Using Former Farmland for Biomass Crops: Massachusetts Landowner Motivations and Willingness to Plant

David Timmons

Producing biomass energy requires extensive land resources. In western Massachusetts, where almost 90 percent of former farmland is no longer in commercial use, we study factors that motivate landowners to grow biomass energy crops. A geographic information system model identifies a landowner population, and a contingent valuation survey reveals payments landowners are willing to accept (WTA) for growing biomass crops. The median WTA estimate is \$321 per hectare per year, which is high compared to regional land rental rates. Nonpecuniary factors appear to be as important in landowner acceptance as profit opportunities, especially for nonfarmer landowners.

Key Words: abandoned farmland, biomass energy crops, contingent valuation, willingness to accept

Replacing fossil fuels to reduce anthropogenic climate change represents one of the great challenges of our time. The Intergovernmental Panel on Climate Change (IPPC) estimates that keeping the global mean temperature increase to 2 degrees Centigrade will require reducing world carbon dioxide (CO_2) emissions 50 percent to 85 percent relative to emissions in 2000 (IPCC 2007), implying an almost complete replacement of fossil energy. Biomass energy is one of several renewable energy alternatives. This study looks at circumstances under which land for biomass energy production might be made available.

Compared to other renewable energy sources, biomass energy is particularly dependent on available land. For electricity production, for example, Pimentel et al. (2002) estimated that producing forest biomass electricity required 71 times more land area than collecting solar energy with photovoltaic panels. While converting biomass to thermal energy is somewhat more efficient than converting it to electricity, any form of biomass energy would require a great deal of land to replace a significant portion of current fossil fuel use. For example, in Massachusetts about 84,000 square kilometers of switchgrass would be required to meet all of Massachusetts' current energy demand (Energy Information Administration 2013).[1] This is 4.2 times the land area of the commonwealth. But no single renewable energy resource can replace

[1] This assumes a switchgrass yield of 9.5 metric tons per hectare (Timmons 2012), 18.4 gigajoules of potential energy per metric ton of switchgrass (McLaughlin et al. 1996), and conversion efficiencies similar to present ones.

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The views expressed are the author's and do not necessarily represent the policies or views of any sponsoring agencies.

Agricultural and Resource Economics Review 43/3 (December 2014) 419–437

fossil fuel—a portfolio of renewable energy resources along with energy conservation will be required. Since biomass is also one of the least expensive renewable alternatives (de Vries, van Vuuren, and Hoogkijk 2007), it could be a valuable part of such a renewable energy portfolio.

In addition to mitigating climate change, producing biofuel is mandated by the U.S. Energy Independence and Security Act (EISA) of 2007 to replace vulnerable imported oil supplies. While most biofuel produced in the early years of the EISA mandate was corn ethanol, biofuel will increasingly be produced from cellulosic biomass crops such as switchgrass that, unlike corn, can be grown on marginal land without displacing food crops. Thus any marginal or idle farmland is of particular interest for future biomass energy production. In a global study of potential for using abandoned agricultural land for biomass energy crop production, Campbell et al. (2008) reported a high concentration of former farmland in the eastern United States. The extent of former farmland in Massachusetts is clear from the U.S. Department of Agriculture's quintennial Census of Agriculture. In 1905, 47 percent of western Massachusetts land area was agricultural (crops and pasture). By the 1954 census, the agricultural proportion had dropped to 24 percent, and by 2007, to only 5 percent of land area (USDA 2009). Timmons (2012) estimated that about 350,000 metric tons of switchgrass could be raised each year on western Massachusetts crop and grass land. This study looks at landowner willingness to plant biomass energy crops on this land, with a particular interest in nonfarmer motivations, since much of the former farmland in Massachusetts is now owned by nonfarmers.

Potential environmental impacts from biomass crop production also need to be considered. For example, switchgrass production causes less nitrogen pollution than producing corn for ethanol (Costello et al. 2009), yet switchgrass profits are maximized with significant fertilizer use (Brummer et al. 2001, Nelson, Ascough, and Langemeier 2006, Lemus et al. 2008). Increased use of idle farmland could lead to more water pollution from nitrogen fertilizer use or to changes in wildlife habitat. This study finds that such concerns are in fact widely held by Massachusetts nonfarmer landowners and that successfully addressing such environmental issues is thus essential to wider adoption of biomass crops.

A primary objective of this study is estimating payments or rents required to motivate landowners to make their lands available for producing biomass energy, as well as how such payments might depend on other land use considerations. We use a geographic information system (GIS) study to identify the landowner population of interest and then conduct a contingent valuation (CV) survey that queries landowners about their willingness to plant biomass crops. We report land and landowner statistics of interest, estimate median and mean willingness to accept (WTA) planting bids, and present a binary logistic model that predicts bid acceptance based on bid level and vectors of land and owner attributes. Together, these measures provide a picture of landowner attitudes about biomass crops and about prospects for making former farmland available for biomass production. Results support the theoretical proposition that landowners gain utility from both pecuniary and nonpecuniary benefits and suggest that the nonpecuniary considerations may be particularly important in landowner decisions to plant biomass crops.

Cellulosic biomass production in the United States is still in its infancy and many uncertainties exist, including where biomass crops will be grown and in what quantities. This study contributes to understanding the future biomass energy resource by examining conditions under which western Massachusetts landowners would be willing to supply land for biomass crop production.

Previous Research

A review of the literature finds few landowner surveys related to biomass crops and finds mostly surveys aimed at farmers. A Minnesota study (Smith et al. 2011) asked agricultural landowners about planting perennial energy crops at net land incomes that differed from current net incomes. Researchers found that 45 percent of respondents would grow energy crops generating incomes similar to their current incomes, the proportion rising with net income potential. Only 4 percent were willing to grow energy crops for a lower net income. Though the survey included nonfarmer owners of agricultural land, results for that group were not reported separately.

A study in the southeastern United States asked farmers whether they would plant switchgrass at farmgate prices ranging from \$44 to \$132 per metric ton (Qualls et al. 2012). Probability of planting switchgrass was found to range from 44 percent for the lowest price to 53 percent for the highest price. Researchers also found that several nonfinancial factors significantly and positively influenced the switchgrass planting decision, including the perceived importance of switchgrass for improving the environment, for reducing crop inputs, for contributing to national energy security, and for diversifying farm incomes.

An earlier Tennessee study asked farmers an open-ended question about how many acres they would plant to switchgrass under self-defined "profitable" conditions (Jensen et al. 2007). The majority of farmers were not familiar with the idea of growing switchgrass for energy. Younger farmers, those with more education, and those with greater off-farm incomes were more likely to be interested. Farmers who had higher current net incomes per acre were less interested.

A qualitative survey in Iowa using a convenience sample of 52 farmers and farm industry representatives found potential biomass crop profitability to be an important but not exclusive factor in deciding to plant switchgrass (Hipple and Duffy 2002). Other factors such as probability of success, compatibility with current crops, consistency with farmer values and beliefs, and aesthetic and wildlife impacts were also important. The study reported that many farmers were taking a "wait and see" approach to biomass crops.

While there is little previous research on biomass crop planting decisions by nonfarmer landowners, there are many empirical studies of forest harvesting by owners of nonindustrial private forests, situations that may be similar to biomass crop planting. For example, Newman and Wear (1993) rejected a null hypothesis that industrial and nonindustrial owners had identical profit functions. While both groups were found to manage forests in a manner consistent with profit maximization, nonindustrial owners exhibited higher values for standing timber. The differences in supply behavior by the two groups were found to be complex and not completely explained by simple price differentials.

Binkley (1981) proposed a forest landowner model where landowners maximize utility with respect to both potential income from forest land and amenities that land may provide:

$$\max U = U[a,i] \tag{1}$$

where U is utility, a is land amenities, and i is landowner income. A number of subsequent forest studies developed models based on this same premise (Boyd 1984, Max and Lehman 1988, Hyberg and Holthausen 1989, Pattanayak, Abt, and Holmes 2003). In this study, we define land amenities broadly, as any nonpecuniary benefits of land ownership. These could include recreational land use, aesthetic value, and any psychological benefits owners receive from owning land or using it in a particular way. We assume that such amenity values apply to nonforest lands such as potential biomass crop land and perhaps especially to land owned by nonfarmers, which is common in western Massachusetts.

None of these theoretical forest models provides any guidance as to how amenity and income values might enter a landowner's utility function or how landowners might weigh potential land income against potential loss of land amenities. But empirical studies of forest harvesting support the notion that landowners derive utility from both income and land amenities (Amacher, Conway, and Sullivan 2003). For example, Conway (2003) found timber price to be a positive and significant predictor of harvest as expected but also found that owner debt-to-income ratio was positive and significant. Owner intent to bequeath timber land was negatively associated with timber harvest, as was absentee ownership. Clearly, landowner behavior is complex with respect to land use decisions and difficult to adequately model.

This study seeks empirical evidence as to how landowners weigh biomass crop income against other land values to better understand the cost and potential energy production of biomass crops. Existing crop and grass lands in western Massachusetts could produce about 350,000 dry metric tons of switchgrass per year at 9.5 metric tons per hectare (Timmons 2012), the energy equivalent of more than one million barrels of oil per year.

Methods

We conduct a landowner survey in western Massachusetts to determine likely payments required to secure land for biomass crop production and to assess landowner attitudes and characteristics that may be associated with willingness to plant. Because there is no established biomass crop industry in western Massachusetts, we use a CV survey in which biomass crop production is treated as a hypothetical good.

Landowner Survey

The population of interest is Massachusetts landowners in Berkshire, Hampshire, Hampden, and Worcester counties[2] who have appropriate land for biomass crop production. We identified this population with a GIS model that used publicly available data on land use and soils.

We used soil maps from the SSURGO (soil survey geographic) database of the Natural Resources Conservation Service (NRCS) to identify potential agricultural soils (NRCS 2007). The SSURGO data tables include yield estimates for crops that are common in an area. For Massachusetts, yield estimates are provided on many soil types for hay, corn, potatoes, and other crops. For this study, we assumed that a yield estimate for any crop indicated a soil that is or

[2] GIS soil maps for Franklin County were unavailable at the time of the study so that county was excluded.

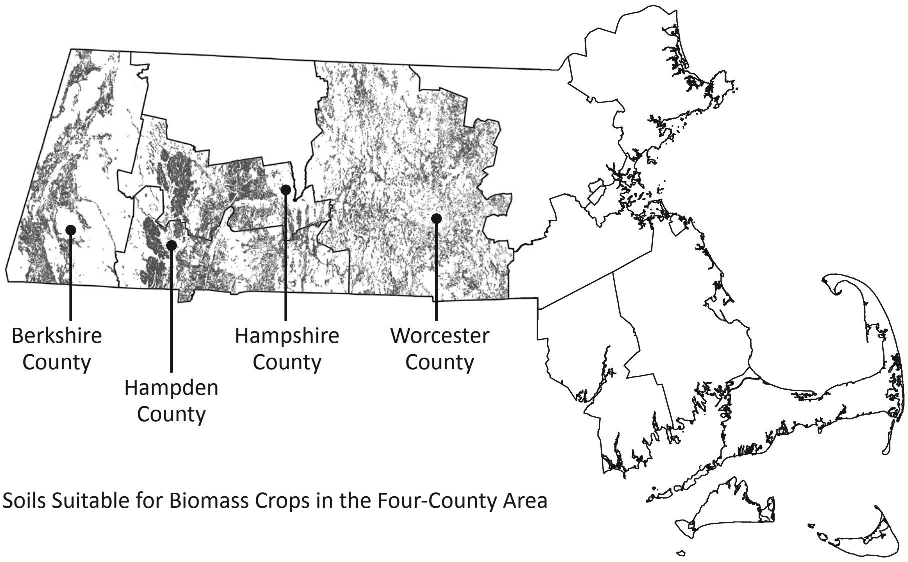

Figure 1. Soils with a Yield Estimate for Some Crop

was used for agriculture. Excluded soils had no yield rating (even for hay) and were generally steep, stony, wet, or some combination of these. Using these soil criteria excluded some land that might appear to have potential based solely on land use maps. Figure 1 indicates soils with crop potential, which comprise 34 percent of the four-county land area (though much of the potential crop area is developed or forested).

From the land with suitable soils, we selected land for inclusion with uses including crop land, pasture, and other undeveloped and nonforested land using land use maps from the Massachusetts Office of Geographic Information (2005). We removed potential production areas less than one contiguous hectare in size and retained the remaining areas as candidate switchgrass plots.

We then identified ownership of the candidate plots using GIS tax assessor maps and matched landowner names and mailing addresses with tax record parcel numbers. Survey coverage was limited to the 64 towns[3] (of 135) in the four-county area that use GIS tax maps.

The GIS study identified 5,162 candidate plots in townships with GIS tax maps. We excluded nonprivate individual landowners such as businesses, institutions, and government agencies. We also removed landowners without complete mailing address information and duplicate landowner records (since many owners hold multiple parcels). This resulted in 926 potential subjects for the study. While these are a subset of landowners in western Massachusetts, they represent the entire population that could feasibly be included.

A focus group of volunteer landowners (not randomly selected) helped to develop the survey instrument. We established bid amounts for the survey from the open-ended responses of the focus group. Bid levels of $124, $371, $618, $741, $865, $1,112, and $1,359 per hectare were selected ($50, $150, $250, $300, $350, $450, and $550 per acre). Additional landowners reviewed a

[3] All New England rural areas are parts of towns, which are called townships in other parts of the United States.

draft survey instrument in an open-dialog format. We conducted an initial pilot survey with 98 randomly selected landowners before conducting the main survey (results from the pilot are not included here).

The survey instrument first presented landowners with questions related to their attitudes about biomass energy in general and then gave a short description of biomass crops. Landowners were asked about their interest in biomass crops and about the importance of specific aspects of biomass crops (e.g., income potential and impacts on wildlife). Next were the CV question and follow-up questions, which varied depending on whether respondents accepted or declined the proposition. The questionnaire then asked landowners about their attitudes on environmental issues and reasons to own land in Massachusetts. The questionnaire ended with demographic questions and an open-ended comment section.

The dichotomous-choice CV question was intended to determine whether a landowner's WTA amount was greater or less than the hypothetical bid. We took care to define the proposition as a net profit, i.e., an amount remaining after deducting all relevant expenses for crop production. Specifically, the CV question was:

> *Please consider carefully the following imaginary situation*.
>
> Consider a situation where you could plant (or have someone else plant) some or all of your fields with a grassy or woody biomass crop (your choice). Assume you had a guaranteed market for the crop.
>
> If you could cover all expenses for planting, maintaining, and harvesting the crop (including your time) and could make the net profit per acre shown below, would you plant at least some of your fields?
>
> *Remember that your fields will not be available for other uses as long as they are planted in biomass crops.*
>
> For a profit of [bid] per acre per year, I would:
>
> ○ not plant ○ plant

The complete questionnaire and more details about survey methodology are included in Timmons (2011).

Binary Logistic Model

To gain insight into factors leading respondents to accept or decline the planting proposition, we use a binary logistic model with a respondent's binary choice of accepting or declining the planting bid as the dependent variable. We include independent variables in the analysis based on theoretical determinants of landowner WTA the hypothetical planting proposition where WTA is based on changes in landowner utility related to the planting decision. Based on the literature on nonindustrial private forest management, landowner utility stems from a combination of land income and land amenities (Binkley 1981, Max and Lehman 1988, Dennis 1989).

We follow Cameron (1988) and use the bid function or random WTA approach to directly model landowner WTA a hypothetical planting proposal. Let WTA be a function of underlying utility:

(2) $$WTA = h(m, b, \mathbf{k}, \mathbf{o}, \mathbf{s})$$

where h is the random WTA function, m is exogenous income, b is the hypothetical bid for planting biomass crops, and vectors of observable land characteristics ($\mathbf{k}$), landowner characteristics ($\mathbf{o}$), and landowner attitudes ($\mathbf{s}$) indicate unobservable utility. The binary logistic model for probability of acceptance is

(3) $$Pr(yes) = 1 / (1 + e^{-\Omega})$$

where the form of Ω to be estimated is

(4) $$\Omega = \beta_0 + \beta_1 m + \beta_2 b + \beta_3 k + \beta_4 o + \beta_5 s + \varepsilon.$$

For the binary logistic model, we treat the bid variable as continuous ($50, $150, $250, $300, $350, $450, and $550 per acre) and expect its coefficient to be positive.

Land characteristic variables include hectares of grass land owned and hectares of crop land owned calculated from owner-reported total land ownership and proportions of each type of land. We expect hectares of grass land to increase probability of acceptance, as grass land is likely the most suitable area for biomass crops, and owning more hectares increases income potential. This is consistent with studies of nonindustrial forest management, which find larger ownerships more likely to be harvested (Amacher, Conway, and Sullivan 2003). The effect of owning more crop land is likely negative: while such land could be used to grow biomass crops, it may be more profitable in other agricultural uses. Biomass crops are generally thought to be a relatively low-value agricultural commodity, and a recent study confirmed that corn is more profitable than cellulosic crops at foreseeable cellulosic crop prices (James 2010). Both of the land variables are continuous.

Several variables describe landowner demographic characteristics, such as income category. We convert income and other categorical survey responses to binary variables for the binary logistic model. Theory suggests that higher incomes reduce the probability of planting if using land for biomass crops reduces any existing amenity value and if amenities are normal goods (Binkley 1981).

We include a binary variable for education beyond high school. Education may have a positive effect on acceptance since better-educated citizens may be more familiar with new developments in biomass crops. Education has frequently been found to be a significant and positive predictor of nonindustrial forest harvesting (Amacher, Conway, and Sullivan 2003).

A binary variable indicates farmers—respondents who self-identify as farming for income and report more than 1 percent of household income from land-based activities. This is roughly equivalent to the definition used in the USDA Census of Agriculture, which defines a farm as “an operation that produces, or would normally produce and sell, $1,000 or more of agricultural products per year” (USDA 2009, p. A-1). Farming has an uncertain effect on acceptance probability. While farmers are likely better equipped to implement agricultural initiatives than other landowners, they may also be more risk-averse since a portion of their existing incomes is derived from current land use. And they may be more price sensitive, comparing potential biomass crop profit to expected profit from alternative crops. Farmers may both own and rent land; in the four-county region, the 2007 Census of Agriculture reported that 13.2 percent of farms incurred cash rental expenses including land and building rent (USDA 2009).

Several variables indicate landowner attitudes that may be important in biomass planting decisions. The *positive feeling about biomass energy* binary variable indicates respondents who indicated positive or very positive feelings about biomass as an energy resource. WTA a planting proposition is expected to increase with positive feelings about biomass energy, all else equal.

We define a *strong environmentalist* as a respondent who chose the strongest level of agreement with all four questionnaire statements about environmental values: "I would be pleased if a rare or threatened species was found on my land," "My land should provide for the needs of future plant and animal populations," "I have a responsibility to leave my land in at least as good condition as I found it," and "Climate change is an important problem for society to address." The effect of this variable is uncertain; while strong environmentalists presumably want the best outcome for the environment, they may not be certain that biomass crops provide that outcome. In particular, though biomass is a renewable form of energy, cropping of any kind can have negative environmental effects relative to native vegetation. Biomass combustion also releases some air pollutants.

We include a binary variable to identify landowners with strong opinions about crop appearance, indicating landowners who both rated crop appearance as quite or very important and said that enjoying scenery was a quite or very important reason to own land. Strong opinions about crop appearance may have a negative impact on planting if landowners consider biomass crops as less attractive than the current land use.

A binary variable indicating recreation importance identifies respondents who rated personal recreation as a quite or very important reason to own land. If landowners already obtain recreation amenities from their land, changing land use by growing biomass crops could negatively affect this amenity value.

The variable *wildlife habitat important* reflects responses that impact on wildlife habitat was a quite or very important consideration in planting biomass crops and also that providing wildlife habitat was a quite or very important reason to own land. Wildlife may provide another important amenity value for landowners. The actual impact of biomass crops on wildlife is uncertain.

Results

Of the 926 landowners contacted, 261 (28 percent) responded. This analysis includes data from the 192 landowners (21 percent) whose responses were complete enough to be included in the binary logistic model. Those landowners reported owning a total of 6,029 hectares (14,898 acres) in 403 parcels.

Land-based income (farming, logging, etc.) accounted for less than 1 percent of household income for 68 percent of respondents and for less than 10 percent of income for 87 percent of the landowners. Only 5 percent received more than half of their household incomes from their land. The sample includes 41 farmers as previously defined (21 percent of the sample). In addition to the 21 percent of landowners defined here as farmers, 10 percent reported farming for income (but received less than 1 percent of household income from farming) and 42 percent reported farming but not for income (e.g., for home consumption). Only 27 percent of landowners in the sample reported not farming at all.

To assess the risk of non-response bias, we compared demographic data from the survey to regional data from the American Community Survey (U.S. Census Bureau 2008). We retrieved records for individuals over 18 years of age from households who owned homes with lots at least four hectares (ten acres) in size. These data established that the survey sample is demographically similar to the landowner population of interest, as shown in Table 1. While the survey sample is slightly older, is better educated, and has slightly higher income than the general landowner population in this region, cross-tabulation of demographic characteristics with hypothetical biomass crop planting decisions shows no strong statistical correlation between WTA and age ($\chi^2 = 1.54$, $p = 0.67$), education ($\chi^2 = 3.52$, $p = 0.32$), or income ($\chi^2 = 2.33$, $p = 0.68$). This provides confidence that the survey sample is sufficiently representative of the landowner population as a whole. The landowner survey sample also has a greater proportion of farmers than the general landowner population.

Respondents generally rated their knowledge of biomass energy as low with 71 percent saying they had very little or little knowledge of biomass energy. On the other hand, 57 percent had positive or very positive attitudes about biomass energy while 37 percent were neutral and only 6 percent were negative or very negative. Landowners generally felt positive but uninformed about biomass energy.

Given a hypothetical payment for planting biomass crops, 54 percent of responding landowners would accept the proposition (n = 192; an equal proportion of the full 261 respondent sample was willing to plant). For those

Table 1. Survey Respondents' Age, Education, and Income Compared to the Population of Western Massachusetts Owning More Than Ten Acres of Land

	Percent		
	Western Massachusetts	**Survey Sample (n = 192)**	**Sample Compared to Population**
Age			
18–34 years	6	1	–5
35–54 years	42	24	–18
55–74 years	40	65	25
More than 75 years	13	10	–3
Education			
Less than high school	6	1	–5
High school	46	15	–31
Two-year or four-year college	41	41	0
More than two- or four-year college	7	43	36
Income			
Less than $15,000	6	2	–4
$15,000–$34,999	12	9	–3
$35,000–$74,999	28	29	1
$75,000–$150,000	45	36	–9
More than $150,000	9	24	15

Note: The western Massachusetts data are based on American Community Survey microdata (U.S. Census Bureau 2008).

declining (n = 89), the main reasons given and proportions citing those reasons were:

- "Other uses of my fields are more important to me" (56 percent).
- "I would need more details about planting, managing, and/or harvesting the crop" (42 percent).
- "The suggested profit was too small" (40 percent).
- "I would never consider growing a grassy or woody biomass crop" (10 percent).
- Other reasons—narrative answers (36 percent).

Regarding a choice between a woody biomass crop (e.g., poplar) and a grassy crop (e.g., switchgrass), 57 percent preferred a grassy crop while only 5 percent preferred a woody crop and 35 percent were neutral or undecided. The apparent preference for grassy crops over woody crops may be an important factor in biomass crop acceptance. But note that the questionnaire included only one photo each of grassy and woody crops, and results may be sensitive to the specific photos chosen.

Respondents rated seven considerations for planting biomass crops on a five-part Likert scale as shown in Table 2. Among those who would consider planting a biomass crop, *impact on wildlife habitat* was most cited as a quite or very important consideration (59 percent). More research as well as education are needed on wildlife impacts of biomass crops as this is clearly a large concern of landowners.

Table 2. Importance of Factors in Considering Whether to Plant a Biomass Crop

	Percent of Respondents				
	Not Important	Slightly Important	Fairly Important	Quite Important	Very Important
Possible income from the crop	14.1	22.0	24.6	14.1	25.1
Appearance of the crop	16.8	18.8	24.6	19.9	19.9
Impact on wildlife habitat	5.8	10.5	24.6	28.8	30.4
Ease of walking through fields with crops	24.7	21.6	25.8	17.9	10.0
Possible chemical fertilizer or herbicide use in production	11.1	13.2	21.7	19.0	34.9
Final use of the crop – heating, electricity generation, or transportation fuel; small-scale or large-scale	34.7	16.3	21.1	15.8	12.1
Whether you could use the crop to heat your own home or buildings	30.4	23.6	20.9	15.7	9.4

Note: n = 192.

Possible chemical fertilizer or herbicide use in production was cited as a quite or very important consideration by 54 percent of the respondents and was most often selected as a very important factor (35 percent). Here we assume that landowners who consider chemical use important have concerns (i.e., they might be predisposed to restrict chemical use on their lands). Among nonfarmers, 61 percent felt that chemical use was quite or very important while only 28 percent of farmers shared this view, a significant difference ($\chi^2 = 13.1$, $p < 0.001$).

Binary Logistic Model Results

A total of 192 respondents answered all questions for variables in the binary logistic model and are included in the analysis. Table 3 shows descriptive statistics for the variables in the model.

The omnibus test of model coefficients yields a chi-square score of 52.0 ($p < 0.001$), indicating that the variables in the model are collectively significant. The Nagelkerke pseudo R-square measure (used in logistic models) is 0.32. The Hosmer-Lemeshow test (a test used for binary logistic model specification where the null hypothesis is proper specification) returns a chi-square statistic of 4.83 ($p = 0.78$), indicating that the model is likely properly specified.

Table 3. Survey Sample Descriptive Statistics for Variables in the Binary Logistic Model

Variable	Type	Mean	Std. Dev.	Min.	Max.
Willing to plant (dependent variable)	Binary	0.54	—	0.00	1.00
Bid, hundred dollars per hectare	Interval	7.64	3.86	1.24	13.59
Grass land hectares	Interval	7.93	15.93	0.00	129.50
Crop land hectares	Interval	8.18	34.01	0.00	400.65
Household income less than $15,000	Binary	0.02	—	0.00	1.00
Household income $15,000–$34,999	Binary	0.09	—	0.00	1.00
Household income $75,000–$149,999	Binary	0.36	—	0.00	1.00
Household income $150,000 or more	Binary	0.24	—	0.00	1.00
High education	Binary	0.84	—	0.00	1.00
Farmer	Binary	0.21	—	0.00	1.00
Positive feeling about biomass energy	Binary	0.57	—	0.00	1.00
Strong environmentalist	Binary	0.10	—	0.00	1.00
Appearance is important	Binary	0.15	—	0.00	1.00
Recreation on land is important	Binary	0.56	—	0.00	1.00
Wildlife habitat is important	Binary	0.45	—	0.00	1.00

Note: n = 192.

We use two methods to determine that variables do not exhibit excessive collinearity: (i) we calculate correlation coefficients and find them to be less than 0.5 in all cases, and (ii) we enter the variables in a linear regression model where we calculate variance inflation factors and observe no values greater than 2.0. Testing reveals no evidence of heteroskedasticity.

Estimates and probabilities for variable coefficients are shown in Table 4. As expected, the *bid* coefficient estimate is positive and statistically significant ($p = 0.009$). The *farmer* coefficient is negative and highly significant ($p = 0.005$), indicating that farmers are less likely to accept the planting proposition. Western Massachusetts farmers may have better per-hectare income opportunities than those presented by biomass crops. We also interact the *farmer* variable with low, medium, and high bid-level variables in a separate model with the same specification except for the additional variables (results not shown). All of the farmer-bid-level coefficient estimates are negative, suggesting that farmers are less likely to accept even at the highest bid levels. The farmer-medium-bid and farmer-high-bid coefficients are statistically significant ($p = 0.043$ and 0.013 respectively).

The *grass land hectares* coefficient is positive and statistically significant ($p = 0.017$). Existing grass lands such as former dairy pastures are likely the

Table 4. Binary Logistic Model Variables and Results for Dependent Variable: Binary Willingness-to-Accept Decision

Variable	*b*	*se*	p > |*z*|	Average Marginal Effect (*dy*/*dx*)
Constant	–2.307**	0.773	0.003	—
Bid, hundred dollars per hectare	0.119**	0.046	0.009	0.023
Grass land hectares	0.066*	0.027	0.017	0.012
Crop land hectares	–0.005	0.007	0.488	–0.001
Household income less than $15,000	0.398	1.389	0.774	0.074
Household income $15,000–$34,999	–0.676	0.670	0.313	–0.128
Household income $75,000–$149,999	0.485	0.451	0.282	0.091
Household income $150,000 or more	–0.027	0.507	0.958	–0.005
High education	0.801	0.524	0.127	0.153
Farmer	–1.518**	0.535	0.005	–0.283
Positive feeling about biomass energy	1.215**	0.348	0.000	0.243
Strong environmentalist	1.119	0.679	0.100	0.196
Appearance is important	–1.860**	0.585	0.001	–0.337
Recreation on land is important	0.527	0.382	0.167	0.099
Wildlife habitat is important	–0.354	0.407	0.383	–0.066

Notes: $n = 192$; $\chi^2 = 52.0$, $p < 0.001$; Nagelkerke pseudo R-square = 0.32. Asterisks: * significant at the 0.05 probability level; ** significant at the 0.01 probability level.

most suitable locations for biomass crops. Note that this result indicates higher probability of planting by those who not only own grass land but also have large land holdings. The estimated *crop land hectares* coefficient is not significantly different from zero ($p = 0.488$).

The five income categories from the questionnaire are represented by four binary variables with the middle income category omitted as the reference category. If higher incomes decrease biomass planting, the coefficients of the lower-income categories would be positive (those with lower incomes would be more likely to plant) and the coefficients of the upper-income categories would be negative (those with higher incomes would be less likely to plant). But in this survey the coefficient signs are inconsistent, and none of the four income-category coefficients is statistically different from zero. This apparent lack of an income effect is consistent with some but not all studies of forest landowner behavior (Amacher, Conway, and Sullivan 2003).

Positive feeling about biomass energy has a positive and highly significant coefficient ($p < 0.001$), another indication that factors beyond profit maximization drive land use decisions.

The coefficient for the *strong environmentalist* variable is positive and significant at the $p = 0.10$ level. The lack of greater significance may reflect perceived environmental ambiguities associated with producing biomass crops: some environmentalists may give more weight to local environmental problems of biomass energy production (e.g., nitrogen pollution, air pollution), some may give more weight to global benefits (e.g., reduced CO_2 emissions), and others may not have enough information to judge environmental effects of biomass. The strong environmentalists are a small group (10.4 percent of the sample) that strongly agreed with all four environmental positions, including the statement that climate change is an important problem for society. Even this very committed environmental group may not be sure about planting biomass crops.

By contrast, strong feelings about land appearance reduce acceptance probability and are highly significant ($p = 0.001$). Again, profit maximization is not a landowner's sole objective.

Coefficients for the variables reflecting importance of recreation and wildlife habitat are not statistically significant in the binary logistic model. There are two possible explanations for this, one being that importance of these amenities truly does not affect planting decisions. An alternative explanation is that while some landowners value amenities like recreation and wildlife habitat, they do not have enough information to judge whether planting biomass crops would affect these amenities or whether the effect would be positive or negative. For example, MassAudubon planted approximately 16 hectares of switchgrass specifically for bird habitat (not fuel) at its Arcadia wildlife sanctuary in Easthampton, Massachusetts. We assume this is not commonly known by landowners, and the survey provided no information at all on biomass crop effects on wildlife. Since a majority of landowners considered habitat effects to be important in the planting decision (Table 2), such wildlife concerns may ultimately prove important despite the lack of statistical significance in the binary logistic model.

To compare magnitudes of coefficients in the binary logistic model we compute marginal effects. Table 4 shows average marginal effects of all variables (but note that marginal effects in a binary logistic model are not constant). We also examine marginal effects separately for two binary variables: *positive feeling about biomass energy* and *appearance important*. For each of these binary variables we calculate the marginal effect of 1 versus 0 with the bid at \$300. We then hold both of the binary variables at 0 and calculate marginal effects of bids in \$100 increments over \$300 (since marginal effects are not constant) and sum the marginal effects of \$100 bid increases to approximate the total effects of larger bid increases.

This procedure reveals very strong effects of some land-amenity variables. To equal the marginal effect of land appearance being important, the planting bid would have to be increased from \$300 to about \$1,600 per hectare. To equal the marginal effect of a positive feeling about biomass energy, the planting bid would have to be increased from \$300 to about \$1,200 per hectare. These results suggest that nonfinancial values are very important in the utility functions of western Massachusetts landowners, in some cases more important than income from the land. Attention to such amenity values may indeed be the only practical method to obtain some landowners' approval for biomass production since increasing land payments to as much as \$1,200 to \$1,600 per hectare is unlikely to be financially feasible.

Median and Mean Willingness to Accept

One purpose of the landowner survey was to determine median and mean WTA values for planting biomass crops. These can be interpreted as rents landowners would require to make their land available for biomass crops: since hypothetical bids were for profit net of all expenses (including time), the payment reflects only returns to land.

Median WTA occurs where there is a 50 percent probability of landowner bid acceptance, which is in the \$124–\$371 per hectare bid range. Specifically, we estimate median WTA at \$321 per hectare assuming a linear change in probability of acceptance between the \$124 and \$371 bids.

While for most purposes median WTA is likely the best measure, the mean provides an alternative measure that reflects the WTA of all respondents, some of whom have WTA that is much higher than the median. Coefficients from the binary logistic model can be used to generate an estimator of the mean. In a WTA model with only the bid as an independent variable, a mean estimate can be obtained by simply dividing the negative of the estimated constant, $-b_0$, by the estimated bid coefficient, b_1 (Buckland et al. 1999). But because the presence of other covariates biases such estimates, Buckland et al. suggest an alternative mean estimation method.

The mean estimation procedure employs binary logistic models in two stages. In the first stage, we estimate the full model with all covariates (Table 4). We use these estimates to calculate the acceptance odds for each of the n respondents in the sample. We pool respondents into J groups corresponding to the J bid levels in the study and calculate mean acceptance odds for each group. We use these to generate predicted acceptance for each group where mean odds less than 1 result in prediction of rejection. We then use the resulting binary acceptance variable in a second-stage binary logistic model using J observations from the J bid-level groups with bid level as the sole independent variable. Finally, from this model we obtain an unbiased mean estimate by dividing $-b_0$ by b_1 (Buckland et al. 1999).

Using this procedure, we calculate a mean WTA estimate of \$658 per hectare per year, which is substantially greater than the \$321 per hectare median estimate. A portion of the landowner sample, especially farmers, requires high levels of compensatory payment for land use—only 37 percent of farmers accepted the planting proposition at the highest bid of $1,359 per hectare. Western Massachusetts farmers apparently have more profitable opportunities than biomass crops, and planting of biomass energy crops is unlikely in such situations.

If these WTA estimates are also representative of land rents that owners would require to make land available for biomass production, results suggest that Massachusetts landowners expect returns on land that are substantially higher than current land rents in the region. According to USDA (2010), crop land rental rates average $132 per hectare in the northeastern United States and pasture land averages just $63 per hectare. While no state-level figures are reported for New England, reported 2010 crop land rates in the northeastern United States ranged from $109 per hectare in New York to $173 per hectare in Delaware. To find the $321 median rent required by Massachusetts landowners, one would have to go to crop land in the Corn Belt ($361 per hectare) or the Pacific coast ($518 per hectare). This land payment requirement is one factor in high switchgrass production costs estimated for Massachusetts, which start at about $97 per dry metric ton (Timmons 2012), substantially more than found in studies from other parts of the country (Epplin et al. 2007, Duffy 2008, Perrin et al. 2008). This western Massachusetts result supports conclusions from a national study by Khanna et al. (2011), which used a general-equilibrium model of biomass and nonbiomass crop production to determine that producing the technically feasible biomass supply could require biomass prices significantly higher than found today.

Qualitative Results

Comments and questions from the open-ended section of the questionnaire provide a more nuanced view of biomass potential than the quantitative data: many landowners would consider biomass crop production under certain circumstances or if specific concerns were resolved. This suggests greater long-run landowner participation potential than indicated by the quantitative data analysis. A sampling of comments follows.

> "If the USA or Massachusetts is in a desperate situation re. energy, the equation changes and I would be more ready to consider changing the hayfields (alfalfa) over to a biofuel."

> ". . . a section of one field was planted with sunflowers to provide a biomass source of fuel. The birds loved it and we loved it. For us, sunflowers would be preferable to switchgrass."

> "Like the concept and consider it a good fuel source. Use of biomass energy would need to still permit cleaner air, not contribute to asthma, etc."

> "Is switchgrass an invasive species? Is switchgrass poisonous for animal consumption? Once planted and a decision is made to change crop—how do you get rid of it?"

> "Because open field acreage in Massachusetts has declined sharply due to development, etc., the remaining fields are precious resources for many wildlife species. Thus we prefer grass to trees and would carefully study the effect on wildlife of any biomass product proposal . . . "

> "Our interest in this is highly dependent on the value of the crop toward controlling climate change, how bio-fuel is managed, who gets the profit, etc. If and when it is deemed the best and most important use of our land, we will consider it."
>
> "I am not a big fan of monoculture management."
>
> "My concerns: (1) Is biomass an efficient source of energy? (i.e., how much energy does it take to convert it into energy vs. its output?) (2) Is it a clean source of energy? (3) Will its production displace food production and cause food prices to increase worldwide? (4) Will it displace the locally grown /organic farm production . . . ?"

Many of these comments reflect our general finding that nonpecuniary considerations are primary in landowner considerations about using land for biomass crops. A number of comments also reflect the importance of environmental questions.

Conclusions

Biomass energy production requires an extensive land resource, and making such land available without affecting food prices is a significant challenge. Some parts of the world, including the eastern United States, have significant quantities of farmland that is no longer in production. This study finds many Massachusetts landowners interested in the possibilities of biomass energy crops. Results of a survey support the theoretical proposition that both income and land amenities play roles in landowner utility maximization, and the statistically significant amenity variables have large marginal effects on planting decisions: landowner feelings about both crop appearance and biomass as an energy source have larger effects on planting decisions than any plausible biomass crop profit or land rental payment.

Several potential land amenities that appear important in the univariate analysis do not appear to have significant effects on biomass crop planting decisions. For example, 58 percent of respondents considered impact on wildlife habitat to be very or quite important, though this consideration is not statistically significant in the binary logistic model, perhaps because the effect of biomass crops on wildlife simply is not clear to respondents. As the biomass industry develops, actual impacts on wildlife may sway landowners' opinions on biomass crops. The large marginal effects of other nonfinancial concerns suggest that a clear verdict on biomass crop habitat value might be a decisive factor in some landowner planting decisions.

A nascent biomass crop industry must consider cropping systems with multiple landowner objectives in mind. Environmental ambiguities also need to be more clearly resolved for landowners, who must weigh the global benefits of producing renewable energy (e.g., reduced carbon emissions) against impacts of their land use decisions on local ecosystem services. Education will likely be another important component of biomass crop development as landowner knowledge and attitudes about biomass crops clearly play a large role in their willingness to plant.

Production of biomass energy crops will invariably have some relationship to food production and to food prices since the two products can use much of the same land resource. This study suggests potential for a minimal impact on food prices. First, there is currently an unused land resource that is available for biomass production, that is, a new land supply that could at least partly offset new demand for crop production. In addition, Massachusetts farmers currently producing food crops require land returns that are unlikely to be generated by biomass crops at foreseeable energy prices. In Massachusetts at least, biomass crops are unlikely to displace existing food production, though high biomass energy crop prices might displace food production elsewhere.

The median landowner WTA level of $321 per hectare is high by both regional and national standards, especially for what may in some cases be marginal farmland, implying relatively high production costs. This finding supports results of Khanna et al. (2011), which suggested that producing the technically feasible biomass supply could require biomass prices significantly higher than found today. Our study also shows that nonpecuniary considerations have a large impact on biomass crop planting decisions, at least by nonfarmer landowners, so that the final cost of biomass could vary greatly depending on the particular circumstances of its production and how appealing those are to landowners. Though prices are often considered the main influence on behavior, prices will clearly not be the only motivator of landowner participation in biomass energy crop production. Attention to landowner concerns and amenity needs may also be needed to bring inactive farmland into use.

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