	21	2	3.3	5	1.5
mulch	63	1	13.8	70	20.2
Small-dimension lumber	26	5	29.6	75	27.1
Other	37	30	72.5	100	31.0

Table 2.—Percentage of responses regarding future demand of products from small-diameter-stem woody material.

	Chips for energy	Chips for pulp and paper	Chips for composite wood	Chips for other use	Shredded wood/ hog fuel	Mulch	Small-dimension lumber	Other
Responses								
No. of responses	17	14	16	12	13	11	9	6
No demand (%)	18	0	13	17	38	36	22	33
Moderate demand (%)	59	71	75	67	54	64	56	67
High demand (%)	24	29	13	17	8	0	22	0
Weighted responses								
No. of responses	17	14	16	12	13	11	9	6
No demand (%)	0	0	0	0	38	11	0	0
Moderate demand (%)	67	65	97	79	63	89	53	100
High demand (%)	33	35	3	21	0	0	47	0

The perception of general respondents is that chips for composite wood products and chips for pulp and paper are the leading products that can benefit from debarking; 83 percent of respondents are optimistic that debarking is valuable for pulp and paper or for composite wood as well (selecting somewhat more valuable, moderately high increase in value, or very high increase in value). However, based on weighted responses where greater emphasis is given to the responses of those who actually manage/process that product, chips for other use (93%), dimension lumber (91%), and chips for pulp and paper (86%) are the three main candidate products about which respondents are most optimistic regarding the benefit from debarking. In addition, 38 and 35 percent of respondents believe that debarking can highly increase the value of chips for energy and chips for composite wood products, respectively. On the other hand, shredded wood/hog fuel and mulch do not seem to be expected to receive much benefit from debarking; most responses fall under the category of no increase in value to a little more value.

Perception on "benefit of debarking in respondent's operation"

Figure 3 summarizes the respondents' perception of how their own operations would benefit from a small-diameter-stem debarking facility. Seventy-six percent of the respondents were positive (slight, moderate, high, or extreme) that a small-diameter-stem debarking facility would add benefit to their operation. The most common response (38%) was

Table 3.—Perception regarding benefit of debarking of small-diameter woody stems for different forest products.

	Chips for energy	Chips for pulp and paper	Chips for composite wood	Chips for other use	Shredded wood/ hog fuel	Mulch	Small-dimension lumber	Other
Response								
No. of responses	25	23	22	19	19	19	16	4
No increase in value (%)	44	13	9	47	63	58	25	50
A little more value (%)	24	4	9	16	16	11	19	0
Somewhat more valuable (%)	12	35	55	26	16	21	50	50
Moderately high increase in value (%)	12	22	14	11	5	11	6	0
Very high increase in value (%)	8	26	14	0	0	0	0	0
Weighted responses								
No. of responses	25	23	22	19	19	19	16	4
No increase in value (%)	11	14	8	7	50	96	9	—
A little more value (%)	30	1	14	0	50	4	0	—
Somewhat more valuable (%)	0	34	43	93	0	0	91	—
Moderately high increase in value (%)	59	14	0	0	0	0	0	—
Very high increase in value (%)	0	38	35	0	0	0	0	—

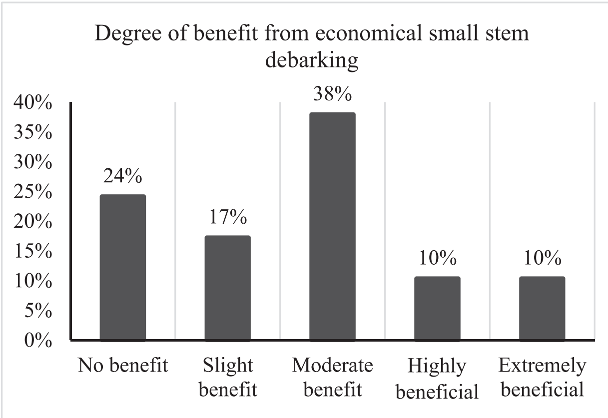

Figure 3.—Percentage of respondents whose operations would benefit to various degrees from the availability of small-diameter-stem debarking facility.

that their operation would have moderate benefit from an economical small-diameter-stem debarking facility. The specific benefit to each operation would vary, with one respondent noting that ''the potential benefit would be in accessing previously high-graded stands that are closer to the mill and lowering the transportation costs of the fiber.'' It is important to note, however, that the feasibility of small-diameter-stem debarking of forest material has not yet been established. Furthermore, additional impediments to the use of small-diameter-stem debarking likely exist, especially with respect to landowner preferences and willingness to harvest, which are more complex than a simple economics-based decision (McGill et al. 2008, Saulnier et al. 2017, Jiang et al. 2018). However, the results of this analysis suggest that continued research to develop feasible systems for small-diameter-stem debarking is likely to find a welcome reception in the forest products community.

As given in Table 1, the top three products in terms of current market coverage among respondents are chips for pulp and paper (38.5%), chips for composite woods (15.8%), and chips for energy (12.6%). These top three products were chosen for closer analysis to see their strength of association with responses to the other questions (1, 2, 5, 6, and 7), which assessed the respondents' type of work, current use of small-dimension material, expected future demand, effect of debarking on value, and benefit to the respondent's operation.

As per Table 4, Freeman theta values for all the pairs are less than 0.4 (weak association), meaning that the occupation of respondents (harvester/logger, buyer/processor, consultant, or other) is not associated with their perception of debarking or with their perception of future demand for certain products.

As per Table 5, we can say that there is very weak correlation between opinions regarding future demand and usefulness of debarking for the top three products (SRCC values are less than 0.2 for all the pairs). In other words, opinions regarding the usefulness of debarking for a product are not affected by what respondents think of future demand for that product.

The SRCC between responses for perception regarding ''benefit of debarking in respondent's operation'' and responses for ''future market perception of chips for pulp and paper'' was 0.5 with a *P* value of 0.075. This is not a significant correlation at the 5 percent level of significance but is a moderate correlation at the 10 percent level, meaning that those who think there will be an increase in demand for pulp and paper may also think that debarking would be beneficial for their operation. However, SRCC values were negative when calculated by pairing ''benefit of debarking'' with ''future market perception of chips for composite wood products'' (–0.3) as well as with ''future market perception of chips for energy'' (–0.2). These are weak negative correlations and are not significant even at the 10 percent level of significance. There is also not a strong correlation (0.1) between the percentage of current product that comes from small-diameter woody material (Question 2) with the perception regarding ''benefit of

Table 4.—Freeman theta values between occupation of respondents and various other responses including perception regarding debarking.

Response	Occupation of respondents (Question 1)
Percent of current product from small-stem-diameter material (Question 2)	0.347
Future market perception of chips for pulp and paper	0.271
Future market perception of chips for composite wood	0.262
Future market perception of chips for energy	0.27
Perception on usefulness of debarking for chips for pulp and paper	0.289
Perception on usefulness of debarking for chips for composite wood	0.276
Perception on usefulness of debarking for chips for energy	0.168
Perception on benefit of debarking in respondent's operation	0.1

Table 5.—Spearman rank correlation coefficient (SRCC) and P *values between various responses.*

Paired responses for calculating SRCC	SRCC	*P* value
Future market perception of chips for pulp and paper		
Perception on usefulness of debarking for chips for pulp and paper	0.07	0.81
Benefit of debarking in respondent's operation	0.5	0.075
Percentage of current product that comes from small diameter	−0.3	0.33
Future market perception of chips for composite woods		
Perception on usefulness of debarking for chips for composite wood products	−0.04	0.88
Benefit of debarking in respondent's operation	−0.3	0.25
Percentage of current product that comes from small diameter	−0.2	0.43
Future market perception of chips for energy		
Perception on usefulness of debarking for chips for energy	0.15	0.58
Benefit of debarking in respondent's operation	−0.2	0.45
Percentage of current product that comes from small diameter	−0.4	0.11
Benefit of debarking in respondent's operation		
Percentage of current product that comes from small diameter	0.1	0.56

debarking in respondent's operation.'' Hence, we can say that the amount of small-diameter woody material that respondents are currently handling does not impact their views regarding the usefulness of debarking in their operation.

The percentage of current product that comes from small-diameter woody material (Question 2), when paired with respondents' opinions regarding future demand of all the top three products, results in SRCC values that are negative (–0.3 for chips for pulp and paper, –0.2 for chips for composite woods, and –0.4 for chips for energy). The magnitudes of these correlations are not strong, and the high *P* value of the coefficients precludes conclusions about those relationships.

The perception of the impact of small-diameter-stem debarking on the respondents' individual operations is thus not impacted by occupation or the current amount of small-diameter-stem material that is being processed. However, both the perceived value and future demand are impacted by the current amount of small-diameter woody material that is being processed. This implies that the overall benefit of small-diameter-stem debarking is evenly understood across the surveyed population, while the respondents who supply a particular market see a greater value increase due to debarking for that particular market.

Opinions regarding the benefit of debarking for a particular market do not show a relationship to the perception of future markets for debarked material, implying that the relative value of debarking depends not on the status of the future market but rather on the characteristics of the materials used for that market. While the understanding of small-diameter-stem debarking is relatively uniform across the industry, persons supplying particular markets have a greater appreciation of the value that the process brings to that market. Thus, their input is especially critical when specifying performance characteristics of small-diameter-stem debarking systems.

These results should be interpreted with cognizance of the limited size of the data set, keeping in mind that categories with fewer responses (i.e., ''other'' markets) may be less representative of the population as a whole. Also, the survey does not directly address perceptions regarding ecosystem service impacts of small-diameter-stem debarking, a topic that should be addressed in any development of new forest utilization technology.

Conclusions

Small-diameter woody material makes up a significant portion of respondents' markets, accounting for about 30 percent of all material. The most common current use is for chips for pulp and paper, while shredded wood/hog fuel is the least common. Respondents who are currently serving a given market tend to be more optimistic about that market's future than the overall average for respondents. The greatest optimism for the benefit of economical debarking is associated with markets for small-dimension lumber, chips for composite lumber, chips for pulp and paper, and chips for other uses. Overall, the economical debarking of small-diameter-stem woody material is perceived to be beneficial for the majority of respondents, with over half indicating a moderate to extreme benefit. These responses do not appear to be impacted by respondent occupation or by their current amount of small-diameter woody material being utilized. These findings suggest that the development of economical small-diameter-stem debarking systems has the potential to be a valuable tool for wood products professionals in Pennsylvania.

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