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Research paper

How willing are different types of landowner to supply hardwood timber residues for bioenergy?

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ABSTRACT

Among bioenergy feedstocks, timber and crop residues offer low marginal cost of production and low risk of indirect land use change that can boost greenhouse gas emissions. The potential economic supply depends on the willingness of producers to make residues available. Previous studies show that willingness to supply annual crop residues depends upon prices, attitudes toward bioenergy, biophysical setting, and demographic traits. For timber residues, a smaller literature on non-industrial private forest owners found similar results, but little is published about what drives the availability of timber residues from large public and commercial forests.

Combining survey data on small-scale forest owners with interview data on managers of large-scale commercial, public and conservancy-owned forests, we find that willingness to provide timber residues varies by landowner type. At prices of \$4-11 Mg^{-1}, most commercial forest managers are willing to permit residue removal at timber harvest. At higher prices of \$13-26 Mg^{-1}, up to half of non-industrial private forest owners are also willing. However, among managers of large-scale public and conservancy forests, environmental conservation rules and/or insufficient motivation largely prevent the removal of timber residues at harvest. Future projections of timber residue supply should explicitly account for differences in the willingness of each type of forestland owner to supply residues as a bioenergy feedstock.

1. Introduction

Timber residues serve as a potentially significant biomass source in meeting growing U.S. and global energy needs [1]. As a low-cost by-product of existing harvest and processing activities, residues provide an alternative to dedicated biomass crops that avoids the food price and land use change consequences of growing dedicated energy crops on agricultural land [2–4].

Timber residues are defined as the remaining tops and branches that are left behind after timber harvesting operations, which include both stand thinning and final cuts. During thinning operations, loggers remove slower growing or defective trees in order to provide more space and better growing conditions for the remaining trees. At final cuts, loggers remove pre-selected trees in high-value forest stands or else clear an entire lot of marketable timber, leaving tops, branches, and defective wood. Timber residues are typically left on the ground at the tree harvest site or at the landing site where tops and branches are removed [5].

The low value of timber residues makes them a potentially competitive bioenergy feedstock. Like crop residues, timber residues can be processed into cellulosic ethanol [2] or cofired for electricity [6]. As byproducts, neither one displaces an existing land use. The use of timber residues for electricity could be one of the most cost-effective ways of voluntarily reducing CO_2 emissions, due to the utilization of existing infrastructure [7]. Yet the mere existence of timber residues does not assure that those residues will become available for bioenergy uses. Just as with herbaceous bioenergy feedstocks, an important distinction exists between the biophysical availability and the economic supply of timber residues for bioenergy [8].

While studies have projected the biophysical and economic availability of U.S. wood and timber residues in aggregate [1] and for family forests [9], less is known about the landowner traits that determine economic availability. Of these economic supply studies of forest biomass, most focus on the Southern United States [10–12], which comprises about 40% of the nation's 208 million hectares of timberland. Fewer studies have examined the drivers of residue supply in the multispecies, multigenerational hardwood forests of the Northern Tier of the United States [13–15], which comprises 32% of the nation's

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timberland.

Most studies of U.S. Northern Tier timber markets focus on non-industrial private forest (NIPF) landowners [9,13,14,16], who control 36% of U.S. forestland (meaning forested land, regardless of timber yield) [17]. Among these landowners, the leading factors shaping decisions to supply timber residues from their forestland are socio-demographic characteristics, forest management objectives, and stand characteristics [10,12,15]. Other characteristics such as owner's knowledge of wood-based bioenergy [11], owner age, stand area, ownership objectives, and tree species mix also affect timber residue supply decisions [12]. Landowner attitudes towards forest management and bioenergy as well as opinions about the importance of climate change are also important drivers of willingness to supply timber residues [10,16].

The literature surrounding the economic determinants of timber residue supply by large-scale timberland managers is sparse. This seems surprising, in light of the fact that most U.S. forestland is managed under federal (31%), corporate (18%), or state (9%) ownership. The limited literature on timber residues from large-scale forests focuses on public ones, particularly with regard to residue removal to manage wildfire risks [18,19]. However, we are aware of no studies of timber-residue supply decisions by large-scale commercial timberland managers.

Forests in northern Michigan and Wisconsin have four broad types of ownership, a pattern typical of mixed hardwood forests across the United States. Owner types include 1) the aforementioned NIPFs, 2) large corporations (including Timber Industry Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs)), 3) public forests (federal and state), and 4) non-governmental organizations (NGOs). In Michigan, over half of the 7.7 million hectares of timberland are held privately, with the remainder belonging to the state and federal government. Private forestlands are split roughly evenly between large-scale commercial and NIPF owners [5]. Due to similarities in how TIMOs and REITs manage forestland, we will combine them into a single category of large-scale commercial ownership.

The goal of this research is to understand how the determinants of timber residue supply vary across these distinct types of forest landholders, with special attention to the large-scale owners in order to fill a gap in the literature. Two key research questions arise regarding the prospects for the economic supply of timber residues:

1) Do managers of different ownership types vary in their management objectives?
2) What factors most affect the decision to supply timber residues for managers of each ownership type?

The rest of this article is devoted to answering those questions. Along the way, we describe the geographic and economic setting, the conceptual model that guided the research, and the distinct empirical methods used to study timber residue supply decisions by managers of large-scale versus small-scale forests. After discussing results at both scales, we elucidate the striking differences in forest management based on the divergent objectives of forest managers. We close by interpreting what those differences imply for making estimates of the potential supply of timber residues for bioenergy and other purposes.

2. Materials and methods

2.1. Geographic and economic setting

The potential for a significant timber residue supply in Upper Michigan and Wisconsin arises from the region's well-established wood products industry that provides saw timber, oriented strand board, paper pulp, and other forest products [20]. Extensive forests support that industry. The land on which those forests grow belongs to all four types of owners described above. Although each of the four groups manages a large area of forestland, the membership of the groups ranges from very small (just one large-scale NGO forestland owner with over 10,000 ha in Michigan's Upper Peninsula) to very large (thousands of NIPF landowners). To elicit willingness to supply timber residues from such different populations, it would be inappropriate to rely solely upon statistical methods, especially given the objective of representing how land is managed, rather than how average managers behave. Hence, we use mixed methods that combine quantitative and qualitative measures. Specifically, we conduct a multiple regression analysis of survey data on a stratified, representative sample of NIPF landowners to infer how that large, heterogeneous population behaves. We combine those results with structured interviews with managers of large-scale timber holdings whose testimony describes the management of areas equal to hundreds or thousands of NIPF landowners.

2.2. Conceptual model

Timber residues become available during harvesting operations, so the forestland manager decides (consciously or not) whether and how to make those residues available for removal. For convenience, we will treat forestland owners and managers as one. Although professional managers are the decision makers for most large commercial forests and some NIPFs, the incentives for professional forest managers are highly aligned with the objectives of the firms or individuals that employ them. The land use objectives of non-industrial owners of forestland can differ significantly from those of commercial, industrial owners. For generality, we assume that all forest owners or managers seek to maximize utility with respect to the use of their forested land. Utility, in turn, comes from the forest owner's consumption of marketed goods and services, as well as the environmental amenities and disamenities associated with the noise and disturbance of collecting timber residues.

We assume that the utility that the forest owner derives from their forested land is increasing in environmental amenities, knowledge of and favorable attitudes toward bioenergy, and also in consumption of marketed goods that can be purchased with income from timber sales. We assume too that utility may be decreasing in disamenities associated with forest harvest operations. A key driver of a manager's willingness to supply land for timber residue removal is the area of forestland under the manager's purview. Because consumption of marketed goods depends upon income and income from stumpage fees depends in part upon forestland area owned, we hypothesize that the price of residues and the forestland area made available for timber residues will positively influence revenue, consumption, and utility. On the other hand, the area devoted to timber residues is likely to reduce environmental amenities (such as biodiversity) and add to disamenities of harvest (such as noise and traffic), both of which will reduce overall utility. With these factors in mind, the forestland manager's willingness to make land available for timber residue harvest is likely to depend upon the following categories of variables: the area of forestland managed, the price of timber residues, and preferences regarding environmental amenities, bioenergy, and timber harvest disamenities. Hence, empirical measures of these variables should be part of any model to estimate the economic supply of forestland for timber residue harvest. (More economically formal, mathematical presentations of the theory behind the timber residue supply function may be found in Refs. [21,22].)

2.3. Data and empirical methods

As described above, ownership of forestland in northern Michigan and Wisconsin consists mostly of commercial/industrial, public (federal and state), and non-industrial private (NIPF), each with shares over 20%. A small share is owned by NGOs. The first two classes of ownership are highly concentrated. In Michigan's heavily forested Upper Peninsula (U.P.), 63% of timberland is held privately, with the balance owned by state (24%) and federal (13%) government [5]. The

dominant private share is consistent with the Northern United States as a whole, where 74% of forestland is privately held (as compared to 58% nationally) [1]. Over a third of U.P. private forestland is held by the seven large landowners who each manage over 10,000 ha enrolled in the Michigan Commercial Forest program [5]. Land in national and state forests is similarly concentrated. Northern Wisconsin has two national forests (Chequamegon and Nicolet) and northern Michigan has four (Ottawa, Hiawatha, Manistee, and Au Sable). Both states have similarly small numbers of large state forests. The northern halves of these two states are also home to thousands of NIPF owners with small tracts of forest.

For purposes of empirical research design, we have three populations of forestland managers in the region, each of which manages over 20% of forestland area, plus a small but distinct fourth population. Those populations are: 1) NIPF owners (over five thousand in northern Michigan and Wisconsin), 2) large-scale private forest managers (7 in Michigan's Upper Peninsula), 3) large state and federal forests (Michigan's Upper Peninsula has two of each; there are 6 federal and 13 state forests in the northern halves of the two states), and 4) NGO's (The Nature Conservancy is the sole NGO with over 10,000 ha in Michigan). Given the large population of NIPF landowners, a representative, random sampling process followed by standardized data collection and statistical hypothesis testing was the most suitable path to draw inferences about motives and willingness to supply timber residues. In the next subsection, we describe the sampling, survey, and analytical methods followed.

For the very small populations who manage large-scale forestlands in the region, statistical regression methods are infeasible (too few degrees of freedom) and standardized questionnaires are often ill-suited. However, case study methods offer an appropriate balance of reliance on a prior conceptual model and adaptability to small samples [23,24]. In order to accommodate their heterogeneity and time constraints, we conducted semi-structured interviews with forest managers of public and large-scale private forestland. We first describe methods for the NIPF owner survey, followed by the interviews of large-scale forestland managers.

2.3.1. Survey methods for non-industrial private forest (NIPF) owners

The survey of NIPF owners, was conducted by postal mail during the winter of 2014–15. It targeted owners with a minimum of 4 ha of forestland in a 76-county sub-region northern Michigan and Wisconsin with ample forested land and limited agricultural growing capacity (Fig. 1). The survey explored their willingness to make timber residues available at various stated payment levels. The sample was clustered by county and stratified at both county and household levels. In order to represent differing levels of vegetative cover, the 76 counties were stratified between high (> 20%) and low (< 20%) grassland cover, with each category accounting for half of six randomly selected counties in Wisconsin and twelve in Michigan (as Michigan counties are roughly half the size of Wisconsin ones) [22].

Within each county, we targeted 96 (Michigan) or 192 (Wisconsin) non-institutional landowners with four or more hectares of rural land, based on county-level property tax records [22]. At the second stage, we stratified the sample into large (> 40 ha) and small (4–40 ha) landholdings as well as by participation or non-participation in forest management programs, specifically Michigan's Qualified Forest and Commercial Forest programs and Wisconsin's Managed Forest Law. From the resulting four strata in each county, we selected 24 participants in Michigan counties and 48 Wisconsin ones, with the goal of creating a balanced sample (dark colored counties in Figure (1)). Forest program participant landowners with over 40 ha were over-sampled due to their low incidence in the population. The econometric estimates below are weighted by the inverse probability of selection [21].

From the final sample of 2170, we received responses from 51.8% [22]. Just over 750 records (34.6%) were sufficiently complete to be usable for econometric analysis.

The survey questions, which map to the conceptual model, include demographic questions, education level, and forest characteristics, income sources, and bioenergy knowledge. Preferences regarding environmental amenities and harvest disamenities were measured using 5-point Likert scales and were subsequently consolidated into a smaller set of factors using factor analysis.

The questionnaire presented respondents with a pair of choices about the NIPF landowner's willingness to contract for timber harvest or stand thinning ("stand improvement") in exchange for payment. Wording of the stumpage price offers was as follows (note that the original survey used English units, but all results are converted to SI units) [21]:

1) "if [the company harvesting your timber] offered you a contract for

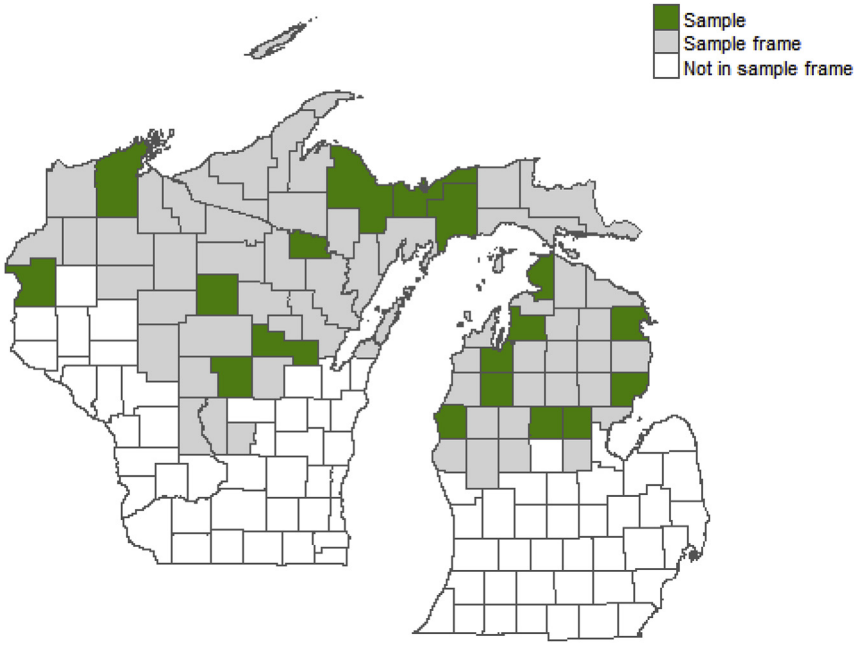

Fig. 1. Sample frame for the 2014–2015 GLBRC survey.

Table 1
NIPF owners willing to sell timber residues at four stumpage payment levels (percent).

Response (percent)	At next timber final cut (N = 938)					At next stand thinning (N = 899)				
	Payment ($/hectare)					Payment ($/hectare)				
	38	75	150	225	Over-all	38	75	150	225	Over-all
Yes	45	47	58	63	53	39	42	56	64	51
No, no plans	19	19	15	12	16	19	18	17	10	16
No (no explanation)	3	4	3	3	3	3	4	4	2	3
No, maybe if higher payment	16	14	16	8	13	21	15	17	8	15
No, never	16	17	8	14	14	17	21	6	16	15

NB: Results are computed using survey weights (inverse probability of sample selection) to adjust for the effect of sample stratification.

$__ per acre to remove woody biomass from your forested land at the time of your next timber harvest, would you agree to the offer?" and

2) "if [the company contracting to thin your timber] offered you a contract for $__ per acre to remove woody biomass from your forested land at the time of your next stand improvement, would you agree to the offer? (such as forest thinning, junk wood removal, or habitat restoration)."

The dollar payment per hectare for woody biomass (timber residues) varied randomly across surveys, with four payment rates ($37, $75, $150, $225 ha^{-1}). To each question, respondents could answer, (a) "yes, I would be willing to sell my woody biomass; " (b) "no, I do not have plans to harvest timber/conduct stand improvement from my forested land; " (c) "no," with no detail; (d) "no, I would sell my biomass if the payment were higher; " or (e) "I would never sell woody biomass from a timber harvest."

2.3.2. Interviews with large-scale forestland managers

Due to the concentration of large-scale forest tracts in Michigan's heavily forested Upper Peninsula (U.P.) and its central location in the northern Great Lakes forestlands, we chose this area for interviews with managers of large-scale forestlands. The ownership of forestland in the U.P. is highly concentrated, with 37% in public forest (with 776,000 ha of MDNR and over 400,000 ha of USFS) [25] and 22% (696,000 ha) under management by the top six large-scale commercial firms [5].

Seven private landowners in the area had enrolled 10,000 ha or more in Michigan's Commercial Forest Program (CFP) [26] as of January 1, 2016. Of those seven, all but one commercial firm was available for in-person interviews or interviews over the phone. We interviewed five commercial firms that owned the following CFP land areas: Weyerhaeuser [formerly Plum Creek], 222,046 ha; GMO Threshold Timber, 169,107 ha; Keweenaw Land Association, Ltd., 62,465 ha; Molpus (MWF Ned Lake & Lake Sup. Timber), 60,476 ha; and Longyear/Turner/JML Heirs, 26,191 ha. Only the Forestland Group (157,527 ha) was unavailable. The seventh landowner by area, The Nature Conservancy (10,260 ha), was included to represent management by a conservation NGO [5]. To capture the potential for timber residue supply from public forests, we interviewed timber managers with the Michigan Department of Natural Resources (MDNR, 800,000 ha) and the U.S. Forest Service (USFS, 400,000 ha) [5]. The final set of large-scale forestland managers plus one consultant included nine key informants, representing 77% of large-scale commercial forestland, 100% of large-scale NGO forestland, and 100% of federal and state forestland in the Upper Peninsula. During May–September 2016, we interviewed seven informants in person and two by telephone.

The semi-structured interviews [27,28] followed a script with five different sections (see Supplemental Materials). The first introduced the researchers and our goal of learning, "the conditions under which landowners would supply biomass/slash for bioenergy." After a set of background questions about energy biomass, timberland holdings, and timber harvest contracting, we asked whether (and how), the firm handles timber residues, especially for bioenergy uses. If the manager reported currently harvesting timber residues, we asked about contract terms with the logger. If the manager had not harvested timber residues, we asked them to consider the hypothetical,

> "Suppose that market demand for timber slash jumped so dramatically that you began seriously to consider harvesting residues at time of timber harvest. What would be the biggest barriers to harvesting & selling slash? What kind of contract terms would you need (term of contract, location of sale, pricing)?" [5].

3. Results

We find that objectives vary sharply across the types of forestland owners. Those different objectives, in turn, drive divergent willingness to supply timber residues as energy biomass. Private landowners are chiefly motivated by profitability, and at the right price, virtually all forestland controlled by large-scale owners could generate timber residues. NIPF owners are heterogeneous; no more than 55% would be willing to supply timber residues, even at high prices. Although price is a strong motive for NIPF owners, environmental amenities play a negligible role. As for public forest managers, when it comes to removing timber residues, the rules they must follow are so cumbersome and their compliance personnel so heavily burdened (particularly in federal forests) that they offer scant potential to supply timber residues. Finally, the conservation NGO we interviewed is uninterested in removing timber residues due to conflict with its ecological management objectives. The following paragraphs give a fuller account.

3.1. NIPF survey statistical results

The survey-weighted percentages of landowners willing to sell timber residues at four different prices per hectare appear below in Table 1. On average, over 50% are willing to sell residues at the next final cut or next stand thinning. In general, the descriptive statistics are consistent with the expectation that the probability of accepting an offer to harvest timber residues should increase with the stumpage payment offered. However, Table 1 lacks information on how the non-price variables tend to affect NIPF owners' willingness to allow timber residue removal.

To control for the effects of all relevant variables on the decision whether to supply timber residues, we econometrically estimated the probability that an NIPF owner was willing to make timber residues available using a binary probit model of Eq. (2) at the time of 1) the next timber harvest and 2) the next stand thinning. For details and descriptive statistics, see Ref. [21].

Responses to stated preference questions on bioenergy attitudes, environmental amenities, and harvest disamenities were condensed into three factors [21]. After a factor-based axis rotation [29], we analyzed the loadings for the retained factors. The first factor has high

Table 2
NIPF owner willingness to supply timber residues at next timber harvest or stand thinning (bivariate probit marginal effects, weighted by inverse sampling probability).

Variable	At Next Timber Final Cut (N = 751)			At Next Stand Thinning (N = 754)		
	Marginal Probability	Std. Dev.	p-value[a]	Marginal Probability	Std. Dev.	p-value[+]
Income						
Price offered	0.0039***	0.0012	0.001	0.0052***	0.0012	0.000
Income	-9.55×10^{-7}	6.31×10^{-7}	0.131	-1.61×10^{-7}	6.37×10^{-9}	0.801
Demographics						
Age (yrs)	0.0036	0.0036	0.316	0.0027	0.0035	0.435
Male (0/1)	0.1660*	0.0880	0.061	0.1496*	0.0877	0.094
Farmer (0/1)	0.1174	0.0798	0.154	0.0328	0.0899	0.716
Education (yrs)	0.1436**	0.0711	0.043	0.1554**	0.0718	0.031
Ag zoning (0/1)	−0.2347***	0.0766	0.003	−0.1430*	0.0777	0.069
Residential zoning (0/1)	0.2505***	0.0786	0.006	0.1986**	0.0883	0.036
Duration on land (yrs)	−0.0043*	0.0025	0.090	−0.0029	0.0025	0.247
Is resident of land (0/1)	−0.0527	0.0800	0.514	−0.0438	0.0808	0.589
Forest Characteristics						
Mixed forest (has)	−0.0008	0.0005	0.103	−0.0015*	0.0008	0.059
Single-species (has)	0.0015	0.0015	0.307	0.0018***	0.0008	0.010
Other forest (has)	0.0023	0.0053	0.661	0.0020	0.0023	0.411
Has mixed forest over 10 years old (0/1)	0.0781	0.1049	0.454	0.1263	0.1012	0.218
Single-species forest > 10 years old (0/1)	0.0739	0.0718	0.307	−0.0715	0.0708	0.314
Land use						
Timber harvest experience (0/1)	0.2521***	0.0698	0.000	0.1709**	0.0734	0.022
Uses forest for personal use (0/1)	0.1083	0.1051	0.301	0.1497	0.1002	0.145
Knowledge						
Landowner has heard of bioenergy (0/1)	−0.0412	0.1095	0.710	−0.1470	0.1112	0.207
Knows slash can be feedstock (0/1)	−0.1373*	0.0725	0.061	−0.1816**	0.0741	0.016
Has seen a pile of slash (0/1)	0.0464	0.0750	0.536	−0.0536	0.0743	0.472
Attitude factors						
Pro-bioenergy	0.0606	0.0384	0.116	0.0468	0.0374	0.211
Conservationist	−0.0352	0.0431	0.415	−0.0330	0.0445	0.459
Disamenities of noise/smell	−0.0292	0.0394	0.459	−0.0995**	0.0409	0.015

[+]p-values reported are from the original probit regression coefficients; [α] Robust standard errors.
*, **, *** Significant at the 10%, 5%, or 1% level.
Marginal probabilities calculated at the mean value of the respective explanatory variable.

loadings associated with pro-bioenergy attitudes, such as a belief that the use of bioenergy feedstocks in place of fossil fuel will help mitigate climate change. The second factor carries two high loadings related to loss of environmental amenities, specifically biodiversity and soil quality. The third factor carries two high loadings that are related to noise and smell disamenities. Cronbach's alpha for each grouping of items with the highest loadings in each of the three factors is above 0.70 and below 0.82, which places them within the recommended range for variables with high correlations in underlying latent factors [30].

The results of the bivariate probit model appear in Table 2, with coefficient estimates presented as marginal effects calculated at the mean of the data. We dropped forest program participation as an explanatory variable because it had guided sample selection. In order to check whether its inclusion in sample selection had caused endogeneity among explanatory variables, we conducted instrumental variable tests in bivariate probit robustness checks that showed no cause for concern [21].

The interpretation of results showed first that, consistent with the conceptual model, the price offered and previous experience with timber harvest were strong drivers of willingness to supply timber residues, both at timber final cut and at stand thinning. Ownership of single-species forest had a small but highly significant positive effect at stand thinning, perhaps because single species forests tend to be even aged, and their owners appreciate an income-earning opportunity prior to timber harvest. We could not reject the hypotheses that environmental and bioenergy preferences had no effect on the timber residue decision. Contrary to expectations, respondents who knew that timber slash (residues) can be used as a bioenergy feedstock were less inclined to make timber residues available for removal.

3.2. Interview results

The interviews revealed that large-scale timber managers' objectives and decisions differ strongly by ownership type. Commercial firms like Molpus and Weyerhaeuser are broadly willing to permit the harvest of residues if loggers are willing to pay them a higher stumpage fee. Marketing of the residues would fall to the loggers, as the timberland management firms are not interested in seeking out residue markets [5]. By contrast, NGOs and managers for the state and federal forestlands are largely unwilling to harvest or supply residues, except under very specific conditions.

In highly congruent terms, the large-scale commercial firms emphasized that profitability is their top criterion for decisions about timber residues—and everything else. Noting that the primary goal of his company is to achieve high returns for its investors, the Weyerhaeuser Senior Resource Manager for the Lake States said, “We're not against doing anything if there's a market for it” [5]. Other managers added caveats about protecting the resource base, but the message remained the same. The operations manager of the Keweenaw Land Association used these words to describe the decision lens he and his peers use to decide on supplying timber residues,

> “The two questions are 1) Can we make money? and 2) Can we do it without damaging standing timber? If yes, foresters implement.”

Environmental amenities and production disamenities entered the decisions of large-scale commercial managers only to the extent that they affect certification of socially responsible production practices. All the large-scale commercial forest firms participate in the certification program of either the Forest Stewardship Council (FSC) or the Sustainable Forest Initiative (SFI). Production guidelines under these

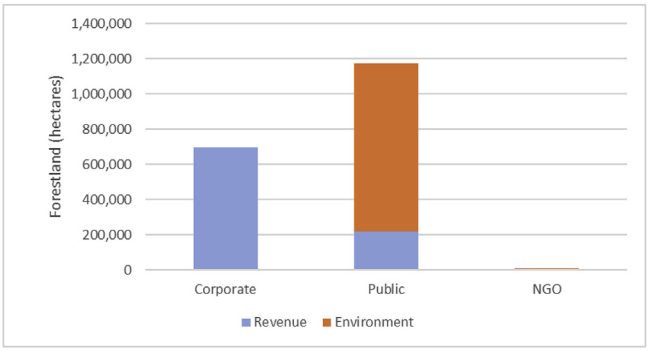

Fig. 2. Managers' objectives weighted by forestland controlled, three ownership types, Upper Peninsula of Michigan, USA, 2016.

programs typically govern the minimum amount of biomass left on the forest floor. The managers at Weyerhaeuser, Molpus, Longyear, and the Keweenaw Land Association made clear that following these guidelines was necessary for participating competitively in the marketplace [5]. The overriding message about environmental stewardship was that it matters only to comply with rules of the Commercial Forest Program and SFI or FSC certification. When it comes to timber residue harvest, the key decision factor is the stumpage price premium offered [5].

The one conservation NGO among the large-scale private landowners in the interview sample, The Nature Conservancy (TNC), had starkly different timber management objectives from the large-scale commercial firms. The consultant that manages its U.P. forestlands for TNC explained that its primary foci are biodiversity and restoration of the forest. TNC does not currently engage in the removal of tops and branches for chipping, as removal typically does not align with their overall forest health goals. NGOs like TNC are unwilling to supply timber residues, so their lands do not belong in projections of likely potential supply of residues for bioenergy.

As public land managers, the federal and state foresters technically have a mandate for mixed use that includes revenue generation alongside natural resource protection and public access. The National Forest Management Act requires that the USFS manage National Forest System lands for a variety of uses on a sustained basis to ensure in perpetuity a continued supply of goods and services to the American people. The Act also establishes analytical and procedural requirements for developing, revising, and amending forest plans. The Forest Timber Program Manager at the Hiawatha National Forest explained in interviews that the management structure is largely similar across federal forests. Each forest plan designates areas of land suitable for timber harvest. To implement the plan from year to year, foresters propose specific tracts to harvest. However, every USFS timber harvest proposal must meet the requirements of the National Environmental Policy Act (NEPA). According to the manager at Hiawatha National Forest, the NEPA public engagement process slows down the timber harvest process by about two years per proposal [5]. NEPA and the Endangered Species Act make it very difficult to harvest timber, much less residues, he explained. At the time of the 2016 interview, the Hiawatha National Forest had been operating at around 37% of its Allowable Sale Quantity of timber under its forest management plan. Faced with the urgency of fighting forest fires and managing with limited personnel resources, the Forest Timber Program Manager acknowledged that timber revenue generation is not a priority at the Hiawatha National Forest. His interview indicates that the supply of timber residues from national forests in the area is negligible and likely to remain so [5].

While unrealized, the potential for timber residue supply from state forests is greater than from national forests. The spatial extent is large, for the state of Michigan manages the largest dedicated state forest system in the nation at 1.6 million hectares [31]. There are about 776,000 ha of timberland managed by state and local governments in the Upper Peninsula [25]. Additionally, the procedures to approve timber harvest are less cumbersome. Like USFS foresters, MDNR foresters follow individual forest plans and regional plans that outline overarching objectives. According to the State of Michigan's Timber Sale Specialist, “We follow a process that is comparable to NEPA, but with much fewer rules” [5]. This enables MDNR managers to move more quickly than the USFS to conduct more timber harvests. It also means that for most timber sales, the MDNR can include residues in a bid if they think it might generate additional profit. Despite these advantages over national forests, the supply availability is modest. According to the same source,

> “They're having difficulty getting bids on those sales because there's not a high enough demand [for residues].”

Apparently, the MDNR is potentially open to timber residue removal, but it finds that few loggers have chipping equipment or are interested. Market prices for timber residues have been too low to induce the MDNR or its contract loggers to consider seriously whether to supply them.

4. Discussion: willingness to provide timber residues by ownership type

In answer to our first research question, the objectives of forestland managers varied strongly by ownership type. For private owners of forestlands, whether large or small in scale, income generation was an important objective but not an overriding one for many NIPF owners. For managers at the large-scale commercial firms, it was the primary objective. By contrast, environmental quality was the sole objective for NGO and the dominant one for USFS national forests. As of 2016, the mixed use objective of the USFS effectively did not extend to timber residue removal. The State of Michigan Department of Natural Resources (MDNR) was open to timber residue sales that complied with its environmental stewardship rules, but prices have never reached a level that MDNR timber managers found attractive. The personal interviews revealed that timber residues are potentially available on all privately managed commercial forestland, well under half of government land, and none of the environmental NGO land. Fig. 2 reflects these findings in weighting managers' objectives by the area of forestland they control. The public forestland bar reflects a mixed use policy that in theory makes revenue objectives equal to environmental ones, but in practice allows only 37% of the timber sales objective to be met in national forests. We treat this value as indicative of potential timber residue availability in public forests generally if higher prices were to occur (represented here as 37% of 50% land use for timber sales under the mixed use mandate, so only 18% of public forestland is practically available).

To answer our second research question, we restrict summary answers to the private owners of forestlands, who were open to timber residue supply. As summarized in Table 3, among the six determinants originally hypothesized to motivate timber residue supply, the

Table 3
Summary of determinants of timber residue supply by major variable and sign.

Major variable	NIPF	Commercial
Price of timber residue	+ +	+ +
Environmental amenities	NA	(a)
Disamenities from residue removal	- (b)	(a)
Bioenergy preference	NA	NA
Forest type = single species	+ (b)	NA
Owner previously harvested timber	+ +	+ +

(a) Applies only to conformity with sustainable harvest label requirements, which require leaving on forest floor a minimum percentage of timber residues.
(b) Significant at time of stand improvement (thinning), not at harvest.
Data for NIPF from Ref. [21]; data for Commercial from Ref. [5].

stumpage price premium for timber residue removal and prior timber harvest experience were the strongest motivators for private owners of forestlands, whether large or small in scale. The importance of biomass price stands out, given that some prior studies (e.g. Ref. [12]) omitted this key economic variable [13], which could have biased their statistical findings about other determinants. In addition to price and prior experience, small-scale (NIPF) owners were also concerned about the noise and smell disamenities of residue removal, and were more motivated to sell residues from single species forests. Large-scale commercial forest managers cared about environmental and harvest amenities only insofar as these affected compliance with guidelines for sustainability certifications.

Given that the regional market for wood chips as a bioenergy feedstock has been in decline during the past five years, there are several threshold conditions that would need to be met to rebuild the market. In general, large-scale commercial forestland managers showed great willingness to supply timber residues if the price exceeded their costs. Several managers of commercial forestland cited a range of $2–5 per green ton of residues at the forest site. The expected harvest yield is roughly five green tons per hectare, for a stumpage cost of $10–25 per hectare. Because moisture accounts for half of green weight, the minimum stumpage cost is $4-11 Mg^{-1} oven-dry ton at the forest site. The comparably competitive stumpage fee for NIPF forestland owners would fall below the lower bound survey value of $38 per hectare. Given the associated expected probability of NIPF supply, that translates to $30-60 Mg^{-1} oven-dry ton at the forest site.

5. Conclusion

Our findings highlight a stark difference between private landowners (whether large or small) and public or NGO landowners. Among private owners of forestland, there are three lessons. First, landowners are much more open to selling bioenergy feedstocks as a byproduct, like timber residues, than as a main product. Put in the timber context, owners of forestland are much more willing to supply residues at time of timber harvest than they are to harvest timber for bioenergy uses [13,14,32] or to convert land from forest to production of a bioenergy feedstock crop (including a tree crop) [22]. Second, small-scale (NIPF) private landowners are less willing to supply timber residues than are large-scale commercial landowners. About half of NIPF owners can be motivated by stumpage payments, but the other half resist removing timber residues altogether. Third, environmental and bioenergy motives carried little weight in motivating timber residue harvest among NIPF owners, despite being important deterrents to converting land to produce dedicated bioenergy crops among the same respondents [22]. The only indirect evidence of a role for bioenergy sentiments was the fact that NIPF owners who were aware that timber slash can be used for bioenergy were less prone to allow timber residue removal.

Our interview results from large-scale commercial, public, and NGO forest managers reveal a sharp bifurcation of views on willingness to supply timber residues for bioenergy markets. Large-scale commercial managers were very open to supplying timber residues if stumpage revenues exceed expected costs. Their sense of costs was nuanced, including potential damage to growing trees by dragging tree tops and branches out of the forest. Yet, they were readily willing to supply residues if all costs were covered, implying a stumpage fee increment of $4-11 Mg^{-1} oven-dry ton. By contrast, public and NGO foresters were either fundamentally unwilling (in the case of TNC) or else so hamstrung with other constraints that timber residue harvest simply did not make it onto the radar screen (USFS). These findings dovetail with case study interviews from across the United States that found timber residue supply from U.S. public forests to be sharply constrained by staff and budget shortages and time demands for environmental compliance [18]. State foresters, however, indicated *potential* willingness to supply timber residues, but they also indicated that they had not previously done so due to insufficient demand (MDNR).

Given the differences in the willingness of different types of forest owner to supply timber residues, future projections of the economic supply of timber residues should take care to distinguish likely supply across forest ownership types. When taking into account the reluctance of public and NGO forest owners, such projections are likely to show a more limited supply of timber residues than studies that assume uniform willingness.

Notes

Seniority of authorship is shared. The authors obtained informed consent from all research subjects, and the Michigan State University Institutional Review Board deemed this project to be exempt from U.S. federal regulations regarding experimentation with human subjects. Survey data are publicly available at: https://lter.kbs.msu.edu/datatables/536. All interviewees quoted here have given the authors permission to publish their words.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biombioe.2019.01.026.

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MICHIGAN STATE UNIVERSITY

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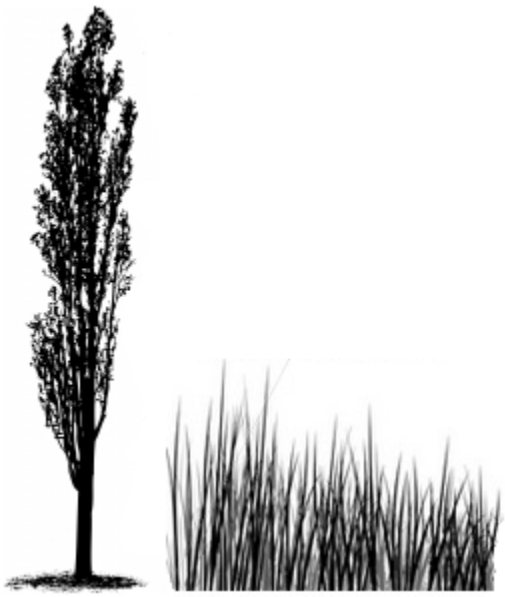
BIOENERGY AND LAND USE

WE NEED YOUR HELP!



The purpose of this study is to understand your views about bioenergy and rural land use. There are no right or wrong answers because people have different attitudes and uses for their land.

YOUR OPINIONS MATTER

By completing this questionnaire you are helping to inform the design of future policies that better reflect the views and concerns of Michigan and Wisconsin landowners.

«Owner_ID»

WHO SHOULD FILL OUT THIS SURVEY?

1. Did you own 10 or more acres of undeveloped rural land (forest, grassland, or farmland) in 2013?

☐ No ⟹ *If NO, please do not fill out the questionnaire and return it to us in the provided prepaid envelope. Thank you for your time!*

☐ Yes ⟹ *If YES, please continue with the questionnaire.*

2. Are you the main decision maker with respect to how your undeveloped rural land is managed and used? (*Note*: If decision making is shared by more than one person either may complete this survey.)

☐ No ⟹ *If NO, please give this questionnaire directly to the person who makes the land management decisions for your rural land.*

☐ Yes ⟹ *If YES, please continue with the questionnaire.*

SECTION A: CURRENT LAND MANAGEMENT PRACTICES

A1. In 2013, in what county was most of your rural land located? _____

A2. Did you own rural land in more than one county in 2013? ☐ No ☐ Yes

A3. How many acres of rural land did you own in 2013? _____ ACRES

A4. Did you rent out any of your rural land to others in 2013?

☐ Yes ☐ No ⟹ *If NO, please skip to question A5 below.*

IF YOU ANSWERED YES:

a. How many acres of your rural land did you rent out in 2013? _____ACRES

A5. Did you rent in any rural land from others in 2013?

☐ Yes ☐ No ⟹ *If NO, please skip to question A6 below.*

IF YOU ANSWERED YES:

a. How many acres of rural land did you rent in from others in 2013? _____ACRES

A6. Did you farm any of the rural land you owned in 2013? (*Note*: Do not include land you rented out to others)

☐ Yes ☐ No

A7. Have you ever grown corn on your land or rented it out for corn production? ☐ Yes ☐ No

A8. Have you ever had timber harvested from the rural land you own?

☐ Yes ☐ No ⟹ *If NO, please skip to question A9 below.*

IF YOU ANSWERED YES:

a. What was the year of the last timber harvest? _____

A9. How would you describe the rural land you owned in 2013?

Description	Acres of Rural Land
Agricultural Cropland	
Corn	_____ ACRES
Soybeans	_____ ACRES
Wheat	_____ ACRES
Other row crops or vegetables (small grains, beans, melons, etc)	_____ ACRES
Hay or alfalfa (in rotation with other crops)	_____ ACRES
Fruit trees or berries	_____ ACRES
Fallow or idled cropland (including set-aside, easements, etc)	_____ ACRES
Other (please explain): _____	_____ ACRES
Farmable Non-Crop Land	
Hay or alfalfa (continuous; not in rotation with other crops)	_____ ACRES
Livestock pasture	_____ ACRES
Open grasslands (mixed grassland, native prairie, etc)	_____ ACRES
Shrub or Scrub (low growth bushes or trees, abandoned cropland, etc)	_____ ACRES
Other farmable non-crop land (land that could be farmed if cleared)	_____ ACRES
Forest and Woodland	
Mixed natural forest (e.g., pine, oak, beech, maple)	_____ ACRES
Single species tree plantations (e.g., pine, poplar, willow)	_____ ACRES
Other (please explain):_____	_____ ACRES
Other	
Any other rural land (e.g., wetlands, lawn and garden)	_____ ACRES
Other (please explain):_____	_____ ACRES

A10. Was any of your land enrolled in a public land conservation program in 2013? (*check all that apply*)

☐ Conservation Reserve Program (CRP)
☐ Managed Forest Law (MFL)
☐ Conservation Stewardship Program (CSP)
☐ Commercial Forest Program (CF)
☐ Environmental Quality Incentive Program (EQIP)
☐ Qualified Forest Program (QF)
☐ Other (please explain):_____

A11. Was livestock raised on your rural land in 2013?

☐ Yes ☐ No ⟹ *If NO, please skip to question A12 below.*

IF YOU ANSWERED YES:

a. What type of livestock did you raise (dairy cows, beef cattle, goats, etc)? _____
b. How many head of this type did you raise? _____ HEAD

A12. How did you or other family members use the rural land that you owned in 2013?

Agricultural Cropland (*Check all that apply*)

☐ Income from land rented out to agricultural or forest product growers or the sale of these products

☐ Income from land rented out for recreation purposes (e.g., hunting, fishing, motorized recreation)

☐ Personal use for recreation (hunting, fishing, motorized recreation, hiking, solitude)

☐ Other (please explain): _____

Farmable Non-Crop Land (Pasture, grassland, other open space) (*Check all that apply*)

☐ Income from land rented out to agricultural or forest product growers or the sale of these products

☐ Income from land rented out for recreation purposes (e.g., hunting, fishing, motorized recreation)

☐ Personal use for recreation (hunting, fishing, motorized recreation, hiking, solitude)

☐ Other (please explain): _____

Forested Land (*Check all that apply*)

☐ Income from land rented out to agricultural or forest product growers or the sale of these products

☐ Income from land rented out for recreation purposes (e.g., hunting, fishing, motorized recreation)

☐ Personal use for recreation (hunting, fishing, motorized recreation, hiking, solitude)

☐ Other (please explain): _____

A13. In 2013, was any of your rural land in a conservation easement? ☐ No ☐ Yes

A14. In 2013, was any of your rural land located within a forest reserve such that timber production was restricted due to legislation or other administrative regulation?

☐ No ☐ Yes

A15. Did you have a written forest management plan in 2013? ☐ No ☐ Yes

A16. Was any of your forested land used to graze livestock in 2013? ☐ No ☐ Yes

A17. If applicable, what is the approximate age of your largest tract of mixed forest?

☐ Less than 5 years (young) ☐ 6-10 years (medium) ☐ More than 10 years (older)

A18. If applicable, what is the approximate age of your largest tract of single species tree plantation?

☐ Less than 5 years (young) ☐ 6-10 years (medium) ☐ More than 10 years (older)

A19. Please check the box that best represents your agreement with each of the following statements about your rural land.

	Yes	No	Uncertain
I would rent out land for agricultural production if offered a satisfactory economic return.	☐	☐	☐
I would rent out land for the establishment of a tree plantation if offered a satisfactory economic return.	☐	☐	☐
My family or friends would dislike it if I rented out land to grow crops or harvest timber.	☐	☐	☐
I would be willing to sell my land if were to be used for growing crops or timber harvesting.	☐	☐	☐
I would be willing to sell my land if it were to be used for recreation (e.g., hunting, fishing).	☐	☐	☐
I would be willing to sell my land if it were to be used for development (e.g., built structures).	☐	☐	☐
I would never sell the rural land that I own.	☐	☐	☐
I plan to sell most of my land within the next 10 years.	☐	☐	☐
I plan to pass most of my land onto an heir or other family member within the next 10 years.	☐	☐	☐
I plan to subdivide part or all of my land within the next 10 years.	☐	☐	☐
I plan to reforest part or all of my land within the next 10 years.	☐	☐	☐
I plan to convert most of my land to another use within the next 10 years.	☐	☐	☐
Within the <u>past</u> 10 years, I converted land from cropland into grassland or forest.	☐	☐	☐
Within the <u>past</u> 10 years, I converted land from grassland into forest.	☐	☐	☐

SECTION B: BIOENERGY

BIOENERGY is energy that comes from a biological source such as crops, grasses, or trees. These materials are often called bioenergy feedstocks. They can be burned to generate heat or electricity or refined to make a liquid fuel such as ethanol. Today, the most common form of ethanol in the United States comes from corn grain. It is possible, however, to make ethanol from other plants and materials.

B1. Prior to this survey, had you heard of bioenergy? (*check one*)

☐ No ☐ Yes

B2. Prior to this survey, did you know that ethanol could be produced from other plant-based materials such as grasses or trees in addition to corn grain? (*check one*)

☐ No ☐ Yes

B3. Prior to receiving this survey, were you aware that the following materials could be used for bioenergy feedstock? (*check one for each option*)

a. Corn residues (stalks, cobs, leaves)	☐ No	☐ Yes
b. Switchgrass	☐ No	☐ Yes
c. Hybrid poplar trees	☐ No	☐ Yes
d. Forest slash (tree tops, branches)	☐ No	☐ Yes

B4. Prior to receiving this survey, have you seen any of the following materials in person? (*check one for each option*)

a. A pile or bale of corn residues	☐ No	☐ Yes
b. A field of switchgrass	☐ No	☐ Yes
c. A row of hybrid poplar trees	☐ No	☐ Yes
d. A pile of forest slash	☐ No	☐ Yes

SECTION C: BIOENERGY FEEDSTOCKS

In the following pages, we ask about your willingness to rent out land for the production and harvesting of different bioenergy feedstocks. Please start by reading the descriptions below and consider what it might be like to rent out different land types (cropland, farmable non-cropland, forest land, etc.) for each feedstock. There are many types of feedstocks but we only ask about four of them. They are:

(1) **CORN.** An annual crop that is typically grown for grain. Most grain is used as animal feed, food or converted into ethanol. The crop residues (stalk, leaf, husk, cob, etc.) are often left in the field following grain harvest but could also be collected and used as bioenergy feedstock.

(2) **SWITCHGRASS.** A native, warm-season perennial grass. At present, switchgrass is not widely cultivated. It is occasionally planted for conservation purposes (riparian buffers, wildlife cover, etc.) but most often appears as one component in mixed-species grasslands. For production as a bioenergy feedstock it would be grown in monoculture as a single-species plantation.

(3) **HYBRID POPLAR.** Fast-growing trees that are closely related to cottonwoods and aspens. Production takes the form of a dedicated, single-species tree plantation. The stand is managed in a way that makes them more like an agricultural crop than a forest.

(4) **WOODY BIOMASS.** Forest residues that are generated from management activities such as timber harvesting or stand improvement practices (forest thinning, junk wood removal, habitat restoration). These residues include low-value forest products such as slash (downed tree tops, branches) or small diameter, non-merchantable trees. This biomass can be chipped and sold as bioenergy feedstock.

Each bioenergy feedstock can be grown on cropland, farmable non-crop land (pasture, grassland, shrub land) or forest land. The exception is woody biomass which can only be harvested from forested land.

Questions start on the next page: While these scenarios are hypothetical, please respond as if you are faced with an actual decision. You may respond 'yes' to as many scenarios as you want, or none at all.

CORN

Planted:	Every spring
Harvested:	Every fall
Fertilized:	Yearly
Growth height:	6–10 feet
Number of visits by renter:	5–7 per year
End use of harvested materials:	Corn for grain & residues for bioenergy feedstock
Soil erosion:	High compared to other bioenergy crops
Greenhouse gas emissions:	High compared to other bioenergy crops
Nutrient and chemical runoff:	High compared to other bioenergy crops
Biodiversity:	Low compared to other bioenergy crops
Rental rate paid to you:	**See below**

***Instructions**: When responding, please consider each scenario separately. In other words, when you respond to the offer for cropland, imagine that the options for non-crop land or forest land do not exist.*

C1. If somebody offered to rent your cropland to grow corn for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any cropland.
- ☐ I would rent out cropland to grow corn if the rent were higher.
- ☐ I would never rent out cropland to grow corn.

C2. If somebody offered to rent your farmable non-crop land (pasture, grassland, shrub land, etc) to grow corn for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any farmable non-crop land.
- ☐ I would rent out farmable non-crop land to grow corn if the rent were higher.
- ☐ I would never rent out farmable non-crop land to grow corn.

C3. If somebody offered to rent your forested land to grow corn for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any forested land.
- ☐ I would rent out forested land to grow corn if the rent were higher.
- ☐ I would never rent out forested land to grow corn.

SWITCHGRASS

Planted:	Spring of the first year
Harvested:	Every fall starting in second year
Fertilized:	Yearly
Growth height:	4–6 feet
Number of visits by renter:	2–3 per year
End use of harvested materials:	Bioenergy
Soil erosion:	Low compared to other bioenergy crops
Greenhouse gas emissions:	Average compared to other bioenergy crops
Nutrient and chemical runoff:	Low compared to other bioenergy crops
Biodiversity:	High compared to other bioenergy crops
Rental rate paid to you :	**See below**

***Instructions**: When responding, please consider each scenario separately. In other words, when you respond to the offer for cropland, imagine that the options for non-crop land or forest land do not exist.*

C4. If somebody offered to rent your cropland to grow switchgrass for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any cropland.
- ☐ I would rent out cropland to grow switchgrass if the rent were higher.
- ☐ I would never rent out cropland to grow switchgrass.

C5. If somebody offered to rent your farmable non-crop land (pasture, grassland, shrub land, etc) to grow switchgrass for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any farmable non-crop land.
- ☐ I would rent out farmable non-crop land to grow switchgrass if the rent were higher.
- ☐ I would never rent out farmable non-crop land to grow switchgrass.

C6. If somebody offered to rent your forested land to grow switchgrass for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⇨ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any forested land.
- ☐ I would rent out forested land to grow switchgrass if the rent were higher.
- ☐ I would never rent out forested land to grow switchgrass.

HYBRID POPLAR TREES

Planted:	Spring of the first year
Harvested:	5–10 years after planting
Fertilized:	Every 2–4 years
Growth height:	20–30 feet
Number of visits by renter:	1–2 per year
End use of harvested materials:	Bioenergy
Soil erosion:	Low compared to other bioenergy crops
Greenhouse gas emissions:	Low compared to other bioenergy crops
Nutrient and chemical runoff:	Average compared to other bioenergy crops
Biodiversity:	Average compared to other bioenergy crops
Rental rate paid to you :	**See below**

***Instructions**: When responding, please consider each scenario separately. In other words, when you respond to the offer for cropland, imagine that the options for non-crop land or forest land do not exist.*

C7. If somebody offered to rent your cropland to grow hybrid poplar for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⟹ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any cropland.
- ☐ I would rent out cropland to grow hybrid poplar if the rent were higher.
- ☐ I would never rent out cropland to grow hybrid poplar.

C8. If somebody offered to rent your farmable non-crop land (pasture, grassland, shrub land, etc) to grow hybrid poplar for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⟹ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any farmable non-crop land.
- ☐ I would rent out farmable non-crop land to grow hybrid poplar if rent were higher.
- ☐ I would never rent out farmable non-crop land to grow hybrid poplar.

C9. If somebody offered to rent your forested land to grow hybrid poplar for $15 an acre per year, would you rent any of it out?

☐ Yes, I would be willing to rent out ⟹ _____ ACRES

☐ No (*Choose one explanation*)

- ☐ I do not own any forested land.
- ☐ I would rent out forested land to grow hybrid poplar if the rent were higher.
- ☐ I would never rent out forested land to grow hybrid poplar.

WOODY BIOMASS

Harvested:	Once every 15–20 years; at the same time as another forest activity
Number of visits by contractor:	8 – 10 visits in year of harvest
End use of harvested materials:	Bioenergy
Soil erosion:	Very low compared to other bioenergy crops
Greenhouse gas emissions:	Very low compared to other bioenergy crops
Nutrient and chemical runoff:	None
Biodiversity:	High compared to other bioenergy crops
Payment made to you :	**See below**

***Instructions**: Imagine you are planning a timber harvest or other stand improvement (forest thinning, junk wood removal, habitat restoration) on your forested land. A forestry company offers to pay you for the removal of woody biomass as part of the contract agreement. This would be a one-time payment.*

***Note**: If you do not own any forested acres you may skip to Question D1 at the top of the next page.*

C10. If the company offered you a contract for $15 an acre to remove woody biomass from your forested land at the time of your next timber harvest, would you agree to this offer?

- ☐ Yes, I would be willing to sell my woody biomass
- ☐ No (*Choose one explanation*)
  - ☐ I do not have plans to harvest timber from my forested land.
  - ☐ I would sell woody biomass from a timber harvest if the payment were higher.
  - ☐ I would never sell woody biomass from a timber harvest.

C11. If the company offered you a contract for $15 an acre to remove woody biomass from your forested land at the time of your next stand improvement activity (such as forest thinning, junk wood removal, or habitat restoration), would you agree to this offer?

- ☐ Yes, I would be willing to sell my woody biomass
- ☐ No (*Choose one explanation*)
  - ☐ I do not have plans for a stand improvement activity on my forested land.
  - ☐ I would sell woody biomass from stand improvement if the payment were higher.
  - ☐ I would never sell the woody biomass from a stand improvement activity.

SECTION D: BIOENERGY KNOWLEDGE AND OPINIONS

D1. Please check the box that best represents your agreement with the following statements related to bioenergy and the environment. There are no right or wrong answers.

	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
Developing renewable energy (e.g., wind, solar, bioenergy, hydro-electrical) is important to our nation's future.	☐	☐	☐	☐	☐
Bioenergy should be prioritized over other forms of renewable energy such as wind or solar power.	☐	☐	☐	☐	☐
Burning bioenergy feedstocks to generate electricity instead of burning coal is worth the extra cost.	☐	☐	☐	☐	☐
Substituting bioenergy feedstocks for fossil fuels will help mitigate climate change.	☐	☐	☐	☐	☐
Growing bioenergy feedstocks on cropland will increase competition with food needs.	☐	☐	☐	☐	☐
Increased bioenergy feedstock production will result in significant forest loss.	☐	☐	☐	☐	☐
Government should allow regular harvesting of public forest land and CRP land for bioenergy purposes.	☐	☐	☐	☐	☐
Biodiversity should be maintained when land use is changed.	☐	☐	☐	☐	☐
Liquid biofuels are a promising alternative energy technology that will be successful in the future.	☐	☐	☐	☐	☐
The use of fossil fuels can be harmful to human health and the environment.	☐	☐	☐	☐	☐
The world will run out of fossil fuels (e.g., oil, natural gas) in the next 50 to 120 years.	☐	☐	☐	☐	☐

D2. Please check the box that best represents your agreement with the following statements related to potential concerns with renting land for bioenergy feedstocks. There are no right or wrong answers.

When I think about renting out my land for bioenergy feedstocks I am concerned about:	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
The potential smell	☐	☐	☐	☐	☐
Noise from harvesting, planting, or other activities	☐	☐	☐	☐	☐
Potential legal costs of contracting	☐	☐	☐	☐	☐
The length of the contract	☐	☐	☐	☐	☐
The possible need for insurance	☐	☐	☐	☐	☐
Having other people on my land	☐	☐	☐	☐	☐
The land changing in a way that I can no longer use it as I want	☐	☐	☐	☐	☐
How profitable it will be	☐	☐	☐	☐	☐
A lack of information about the potential feedstocks	☐	☐	☐	☐	☐
The use of pesticide and fertilizer on my land	☐	☐	☐	☐	☐
The loss of biodiversity on my land (e.g., insects, birds, mammals, plants, etc)	☐	☐	☐	☐	☐
The risk of lower soil and water quality	☐	☐	☐	☐	☐

SECTION E: BACKGROUND INFORMATION

This last section asks for background information to help identify patterns among different kinds of landowners. Your answers here are important and will be completely confidential.

E1. What is your age? _____ YEARS

E2. What is your gender? ☐Male ☐Female

E3. Including yourself, how many members are in your household? _____

E4. Are you a farmer or do you do farm work? ☐Yes ☐ No

E5. What was your total household income in 2013?

☐Less than $25,000
☐$25,000 to $49,999
☐$50,000 to $99,999
☐$100,000 to $149,999
☐$150,000 to $199,999
☐$200,000 and above

E6. What is the highest level of education you have completed?

☐Less than 12 years
☐High school or GED degree
☐Some college (including AA, AS degrees)
☐4-year college degree
☐Some graduate work
☐Graduate degree

E7. Is any part of your rural land restricted by zoning in any way? *(Check all that apply)*

☐Zoned for agricultural use
☐Zoned for residential use
☐Zoned for industrial use
☐Zoned for forest use
☐Not restricted by zoning
☐I am uncertain

E8. How long have you owned your rural land? _____ YEARS

E9. Was any of your rural land controlled by another family member before you became owner?

☐Yes ☐No

E10. Do you have a residence on your rural land? ☐Yes ☐No ⟹ *If NO, skip to E11*

IF YOU ANSWERED YES:

a. How many weeks per year do you spend at this residence? _____ WEEKS PER YEAR

E11. What is the ZIP code of your permanent residence? _____

E12. If you <u>rented out</u> any of your rural land in the last 2 years, what was the most common rental rate?

Cropland: $_____per acre Pasture: $_____per acre Forest: $_____per acre

Do you have any comments? (Optional)

_____

_____

_____

_____

_____

_____

_____

_____

THANK YOU

If you have questions about the research or any part of the questionnaire, you may contact:

Dr. Scott M. Swinton at 1-517-353-7218, by e-mail at swintons@msu.edu**,** or by postal mail at Department of Agricultural, Food, and Resource Economics, Michigan State University, East Lansing, MI 48824-1039.

Dr. Brad Barham at 1-608-265-3090, by e-mail at barham@mailplus.wisc.edu, or by postal mail at Department of Agricultural and Applied Economics, University of Wisconsin-Madison, Madison, WI 53706-1503.

Semi-structured Personal Interview Guidelines with Forestland Managers:

Conditions for Availability of Timber Residues for Bioenergy, Upper Peninsula, Michigan

(June 2016)

1. Introducing Questions
   - **Explain Purpose**. Collab between UofW and MSU with funding from the US Department of Energy to try to get idea of the conditions under which landowners (or loggers) would supply biomass/slash for bioenergy. We are trying to understand how this part plays into bioenergy supply for the future….we want to understand how they think about these things for future research.
   - **Explain their role**. Ex: Would like to ask them a few questions since we've identified them as a key player in our interest area.
   - **Ask permission to:**
   - 1. Record
   - 2. Attribute
2. Background questions

   Interviewee:

   - **Can you tell me a little about your current role in this business?**

   Company:

   - **What is the corporate decision-making structure, particularly when it comes to forest land use?** (is there a person or department that does this, or is it a board decision, etc…)
   - **Can you tell me a little about your business model?** Try to get the interviewee talking, to indirectly and organically answer questions below.
     - How many acres in northern tier (important question, since this changes all the time and we want a good idea of size.)
     - How is land use divided (is it all managed for timber harvest?)
     - How do you decide on what timber to harvest? Where to harvest? When to harvest?

- Do you work with a particular logger/do you own your own logging/mill operation?
- Do you currently require the harvest of biomass/slash (small diameter stuff)? Why/why not?
    - If yes, ask about their current contracts for woody biomass supply (what kind, what for, etc) and how long they run.

*If NO, this is a good time to move into Follow Up Scenarios (choose #1 or #2 depending on responses to these last questions).

3. Follow-up Supply Scenario #1
    - **Have you considered (harvesting/increasing harvest) of timber slash?**
    - **Suppose that market demand for timber slash jumped so dramatically that you began seriously to consider harvesting slash at time of timber harvest**.
        - What would be the biggest barriers to harvesting & selling slash?
        - What kind of contract terms would you need?
            - Term of contract (years)
            - Location (At harvest site? Delivered?)
        - Price (what unit? Per ton? Per acre?)

4. Follow-up Supply Scenario #2 (Specifying Questions)
    - **Can you imagine a scenario where you would plant and manage land to grow dedicated bioenergy crops (such as poplar, willow, or switchgrass)?**
    - Under what conditions would you seriously consider doing this?
    - How much would you have to earn (per acre) to switch to dedicated bioenergy crops?

5. Other info to gather to help with the above (though perhaps slightly riskier/not as necessary to flat-out ask
    - Under what terms do you currently sell timber products?
    - Do you have a long-term net revenue or return-on-investment target?