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Family forest owner preferences for biomass harvesting in Massachusetts

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ABSTRACT

U.S. forests, including family-owned forests, are a potential source of biomass for renewable energy. Family forest owners constitute a significant portion of the overall forestland in the U.S., yet little is known about family forest owners' preferences for supplying wood-based biomass. The goal of this study is to understand how Massachusetts family forest owners feel about harvesting residual woody biomass from their property. The study estimates the probability that Massachusetts landowners will harvest biomass as part of a timber harvest using data from a survey of 932 Massachusetts family forest owners. Logistic regression results suggest that the likelihood of harvesting for biomass is quite low, and that the supply of participation in biomass harvesting is inelastic with respect to price. These low probabilities may be due to the method used to account for preference uncertainty, as well as the unique nature of Massachusetts forests, forest markets, and landowner attitudes in comparison to other states (e.g., Minnesota). The study suggests that it would be more effective to target renewable energy policy toward different regions and/or markets rather than develop a uniform national policy.

1. Introduction

U.S. forests, which are potential sources of biomass for renewable energy, make up 33% of the land in the country (Smith et al., 2009). Federal policies underscore the important role that private forests may play in the future of biomass for bioenergy, including the Energy Policy Act of 2005, Energy Independence and Security Act of 2007, 2008 U.S. Farm Bill, and the USDA Biomass Crop Assistance Program (BCAP). Unfortunately, little is known about forest owner preferences for managing their land for biomass harvesting. We know even less about family forest owners' preferences regarding this issue. Family forest owners, defined as “families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land” (Butler, 2008, p.3), have the potential to play a significant role in biomass supply for renewable energy. Indeed, over one-third of the forests in the United States are family forest owned (Butler, 2008), and in the Northeast, this percentage is even greater. In Massachusetts, over half of the forests, approximately 1.7 million acres, are family forest owned (Butler, 2008).

The goal of this research is to understand how Massachusetts family forest owners feel about harvesting residual woody biomass from their property.[1] In recent years, the topic of biomass harvesting has generated considerable discussion among Massachusetts forest owners, policymakers, conservation organizations and municipal officials. Several forest-based biomass electric power plants had been under consideration in the state and generated intense public comment. As a result, the State commissioned a report from the Manomet Center for Conservation Sciences, which was released in June 2010, to analyze the scientific, economic, and technological impacts of using forest-based biomass for generating energy in Massachusetts (Manomet, 2010). The findings of this study resulted in proposed amendments to the current Renewable Portfolio Standard Class I (RPS) regulations that limit eligibility of woody biomass fuels (DOER, 2010) and are incorporated into the current RPS Biomass draft regulations to be filed as final after July, 2011.

In order to understand the likelihood that woody biomass from family forests could be a source for bioenergy facilities, to understand the effectiveness of renewable energy policy, and to help design policy to meet bioenergy goals, it is important first to understand what motivates an individual to supply forest biomass for the purposes of

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[1] For purposes of our study, residual woody biomass is defined as trees that have traditionally been used for firewood and portions of trees, such as tree limbs, tree tops, needles, and leaves, not able to be used as other forest products. Harvesting residual woody biomass most often happens as part of a timber sale (harvest).

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bioenergy. We first examine how family forest owners in Massachusetts feel about harvesting biomass from their land for the purpose of biomass energy based on a survey of Massachusetts family forest owners. We compare these results to those derived from an independent study of forest owners in Minnesota (Becker et al., 2010) to identify important regional differences, and we then make policy recommendations based on our results.

2. Background

The existing biomass literature, although extensive, does not fully address the question of what motivates a private forest owner to include biomass as part of their harvest. Some of the studies provide assessments of the impact of managing forestland for biomass harvesting in different regions of the U.S., including Kelty et al. (2008), Munsell and Germain (2007), and Timmons et al. (2007). Other studies discuss the biophysical availability of forest-based biomass as an input in the bioenergy industry. For example, a detailed national study by Perlack et al. (2005) indicates that the U.S. biophysically has the resource base needed to successfully undertake biomass harvesting for energy production. The study focuses on the largest sources of biomass resources — forestland and agricultural land. Of the 1.3 billion dry tons of annual biomass potential from these sources, roughly one-quarter could be derived from forests and three-quarters from agricultural land. Benjamin et al. (2009) discuss the Northeastern forest region's ability to supply feedstock to a sustainable forest bioindustry. The study concludes that the region has the potential for a successful bioindustry, but that further research is needed on how various stakeholders' opinions and perceptions regarding the forest bioindustry would impact supply and demand for forest biomass. The Massachusetts-based Manomet report's (2010) estimates of wood-based biomass availability are based, in part, on historical harvesting practices, not direct elicitation of landowner preferences. Galik et al. (2009) conduct a supply analysis of forest biomass in the Southeastern U.S. The authors explore the regional bioenergy potential, the interaction of logging residues and roundwood supply, and the potential supply costs of forest biomass. They find that biomass supply varies by state, and that the availability of logging residues will impact the resource price as well as the market decisions made by forest owners and users, including the location decisions by new processors.

Few studies address the forest owner behavior component of biomass supply. Butler et al. (2010) estimate the biophysical and social availability of wood from family forests in the North (i.e., the 20 state regions from Maine to Maryland and Minnesota to Missouri). The authors find that social factors (e.g., ownership objectives, harvest expenditures, and harvesting intentions) had a greater impact on wood availability than biophysical factors (e.g., slope). The authors estimate that only 38% of the family forest owned wood in the North is both biophysically and socially available; the majority of this reduction in availability is due to ownership attitudes. The authors conclude that understanding the motivation of family forest owners is critical to understanding the availability of wood in the northern U.S. states.[2] Joshi and Mehmood (2011) consider the availability of logging residues and non-marketable small-diameter trees for bioenergy production by Southern family forest owners who own more than 20 ac of forestland. Short of estimating a supply curve (the authors exclude the price of biomass from their analysis), the authors find ownership objectives, acreage (i.e., total area owned), species, and survey respondent age to be important. Shivan and Mehmood (2010) analyze Southern U.S. landowners' policy preference for promoting wood-based bioenergy. Shivan and Mehmood indicate that respondents prefer tax-based policies over direct subsidies, but do not address the factors that affect biomass supply.

A study by Becker et al. (2010) provides one regional exploration in the supply of woody biomass by family forest owners. The authors surveyed family forest owners in Minnesota to examine what motivates their willingness to supply residual woody biomass, defined as "the by-product of forest management activities, including trees not used for timber production and tree limbs, treetops, needles and leaves." The authors asked respondents to assume they would harvest timber on a portion of their forest and to indicate if they would be willing to supply residual woody biomass at various prices per acre. The study found that roughly 60% to 70% of landowners, owning an average of 124 ac of forests, would be willing to harvest biomass with prices ranging from \$0/ac to \$15/ac. Factors that influence their willingness to supply residual biomass include the price of biomass, landowner attitudes and beliefs, how far they live from their forest, respondent age, and whether their primary ownership objective is to produce income from timber or agriculture.

Various factors are likely to influence the potential for successful wood-based biomass harvesting for bioenergy facilities across the U.S., including forest ownership, forest types, forest markets and landowner attitudes. Moreover, the size of average land holdings has been shown to have a significant, positive effect on harvesting in general (Beach et al., 2005). For example, in southern New England, where forest ownership is dominated by small parcel sizes and a high number of families who place low priority on timber income from their land, family owner preferences are primarily focused on amenity-based benefits (e.g., aesthetics, recreation, nature, and privacy) (Butler, 2008). If harvest occurs on these lands, it is oftentimes partial or selective in nature (McDonald et al., 2006) — some trees are harvested and others, perhaps, are left to be harvested at a later date. For example, in Massachusetts, approximately 63% of the state is forested and 53% of that land base is owned by roughly 293,000 family forest owners with an average parcel size of 6 ac (Butler, 2008; Smith et al., 2009). While over half of the commercial timber sales by area in the state come from family forest lands, this area reflects less than 1% of total private forest holdings (McDonald et al., 2006). According to McDonald et al. (2006), average harvest intensity on private lands in Massachusetts is 40 m^3/ha. Harvest intensity is somewhat higher on state lands (63 m^3/ha), but in general represents only 20 to 30% of total growing stock (i.e., approximately 200 m^3/ha). In general, the vast majority of harvest is light or partial in nature, in keeping with the overwhelming preference of owners for aesthetics, privacy, and nature. Minnesota, on the other hand, provides a much different situation. There, family forest ownerships are based on average parcel sizes of 28 ac, and pulp markets are robust. Timber harvesting in this region of fast-growing hardwoods (e.g., poplar, aspen) is much more prevalent than in developed regions of the Northeast (Smith et al., 2009).

This paper explores landowner attitudes and beliefs about biomass harvesting in Massachusetts, where family forest owners are responsible for over half of all forest in the state (Butler, 2008). Our research finds landowners to be only marginally willing to harvest residual woody biomass as part of a harvesting operation, and that willingness is not greatly influenced by price. This finding may be due to the landowner, the current market for forest products in the region, and forestland characteristics unique to Massachusetts. This research result may have implications for other states in the Eastern U.S. with similar social, economic, and ecological considerations.

3. Methods

We developed a mail survey for the purpose of investigating the likelihood of private forest owner participation in residual woody biomass harvesting in Massachusetts. Four focus groups held across

[2] Note that there is uncertainty from the individual landowner about whether to harvest and, if harvesting, how much to harvest. Family forest owner surveys indicate harvesting to be a very low priority (e.g., Butler, 2008; Belin et al., 2005; Finley and Kittredge, 2006; Rickenbach et al., 1998); however over half commercial timber sales by area in the state over 20 years come from family forest lands (McDonald et al., 2006).

the state pre-tested the survey, gauged comprehension, and gave us deeper insight into landowners' motivations. Four concurrently conducted focus groups provided landowners' general impressions of biomass harvesting (i.e., no survey pre-test). The final survey asked questions about land ownership (e.g., total size of landholdings and acres of forested land, primary residence distance from forested land, history and planned land management activities, enrollment in land management programs such as the Tree Farm program), owner beliefs (e.g., reasons for owning forestland, beliefs about the harvest and use of biomass), socioeconomic characteristics (e.g., age, gender, income, education), and preferences for harvesting biomass.

Conducted in May, 2010 (prior to the release of the Manomet (2010) report), the survey was mailed to a random sample of 932 individuals who own at least 10 ac of land in 152 cities and towns reflecting the ecological diversity of forestland in Massachusetts. Property tax rolls provided the information on these individuals who may or may not reside in Massachusetts. We developed and implemented the survey following Dillman's Tailored Design Method (Dillman et al., 2009), achieving a response rate of 47%.

In the survey, respondents were presented with information about harvesting residual woody biomass, described as "trees that have traditionally been used for firewood and portions of trees, such as tree limbs, tree tops, needles, and leaves, not able to be used as other forest products." Each respondent was asked to assume that they were working with a forester to negotiate a timber sale from their land. The landowner would receive $500/ac to harvest timber from their land, and at the same time residual woody biomass would be removed. This $500/ac amount is based on a range of 2009 stumpage prices paid for actual partial harvests in central Massachusetts (Kittredge and Catanzaro, 2011). The biomass harvest would follow best management practices designed to control erosion and protect water quality and leave 20% of post-harvest residual biomass on the forest floor. Each respondent was then presented with a price per acre for biomass harvesting and a destination for the residual woody biomass harvest. The survey tested four prices: $0, $50, $250, and $500/ac to remove residual woody biomass; and three biomass destinations: "heat a local school," "produce a gasoline substitute," and "go to an electric power plant," for a total of 12 scenarios. Each respondent was presented one scenario that asked their willingness to accept the offer.

The residual woody biomass per acre prices presented were designed to test a very wide range of values. Based on mill tally of several 2009 partial harvests of common forest types in central Massachusetts that included biomass as a product, a typical timber harvest provided an average of 65 tons of biomass per acre (John Clarke, Personal communication. January 13, 2010). Actual Massachusetts stumpage prices for biomass from 2007 to 2010 ranged from $0/ton to $3/ton (Kittredge and Catanzaro, 2011), resulting in per acre net revenues ranging between $0 and $200/ac. The net revenue values used in the survey ($0/ac, $50/ac, $250/ac, and $500/ac) were designed to test a very wide range of values, including those well beyond current market range. There is uncertainty about how the biomass and timber markets might evolve in the future, thus we knowingly present an upper bound to biomass prices.

The aesthetics of timber and woody biomass harvesting was also a factor in our study, as we posit that it plays a significant role in shaping landowners' attitudes towards biomass removal. While some people may not wish to harvest timber or wood-based biomass if the results are aesthetically displeasing to them, others may wish to harvest biomass if viewed as an aesthetic improvement. To consider this issue, the survey includes three forest illustrations: one of a forest that has not had a timber or biomass harvest, one that has had timber harvested but not biomass, and one that has both timber and biomass harvested (Fig. 1). The survey asked respondents to rank these illustrations on a scale of 1 to 3, where 1 is most appealing and 3 is least appealing. Illustrations were used instead of pictures to reflect a representative forest as opposed to a definitive one.

The survey gathered land ownership information, including the amount of forested acreage owned in Massachusetts, land tenure, if their home (primary residence) is on their forestland, whether trees have been harvested and sold from the Massachusetts land since it was acquired, and whether the respondent has any plans to harvest and sell trees from the Massachusetts land in the future. In addition, two questions sought to capture how engaged the owner is in traditional forestry: is the respondent's land enrolled in any type of current use property tax program (e.g., Massachusetts Chapter 61, 61a, 61b),[3] and does the respondent have a written management plan. The survey asks several questions about landowner opinions and beliefs. Respondents rated, on a scale of 1 to 5, how important ownership of their land was for production of sawlogs, pulpwood or other timber products, and how important the owner believes it is to leave their land unmanaged and to let nature take its course. "Not important" on the scale is reflected in a rating of 1 and "very important" is a rating of 5.

The survey asks respondents to rate on a scale of 1 to 5 how much they agree with seven questions concerning the use and harvest of biomass (Table 1). A rating of 1 means the respondent strongly disagrees, while a rating of 5 means the respondent strongly agrees. While a review of the correlation coefficients of the responses to these seven questions does not indicate the presence of high pairwise correlation (all are below 0.65), the nature of the questions' content suggest these variables might be related. Cronbach's alpha is a coefficient of reliability that measures how closely related items are as a group, as indicated by a coefficient greater than 0.7 (Nunnally, 1978). For these seven variables, the alpha coefficient is 0.82, suggesting the use of principal components analysis. Principal components analysis is a statistical technique that groups together collinear variables to form a composite index (Kennedy, 2003). Principal component loadings define the composite index, and loadings greater than 0.50 indicate a strong association between the variable and the index (Finley and Kittredge, 2006; Hair et al., 1998). We performed principal components analysis on the seven biomass opinion variables. To do this, respondents who answered any of the questions as "Don't Know" were changed to missing; missing variables were then imputed only for respondents who answered at least four of the seven questions, resulting in 207 observations not needing any imputation and 144 observations needing between one and three question values imputed. Table 1 presents the loadings for the two factors that resulted from the analysis. Based on the biomass opinion variables, Factor 1 reflects concern about the negative environmental impact of biomass removal, and Factor 2 reflects the belief that biomass could have a positive economic impact. These two factors account for 65% of the total variance in these seven questions.

Gathered socioeconomic characteristics include age, education level, income, and gender. Respondents checked one of seven age categories to indicate their age. Based on results from previous research (see Stevens et al., 2002 and LeVert et al., 2009), we are able to condense these into two categories for the analysis: those 65 years old and older, and those younger than 65 years old. Education is coded as three categories: a high school diploma/GED or less, some college or associate/technical degree, and bachelor/graduate degree. The analysis omits the middle education level. Three categories describe household before-tax income: income less than $50,000 per year, income between $50,000 and $100,000 per year, and income greater than or equal to $100,000 per year. The analysis omits the middle income category. Table 2 lists the variables used in our analysis, their means, and their associated variable definitions.

[3] In Massachusetts, Chapter 61 is a program for owners of at least 10 acres of contiguous forestland interested in keeping their land in its current undeveloped use. It requires long-term, sustainable timber management based on a state-approved management plan that must be renewed every 10 years. Enrolling in Chapter 61 reduces forestland valuation to reflect its value for growing timber instead of houses. Chapter 61a is a similar program but for farmers. Chapter 61b, similar to Chapter 61, is for forest owners but does not require a written management plan. Chapter 61b offers a smaller reduction in assessed valuation than Chapter 61.

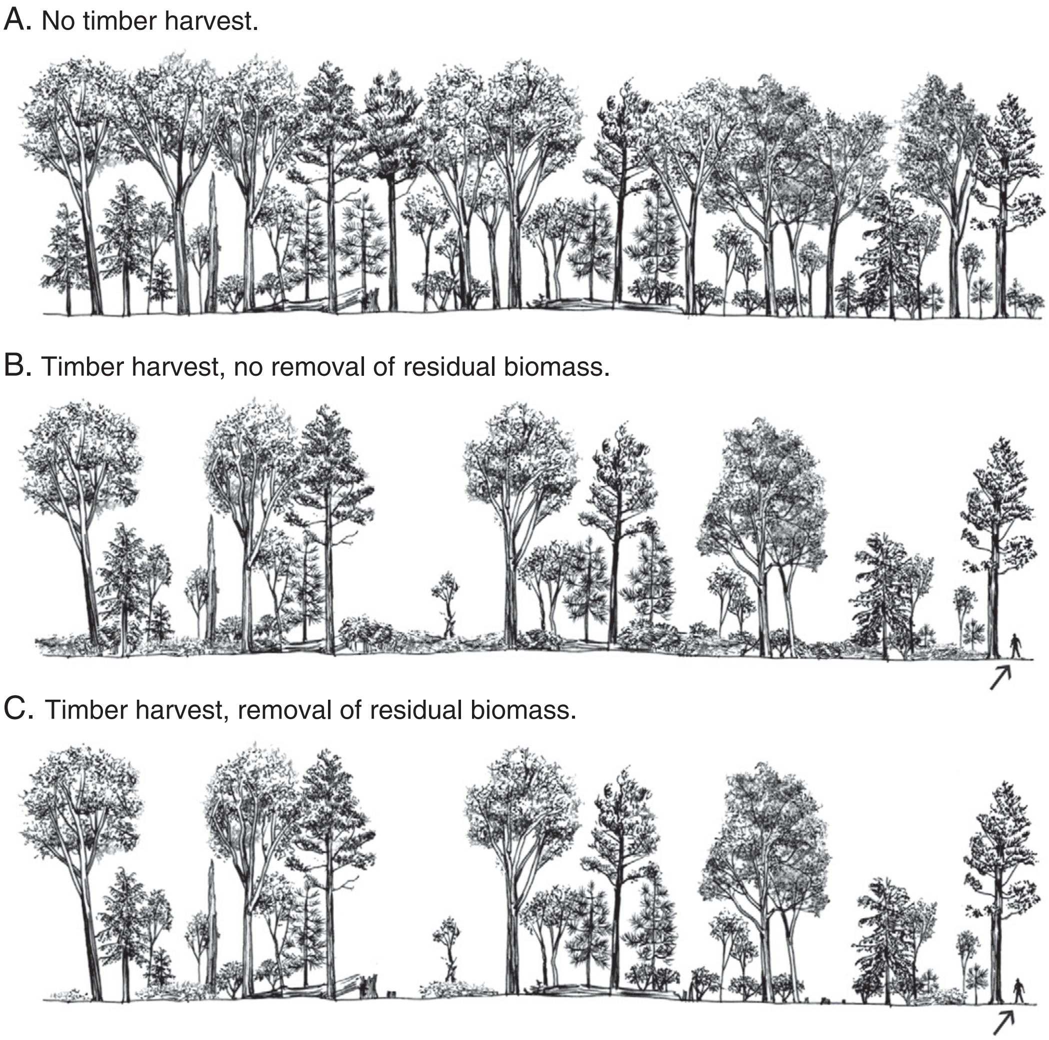

Fig. 1. *Forest illustrations presented in survey.* Illustration A reflects a forest that has not been harvested. Illustration B reflects a forest that has had a timber harvest but no removal of residual woody biomass. Illustration C reflects a forest that has had a timber harvest and removal of residual woody biomass.

4. Model

We use a logit model (Greene, 2007) to analyze these data. In this model, the dependent variable is the yes/no response to the willingness to accept question (1 means the respondent would harvest biomass given the conditions presented, 0 means the respondent would not harvest biomass under given conditions). The probability of a respondent accepting the scenario is a function of several independent variables: biomass harvesting parameters and owner/land characteristics.

In the logit model, the probability of a respondent accepting the offer is a function of y_i^*, a latent dependent variable, meaning that while it is unobserved and continuous, it reflects the respondent's true feeling towards the choice. The factors we believe explain this decision are represented by vector x_i, regression coefficients estimated by the model (vector β); as well as an unobserved error term, ε, as shown in Eq. (1):

$$y_i^* = \beta x_i + \varepsilon, \tag{1}$$

where $y_i = 1$ if $y_i^* > 0$ and $y_i = 0$ if $y_i^* \leq 0$. The probabilities for y_i are shown in Eqs. (2) and (3), given a cumulative distribution function, F (.):

$$Prob(y_i = 1) = F(\beta x_i) \tag{2}$$

$$Prob(y_i = 0) = 1 - F(\beta x_i) \tag{3}$$

When $F(.)$ has a logistic distribution, the probability of acceptance becomes:

$$Prob\ (y_i = 1) = \frac{e^{\beta x_i}}{1 + e^{\beta x_i}}. \tag{4}$$

4.1. Uncertainty-adjusted WTA

Since the charge by the National Oceanic and Atmospheric Administration's Blue Ribbon Panel on contingent valuation to allow respondents to express their uncertainty with regards to their answers to hypothetical valuation scenarios (NOAA, 1993), a significant amount of literature has focused on the issue of preference uncertainty in contingent valuation (Hanemann and Kristrom, 1995; Li and Mattsson, 1995; Akter et al., 2008). Uncertainty may arise for a number of reasons. For example, respondents may not have experience with the choice they are presented, they may not understand what it is they are valuing, the market for substitutes may be unpredictable to respondents, and the questionnaire itself could elicit uncertainty with respondents, to name a few (Shaikh et al., 2007). While it is widely accepted that there is likely uncertainty in responses to willingness to pay and willingness to accept questions, it

Table 1
Biomass survey opinion questions and rotated principal components loadings by factor.

Residual woody biomass opinion questions	Mean (Std. Dev.)[a]	Rotated factor loadings	
		Factor 1: Concern about negative environmental impact	Factor 2: Belief of a positive economic impact
1. Utilization of residual woody biomass for energy could positively impact the local economy	3.27 (1.22)	−0.1428	0.8883
2. Harvesting residual woody biomass can be a supply of renewable energy	3.69 (1.20)	−0.1970	0.8437
3. Leaving residual woody biomass in piles on my property is important to wildlife habitat	3.41 (1.18)	0.7746	0.0295
4. Removing residual woody biomass on my property depletes soil nutrient levels	3.41 (1.26)	0.7763	0.0197
5. Utilization of residual woody biomass will increase air pollution	2.95 (1.31)	0.6953	−0.3216
6. Harvesting residual woody biomass will result in significant deforestation	2.78 (1.33)	0.7350	−0.2740
7. Utilization of residual woody biomass for energy could positively impact the United States' ability to address climate change	2.93 (1.27)	0.1588	0.7369

[a]Mean and standard deviation reflect the sample of respondents who comprise Factor 1 and Factor 2. The Likert scale ranges from 1 to 5, where 1 is “strongly disagree” and 5 is “strongly agree.”

is not clear how best to address the issue (Shaikh et al., 2007; Akter et al., 2008).

We apply one commonly-used approach to incorporate uncertainty: we follow the yes/no willingness to accept (WTA) question with a question that asks respondents to rate how certain they are of their answer, on a scale of 1 (uncertain) to 5 (certain). As discussed by Loomis and Ekstrand (1998), this approach assumes that respondents understand and can accurately communicate their level of certainty, and it assumes that the certainty scale is interpreted the same way by each respondent (i.e., a 1 means the same to each individual). Similar to the method employed by Champ et al. (1997), we re-coded an affirmative response to the WTA question as a “no” if that respondent also stated a certainty level below 5 (“certain”). We re-coded a WTA response as missing if a respondent did not provide an answer to the uncertainty question, and we did not re-code a negative response to the WTA question.

We prefer this uncertainty-adjusted approach because the literature indicates that it also provides a safeguard against hypothetical bias in contingent valuation studies (Akter et al., 2008; Champ and Bishop, 2001). While Akter et al. (2008) discuss how incorporating preference uncertainty may not produce more efficient welfare estimates, Shaikh et al. (2007) discuss how excluding preference uncertainty could result in bias. Our main focus in this analysis is to understand the factors that influence forest owner willingness to participate in biomass harvesting, thus our preferred model and the following discussion reflects the uncertainty-adjusted model.

Table 2
Means and definitions of variables.

Variable	Mean (Std. Dev.)	Definition
Biomass price	$205.24 (200.06)	Expected net revenue per acre ($0, $50, $250, $500)
Destination local school	0.33 (0.47)	Biomass going to heat a local school (1 if yes, 0 otherwise)
Destination electric power plant	0.34 (0.48)	Biomass destined for an electric power plant (1 if yes, 0 otherwise)
Top rank Illustration A	0.73 (0.45)	Respondent ranked Illustration A, the unmanaged forest, as most appealing (1 if yes, 0 otherwise)
Forested acres owned	49.72 (65.42)	Amount of forested acres owned
Home on woodland	0.66 (0.47)	Respondent's home is on woodland(1 if yes, 0 otherwise)
Trees harvested in past	0.42 (0.49)	Has had trees harvested and sold since acquisition (1 if yes, 0 otherwise)
Plans to harvest in future	0.51 (0.50)	Plans to harvest and sell trees from land in future (1 if yes, 0 otherwise)
Chapter 61 enrolled[a]	0.34 (0.47)	Enrolled in a current use plan (1 if yes, 0 otherwise)
Management plan	0.20 (0.40)	Respondent has a written management plan (1 if yes, 0 otherwise)
Manages for timber	0.19 (0.39)	Land is important/very important for the production of timber products (1 if yes, 0 otherwise)
Manages for nature	0.29 (0.46)	Important/very important to leave land unmanaged and let nature take its course on the land (1 if yes, 0 otherwise)
Biomass factor: negative environmental impact	−2.15e−09 (1)	Factor describing concern about the negative environmental impact of biomass removal
Biomass factor positive: economic impact	−2.44e−09 (1)	Factor describing belief that biomass could have a positive economic impact
Age 65 years or older	0.38 (0.49)	Respondent is 65 years or older (1 if yes, 0 otherwise)
Lower education	0.17 (0.37)	Respondent has a high school diploma or less (1 if yes, 0 otherwise)
Higher education	0.59 (0.49)	Respondent has bachelor or graduate degree (1 if yes, 0 otherwise)
Income less than $50,000	0.24 (0.43)	Household annual income less than $50,000 (1 if yes, 0 otherwise)
Income more than $100,000	0.40 (0.49)	Household annual income $100,000 or greater (1 if yes, 0 otherwise)
Gender	0.74 (0.44)	1 if male, 0 if female

[a]Chapter 61 is a current use property tax program requiring long-term, sustainable timber management based on a state-approved management plan. Enrolling in the program reduces forestland valuation to reflect its value for growing timber instead of houses. Chapter 61a is a similar program but for farmers. Chapter 61b, similar to Chapter 61, is for forest owners but does not require a written management plan. Chapter 61b offers a smaller reduction in assessed valuation than Chapter 61.

5. Results

Of all 429 survey respondents, 273 individuals provided enough information to be included in the analysis. This section reflects statistics for all survey respondents (see Table 2). It is worth noting that the characteristics of the analysis sample do not deviate substantially from that of the full sample; in some cases, statistics were identical.

Approximately 38% of the sample are over the age of 65, 35% are between 55 and 64 years old, and 27% are younger than 55. The majority (74%) of respondents are male. Over half the sample (59%) has either a bachelor's or graduate degree, and nearly one-quarter has some college or an associate/technical degree. Over 75% of the sample has household income greater than $50,000.

On average, respondents own 50 ac of forest, and 66% live on their forestland. In each case, at least half the sample said that the following are very important reasons for owning their land: to enjoy beauty or scenery, for privacy, and as part of a home or vacation home. For the respondents who provided unique rankings for each illustration, 73% said that Illustration A (see Fig. 1), the unmanaged forest, is the most appealing to them; 16% preferred Illustration B (i.e., timber harvest with no residual biomass removal), and 11% preferred Illustration C (i.e., timber harvest with residual biomass removal). A little over 42% said they had experience with harvesting and selling timber in the past, while 49% said they would never harvest in the future. Approximately 20% have a written management plan for their land, and 34% of the sample is enrolled in some form of Chapter 61/current use tax program.

We tested for non-response bias by calling a random sample of 10% of non-respondents and obtaining answers to key survey questions. We selected survey questions that describe respondent landholdings (acreage), behavior (traditional forestry participant) and attitudes (about land management). A statistical comparison of the response and non-response groups (*t*-test) indicates that there is no difference between them for acreage of forestland owned in Massachusetts and whether or not they have a written forest management plan. We might have expected greater acreages or existence of a management plan to influence the economic viability of participation, but this was not the case. The statistical comparison showed a difference between the groups regarding how important the owner believes it is to leave their land unmanaged and to let nature take its course. Non-respondents were more likely to give more importance to this statement as a reason for owning their forestland than respondents. Thus, it appears that non-respondents would probably be less interested in harvesting woody biomass than respondents.

The estimation results indicate that the price of biomass, landowner management, beliefs and characteristics play a role in determining views towards the likelihood of harvesting biomass (Table 3). As expected, respondents are more willing to harvest biomass from their forestland when the price of biomass is higher. Most of the landowner characteristic results conformed to expectations, with one exception discussed below. For example, respondents who plan to harvest their land in the future are more likely to harvest biomass. This is not unexpected, because these individuals are actively planning to manage their land, and because biomass harvesting, as a by-product of harvesting, is essentially a type of management activity they may be more open to participation, all else equal. Respondents who are currently enrolled in a Massachusetts current use property tax program are more likely to harvest biomass. These individuals currently enjoy a reduced tax assessment from enrolling their land in a program and might be amenable to biomass harvesting because it offers additional income. In addition, depending on the current use program, these individuals might be required to harvest and thus may be more open to harvesting.[4] However, respondents who currently have a written management plan for their land expressed that they are less likely to harvest biomass from their forestland. This outcome is not expected, and the interpretation of this result is unclear. Perhaps these individuals have a management plan for the purpose of being a good steward of their forestland, and removal of biomass does not mean good stewardship to them, or perhaps they felt biomass harvesting would violate their management plan. Alternatively, these respondents may be satisfied with the level of management they currently have on their property and uninterested in additional levels of management.[5] As expected, respondents who felt that biomass harvesting could have a positive economic impact are more likely to harvest biomass. Interestingly, however, respondent perception of a negative environmental consequence of biomass was not a significant variable in the model. Finally, male respondents are more likely to harvest biomass from their property. It is also interesting to note that respondent income level has no impact on the decision to harvest woody biomass.

Out of 429 observations, the calibration method we use to address preference uncertainty resulted in 109 affirmative WTA responses being changed to negative responses because respondents were not certain of their answer at a level of 5. One affirmative response was changed to missing because this respondent did not provide an answer to the uncertainty scale. Other options to the certainty scale approach to address preference uncertainty include providing a “Not Sure” option as done by Becker et al. (2010); however, the motivations underlying the “Not Sure” approach may be different from those underlying the certainty scale approach (Samnaliev et al., 2006).

Table 3
Uncertainty-adjusted WTA results for logistic regression.

Variable	WTA coefficient[a] (n = 273)
Biomass price	0.0021**
Destination local school[b]	0.2173
Destination electric power plant[b]	−0.2530
Top rank Illustration A	−0.2927
Forested acres owned	−0.0022
Home on woodland	−0.0760
Trees harvested in past	0.2660
Plans to harvest in future	1.0749**
Chapter 61 enrolled	0.8849**
Management plan	−1.2312**
Manages for timber	−0.4521
Manages for nature	−0.0486
Biomass factor: negative environmental impact	−0.2029
Biomass factor: positive economic impact	0.5109**
Age 65 years or older	0.0493
Lower education[b]	0.2651
Higher education[b]	0.3005
Income less than $50,000[b]	−0.0156
Income more than $100,000[b]	−0.2249
Gender	1.0166*
Constant	−3.740***

[a]Significance denoted as: ***1%, **5%, *10%.
[b]To avoid the so-called “dummy variable trap” (see Kennedy, 2003), the analysis omits one option for each of these variables.

5.1. Probability results

We calculate the probability that respondents said they would be willing to accept the biomass harvesting offer for each per acre biomass price presented, evaluating the other variables at their sample means. The likelihood of participation increased with price, as expected, but not by a great amount (Table 4). From $0/ac to $500/ac, average participation rate was quite low, ranging from 7% to 17%.

[4] The authors thank an anonymous reviewer who noted that some respondents also may believe they are required to harvest as part of a current use program.

[5] It is worth nothing that 92% of the respondents who have a management plan said they either harvested in the past or plan to in the future.

Table 4
Estimated probabilities of participation by biomass price.

Biomass price[a]	Participation probability
$0/ac	6.8%
$50/ac	7.5%
$250/ac	10.9%
$500/ac	16.9%

[a]All other variables are set to their mean value, see Table 2.

5.2. Supply response

These probabilities enable us to construct a supply curve of participation for the "average" respondent (Fig. 2). The supply curve provides information on the price elasticity of supply. Using the mean biomass price of $205.24/ac, the supply curve indicates that forest owner participation in biomass harvesting is not greatly influenced by a change in price (i.e., price per acre); the price elasticity of supply is inelastic at 0.4, meaning that a 1% increase in price leads to a 0.4% increase in participation.

6. Discussion

This study seeks to understand how Massachusetts family forest owners feel about harvesting residual woody biomass from their property, and estimates low participation rates by Massachusetts family forest owners. The study shows biomass destination and "No Timber Harvest" as a top-ranked illustration choice (i.e., Illustration A) to be insignificant factors in the decision, and an inelastic supply of participation in biomass harvesting.

Results indicate that even at biomass prices that well-exceed current market levels, forest owner participation rates are low: at $500/ac for woody biomass, only 17% of respondents would participate. These low participation rates concur with Butler et al.'s (2010) regional study of northern U.S. wood supply that used a very different analytical model and technique.

These findings provide implications for policy within Massachusetts and other states with similar timber markets, ownership characteristics (e.g., ownership size, landowner demographic profiles, ownership goals), and socioeconomic circumstances (e.g., population density, real estate values). In Massachusetts, policies that provide incentives to landowners to supply wood-based biomass for bioenergy (e.g., BCAP) need to consider other factors besides price. This study shows that forest owner attitudes towards forest management and biomass can be important elements of the decision process. Future harvesting plans and enrollment in current use taxation programs positively influence the decision, while having a written management plan negatively influences the decision. The perception that biomass could have a positive economic impact results in higher participation rates, but the perception that biomass could result in negative environmental impacts does not significantly affect landowner decisions. Moreover, forest owner attitudes appear to play a role with survey non-respondents as well; these individuals were even more likely than respondents to prefer to leave the land unmanaged and let nature take its course. This study also shows that over 25% of respondents were uncertain about their answer to the WTA question. Biomass harvesting is not a commonplace source of renewable energy in Massachusetts, and it is likely that forest owner uncertainty could be related to unfamiliarity with this market.

A comparison of the results of this study to an independent biomass survey conducted in Minnesota (Becker et al., 2010) indicates regional differences in ownership characteristics, biomass harvesting beliefs and preferences.

As shown in Table 5, there were some notable differences between respondent characteristics in our sample compared to the Minnesota sample. Of particular interest is that Minnesota respondents were more likely to believe that biomass removal depletes soil nutrients and that biomass could be a significant source of energy (Table 5). Also, the average Minnesota respondent owns 124 ac, while the average Massachusetts respondent owns 50 ac. As mentioned earlier, the greater the landholding size, the more likely that timber harvest (and perhaps biomass removal) would occur. There are also differences in the regression analyses results, but it should be kept in mind that the models test slightly different choices and hypotheses. Table 6 indicates the key analytic variables that can be compared across the two studies.

With respect to probability of biomass participation, as shown in Table 6, the Minnesota results indicate 4 to 8 times greater participation rates than our study. However, much of the difference is likely due to the calibration technique for preference uncertainty, which changes a much larger proportion of individual responses to a "no" response than the technique used in the Minnesota study: 26% of the Massachusetts sample was changed to "no," whereas 15% of the Minnesota sample was eliminated. The Massachusetts study changed WTA responses to "no" if WTA responses were anything less than 5 (i.e., "certain"); the Minnesota study removed respondents who indicated they were "Not Sure" of their WTA response. Samnaliev et al. (2006) compared these same two calibration techniques and also found that certainty scale calibration led to lower estimates than "Not Sure" calibration.

Nevertheless, we might expect different results between these two regions because of the differences in timber markets, social factors, and forest types. Massachusetts has high population densities in close proximity to forestlands, resulting in more development pressure and smaller parcel size. Massachusetts has 290,000 family forest owners with an average parcel size of 6 ac (Butler, 2008). As stated earlier, there is no pulp market in Massachusetts, and the common silvicultural practices of partial or selective harvesting are different than the type of

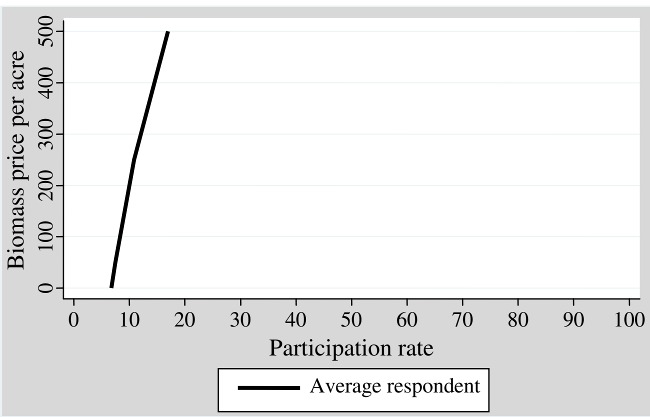

Fig. 2. *Supply response.* Supply curve of participation for the average respondent. Price elasticity of supply, estimated at the mean biomass price per acre, is 0.40.

Table 5
Comparison of mean sample characteristics.

Variable	Massachusetts study	Minnesota study
Respondent age	55–64 years old	59 years old
Gender (male)	74%	>80%
Intentions for future harvesting[a]	51% (plan to harvest and sell trees)	38% (plan a commercial timber harvest)
Believe biomass removal depletes soil nutrients	41%	69%
Believe in biomass as a renewable energy source	51% (could be a supply of renewable energy)	80% (could positively impact U.S. energy independence)
Woodland acreage owned	50 ac (respondents own>=10 ac)	124 ac (respondents own>=20 ac)

[a]The disparity in these statistics is likely to reflect definitional differences. Massachusetts respondents could have included their intentions to sell firewood from their property and harvesting with no future time limit, whereas Minnesota respondents were limited to responding to the question of whether they intend to conduct a commercial timber harvest in the next 10 years.

Table 6
Comparison of binary logit regression model results.

	Massachusetts study	Minnesota study
Scenario presented		
Biomass harvest with a timber harvest	Partial/selective harvest, illustration provided	Harvest most trees 5 in. and greater
Timber harvest price	$500/ac	None provided
Biomass prices	$0, $50, $250, $500/ac	$0, $2, $5, $10, $15/ac
Variable		
Biomass price	+, significant	+, significant
Biomass: positive economic impact	+, significant (Factor 2)	+, significant ("ENERGY")
Plans to harvest in future	+, significant	+, insignificant
Biomass: negative environmental impact	−, insignificant (Factor 1)	−, significant ("SOIL")
Respondent age	+, insignificant (≥65 years)	−, significant (continuous)
Probability Results[a]		
Percent participation	7%–17%	60%–72%

[a]From an econometric standpoint, some of this disparity may be because, in accounting for preference uncertainty, the Massachusetts study provides a correction for hypothetical bias, while the Minnesota study does not. The calibration technique for preference uncertainty in the Massachusetts study changes uncertain individual responses to a "no," whereas the Minnesota study drops uncertain responses.

management common in Minnesota. In Minnesota, the vast majority of the population lives near the urban centers and away from major forested areas; development pressure is different from Massachusetts, and parcel size is larger. Minnesota has 194,000 family forest owners with an average parcel size of 28 ac (Butler, 2008). The timber markets are more robust and diverse in Minnesota than Massachusetts, largely because of the pulp market that historically uses large volumes of low-grade, marginally merchantable material. Moreover, the hardwoods that grow in Minnesota (e.g., poplar, aspen) are fast growing and require clear cutting to regenerate — a practice quite different from a typical Massachusetts harvest on private lands. Overall, Minnesota's larger ownerships, well-established pulp markets for high volumes of low value material, a corresponding emphasis on rapid growing aspen and silvicultural clearcutting, and a logging community well-adapted to this marketplace lead us to expect different preferences for biomass harvesting.

7. Conclusion

The results of our study suggest that policy should vary by region — our Massachusetts study and subsequent comparison with an independent Minnesota biomass study indicate that these markets and landowner participation rates differ considerably. Although some of this difference is due to the way uncertain responses were handled in the two studies, further research is needed to define the regional biomass market differences to determine a more thorough understanding of the range of landowner participation in biomass harvesting activities. A view of other regions, e.g., Southeastern U.S., could provide more insight into the extent of heterogeneity of this market. In any case, it would be a mistake for policymakers at the state or national level to base policy on only one of these studies. Our results suggest that forest owner decisions are based on both market and cultural differences. It would be wise to target renewable energy policy, including policy involving biomass, toward different regions or markets.

In addition, the results of this study suggest the possible role of outreach materials designed to provide owners with information about biomass harvest and their alternatives. Both studies indicate respondent uncertainty (i.e., Massachusetts — 26%, Minnesota — 15%). While this result highlights the need to further explore the choice of calibration technique to address respondent uncertainty on the one hand, it also highlights the need to reduce this uncertainty on the other. This uncertainty could be related to unfamiliarity with the biomass market. Anecdotal evidence from the Massachusetts focus groups support this suggestion — regardless of intensity of management, respondent opinion of biomass harvesting varied widely. Familiarizing landowners with this issue could limit uncertainty and enable policymakers to better understand regional preferences for biomass harvesting. Furthermore, landowners with minimized uncertainty are better positioned to make an informed decision about the future of their forest when someone offers to purchase their standing timber or when they initiate the decision to harvest (e.g., when they are in financial need).

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