Innovation Impacts on Biomass Supply in Maine's Logging Industry

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Abstract

A robust supply chain is critical to ensure a sustainable supply of feedstock to the existing and emerging bioenergy and bioproducts industries. Logging contractors are a key group in this process, since they provide harvesting and transportation services, and their success is directly linked to innovation activities. Surprisingly, very little is known about the innovation system in the logging industry—especially about how it relates to biomass supply. Failure to understand how logging contractors adopt and implement biomass production technologies could lead to failed innovation efforts, unmet development goals, and a lack of properly equipped contractors. This article presents results from a series of case studies of highly innovative logging contractors in Maine. All of the firms had some experience producing biomass within their operations. The firms had also used multiple biomass harvesting technologies. This study highlights the variation in challenges that led to the adoption (or rejection) of biomass as a product innovation—with particular emphasis on harvesting technologies. A major finding of this study was the need for a high degree of collaboration between landowners, logging contractors, and biomass consuming facilities in the innovation process. The future development of the biomass industry is highly dependent on contractors adopting biomass harvesting and related technologies. The innovation process of logging firms is an area that is not sufficiently studied, and this research provides valuable insight into this important component of the forest biomass industry.

Although Maine has had an active biomass market since the 1980s, harvesting biomass still represents a new product to many logging contractors in the region, and they may have to make significant investments and changes in their operations to engage in this market. Contractors that already produce biomass may also be looking to adopt new production practices and technologies to increase efficiencies. Most of the available research on biomass harvesting has focused on assessing productivity, environmental impacts, material recovery, and similar logistical concerns (Dirkswager et al. 2011). To date, little research is available on how logging businesses respond to changes in biomass demand and changes in harvesting technology. A key component of forest biomass development is the innovation process of logging contractors and the factors that influence it.

Background

Innovation theory

Multiple definitions of innovation have been proposed in numerous studies on the subject (Schumpeter 1934, Nelson and Winter 1977, Rogers 2003, Organisation for Economic Co-operation and Development [OECD] and Eurostat 2005, Rametsteiner and Weiss 2006). At the core of innovation definitions is the concept of ''newness,'' which contains elements of change and improvement. One of the most comprehensive publications on innovation studies is the *Oslo Manual* (OECD and Eurostat 2005), a publication used for national innovation studies in the European Union and Canada. The *Oslo Manual* classifies innovation into four types (product, process, organizational, and marketing) and sets the level of adoption with the firm, which means something new to the firm is an innovation. Stone et al. (2011) previously applied this definition to Maine's logging industry and found that biomass production can be considered a product innovation for a logging firm that has never produced biomass before, even if a biomass market has existed in the area for some time. They also found that biomass production can be considered a process innovation for firms already producing biomass, if there is a

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major change in harvesting practices or a new type of machine is added to a harvesting system.

There are two major innovation models that are used to understand innovation adoption and development: the linear adoption process and the innovation system. The linear adoption process is part of the diffusion concept (Rogers 2003)[1] and describes the process that a firm goes through when adopting an innovation. Through this process a firm gathers knowledge, makes a decision, implements the innovation if adopted, and confirms the decision. Rogers (2003) also notes that certain firms vary in their level of innovativeness and categorizes firms by five different classes: innovators (quickest to adopt), early adopters, the early and late majority, and laggards (slowest to adopt).

Another major conceptual model of innovation development is the innovation system. The concept of an innovation system has been studied extensively and appears in a number of publications on innovation (Nelson and Winter 1977, Nelson 1993, Rogers 2003, National Innovation Initiative 2004, OECD and Eurostat 2005), although the exact term ''innovation system'' may not be used. The *Oslo Manual* places the firm at the center of the innovation system with influences flowing to and from the firm from five different components. Stone et al. (2011) previously applied this model to Maine's logging industry and determined the structure and strength of the connections in this system (Fig. 1). These models can be used together or separately to understand the innovation process of firms. As suggested by Rametsteiner and Weiss (2006), this article combines both approaches.

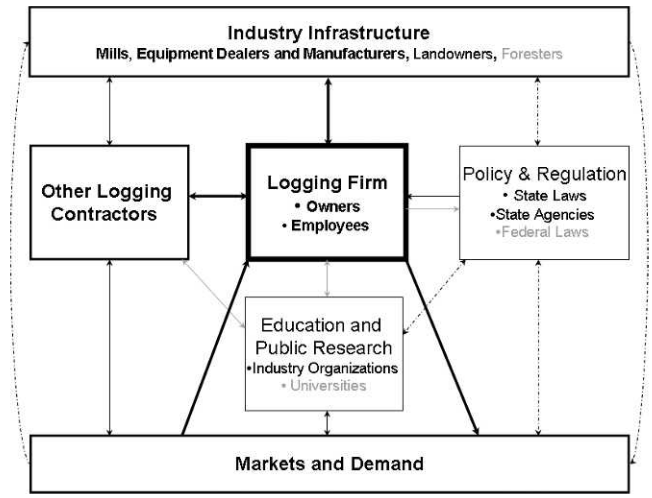

Figure 1.—The Maine logging innovation system redrawn from Stone et al. (2011) and based on basic system design from the Oslo Manual. *Bold font and thicker lines represent stronger and more important connections, while lighter fonts and lines indicate weaker connections. Dotted lines indicate connections not tested in the study.*

Biomass innovation

Most of the available literature on biomass harvesting focuses on harvesting logistics, environmental impact, and potential changes to the forest products industry. Very little research examines these issues from an innovation framework, and even less focuses on logging businesses. Publications that do address components of biomass innovation development have addressed changes to the forest products industry (Soderholm and Lundmark 2009) or specific developments such as district heating plants (Madlener 2007). Several recent publications have examined issues with biomass harvesting and logging firms. Dirkswager et al. (2011) found that markets, equipment and operating costs, access to available material, and regulations were factors impacting biomass harvesting development among Minnesota contractors. In a study of Inland Northwest contractors, Allen et al. (2008) found that despite the fact that logging contractors ranked access to timber sales the most important constraint adversely affecting their business, only 62 percent were considering engaging in fuel reduction harvests on federal lands. Contractors in this study cited the following reasons for their reluctance to engage in fuel reduction harvests on federal lands: concerns over complying with regulations, profitability of sales and fuel reduction operations, concerns that additional services would be mandated as part of the harvest, and difficulties obtaining the credit needed to convert existing harvest setups to perform these harvests. In a recent multiregional review of biomass harvesting, Greene et al. (2011) found that approaches to biomass production vary from region to region and that these differences were largely due to the strength and size of the pulpwood markets in the region. Their study also found that payment on a dry weight basis was only found in the West and that this produced significant changes in biomass harvesting.

Investigations into the issues and infrastructure surrounding biomass use in the Northeast have discovered similar issues. A review of the challenges and opportunities facing the forest bioindustry in the Northeast (Benjamin et al. 2009) concluded that careful consideration must be given to feedstock specifications, existing infrastructure, forest operations, public policy, and social values as the industry grows and develops. Another review of the issues influencing biomass harvesting in the Northeast concluded that demand for forest-derived biomass is likely to increase in the near future, which may increase competition among wood using facilities and strain the existing wood supply (Benjamin et al. 2010). Further, this study noted that cost of production for harvesting operations is highly variable and depends on the harvest method, harvest system, terrain, stem size, stand density, species composition, and other variables. The results from existing studies on biomass harvesting development show that market factors, forest conditions, policy, capital access, forest management, and payment all may impact biomass harvesting adoption.

Project objectives

The overall objective of this research was to better understand biomass harvesting innovation activities among logging contractors in Maine. The methodology outlined in this article will assist researchers in investigating biomass harvesting innovation in other regions. In particular, this article will (1) use the linear adoption process to better understand the factors leading to biomass adoption, rejection, or discontinuance by a logging firm and (2) determine components of the innovation system that are

[1] *Diffusion of Innovations* has multiple editions, the first of which was published in 1962. The newest is the fifth edition published in 2003.

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most important to biomass development and identify areas for improvement in the system.

Methods

A case study approach of highly innovative logging contractors was used to assess biomass-related innovations in this study. As noted by Yin (2003), case studies provide an ideal way to gather qualitative data to answer core study questions. Innovators were selected for this study because they are most likely to have adopted and abandoned multiple biomass innovations, and as noted by Rogers (2003), they play a major role in the diffusion process and they are often opinion leaders in their industry. Sampling only the innovators represents an extremity sampling technique, where samples are drawn from the portion of the population high above the mean with regard to innovation (Eisenhardt 1989).

We found no previous survey or other data available that could be used to locate innovative logging firms, so a mixed-mode survey of forest industry stakeholders was first conducted. The survey list was generated using online database listings, forestry organization lists, and referrals from participants. Respondents to the survey were asked to (1) identify logging contractors in the state that they considered most innovative, (2) rank them in order of innovativeness, and (3) explain the firm's innovation activities. A total of 154 individuals from various organizations in Maine's forest industry were surveyed, and after removing wrong numbers, repeats, and disconnected numbers, the effective sample size was 139. In total, 89 responses were received, which yielded an effective response rate of 64 percent. Cases were then selected by how often they were mentioned and their rank, the regional nature of the response, and the uniqueness of their biomass innovation activities. Based on these criteria, 13 cases were selected, and 10 firms agreed to participate. A semi-structured interview was then conducted with the owner and key personnel of each firm as well as a visit to an active logging site. On occasion, distance and weather prevented an active site visit, so a previous harvest or inactive site was visited as an alternative.

Results and Discussion

Company profiles

The cases provided an excellent opportunity to determine how contractors assess biomass harvesting innovations and what leads contractors to adopt or abandon biomass as a product. This is in part due to the diversity of companies interviewed as shown by differences in firm size, system selection, and biomass production experience and status (Table 1). For example, it was discovered that four cases had been producing biomass for an extended period of time (15 y or more), one had produced biomass at one time but had since abandoned it, and three other cases had produced biomass previously, given it up for a time, and readopted it recently.

Factors influencing the adoption process

The cases also provided valuable insight into the structure of the innovation system and what components influence biomass harvesting and related innovations. The major factors that influenced the adoption of biomass harvesting and related innovation among the cases were market price, market access, cost of innovation, and effect on final site quality (Table 2). In general, the contractors studied put a heavy emphasis on reducing production costs, increasing efficiency, and improving profitability. The results from the cases studied were similar to those from a Romanian study (Duduman and Bouriard 2007), which found that logging firms' struggle to stay in business creates a preoccupation with efficiency and cost reduction. Results from the cases studied also indicate that contractors in Maine have a focus on finished site quality as well. These findings also hold true for biomass innovations and have implications for biomass development.

Market price and access.—The first major consideration by contractors studied when adopting and assessing biomass innovations was the profitability of the operation. Every contractor interviewed mentioned that market price or market access, and in most cases both, had an influence on biomass harvesting innovation. Contractors will give up highly innovative processes or even halt biomass production if prices fall or if the market dissolves. For example, Contractor H had abandoned a highly innovative system for producing biomass with cut-to-length systems because the price had decreased too much. Further, he said that ''The consuming mills just have too strong a hold ... they're ultimately controlling the price of chips and it's just not a profitable venture at this point.'' When asked about possibly readopting biomass in the future, the same contractor further emphasized the importance of markets and price saying ''Only if the price of chips comes back. It's very simple. The whole thing is about money and no matter what you do in logging it comes back to the dollar.'' Contractor J described why he had abandoned biomass after the initial development of the Maine biomass markets in the late 1980s:

> Now, as it comes and goes, I don't find it of interest to get into it again simply because how long is it going to be this time? I know currently the biomass price is way down. Last winter when the BCAP [Biomass Crop Assistance Program] program was going the price was pretty good. The guys were doing pretty good but I guess I want more security in what I am doing and as secure as logging can be as logging round wood is much more secure than being involved in biomass and chipping.

In addition, market availability and price were found to impact equipment adoption and production methods. One prime example was logging residue bundling technology, which several participants had researched and seen at an equipment demonstration. Three of the cut-to-length contractors interviewed stated that this technology was promising and represented an improved way of producing biomass with these systems, but that this machine was too costly given current prices and no facilities currently wanted to purchase the bundles. Another example was the use of grinders. Contractor A found grinders to be more productive, saying a grinder ''is more productive for your logging equipment because you don't have to pile anything. You just delimb it and leave it.'' The issue with grinders, as identified by study participants, was that sometimes facilities do not want grindings or pay much less for the grindings. Contractor C summarized this by saying:

> We know where it is. If they are going to pay me [$X] a ton for biomass tops, it's going to the grinder. If they are going to pay me [$Y<$X], no. If they are going to pay

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Table 1.—Company profile of case study participants including specifics related to biomass production.

ID	No. of employees	Harvest system details[a]	Decade firm established	Biomass production: Experience (y)	Biomass production: Status[c]	BCAP participant (yes/no)[b]
A	45	4 WT	1980s	>20	A-RA	Y
B	NA[d]	CTL, WT (used in combination)	1950s	NA	A	Y
C	30	4 WT	1980s	NA	A	Y
D	20	1 CTL, 1 WT	1980s	>20	A	Y
E	6	CTL, WT (used in combination)	1980s	NA	A-RA	Y
F	30–35	2 WT, 2 CTL (used in combination and separately)	1970s	<5	A	Y
G	NA	2 WT	1990s	>15	A	Y
H	5	1 CTL	1990s	NA	IA-A	N
I	3	1 CTL	1970s	>20	A-RA	Y
J	NA	1 CTL (including feller buncher, processor, and forwarder)	1960s	>5[e]	IA	N

[a] Number of harvest systems by harvest method: WT = whole-tree; CTL = cut-to-length.
[b] BCAP = Biomass Crop Assistance Program, a subsidy program administered through the Farm Services Agency in 2009 and 2010.
[c] A = active; A-RA = active, re-adopted; IA = inactive; IA-A = inactive, abandoned.
[d] NA = not applicable.
[e] This company produced biomass during the 1980s.

> me [$Z>$X] a ton for the biomass tops, it will go to the chipper. We know where the cutoff point is, we know we're the one that brings it up.

This statement also illustrates another key finding, which was that innovative contractors often have an extensive understanding of the prices and productivity levels needed to make biomass innovations possible through organizational innovations designed to measure operation performance. This measure of operational performance was a major component of the implementation phase and was also part of the confirmation phase (Rogers 2003).

Cost of innovation.—Cost of biomass innovations was also found to be a major factor and was a major component of the knowledge and evaluation stages of the adoption process. Capital cost of logging innovations in general was found to be the biggest barrier to innovation development. Contractors in this study are not likely to adopt biomass innovations that require large capital expenditures. Participants felt biomass innovations needed to be easy to introduce into current harvesting systems without major changes or capital expenditure to do it. A prime example of this necessity was the dominance of the chipper and the adoption of equipment modifications and attachments among the cases. Cases found that these innovations were relatively low cost and did not require complete restructuring of their harvesting systems. Contractor J was not interested in readopting biomass for this reason, saying ''Oh, I can't say I wouldn't consider it but in my case, too, if I decided to do biomass I would need to change my harvesting operation a little.'' For biomass innovations to gain acceptance with contractors they need to be easy to integrate, low cost, and have ready market acceptance.

Contractors also considered the effect of biomass adoption on the cost of their current operations. It was discovered that the contractors studied viewed biomass as a by-product and showed little interest in performing ''biomass only'' harvests. This was especially true at current price levels. Five contractors did show a willingness to perform harvests where biomass was the largest product by volume but stated during the site visits that other

Table 2.—Biomass innovation profile of case study participants.

ID	Biomass innovation type	Influences on biomass harvest innovation: Market price	Market access	Cost of innovation	Final site quality	Degree of collaboration with: Landowners	Equipment dealers/manufacturers	Mills
A	Equipment, organizational	x	x	x	x	Limited	Engaged	Engaged
B	Equipment, process	x	x			Limited	Not engaged	Not engaged
C	Equipment, organizational, production/cost tracking	x	x	x		Engaged	Limited	Engaged
D	Process, organizational	x		x	x	Engaged	Limited	Limited
E	Process, marketing, production/cost tracking	x	x	x	x	Engaged	Engaged	Engaged
F	Equipment, process, marketing, production/cost tracking	x	x	x	x	Heavily engaged	Engaged	Engaged
G	Marketing, organizational, production/cost tracking	x	x	x	x	Heavily engaged	Engaged	Not engaged
H	Equipment	x	x	x	x	Engaged	Engaged	Not engaged
I	Equipment, process, marketing, production/cost tracking	x	x	x	x	Engaged	Engaged	Engaged
J	Abandoned all biomass production in 1980s	x	x			Not engaged	Not engaged	Not engaged

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products had to be part of the harvest to make the operation profitable.

Site quality.—It is important to remember that biomass has other uses to logging contractors. For example, eight contractors stated that they use biomass material as part of best management practices work to protect water quality and retain a high finished site quality. Contractors studied were unlikely to give up these advantages of biomass use, especially if they put a high priority on finished site quality. Contractor H discussing this specific issue said the company ''didn't want to give up any quality in our operation just to implement biomass extraction.'' This shows the high value contractors in this study put on site quality. Participants felt that biomass harvesting innovations needed to be easy to introduce into current systems without impacting the cost of producing other forest products or impacting finished site quality.

Innovation system impacts on biomass production

Through the case studies it was found that the innovation system (Fig. 1) can have profound impacts on the adoption of biomass harvesting. As mentioned in the previous section, markets and demand heavily influenced the decision to produce biomass and the adoption of specific harvesting technologies. As shown in Table 2, collaboration and cooperation among the industry infrastructure (landowners, equipment dealers and manufacturers, and mills) and logging firms were also important to harvesting development. The contractors studied had very little connection and interaction with public education and research centers, and the contractors also noted that although policy can have an impact on logging innovations, their ability to influence policy is limited. These findings are consistent with Maine's overall logging innovation system (Stone et al. 2011).

Landowners.—In all situations, regardless of the innovation in question, the firm is the most important component of the innovation system, but the industry infrastructure also plays a major role. For example, landowners play a major role in developing biomass harvest opportunities by providing areas for contractors to test new system configurations, equipment, and techniques. Cases in this study viewed biomass as a way to improve forest growth and generate higher value products in future harvests. The four contractors with the most highly developed biomass systems had access to their own land or landowners that were willing and interested in biomass harvests being used to meet silvicultural goals. Landowners could further facilitate willingness to harvest by giving contractors firm commitments for long-term contracts so that the same contractor can harvest the higher value products produced through thinning and stand improvement operations. Contractor F discussed the importance of working with a landowner in developing a specialized operation with a biomass component saying ''In [year] we had the first processor of that type to come in to do [specialized forestry operation] . . . you know why they work . . . the willingness for [landowner] to take that chance, the landowner to take a chance on us that we would do the work and get done what they wanted to see done.'' This shows how important mutual collaboration is to innovation development.

Equipment dealers and manufacturers.—Equipment manufacturers and dealers were also found to be very important to biomass innovations. Contractors said they would not work with manufacturers and dealers that do not provide proper support and service for machines. Equipment manufacturers that work closely with contractors were able to develop very effective solutions to problems. For example, Contractor I was sponsored by a manufacturer and their associated dealer to go to the manufacturer's factory to see several new technologies in development. Contractor I was especially interested in any biomass harvesting technology they had, and had been discussing their needs with the company since they purchased their first machine from the dealer. The manufacturer had several applicable technologies including one prototype attachment and retrofit that was capable of handling biomass. The manufacturer worked hard to get this innovation operational while Contractor I was at the factory. Contractor I further describes this interaction as follows:

> When we got over there they said they were working on a new concept and they had it on a [machine type] but they didn't have it out in the field yet. So what they did was I was only there for five days and the first three days they got that head on the machine and trouble shot it and then had an operator run [the head] so I could see on the last day and that's the one we retrofitted for this head. So they really worked hard to get that so we could see it.

This contractor later adopted and applied this new technology and has worked closely with the manufacturing company to implement it successfully.

Equipment manufacturers could assist by working with contractors in machine development and by providing effective service and support. Contractor A expressed frustration at a lack of collaboration from equipment manufacturers and dealers on developing some biomass-related equipment innovations saying the ''dealers many times will like to talk innovation and talk with you but they don't do anything. They may try to talk to the manufacturers or they might not even bother to talk to the manufacturers because the manufacturers are generally so stuck in a rut or they're going to do what they're going to do.'' The difference between the experiences of Contractor I and Contractor A working with equipment manufacturers highlights the importance of collaboration and communication between these two groups. The partnership and communication between Contractor I and the equipment manufacturer produced a successful innovation, while Contractor A was experiencing difficulties finding a manufacturer to assist with the advancement of the firm's biomass harvesting systems.

Mills.—Consuming facilities can assist in innovation efforts by providing markets for new biomass products. For example, the contractors that expressed interest in logging residue bundling technology stated that one barrier to adopting the machine was that no facilities were interested in buying the bundles. A similar issue was noted by the two cases using grinders, which illustrates the need for collaboration from consuming facilities when developing harvest techniques.

A recent study of the importance of innovation to the US forest products industry (Hansen 2010) found that European countries (such as Finland) emphasize a healthy innovation system, which is effective at facilitating innovation. This emphasis on effective innovation systems could explain why European countries have been effective at developing forest biomass advancements like biomass district heating plants

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(Madlener 2007), biorefineries (Makinen and Leppahlati 2009), and biomass bundling technology (Pettersson and Nordfjell 2007). As biomass harvesting progresses in Maine and elsewhere, effective communication and collaboration in the innovation system is likely to be a major component of successful innovation efforts.

The biomass crop assistance program: A case of policy intervention

In the winter of 2009 and 2010 the federal government instituted the Biomass Crop Assistance Program (BCAP) through the Farm Services Agency (Federal Register 2009, 2010a). This program provided a subsidy to producers of eligible biomass material, which included logging firms. Several of the firms interviewed participated in BCAP, and they provided insight into the effectiveness of this program. All firms interviewed disliked the program and would rather it had not been implemented. In fact, the program actually led Contractor H to abandon biomass production and a highly innovative harvesting system citing

> [A]t one point we saw biomass prices at a level that was sustainable and [then] we had a wonderful government subsidy there last winter, BCAP and saw it [the biomass market] start to unravel as a result. And now, you know, the mills are all blessed with very low cost material throughout the BCAP program and once the BCAP went away the price remained low.

Contractor E expressed frustration with the program saying ''We get less now for our chip than we did before BCAP came ... all it did was create a dependency at the mills. Now they say they can't run without cheap wood and so it lowered our price. We are all working for less than we did before it started.''

These findings are similar to those of Greene et al. (2011), who found that BCAP disrupted markets and caused price drops in regions that had existing biomass markets. BCAP also failed to generate any adoption of new technologies by the contractors interviewed. Cases A and I, however, did use an increase in funds to experiment with harvesting smaller-diameter stems. A study of policy impacts on innovation among Central European forest holdings (Rametsteiner and Weiss 2006) found that policies aimed at fostering innovation in this area consisted mostly of subsidies and capital injections and were largely ineffective at generating innovation. The results of Greene et al. (2011) and the 10 cases studied show that the same is likely true for biomass harvesting innovation. The BCAP old rule (Federal Register 2009, 2010a) failed to generate innovation in biomass harvesting among the cases studied and actually appears to have harmed innovation efforts. The effect the changes in the BCAP program through the final (new) rule (Federal Register 2010b) will have are unknown, but strong evidence exists that suggests continued subsidizing of forest biomass may be ineffective and potentially harmful.

Conclusions

This research has shown that the linear adoption process and the innovation system, when used in combination, are very effective at understanding and describing the adoption and rejection of biomass harvesting innovations. The results of the case studies show that market access and price, cost of innovation, effect on final site quality, and innovation support from outside the firm are the biggest factors affecting biomass harvesting adoption or rejection. These factors feature prominently in the knowledge, evaluation, implementation, and confirmation phases of the adoption process and have a major impact on the adoption decision of the firm. Biomass was viewed as a by-product by the contractors studied, so harvesting innovations need to be easy to integrate with current harvest systems. Effective biomass harvesting development was found to be heavily dependent on multiple components in the innovation system working together. Increasing collaboration and idea transfer in the innovation system could improve biomass harvesting development. It was also discovered that BCAP was ineffective at generating innovation among the logging innovators studied. The results suggest that subsidizing biomass production and capital injection are not the answer to biomass-harvesting advancement and may in fact be harmful.

Finally, this project has highlighted several areas of improvement in Maine's logging innovation system. Logging contractors currently have little connection with public research and education centers and could benefit from a cooperative research and outreach program similar to the FPInnovations–Forest Engineering Research Institute of Canada (FERIC) Division in Canada or the Oregon Wood Innovation Center run by Oregon State University. A program that provides collaborative research and outreach to logging contractors, landowners, equipment manufacturers, and others could be highly effective at assisting with biomass harvesting innovation development. In addition, policy makers should work collaboratively with stakeholders to make sure that policies are effective at assisting with innovation efforts and are not disrupting markets or hampering innovation efforts. Providing an outlet for logging contractors and other stakeholders to influence and inform policies could be a major step in developing policies that help to generate biomass harvesting innovations. The need for market development and availability means that collaborative efforts should focus on developing stable and diverse markets for forest biomass materials. Further, this research should focus on how units of the innovation system can work together and establish collaborative efforts to assist in innovation efforts and support the other units of the system.

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