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Socioeconomic and Environmental Assessment of Woody Biofuels in Southern United States

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SOCIOECONOMIC AND ENVIRONMENTAL ASSESSMENT OF WOODY BIOFUELS IN SOUTHERN UNITED STATES

A DISSERTATION

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DISSERTATION APPROVAL

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SOCIOECONOMIC AND ENVIRONMENTAL ASSESSMENT OF WOODY BIOFUELS IN SOUTHERN UNITED STATES

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ABSTRACT

SOCIOECONOMIC AND ENVIRONMENTAL ASSESSMENT OF WOODY BIOFUELS IN SOUTHERN UNITED STATES

by Bernabas T. Wolde

Although the emergence of woody bioenergy offers several energy, economic, social, and environmental benefits, forestland owners' willingness to participate in a biomass supply market, how it affects land use choices, and forestland owners' sustainability concerns are not well understood. In addition to these gaps, how much residual biomass forestland owners are willing to retain on site for soil fertility and other environmental benefit purposes and forestland owners' tendency to enroll in public incentive programs are not fully documented. Because private forestland owners manage two thirds of the 214 million acres of forest cover in the southern United States, understanding their response to a growing woody biofuels industry is important, among others towards assessing its sustainability. This dissertation addresses these issues using primary data collected from the southern states of Virginia and Texas, which are among the most resource rich states where private forestland owners play a significant ownership role.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Background

Biochemical and thermo-chemical conversion technologies can be used to produce woody bioenergy from feedstocks including residual biomass such as stumps, branches, and other debris that is left behind after a commercial harvesting of higher value wood products. The types of woody bioenergy products may include bio-power fuels such as flammable biomass for producing electricity, liquid fuels such as ethanol and butanol that can be used as substitute for or in combination with gasoline, and bio-products including a dehydrated high-density compressed pellet that is cheap to transport.

The bioenergy thus produced has several benefits. The energy related benefits include lower dependence on fossil fuels, higher use of renewable energy sources, and improved national energy security. Another benefit is the reduction of potential pest and fire outbreak in over stocked forests, especially during periods that have seen diminishing timber product and pulp prices, such as in recent years (Jackson et al., 2010; Alavalapati et al., 2009). Harvest of woody biomass from thinning and related forest stand improvement measures also contribute to conservation of biodiversity, maintenance of water quality, habitat protection, outdoor recreation, and meeting wood and fiber demand (Joshi, 2009; Beach et al., 2005; Kilgore et al., 2008). Its economic benefits include potential for rural development, and new potential streams of revenue for landowners. The development of wood-energy can also contribute towards employment opportunities, generation of local tax income, diversification of local economies, and reduction of poverty for rural communities (Lal et al., 2011). The ability to produce more of the energy need domestically can also contribute to energy security, and perhaps in the future it could contribute towards stable energy price and trade balance. The indirect and multiplied effects of the growth of this sector on the social, economic, and environmental aspects of the energy market and beyond could be sizeable (Zubrin, 2008).

Acknowledging the benefits of woody bioenergy and availability of the resource base, several support programs are currently available in the US at different administrative levels designed to foster the development of this sector. Notable policy includes the renewable fuel standard (RFS) established by the Energy Policy Act of 2005. This set a target for use of 4 billion gallons of biofuels by 2006 and 7.5 billion gallons by year 2012 (Congressional Research service [CRS], 2011). This target was later expanded with the passing of Energy Independence and Security Act (EISA) in 2007 and later by the Food Conservation and Energy Act in 2008 (CRS, 2012). The expanded target aimed at an annual production to 36 billion gallons of biofuels by the year 2022. It specifically encouraged the production of advanced biofuels from cellulosic biomass by setting a target where it would form no less than 16 billion of the 36 billion gallons of the annual biofuel production target (CRS, 2012). Additionally, there are numerous state and local administration level support systems that foster the growth of advanced biofuels by way of grants, loans, and tax credits (Zubrin, 2008).

In terms of resource base, the southern United States is rich in forest resources, aided by a temperate and subtropical temperature and rainfall climatic pattern (Smith, 2009). Thirteen southern states including Texas, Virginia, and Alabama make up a third of the nation's forest. This area occupies 28% of the total forestland in the country but contributes up to 60% of the national wood supply, making these states important sources of feedstock for woody bioenergy production as well. The biomass reserve is estimated to produce up to 10.5 billion gallons of advanced biofuels per annum. Increased investments in silvicultural treatment and genetic augmentation of forest growth rate have also resulted in notable increase in the region's forest stock over the past few decades (Munsell, 2007), further establishing the region as an important player in the nation's bioenergy production goals.

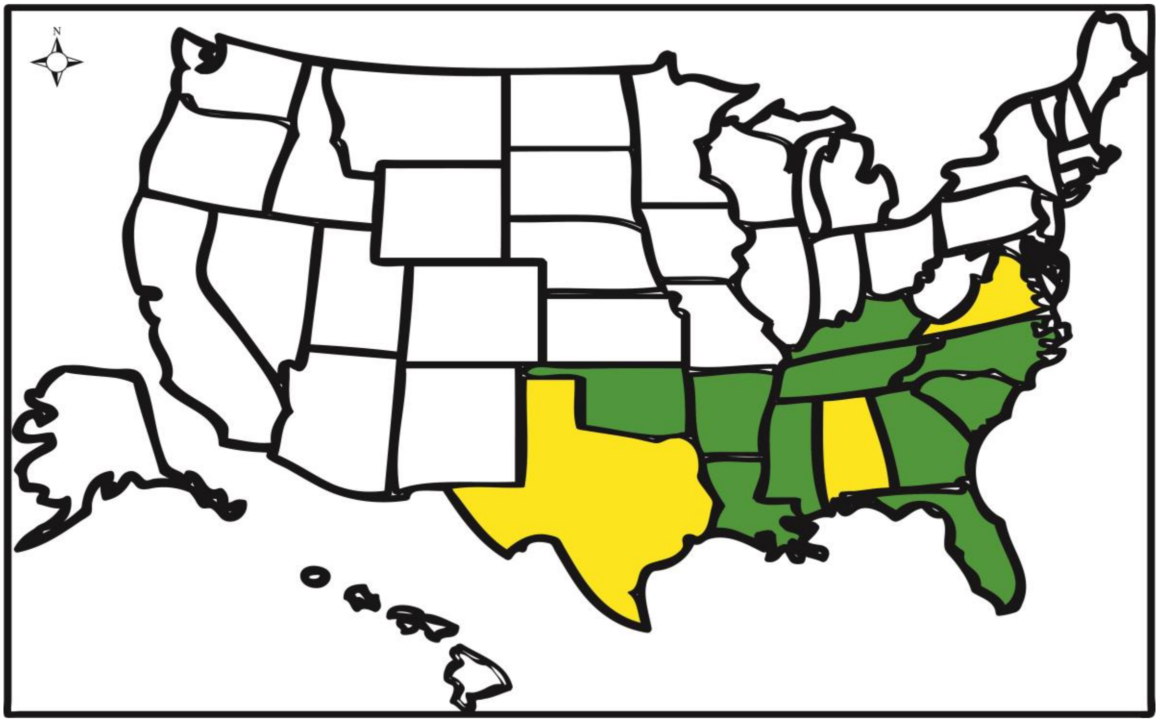

Figure 1. Map of the three states of interest highlighted in yellow with the rest of the southern states highlighted in green

The dominant *pinus* forest types in the South are loblolly pine and slash pine (United States Department of Energy [USDOE], 2011). These account for more than 75% of the forest plantation in the region (McKeand et al., 2003). This tree species also benefits from adapting to the local climate, soil profile, and agroforestry (Schultz, 1997). Additionally, projections estimate up to 34% increase in planted pine forest in the study region by 2060, representing an even increasing abundance of the *pinus* tree species and hence residual biomass that the biofuels sector could use (Hugget et al.,2013).

A significant share of the ownership and harvest of biomass in the southern U.S. takes place from privately owned forestland (Gan, 2007; Prestemon and Abt, 2002). Private landowners account for 60% of the forestland in the South (Oswalt et al., 2009). They are also expected to contribute up to 80% of the woody feedstock for bioenergy in the U.S. (Sample, 2009). Recent trends indicate that the size of forestland managed by private forestland owners has increased by 11% between the years 1993-2003, and this trend is expected to continue in the future (Butler, 2004; Hodges, 2010). Given their important stake in the management of the region's forest resource, understanding their management decisions and willingness to supply biomass for bioenergy is important to understanding the development of woody biofuels. In addition to having a rich resource base that can service the woody biofuels sector, these states also represent diverse geographic and natural conditions. The landowner makeup and bioenergy penetration in the energy sector with regards to the number of processing plants are also not the same (Ethanol Producers Association, 2013). These features create the condition for evaluation of woody biofuels' key stakeholders' response to the sector under different background scenarios.

1.2 Research Objectives

Despite the availability of the resource base and the said benefits of woody bioenergy, the production of cellulosic bioenergy is at its nascent stage. Accordingly, private forestland owners' willingness to supply biomass for bioenergy production is not fully known. How the emergence of woody bioenergy affects forestland owners' land use decisions is also not fully documented. Moreover, the profitability of woody bioenergy, forestland owners' tendency to enroll in public incentive programs, their sustainability concerns, and the factors that explain retention decisions are also not fully documented. This dissertation attempts to address these gaps and is structured in three specific objectives.

Objective 1: understanding the factors that affect forestland owners' decision to allocate currently non-forested land to growing feedstock:

Woody bioenergy provides private forestland owners opportunity as a new revenue source, which they can respond to by allocating currently non-forested land for growing feedstock. Depending on the scale of change and original land use type, such a supply response can have important implications for ecosystem services and the quantity and market price of products displaced by such land use conversion. As such, it is important to understand the factors that explain the proportion of currently non-forested land that forestland owners are willing to allocate for growing feedstock for bioenergy production. This information will help us build profile of forestland owners that are more likely than others to make larger land use changes, understand their motivations, and assess the potential role of policies in affecting such decisions.

While the null hypothesis says that socioeconomic and forestland features do not explain the proportion of non-forested land that forestland owners are willing to allocate to growing pine for bioenergy purposes, the alternative hypothesis says that these factors do explain that decision.

Previous studies

Insights from previous studies suggest that land use pattern is a dynamic allocation process

resulting from the owners' assessment of factors affecting the land's production potential such as market price, technology, policy incentives, substitutability of uses, know-how, land management objectives, economic viability of alternative options, as well as the non-monetary benefits associated with different land use options (Irwin et al., 2001; Lubowski et al. 2008).

Previous studies that model land use change patterns identify the probability, scale, and duration between consecutive land use changes for different driving factors (Green et al., 2002; Wainger et al., 2007). Approaches used by such studies include remote sensing, simulation, and statistical sampling of relevant population (Green et al., 2002). Some of the approaches are especially suited to detect biophysical change after the land use change has occurred while others can model for socioeconomic and policy drivers and corresponding effects both before and after a land use change occurs (Green et al., 2002; Wainger et al., 2007; Adams et al., 1996).

Indirect land use change and feedback effects on market outcomes have been modeled either in general or partial equilibrium setting (Latta et al., 2013). These approaches can be used to quantify changes on the relevant prices and quantity of biomass and bio-products, employment creation, tax revenue, and to simulate how different policy scenarios affect these and other outcomes (Green et al., 2002; Adams et al., 1996). The diverse models and tools used under these approaches have varied needs, capabilities, spatial scale of analyses, time and data requirements, realistic behavior rules, complexity, and land use types and conversions they can handle. They also have different ability in terms of how far in the future they can project results, ability to model social and demographic attributes, and how can they account for differing policy scenarios. The multitude of variations within such models often makes comparison of results difficult (Green et al., 2002; United States Forest Services [USFS], 2003). Meanwhile, survey based data has the potential to provide a direct measurement of change and a basis for projecting market and environmental impacts (Geoghegan et al., 2001). Market informed survey based data can capture reality, and integrate biophysical features with socioeconomic and demographic attributes of the land owners. This enables the prediction of potential land use changes with measurable margins of error.

Feedstocks vary in terms of their cultivation needs, yield and rotation length, energy and greenhouse gas performance, ecosystem services and other relevant attributes. Thus, information on a land use change motivated by a given end use and for a given feedstock type may not be accurate, representative, or relevant to other land use change drivers and feedstocks. This is because the information on the causes and effects of the different types of land use change, land cover, and their broad socioeconomic and environmental implications may not necessarily be the same (Green et al., 2002). Such end product and feedstock specific studies can improve our understanding of the specific nature of land use change and its drivers. The results can serve as a basis for estimating the resulting natural resource and ecosystem impacts, as well as providing the ability to typify forestland owners, all of which may be useful in designing tailored incentives that can influence behavior in desirable directions (Loveland et al., 2002; Alexander et al., 1997).

Objective 2: understanding the factors that affect forestland owners' residual biomass retention decisions, sustainability concerns, and policy preference

Despite the new market opportunity presented by woody bioenergy, over harvesting of residual biomass can have adverse impacts. Forestland owners' choice of how much residual biomass to supply for bioenergy can affect the amount residual biomass available both as a source of nutrient for the soil and for other uses such as fiber products, water quality, timber health and productivity, and forest related ecosystem services. As such, it is important to understand if and which socioeconomic factors affect the proportions of residual biomass forestland owners are willing to supply for bioenergy, their sustainability concerns, and policy preference.

The information on forestland owners' land use decisions and biomass retention decisions is useful to refiners in making logistic decisions such as choice of facility location and facility size and to policy makers in designing production targets, relevant incentive programs, developing best management practices and safeguards. Such information is also useful in assessing the environmental and economic implications associated with an expanding bioenergy industry.

While the null hypothesis says that socioeconomic and forestland features do not explain the proportion of residual biomass the forestland owner is willing to leave unharvested for soil and water quality conservation purposes, the alternative hypothesis says that these factors explain respondents' residual biomass retention rate decision.

Previous studies

Previous related studies on estimating the quantity of biomass available for bioenergy production use biophysical approaches (Goerndt et al., 2012; Perlack et al., 2005). Others determine the factors that explain forestland owners' willingness to supply land and biomass or their willingness to change management practices in response to bioenergy (Shivan et al. 2012; Butler et al., 2010). Although such information helps in estimating the number of forestland owners willing to supply biomass for bioenergy and the quantity of biomass available for bioenergy production under different market conditions, the supply decisions are not always framed in light of the potential implications of excessive residual biomass harvest on soil and water quality. Understanding the proportion of residual biomass that is left unharvested provides context and it may be a more useful information for estimating how the use of residual biomass for bioenergy may affect soil nutrient availability, vegetation, wildlife habitat, and hydrology (Neary, 2002; Burger, 2002). The sustainability concerns considered by previous studies also focus either on soil, water, or wildlife, instead of featuring them altogether (Kuuluvainen et al., 1996; Stidham and Simon-Brown, 2011). Furthermore, limited work assesses clustering pattern among the said sustainability concerns. Focusing on a single aspect of woody bioenergy such as its economic sustainability does not allow us to assess if the same forestland owners also have concerns about other aspects of woody bioenergy such as ecological sustainability, for instance. We can determine this, however, by presenting multiple aspects of woody bioenergy and assessing whether or not the forestland owners' sustainability concerns exhibit clustering patterns. Determining clustering patterns can be useful for the relevant policies and outreach programs in allowing us to target the said clusters at once by combining previously isolated efforts, potentially having synergistic effects. By eliciting sustainability related opinions and policy preferences, we may also be able to assess whether or not forestland owners have concerns about the sustainability implications of their harvest decisions, assess if the said opinions are consistent with scientific findings, and evaluate if they can be influenced by outreach programs and policies.

While the existing studies explain the potential adverse impacts of excessive residual biomass harvest, they mostly focus on the mechanics of the process, providing engineering based solutions (Abbas et al., 2011; Sacchelli et al., 2014). Despite the availability of relevant guidelines on residual biomass harvest rates that also describe the potential adverse impacts of over-harvesting residual biomass, not all forestland owners may benefit from such information. Saving relevant state guidelines or certification requirements that may affect residual biomass harvest rate, residual biomass to harvest is affected by individual preference. Therefore, a better understanding the socioeconomic factors that affect forestland owners' residual biomass harvest rate, sustainability concerns, and preferences can complement previous studies and serve as an important step towards addressing the causes and effects of overharvesting residual biomass. Furthermore, it can serve as a basis to determine the amount of residual biomass available for as a source of nutrient and as a feedstock for bioenergy production. We may also be able to estimate and plan for the market and environmental outcomes that follow such harvesting practices.

Objective 3: understanding the factors that affect forestland owners' tendency to enroll in public incentive program.

Several federal and state sponsored programs such as cost sharing arrangements and tax incentive programs are available to forestland owners, aiming to encourage desirable forest management practices and outcomes. However, enrollment rates in such programs are low and trends indicate an even smaller enrollment rate in the future. We also do not fully understand why some forestland owners are more reluctant than others to enroll in such programs, if past enrollment experiences affect the importance forestland owners attach to future programs, and if forestland owners attach importance to programs that affect others in the supply chain. Among others, such information will help us to identify the profile of forestland owners less likely to enroll in such programs and target them through extension and outreach programs.

While the null hypothesis says that socioeconomic and forestland features do not explain forestland owners' decision to enroll in public incentive programs, the alternative hypothesis says that these factors explain enrollment decisions.

Previous studies

While earlier versions of public programs such as the Agricultural Conservation Program focused on maintaining and enhancing timber value and supply, recent ones have broader objectives including the promotion of sustainability and conservation of soil, water, and wildlife, wildfire mitigation; and enhancement of aesthetics and recreation, invasive species management, forest restoration, encouragement of biodiversity and enhancement of carbon sequestration (Environmental Quality Incentives Program [EQIP], 2011). These different objectives are addressed by a multitude of public programs including the Environmental Quality Incentive Program, the Forestland Enhancement Program, the Conservation Reserve Program, the Conservation Stewardship Program, and the Biomass Crop Assistance Program.

Previous studies on such programs focus on assessing their effectiveness in influencing the purpose and long-term orientation of the target population's forest management practices, measures of effectiveness including income transfer efficiency, return on investment, and economic benefit to society (Hibbard et al. 2003). Other studies use this information and ratings by enrollees and forestry officials to rank different types of programs such as tax incentive, cost sharing, and technical assistance programs as well as the implementing agencies such as state, federal, and non-governmental institutions (Zhang et al. 2009).

Jacobson et al. (2009) surveyed forestry officials and found that forest stewardship, forestland enhancement, and forest legacy programs are among the top rated federal programs. Based on the ranking by relevant stakeholders and the number of participants, technical assistance is preferred both to tax incentives (James et al. 1951) and to cost sharing programs (Kilgore et al. 2004). Brockett et al. (1999) and Hibbard et al. (2003) also reported that tax based policies have limited success in accomplishing their objective in the short term. Polyakov et al. (2008) found that land use changes are inelastic with respect to property taxes. However, Shivan et al. (2010) disclosed that forestland owners tend to prefer tax based policies over cost sharing programs in the context of bioenergy, suggesting that the end product may affect the ranking of different programs.

Previous studies have also assessed if new programs addressed a need that was not met before, increased the acreage of forestland treated by a given practice, increased the intensity of the practice per a given area of forestland, or if the programs simply transferred capital given that forestland owners would have engaged in the prescribed forest management practice even without enrolling in the relevant public program (Polyakov et al. 2008). Esseks et al. (2000) found that two-third of forestland owners would not have made the investment in forest management activities if there was not a cost sharing program.

Studies on enrollment in public programs find that the following factors affect enrollment decision: acreage, income, education, occupation, tenure status, tendency to seek professional advice for forest management, environmental attitudes, absenteeism, and riparian forest ownership (Royer 1987 b). Among others, landowners with higher income, higher level of education, and larger acreage are more likely to enroll in such programs. Furthermore, the initial reasons for joining the programs and their satisfaction with the program once enrolled affected how well forestland owners implement the prescribed forest management practices (Jacobson et al. 1998). Lack of knowledge that the programs existed and the meager amount of financial benefits provided have also been considered as other reasons why forestland owners do not take advantage of financial incentive programs (Anderson 1968). Thus, in addition to increasing the availability of public programs and easing the application process, increasing program visibility may increase enrollment rates (Schaaf et al. 2006). Increasing program payments, prolonging contracts, and coupling financial incentive programs with technical assistance programs might increase enrollment rates and effectiveness of such programs (Fortney et al. 2011).

Given that most forestland owners do not mainly manage their property to generate revenue, Daniels et al. (2010) notes that financial incentives and certification programs seeking to add premium to the forest might not be the best strategies to increase enrollment. The design of such programs should also account for the differences in forest management objectives, forestland features, and other relevant factors, designed and tailored to the priorities of forestland owners.

While these studies provide valuable insights, they tend not to quantitatively measure the factors that explain enrollment decisions and their relative importance. For instance, while they find that forestland owners with large acreage tend to take advantage of such programs more than those with smaller acreage, they do not specify how they distinguish between large and small. In this paper, we find the threshold acreage level that delineates large and small in the context of enrollment in public programs. We also determine thresholds for the other variables used to explain forestland owners' enrollment decisions. We also aim to bridge another research gap by assessing if and how experience with public programs affects the importance forestland owners attach to potential programs. This is done by using hypothetical public programs that aim to encourage private forestland owners to supply woody biomass for bioenergy production. Previous studies also focus mainly on how forestland owners respond to public programs that affect them directly, disregarding programs that affect others in the supply chain and indirectly benefiting the forestland owners. This paper also fills that research gap by assessing how forestland owners respond to public programs that help cover equipment purchase and product hauling cost, which are among the major cost components and a potential hindrance to the development of woody bioenergy.

1.3 Study area and survey design

Study area

The states of Virginia and Texas are home to a large pine forest stock that has an immense potential for servicing the woody biofuels sector United States Geological Survey (USGS, 2013). The Piedmont and coastal regions of Virginia and East Texas are also rich in loblolly pine. The Piedmont and coastal regions of Virginia and East Texas are also rich in loblolly pine. While there is abundant loblolly forest in Virginia planted for timber, the residual supply is quite sizeable (Scrivani, 1998; Hodge et al., 1992). These states also represent diverse geographic and natural conditions. The share of private forestland owners' in the total forest base in these states, their average acreage, socioeconomic makeup, and their likely response to market conditions such as emergent cellulosic biofuels sector cannot be assumed to be similar (Sample, et al., 2005). Furthermore, they exhibit differences in bioenergy penetration in the energy sector with regards to the number of processing plants that are present in these states (Ethanol Producers Association 2013). These features create the condition for evaluation of woody biofuels' key stakeholders' response to the sector under different background scenarios.

The states of Virginian and Texas in the southern US are also among the most productive forest regions in the world where family forestland owners dominate the forest ownership landscape. Sixty-three percent (63%) of Virginia and fifty-four (54%) of East Texas are covered by forests. Most of the timberland in Texas is in the eastern part of the state (Joshi et al. 2014). Consequently, seventy-one percent (71%) of the forest industry's output and the majority of the logging and primary solid wood products sub-industries of the state are also located in East Texas. The forest industry is among the largest employers both in Virginia and East Texas, producing over US$17 billion worth of economic output annually in Virginia and US$5.7 billion annually in East Texas (VDof 2015). These estimates do not include the indirect and induced impacts of the forest industry. Private forestland owners account for more than 66% and 92% of total forestland in Virginia and East Texas, respectively. Private forestland owners' decisions, thus, are important to the forest industry, the economy it supports, and for forest based ecosystem services.

Survey design

The data used towards addressing the three objectives comes from a survey data administered in Virginia and Texas. Feedbacks from several focus group discussions, pilot surveys, and review by Extension professionals working in the US South were used to enhance the survey's readability, consistency with market realities, and comprehensiveness. Values submitted by actual loggers competing to harvest biomass from forestland owners in Virginia in conjunction with insights from extension experts at Virginia Tech and information from stakeholder meetings were used to develop four equally spaced bid values ($800, $1035, $1270, $1500). These bid values were used when asking respondents how much non-forested land they would allocate for pine plantations in future. Each survey mentioned only one bid value and there were equal number of surveys mentioning the different bid values.

The survey question of interest regarding allocation of non-forested land to growing pine for bioenergy was framed as: Facing similar market conditions and risks as the traditional timber and other forest product markets, would you consider planting loblolly pine for energy production on the currently non-forested land such as pastureland and cropland for an offer of {bid value} per acre? Respondents selected either ‘plant’ or ‘not-plant’. The survey question of interest regarding respondents’ choice of residual biomass retention rate was framed as: “If you sell biomass, what percent of the biomass would you insist be left in the woods to ensure soil fertility, biodiversity, or other environmental benefits?” Possible answers included: 0%, 0-10%, 10-20%, 20-30%, and > 30%. The survey question of interest regarding respondents’ choice of enrollment in public incentive programs was framed as: Have you been a beneficiary of a state or federally sponsored financial or technical support program in managing your woodland in the last five years? Respondents could say either ‘yes’ or ‘no’.

The survey also elicited respondents’ socioeconomic data, forest management objectives, previous and planned forest management activities, level of agreement with statements about potential sustainability impacts of harvesting biomass for woody bioenergy, and policy preferences. The complete list and corresponding data on the survey questions can be found in the appendix.

A random number generator was used to select 900 potential respondents with at least 20 acres of forestland from each state. The cutoff point follows from previous studies that identify it as a requirement for an economically viable biomass production (Shivan et al., 2010). The mail survey participants received the first survey, a postcard reminder, and a final reminder with another copy of the survey, following the tailored Dillman approach (Dillman et al. 2009). We obtained 390 responses from the two states, making for a 21.6% response rate. Because some survey participants did not answer all the questions in the survey, 229 responses were used for this study.

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2 FACTORS AFFECTING FORESTLAND OWNERS' ALLOCATION OF NON-FORESTED LAND TO PINE PLANTATION FOR BIOENERGY

2.1 Introduction

A third of the national forest cover and two thirds of the national wood supply come from southern states (Gan et al., 2007). Virginia has 6.4 million hectares of forestland and ranks among the top ten states in the US in its use of bioenergy (Gan et al., 2007; Rose, 2011). A large portion of this forest cover and biomass supply comes from private forestland owners, making them an important stakeholder whose forest management decisions affect market outcomes, biodiversity (Mladenoff et al., 1993), climate change (Nemani et al., 1996), natural vegetation, hydrology (Dickinson, 1991) and ecosystem services such as carbon sequestration at local and regional levels (Drummond et al., 2010).

Woody bioenergy allows for the attainment of numerous social and environmental benefits including reduced risk of forest fire and disease outbreak in addition to increased revenue generation (Gan et al., 2007; Soliño et al., 2010). It also has the potential to increase the competition for wood and its price, as well as make up for the reduced biomass demand caused by mill closures in the past few years, reduce greenhouse gas emissions, reduce dependence on imported fossil fuel, and encourage rural development, among others (U.S. Department of Energy [DOE] and U.S. Department of Agriculture [USDA], 2005). However, industrial fuel, fiber byproducts, and other products consume a significant share of the forest harvest residue currently produced in Virginia (Gan et al., 2007).

One way private forestland owners can take advantage of the growing demand for woody bioenergy is through the allocation of currently non-forested land to growing pine, such as loblolly pine (*Pinus taeda*), for bioenergy purposes. Loblolly pine (*Pinus taeda*) is among the most abundant and productive tree species in the southern US, owing to its adaptability to varied environmental conditions (Schultz, 1997). It is also one of the most favored tree species in southern forest plantations (McKeand et al., 2003), covering more than 1.17 million hectares in Virginia alone (Virginia Department of Forestry [VDoF], 2015). Besides being widely available in the state, forestland owners are familiar with the needs and yield of loblolly pine (United States Forest Services [USFS], 2003) and do not require additional skills or resources apart from what they already possess. However, large scale and sustained land use change can have local and regional impacts on the performance of ecosystem services, wildlife habitat, climate change and biodiversity (Searchinger et al., 2008). Its economic effects may include changes in the market price and quantity of the displaced land use or land cover and pine supply, price of complementary and substitute products and industries, among others (Galik et al., 2009; Susaeta et al., 2013). Furthermore, it can have the social implications such as competition for resources, aesthetics, public health, and national security (Gan et al., 2007). The net effect on the environment also depends on original land use type and scale of change, as well as indirect and feedback effects (Vis et al., 2008; Von Blottnitz et al., 2007]. Whether or not past and planned activities, socioeconomic and demographic attributes of forestland owners, and current land use patterns affect forestland owners' land use decisions in the context of a growing demand for biomass is not fully documented.

Given these uncertainties and the significant stake private forestland owners have, it is important to understand how forestland owners will respond to woody bioenergy by changing the relative proportion of land allocation to different uses and identifying the forestland attributes and socioeconomic factors that would explain such tendency (Lal et al., 2014; Green et al., 2002). This paper aims to address this research gap. As such, the results can be a basis for addressing forestland owners' educational, extension and outreach needs, projecting and planning for the economic, social, and environmental outcomes that could result from such land use change, as well as designing tailored land use and forest management policies.

The paper is organized into six parts.

2.2 Analytical framework

a. Tobit model

The proportion (Prop) of non-forested land (crop and pasture/grazing) allocated for pine, given the total area of non-forested land available to the forestland owner, ranges from 0 to 1. The value of 0 represents that the forestland owner is not willing to allocate any non-forested land to planting pine, while value of 1 represents willingness to allocate all non-forest land available to forest landowner for planting pine. The values between 0 and 1 represent the share of non-forested land that the forestland owner is willing to allocate to pine. Given the left and right censoring, the Tobit model can be used to test if independent variables explain the proportion of non-forested land that forestland owners will allocate for pine. Compared to other discrete approaches such as logit and probit that are suitable for 0 or 1 type of binary responses, this model allows us to capture relationships where the dependent variable can take the value of 0, 1, and those in between. This model has also been used in other crop adoption studies (Norris et al., 1987; Jense et al., 2007).

For the given observation i,

$$\text{Prop} = \begin{cases} 0 \; for \; Y^* \leq 0 \\ Y^* \; for \; 0 < Y^* < 1 \\ 1 \; for \; Y^* \geq 1 \end{cases} \tag{1}$$

The model can be specified as:

$$T = \prod_{\text{Prop}=0} \Phi\left(\frac{(0 - \beta'X_i)}{\sigma}\right) * \prod_{0<\text{Prop}=<1}\left(\frac{1}{\sigma}\right)\phi\left(\frac{(\text{Prop}_i - \beta'X_i)}{\sigma}\right) * \prod_{\text{Prop}=1}\left(1 - \Phi\left(\frac{(1 - \beta'X_i)}{\sigma}\right)\right) + \varepsilon\text{------}(2)$$

Where β is a vector of parameters, X is a matrix of explanatory variables, ε is the error term that is distributed as $N(0, \sigma^2)$**,** Φ is the cumulative distribution function, and ϕ is the probability distribution function (Maddala 1983). The expected value of *Prop* can be determined by:

$$E(Prop_i) = 0*\Phi\left(\frac{(0 - \beta'X_i)}{\sigma}\right) + 1*\left(1 - \Phi\left(\frac{(1 - \beta'X_i)}{\sigma}\right)\right) + \left(\left(1 - \left(\Phi\left(\frac{(0 - \beta'X_i)}{\sigma}\right)\right) + \right.\right.$$

$$\left.\left.\left(1 - \Phi\left(\frac{(1 - \beta'X_i)}{\sigma}\right)\right)\right)\right)*\beta'X_i + \sigma\left(\frac{\phi((0-\beta'X_i)/\sigma) - \phi((1-\beta'X_i)/\sigma)}{\Phi((1-\beta'X_i)/\sigma) - \Phi((0-\beta'X_i)/\sigma)}\right) \text{--------------------}(3)$$

The three terms in Equation (3) are the probability of a zero, probability of one, and the probability of a 0-1 range share, with each probability multiplied by zero, one and the 0-1 range values, respectively. While their signs can be interpreted directly, the coefficients cannot be interpreted as slopes. The marginal effect of change in binary variables on *Prop* is calculated with the delta method based on Equation (3) (Jensen et al. 2007).

The values are multiplied by 100 to produce percentage differences in land allocation between forestland owners in the two clusters, which are determined by the partitioning analysis that is discussed below. The following approach is used to calculate the marginal effect of a change in a continuous variable (X_j) on *Prop*:

$$\frac{\partial E(Prop|x)}{\partial xj} = E(Prop|x, 0 < Prop^* < 1) * \left(\frac{\partial\left(\Phi\left(\frac{(1-\beta' X)}{\sigma}\right) - \Phi\left(-\frac{\beta' X}{\sigma}\right)\right)}{\partial xj}\right) +$$

$$\left(\Phi\left(\left(\frac{(1-\beta' X)}{\sigma}\right) - \Phi\frac{(-\beta' X)}{\sigma}\right) * \frac{\partial E(Prop|x, 0<Prop^*<1)}{\partial xj} + \frac{\partial \Phi\left(-\frac{(1-\beta' X)}{\sigma}\right)}{\partial xj}\right) \text{---------------}(4)$$

b. Partition analyses

The amount of non-forested land a respondent allocates for pine could be a function of how much the land owner depends on working that land for annual income, among other factors. It may be useful to know the threshold level of dependence on the land for income and by how much the land allocation for pine changes beyond that threshold. As such, instead of assuming a consistent linear relationship between the proportion of non-forested land that respondents would allocate for pine and the independent variable, we used recursive partitioning analyses to test for sorting of observations for the independent variables. This approach iteratively determines the threshold for each independent variable delineating optimal clusters of observations, where the clusters behave statistically differently when compared using t-test, but observations within each cluster exhibit comparable behavior with respect to the dependent variable. Such segmentation of observations is useful for better profiling of observations, developing tailored management actions, and enhancing the overall prediction capacity of the model (Muggeo, 2008; Betts et al., 2007). Variables that are binary in nature cannot be partitioned any further. Also, bid values were provided in the survey, instead of being elicited from respondents, and the response to the question containing the bid values is binary. However, dummy versions of the other continuous and multivariate variables are created based on the threshold determined by the partitioning analyses, presented in Table 2.2 under the columns cluster A and cluster B. The marginal effect on *Prop* of being in cluster B compared to cluster A is estimated using the delta method. Results of contingency analyses are also reported to shed light on variables of interest and to support claims made about them in the discussion section.

Table 2.2. Description of variables and thresholds used to determine their respective clusters.

Variable	Description	Cluster A (reference)	Cluster B (alternative)
Price	Continuous		
Forestland	Continuous	<246	≥246
Crop-land	Continuous	<14	≥14
Pasture/grazing	Continuous	<40	≥40
Proportion of pine from forestland	Continuous	<0.2	≥0.2
Primary residence on forested property	No (0),Yes (1)	0	1
Average size of the trees (diameter in centimeters) on the largest parcel	<25.4 centimeters (1), 25.4 - 35.56 centimeters (2), 35.56 - 50.8 centimeters (3), >50.8 centimeters (4)	1, 2	3, 4
Benefited from state/federal program in managing woodland in the last five years	No (0),Yes (1)	0	1
Produce non-timber forest products like evergreen boughs, grapevine	Ordinal, 1 (not at all important)	1,2	3,4, 5

	to 5 (very important)		
Enjoy natural beauty and scenery	Ordinal, 1 (not at all important) to 5 (very important)	1, 2	3, 4, 5
Percent of the biomass to be left in the woods for environmental purposes	None (1), <10% (2), 10-20% (3), 20-30% (4), >30%(5)	1, 2, 3, 4	5
Harvest/supply wood for pulp/paper mill in the past five years	No (0),Yes (1)	0	1
Woody bioenergy will affect sustainable forest management efforts negatively	Ordinal, 1 (strongly disagree) to 5 (strongly agree)	1	2, 3, 4, 5
Gender	(0) male, (1) female	0	1
Number of people in the household	Continuous	<2	≥2
Member of a state forestry or local county environmental association	No (0),Yes (1)	0	1
Developed a written forest management plan in the past five years	No (0),Yes (1)	0	1
Percentage of gross family income from working the land (farming, timber, and others combined)	Ordinal, 1 (None), 2 (< 10%) 3(10% to 25%), 4 (25% to 50%), 5(>50%)	1, 2	3, 4, 5

2.3 Results

a. Respondent attributes

We performed analyses of variance to assess if the first set of respondents, responses received in response to mailing of survey and second mailing of postcard reminder but prior to third mailing of final reminder with another copy of the survey, and the late respondents (responses received after the third mailing was sent out) were statistically different in terms of land holding, age, and income. We did not find any significant difference. We also compared our data with Forest Service's national woodland owner survey data for Virginia to assess its representativeness. Accordingly, while the average size of forestland for the state is 30.35 hectares, the average land holding for respondents of our survey was 34.6 hectares. Considering how we targeted forestland owners with at least 8.1 hectares of forestland, the higher average forestland land holding is to be expected. When we use an 8.1 hectare cutoff point for the national survey data, 35.4% of Virginia's forestland owners are older than 65 years, as compared to 28.12% of our survey respondents. While 83.15% of Virginia's forestland owners are male, 78% of our respondents are male and while 34.5% of Virginia's forestland owners made less than $50,000 a year, 24.92% of our respondents made less than $50,000 a year. Similarly, while 58.5% of Virginia's forestland owners acquired their land through purchase, 56.7 % of our respondents acquired their land through purchase (Garrison, 2015; Forest Inventory Service, 2015). As such, although our data has a slightly higher representation of high income respondents, it is comparable with the national woodland owner survey data for Virginia.

b. Determinants of non-forested land allocation for pine

The average proportion of non-forested land respondents were willing to allocate for pine was 23.1%. The bid value was a significant factor in explaining the proportion of non-forested land that respondents would allocate for pine. For each additional hundred dollars offered, there was a 0.96% (p 0.001) increase in the proportion of non-forested land being allocated for pine. For respondents who said they would not accept the bid value quoted in the survey, a follow up question asked the minimum price they would accept and how much land they would allocate for pine at that price. While the mean bid value for respondents who accepted the prices initially quoted in the survey was $1,177, the mean value of minimum prices reported by respondents that did not accept the initial price quoted in the survey is $1,293. The self-reported minimum acceptable price quoted by forestland owners that did not accept the initial offer also had a positive and significant effect on the proportion of non-forested land that they would allocate to pine. For each additional hundred dollars reported by respondents, there was a 2.6% (p 0.001) increase in the proportion of non-forested land allocated for pine.

Comparatively, forestland owners belonging to cluster B allocated 25.5% less of non-forested land to pine. The contingency analyses show that respondents in cluster B, having forestland greater than the 99.6 hectares threshold identified by recursive partitioning, have odds of 6.06 for planning to harvest/supply wood for saw log or veneer in the next five years (likelihood ratio ChiSquare statistic [LRχ^2] is equal to 5.19, the p value [p] is equal to 0.02) and odds of 4.97 for having built or maintained roads in the past five years (LRχ^2.27, p 0.02). Respondents with acreage less than 99.6 hectares are less likely to develop written forest management plans in the next five years with an odds ratio of 9 (LR$\chi^2$7.76 *p* 0.005) and odds of 4.66 for not planning to supply wood for pulp/paper mills in the next five years (LRχ^2 4.58, *p* 0.032). They also have odds of 6.32 for not planning to clear cut any part of their stand in the next five years (LRχ^2 6.43, *p* 0.011).

Variables pertaining to how land was acquired, age, how long the forestland was owned, ethnicity, level of education, prior information about woody bioenergy, educational needs by specific topics, and a list of forest management activities within the past and coming five years came out as insignificant.

Table 2.3. Summary results of the Tobit model

Variable	**Tobit**	
	Model outputs	**Marginal values**
Price	-.0004*	.000096***
Forestland {≥246 -<246}	-1.16**	0.255***
Crop-land {≥14 -<14}	-0.89**	0.211***
Pasture/grazing {≥40 -<40}	-0.85**	0.200***
Proportion of pine from forestland {≥0.2 -<0.2}	-0.49**	0.104***
Primary residence on forested property {1 -0}	-0.31*	0.070***
Average size of the trees (diameter in centimeters) on the largest parcel {3, 4 -1, 2}	-0.81**	0.193***
Benefited from state/federal program in managing woodland in the last five years {1 -0}	-0.56**	0.112***
Produce non-timber forest products like evergreen boughs, grapevine {3,4,5 -1,2}	0.72*	0.122***
Enjoy natural beauty and scenery {3, 4,5 -1, 2}	-0.27*	0.060***
Percent of the biomass to be left in the woods for environmental purposes {5-1, 2,3, 4}	-0.40*	0.091***
Harvest/supply wood for pulp/paper mill in the past five years {1-0}	-0.46*	0.095***

Woody bioenergy will affect sustainable forest management efforts negatively {2, 3,4, 5-1}	-0.38**	0.072***
Gender {1-0}	-0.51**	0.106***
Number of people in the household {≥2-<2}	-0.35**	0.071***
Member of a state forestry or local county environmental association {1-0}	-0.57**	0.119***
Developed a written forest management plan in the past five years {1 -0}	-0.53*	0.107***
Percentage of gross family income from working the land (farming, timber, and others combined) {3, 4,5-1, 2}	-0.51**	0.109***

***, **, * Indicate significance at 0.01, 0.05, and 0.1 α levels, respectively.

Forestland owners with large proportions of cropland and pasture/grazing land will allocate 21.1% and 20% less land to pine, respectively. If the average tree diameter on their largest parcel (variable used as a proxy for end of rotation cycle) is greater than 35.56 centimeters, respondents will allocate 19.3% less of their non-forested land for pine. At the species composition level, if pine already makes up more than 20% of respondents' existing forest stand, they are willing to allocate 10.4% less non-forested land for more pine.

Having primary residence on the forested property led to a smaller proportion of non-forested land being allocated for pine. Similarly, male forestland ownership, households with two or more members and membership in a local/state environmental association led to smaller proportion of non-forested land being allocated for pine.

If more than 10% of the family income is generated from working the land (farming, timber, and others combined), the predicted share of non-forested land allocated for pine decreases by 10.9%. Having benefited from a state/federal financial or technical program in managing forestland in the previous five years negatively affects the proportion of non-forested land allocated for pine. Respondents without experience with such programs are willing to allocate 11.2% more non-forested land for pine.

Respondents who rate the importance of enjoying natural beauty and scenery for owning and managing their forestland at least 3 on a scale of 1 to 5 (5 being very important) allocate 6% less of the non-forested land for pine. However, respondents who rate the production of non-timber forest products at least a 3 on the same scale, allocate 12.2% more of their non-forested land for pine.

Respondents who say that woody bioenergy energy production has adverse effects on sustainable forest management will allocate 7.2% less non-forested land for pine. Similarly, respondents who say that more than 30% of biomass should be left unharvested to maintain soil quality and other environmental benefits, will allocate 9.1% less of their non-forested land for pine. Prior experiences of having supplied biomass to pulp/paper mill and having developed a written forest management plan in the past five years negatively affect the proportion of land respondents will allocate for pine at 9.5% and 10.7%, respectively.

c. Factors affecting willingness to supply biomass from existing land

Other than allocating non-forested land for growing pine, forestland owners can respond to woody bioenergy by supplying biomass from the forest they currently own. By providing a list of potential motivating factors for supplying biomass from existing stand, we asked forestland owners to rate how important the factors are towards affecting their supply decisions.

Table 2.4. Proportion of forestland owners expressing level of importance they attach to factors that might affect their decision on whether or not to supply biomass from standing forest.

Table 2.4 Proportion of forestland owners expressing level of importance they attach to factors that might affect their decision on whether or not to supply biomass from standing forest.

	Not at all Important (1)	**(2)**	**(3)**	**(4)**	**Very Important (5)**
The price offered	15.22	6.52	11.96	16.30	50.00
Risk associated with losing timber to fire, insects, or other natural occurrences if not harvested or thinned	20.88	13.19	31.87	18.68	15.38
Improvement in scenic and wildlife opportunities from harvesting residues	16.30	7.61	26.09	26.09	23.91
Contribution to improving energy security of the country	17.39	8.70	30.43	26.09	17.39
Contribution to mitigating global climate change problems	25.00	8.70	20.65	25.00	20.65
My property is too small to harvest	38.37	11.63	23.26	9.30	17.44

66.3% of the respondents say that market price is at least a 4 on a scale of 1 to 5 (5 being very important) as a factor affecting their willingness to supply biomass. One of the lesser limiting factors was the respondents' property size. Only 17.44% of the respondents considered small property size to be a very important limiting factor affecting their supply decision. Table 2.4 summarizes the importance given to other factors regarding supply biomass from existing stands.

2.4 Discussion and relevance to bioenergy policies

Price offer has a positive and statistically significant effect on the proportion of non-forested land that forestland owners are willing to allocate for pine. This result holds both for respondents that accepted the bid value initially offered in the survey and those that reported own minimum acceptable prices. As demand for woody biomass increases, leading to higher market price, larger area of non-forested land may be converted to growing pine.

The size of forestland owned by respondents had a negative influence on the proportion of non-forested land that they would allocate for pine. Although forestland owners with large sized forests are more likely to supply biomass, they are less likely than small sized forestland owners to supply non-forested land for growing pine (Becker et al., 2010; Shivan et al., 2010). Allocating more land to a land use type that already occupies a large proportion of total acreage reduces the amount of land available to other land use types and may prove to be beyond what they consider an optimal mix of land use. This outcome may also result from how such land use change would reduce their land use portfolio and render them vulnerable to the risks associated with a less diverse land use type. The proportion of non-forested land that respondents would allocate for pine is reduced when a larger proportion of the land they own is made up of other land use types such as, cropland, or pasture/grazing land. Comparatively, small scale operation of cropland and pasture/grazing land might have diseconomies of scale and may explain respondents' willingness to allocate larger proportion of non-forested land for pine. The tendency of forestland owners with large pine cover to allocate less non-forested land to grow pine suggests an aversion to a single species dominated forest stand and a preference for a diverse species portfolio. Accordingly, respondents with forestland where pine accounts for less than 20% of the forest stand may be interested in achieving higher species diversity to benefit from both fast yield in pine and value in other tree types such as hardwood.

Respondents owning trees with average diameter that is greater than 35.56 are willing to allocate less non-forested land for growing pine. Compared to a stand with average tree size below 35.56 centimeters, such land use change could result in a more unevenly aged stand with varied management needs, smaller volume of biomass being removed per unit area, increased average hauling and logging cost, higher chance for damage to residual stand, and higher potential for site degradation resulting from compaction and rutting. Differences in non-forested land allocation resulting from socioeconomic attributes of forestland owners such as absenteeism, gender, and membership in local/state environmental association may be associated with varying levels of ability to effectively attend to day-to-day management needs, sustainability opinions, or limited development of forest management objectives.

As an investment decision, land use change may involve a significant upfront cost for site preparation, planting, other management needs, and opportunity cost of shifting from the current land use types that have short cash flow cycles to a new land use type that has a longer cash flow cycle. If the respondent is highly dependent on the land for annual income, this reduces the landowner's flexibility to change land use and land cover type. Large scale adjustment of land use pattern could lead to significant change in household cash flow and that may explain why forestland owners that depend on working the land for their income are reluctance to allocate a large portion of non-forested land for pine. Respondents who consider enjoying natural beauty and scenery as an important forest management objective are reluctant to convert large portions of their non-forested land to grow pine. Such respondents may not be motivated by marketing objectives of forest products and may also find the existing stand to be sufficient in meeting their objective. On the other hand, forestland owners that consider the production of non-timber forest products as an important forest management objective are more willing to convert large proportions of their non-forested land to grow pine. Such respondents might find such change as an opportunity to produce more of these forest products.

Compared to forestland owners who are willing to harvest large proportion of residual biomass, forestland owners willing to leave large proportion of residual biomass unharvested for environmental benefits are willing to convert relatively less non-forested land for growing pine. Leaving a large portion of biomass unharvested makes the land use change less likely to be economically viable and may explain their inclination to allocate a smaller portion of non-forested land for pine.

Forestland owners who have supplied biomass to pulp/paper mills are willing to allocate less land for growing pine than those that have not supplied biomass to pulp/paper mills. The recent experience of reduced operation and closure of mills in several states and the resulting reduced demand for biomass may explain the reluctance of such land owners to producing more biomass on previously non-forested land (U.S. Department of Energy [DOE] and U.S. Department of Agriculture [USDA], 2005).

In addition to the amount of non-forested land respondents will allocate for pine, market price also affects respondents' willingness to supply biomass from an existing stand. Price is also one of the variables that any policy measure may be able to influence. The revenue to forestland owners may be directly affected by policy measures that introduce carbon credits or other mechanisms to internalize the externality. Policy measures can also affect prices indirectly by, for example, providing capital support for bioenergy plants and mills to raise their biomass demand. Such measures may be able to affect both the chances and scale of change in land use and the harvest of biomass from of existing stands for bioenergy.

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3 SOIL AND WATER CONSERVATION USING THE SOCIOECONOMICS, SUSTAINABILITY CONCERNS, AND POLICY PREFERENCE FOR RESIDUAL BIOMASS HARVEST

3.1 Introduction

Woody bioenergy has potential socio-economic and ecological benefits and it can use low value biomass such as residual biomass (Chum et al., 2011; Department of Energy [DOE], 2005). Private forestland owners can take advantage of this emerging market by harvesting a larger proportion of residual biomass such as tops, stumps, branches, and other debris that is left behind after a commercial harvesting of higher valued wood products including pulpwood and saw timber. In addition to generating revenue, harvesting residual biomass, 25-45 dry tons of which may be left behind after timber harvests depending on type of harvest, for energy may serve to reduce insect, disease, and fire outbreak risk in dense stands, reduce competition, improve site access, promote seedling establishment, and reduce site preparation needs (Mason et al., 2006; Becker et al., 2011). Compared to other means of availing biomass such as new pine plantations that can tie up resources for a long time, increasing the proportion of residual biomass harvest benefits from processing facilities' existing demand and affordability (Cubbage et al., 2007; Becker et al., 2013).

However, industrial fuels consume 42% of the residual biomass produced in the state of Virginia while fiber byproducts and others consume 39% and 18%, respectively (Gan et al., 2007). The industrial fuel use of residual biomass is mostly done by pulp and paper mills and paperboard manufacturing facilities. Most of these facilities produce and consume the heat and power from such biomass themselves. Others with excess production may be able to sell it to local utilities. The production of woody bioenergy including cellulosic ethanol and increased industrial fuel consumption would, thus, require the harvest of additional residual biomass.

However, given the relatively higher branch and foliage to wood ratio, residual biomass has higher nutrient content compared to saw timber. As such, for a given volume, the harvest of residual biomass can lead to higher nutrient loss from top soils, compared to harvesting timber. Additionally, excessive harvesting of residual biomass can compromise the soil's ability to hold and transfer water as it disturbs and exposes topsoil, reduces litter storage, interception, soil transpiration, and water infiltration rates (Neary, 2002; Heninger et al., 1997; Burger, 2002). These effects could lead to runoff, erosion, discharge of pollutants and sediments to surface and groundwater bodies, nutrient deficiency, and water logging of soil (Greacen et al., 1980; McNabb et al., 2001). These processes can also affect water chemical properties such as pH, nutrient load, biological oxygen demand as well as physical properties such as temperature and turbidity. Such changes in soil and water properties can also have broader implications for nutrient, energy and water cycles; their ability to process pollutants; plant-pest dynamics; microbial community characteristics; and watershed level aquatic and terrestrial biodiversity (Belleau et al., 2006; Neary, 2002). At the stand level, these effects can potentially reduce the fertility and ability of the land to sustain subsequent cycles of forest growth, along with the relevant ecosystem functions. For a given level of biomass removal intensity, harvest practices or tree species with shorter rotation cycles such as loblolly pine (*Pinus taeda L.*), which is important in geographic coverage and commercial terms in the state and the region, may be associated with higher nutrient loss, owing to the fewer years of weathering and atmospheric inputs between the rotation cycles, among others (Vadeboncoeur et al. 2014).

In addition to the environmental implications, the scale of residual biomass harvest can affect its market price and availability for other uses including industrial fuel, fiber and other products (Galik et al., 2009; Thiffault, 2014). As such, there is a need to strike a balance that allows forestland owners to generate revenue from their forestland while mitigating the potential adverse effects of excessive residual biomass harvest (Abbas et al., 2011; Cambero et al., 2014).

In this paper we use survey data to assess the factors that explain forestland owners' residual biomass harvest rate, their sustainability concerns and policy preferences. The following sections are organized in three parts. First we present the data and methods section, where we describe the study area, survey design, and summary description of the methods used to analyze the data. This section is followed by the results and discussion sections, which present a general description of the respondents and feature subsections for the respective specific objectives. The last section presents the summary and conclusion, describing the main findings.

a. Cluster analyses

Cluster analysis, as a data exploration tool for systematically grouping multiple variables, was used to cluster opinions about woody bioenergy's potential environmental impacts by a measure of association. Cluster analysis identifies patterns among variables and helps to identify a given member of a cluster as a representative reduced version of that cluster. It does so by evaluating the proportion of the variation each cluster member contributes to its respective cluster. By identifying the respective representative cluster component for all clusters, a shorter list of variables that represent the larger dataset can be determined. While cluster analysis allows us to assess if there is a pattern of sorting in the variables that can benefit from a targeted approach, identifying representative cluster components allows us to deal with a fewer number of variables without necessarily losing the insight of the longer list of variables (Proust, 2013).

We used the Bartlett test to evaluate if each successive eigenvalue that is generated for a given clustering of variables is significantly different from the other eigenvalues. By testing the strength of correlation and as a stopping rule, the test produces a p value for determining suitability of the data for reduction into clusters. The p values of this test for our data for the three clusters is <0.0001.

b. Partition analyses

In addition to testing the nature of relationship between the proportion of residual biomass the forestland will leave unharvested and the variables used to explain this behavior, the recursive partitioning analyses allows us to determine threshold values for respective variables that may be used to sort observations into clusters. The clusters thus determined have statistical difference when compared to each other in terms of the proportion of residual biomass forestland owners are willing to leave unharvested. However, observations in each group exhibit comparable behavior to one another with respect to harvesting decisions. While the cluster analysis groups variables into non-overlapping clusters, the partition analysis groups observations for the respective variables into non-overlapping segments. Such segmentation of observations into groups helps to improve profiling, increase overall prediction capacity of the model, and allow for tailored recommendations (Muggeo and Vito, 2008; Betts et al., 2007). While binary variables cannot be partitioned any further, the threshold values identified by this approach were used to create dummy versions of the continuous and multivariate variables, presented in Table 3.1 under the columns Reference (Ref.) and Alternative (Alt.). The odds ratio of likelihood to leave more than 30% of the residual biomass unharvested for respondents in Alternative (Alt.) group compared to Reference (Ref.) group was estimated by taking the exponential of the regression coefficients for the respective variable.

c. Ordinal logistic model

Given the ordinal nature of the response to the survey question about the proportion of residual biomass forestland owners would leave unharvested, the ordinal logistic model was used to analyze the data. Instead of the actual distance between two response levels, this model uses the order between the levels. It does an iterative maximum likelihood computation and requires fewer parameters than nominal models. Accordingly, it fits a succession of parallel logistic curves to the cumulative probabilities with the same parameters but different intercept (Greene, 2003).

Each respective curve can be specified as:

$P(y \leq k) = F(\alpha k + X\beta)$ for $k = 1, \ldots, r - 1$ --(1)

$F(x) = \frac{1}{(1+e^{-x})} = \frac{e^{x}}{(1+e^{x})}$ --(2)

where r is the number of response levels and $F(x)$ is the standard logistic cumulative distribution function. Taking the exponential of the respective coefficients gives the proportional odds ratios for the ordered logit model. For a given variable, a proportional odds ratio below one indicates that respondents with attribute in the reference (Ref.) category are more likely to insist that more than 30% of the residual biomass remains unharvested. Similarly, a proportional odds ratio above one for a given variable means that respondents with attribute in the alternative (Alt.) category are more likely to insist that more than 30% of the residual biomass remains unharvested.

The proportionality assumption, which underlies the ordered logistic model, requires that the distance between adjacent ordered responses be equal. This assumption makes a likelihood-ratio test for the proportionality of odds across response categories necessary. With a null hypothesis that the coefficients between the models are the same, a significant result indicates the need to use all alternative approach to model the data. However, the results for this test are insignificant, with a *p* value of 0.18. Although marginally insignificant, this result justifies the use of a single model and a single set of coefficients, as opposed to separate regressions for all pairs of ordered responses. Other that the relevant test statistic being insignificant the ordinal logistic model is preferable to alternative models such as the nominal and multinomial logit because they would lead to potential loss of important information and parsimony from dichotomizing the data.

3.2 Results

a. Description of survey respondents

We used analyses of variance to test for statistical differences between the first set of survey respondents (responses received before the third round of survey was sent out) and the late respondents (responses received after the third round of survey was sent out). This test did not yield a significant difference between two sets of survey respondents. We then used the Forest Service's national woodland owner survey data for Virginia, which is based on a larger number of respondents and conducted across time, as a baseline to test the representativeness of our survey data. Accordingly, the average forestland size for respondents of our survey was 85.4 while the average size of forestland in Virginia is 75 acres. Because we targeted forestland owners with at least 20 acres of forestland, the slightly higher result is to be expected. We then specified a minimum of 20 acres as a cutoff point and compared the two data sets on gender, absenteeism, race, and the way land was acquired. While 61.26% of forestland owners in Virginia said that the forest holding is part of their primary residence and 83.15% are male, 55.83% of the respondents said that the forest holding is part of their primary residence and 77.96% are male. While 91.42% of Virginia's forestland owners are white and 58.32% acquired their land through purchase, 94.82% of our survey respondents are white and 56.66% said they acquired their land through purchase. These results suggest that the two datasets are reasonably comparable. In addition to measuring representativeness, these tests give insights into non-response bias, both results suggesting that it is not a significant problem.

Table 3.1. Descriptive statistics of variables from the final model

Variable	Description	Reference	Alternative
Years land owned	Continuous	<42	≥42
Land acquired by	Bought (1), Inherited (2), Inherited+Bought (1.5)	1.5	1,2
Number of people in the household	Continuous	<4	≥4
Land as investment to generate profit	Ordinal ranging from 1 for 'not at all important' to 5 for 'very important'	1,2, 3,4	5
Enjoy natural beauty and scenery	Ordinal ranging from 1 for 'not at all important' to 5 for 'very important'	1,2, 3,4	5
Percent of gross family income generated from working the land (farming, timber, others combined)	none (1), <10% (2), 10-25% (3), 25-50% (4), >50%(5)	1	2,3, 4,5
Price offered	Ordinal ranging from 1 for 'not at all important' to 5 for 'very important'	1,2	3,4, 5
Supplied wood for pulp/paper	No (0), Yes (1)	0	1

mills in the past five years			
Acres	Continuous	<150	≥150

b. Harvest rate decision

27.5% of the survey respondents said that they would leave more than 30% of the residual biomass unharvested for soil nutrient and other environmental benefit purposes. The table below summarizes the significant results from the regression.

Table 3.2. Summary results significant variables that explains respondents' residual biomass harvest decisions.

Variable	**Coeff.**	**Proportional Odds ratio**
Years land owned {≥42 -<42}	-1.24**	0.28**
Land acquired by {1,2 -1.5}	1.07**	2.93**
Number of people in the household {≥4 -<4}	-1.31**	0.26**
Land as investment to generate profit {5 - ,2,3,4}	-1.23**	0.29**
Enjoy natural beauty and scenery {5 -1,2, 3,4}	0.91**	2.48**
Percent of gross family income generated from working the land (farming, timber, others combined) {2,3,4,5 -1}	-1**	0.36**
Price offered {3,4,5 -1,2}	-1.09**	0.33**
Supplied wood for pulp/paper mills	-1.09**	0.33**

in the past five years {1 -0}		
Acres {≥150 -<150}	-0.72*	0.48*

***, **, * Indicate significance at 0.01, 0.05, and 0.1 α levels, respectively.

Respondents who said enjoyment of natural beauty and scenery as a reason for owning land is a 5 (on a scale of 1 to 5, with 5 being very important), have a 2.48 proportional odds ratio for leaving more than 30% of the residual biomass unharvested. This suggests that they are more likely to leave more than 30% of the residual biomass unharvested. Forestland owners who say the price offer is at least a 3 as a reason to supply biomass for bioenergy (on a scale of 1 to 5, with 5 being very important), have a proportional odds ratio of 0.33 for leaving more than 30% of the residual biomass unharvested. This suggests that they are less likely to leave more than 30% of the residual biomass unharvested. On the contrary, respondents who said land investment to generate profit is very important (5, on the same scale) have a proportional odds ratio of 0.29 for leaving more than 30% of the residual biomass unharvested, suggesting that they are more willing to harvest a greater proportion of the residual biomass.

Forestland owners generating income from working the land (farming, timber, others combined) have a proportional odds ratio of 0.36 for leaving more than 30% of the residual biomass unharvested, suggesting that they are less likely to leave more than 30% of the residual biomass unharvested. Forestland owners who do not generate any income from working the land, on the other hand, are more likely to say they will leave more than 30% of the residual biomass unharvested.

Respondents who have owned forestland for less than 42 years and forestland owning households with less than 4 members have proportional odds ratios of 0.28 and 0.26 for leaving more than 30% of the residual biomass unharvested, respectively. Forestland owners that have supplied wood for pulp/paper mills in the past five years and forestland owners with more than 150 acres have proportional odds ratio of 0.33 and 0.48 for leaving more than 30% of the residual biomass on their land unharvested, respectively. Compared to forestland owners who acquired their land solely by purchase or by inheritance, respondents who acquired their forestland part by purchase and part by inheritance are less likely to insist that more than 30% of the residual biomass be unharvested.

Variables such as gender, income, age, existing land use types and species composition of the forestland, prior experience with state/federal technical or financial assistance in managing forestland in the past five years, ethnicity, level of education, membership in state/local forestry or environmental association, and a list of forest management activities in the past and coming five years such as partial cutting, resulted in insignificant regression coefficients (results not reported).

c. Sustainability concerns

The survey asked respondents how strongly they agreed with statements about potential economic, social, and environmental impacts of harvesting residual biomass for bioenergy on a scale of 1 to 5, with 1 being 'strongly disagree' 5 being 'strongly agree'. The first cluster pooled together opinions regarding the availability and sufficiency of Best Management Practices (BMP) guidelines dealing with harvesting forest biomass and providing adequate information on how to maintain soil and water quality. Cluster 2 had two components dealing mainly with generic economic and sustainable forestry concerns. Components of the third cluster were specific cases of the economic and sustainable forestry practices that are pooled in cluster two. The components of the third cluster dealt with timber productivity and health, soil and water quality, wildlife implications, resource requirement of residual biomass harvest in terms of employees and equipment.

Table 3.3 clusters of sustainability opinions of respondents about harvesting residual biomass for bioenergy production.

Cluster	Cluster members	R^2 with Own Cluster	R^2 with Next Closest	$1-R^2$ Ratio
1	There are sufficient state guidelines and Best Management Practices (BMPs) for harvesting forest biomass	0.80	0.06	0.21
1	When harvesting biomass, soil and water quality can be maintained by implementing forest BMPs	0.80	0.15	0.23
2	Not many landowners have harvested biomass for biofuels production and ended up benefiting	0.76	0.24	0.32
2	Development of forest biomass based bioenergy will affect sustainable forest management efforts negatively	0.76	0.43	0.42
3	Harvesting forest biomass affects soil and water quality negatively	0.71	0.27	0.40
3	Harvesting forest biomass will affect wildlife negatively	0.57	0.19	0.53
3	Harvesting residual forest biomass affects the standing timber growth and health negatively	0.65	0.39	0.57
3	Harvesting forest biomass will require extra employees and equipment	0.17	0.06	0.89

Components of a cluster exhibit patterns of comparable scoring profile. Accordingly, for the first cluster, 89.62% of the respondents said they agreed or had neutral opinion about the sufficiency of BMP guidelines in general and 89.72 said they agreed or had neutral opinion about the ability of these practices to ensure soil and water quality.

For the second cluster, 90.48% of the respondents said they disagreed or had neutral opinions about negative impacts of woody bioenergy on sustainable forest management efforts while 90.29% of the respondents said that they disagreed or had neutral opinions about forestland owners ending up benefiting economically from supplying biomass for woody bioenergy. Thus, in the second cluster, more than 90% of the respondents either disagreed or had neutral opinion about the generic economic and forestry sustainability implications of residual biomass harvest for bioenergy. However, 63.21% of the respondents on average said they agreed or had neutral opinion about the specific sustainability implications of biomass harvest on soil and water quality, wildlife, timber growth and health, and that it needs more employees and equipment.

The most representative components of each cluster are presented in table 3.3. The three representative components, taken together, explain 65% of the variation in the whole dataset. These may be considered as summary representations of forestland owners' sustainability concerns and opinions about best management practices.

Table 3.4. Representative cluster components

Cluster	Most Representative Variable	Cluster Proportion of Variation Explained	Total Proportion of Variation Explained
1	There are sufficient state guidelines and Best Management Practices (BMPs) for harvesting forest biomass	0.80	0.20
2	Not many landowners have harvested biomass for biofuels production and ended up benefiting	0.76	0.19
3	Harvesting forest biomass affects soil and water quality negatively	0.53	0.26

d. Policy Preferences

The survey provided a list of policies and asked respondents how important the policies are towards encouraging them to supply biomass from their forestland for bioenergy production. The policies are such that they help cover part of the cost that forestland owners incurred in the process of supplying the biomass. The list included support programs that cover different types of expenses ranging from management, equipment, hauling, and price guarantee. Two policies dealing with covering management cost were similar except that one is administered by the state while the other is administered by the federal government. In addition to testing if and which policies are considered relevant to their decision, this survey structure allowed us to assess if the implementing agent affects forestland owners' decision.

Nearly 14% of the respondents said they would leave no residual biomass unharvested, meaning that they are willing to supply the entire residual biomass for bioenergy despite the implications for nutrient loss, higher runoff, loss of water quality, and other adverse outcomes that may follow from such a decision. Given the higher vulnerability of these forestland owners to the said impacts, respondents who insist that some portion of the residual biomass remain unharvested were combined into one group and those who are willing to harvest all residual biomass were set in another group for the subsequent analyses.

Table 3.5. Policy preference results of the Cochran-Armitage trend test.

Policy	**Cochran-Armitage test statistics**
Federal cost share programs, for example, the type that covers part of the management cost incurred.	2.14**
State cost share programs, for example, the type that cover part of the management cost incurred.	1.75*
Price support for biomass program similar to what is available for other agricultural products.	0.64
Biomass transportation cost support program to help cover hauling cost.	0.26
Capital support program such as the type that would help finance the cost of equipment purchased to harvest biomass.	0.73

**, * significance at 95% and 90% confidence levels, respectively.

While we did not find a significant trend for policies dealing with price guarantee, hauling, and equipment costs, the Cochran Armitage trend test suggests that forestland owners who are willing to harvest the entirety of the residual biomass prefer state and federal cost share programs that cover part of the management expenses incurred. Although the estimates are significant for both the state and the federal government as implementing agents, they are slightly higher for the federal government sponsored program. This suggests that relatively more respondents would consider federal government sponsored programs more encouraging than a state level program for them to supply biomass from their forestland.

3.3 Discussion

The reasons forestland owners provided for owning the land explains the proportion of residual biomass they are willing to leave unharvested. Compared to forestland owners that do not consider the enjoyment of natural beauty and scenery as an important forest management objective, those that do are likely to leave more than 30% of the residual biomass unharvested. Similarly, compared to forestland owners that consider market price as an important factor affecting their biomass supply decisions, those that attach less importance to price as a biomass supply motivating factor are likely to leave more than 30% of the residual biomass on their land unharvested. The motivation for such respondents is not primarily the generation of revenue, but other factors such as aesthetics, and they are less responsive to price offer as an incentive to change their decision. In contrast, forestland owners that attach more importance to generating profit from their land are likely to harvest large proportion of the residual biomass.

Forestland owners with greater dependence on working the land for their income are also reluctant to leave large proportions of the residual biomass on their land unharvested. Other than the rate of residual biomass removal, several factors including rotation length, consistence of the biomass harvesting practice with relevant best management practices, and nutrient loss compensating management practices such as fertilization may play important roles in determining the long-term productivity of forestlands (Vadeboncoeur et al. 2014). These and other relevant factors being the same, however, a large scale and prolonged removal of residual biomass may have adverse implication for the productivity of forestlands, potentially proving counter-productive to the forestland owner in the long term. Such types of forestland owners may benefit from outreach programs that deal with balancing short term economic gains with long term productivity loss.

Forestland owners who have not supplied wood for pulp/paper mills in the past five years and forestland owners with less than 150 acres are more likely to leave more than 30% of the residual biomass unharvested. Other things being the same, forestland owners with large sized forests sacrifice a greater amount of revenue by leaving a given proportion of the residual biomass unharvested compared to forestland owners that have smaller sized forests. The choice of forestland owners with large forests, in this case larger than the 150 acres threshold identified by the partitioning analyses, to harvest more residual biomass from their land may be explained by their desire to avoid sacrificing potentially large revenue.

In addition to the size of the forestland, the way the land was acquired also explains how much residual biomass forestland owners are willing to leave unharvested. While previous studies have found that forestland owners that inherited their land have different management tendencies compared to forestland owners that purchased their land, (Majumdar et al., 2008), more data is needed to establish what is particular about the combination of purchase and inheritance that it leads to such an outcome.

The difference in opinion about the generic sustainability implications compared to the specific sustainability implications of residual biomass harvest may be a result of how the forestland owners perceive other specific impacts than the ones considered in our study positively, making the net effect favorable. While future research can identify these other specific aspects of woody bioenergy that forestland owners may perceive positively, the results are indicative of the type of concerns forestland owners have and their opinions on the availability and potency of best management practices.

The most representative components for their respective clusters are: sufficiency of state guidelines and Best Management Practices (BMPs) for harvesting forest biomass, the concern that not many landowners have had economic success from harvesting residual biomass for bioenergy, and the concern that harvesting forest biomass affects soil and water quality negatively.

The support for cost sharing programs does not directly interpret into harvest decision and such programs may benefit forestland owners with different residual biomass harvest rate preferences. Moreover, the support for cost sharing programs does not necessarily depend on how much biomass the forestland owner is willing to leave unharvested. However, such programs improve the economic viability of harvest practices such as harvesting residual biomass from hard to reach places that would have otherwise been ignored considering the special equipment, labor, and time needs it would require. Therefore, state and federally sponsored management cost sharing programs may enable forestland owners interested in harvesting biomass at highest intensity level but were held back by cost considerations will now have the resources that will allow them to do so. Decision makers administering or considering similar policy proposals should be aware of the unintentional effects such policies may have in encouraging a harvest practice that does not leave any residual biomass unharvested. As such, these policies may have to be coupled with educational programs so that forestland owners can make best use of the policies and avoid unintended consequences.

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4 Determinants of enrollment in public incentive programs for forest management and their effect on future programs for woody bioenergy

4.1 Introduction

Forests provide positive externalities such as reducing soil erosion, carbon sequestration, water regulation, and aesthetics, for which the private forestland owner is not financially compensated. To account for the public-good nature of these services and the uncompensated positive forest management outcomes, several federal and state sponsored programs provide technical assistance and cost sharing opportunities to forestland owners.

In the context of woody bioenergy, such types of public programs may be justified by how it can reduce greenhouse gas emissions, reduce fire and disease outbreaks in overstocked forests, improve rural economy, and reduce dependence on imported oil (Gan et al. 2007). As an emerging market opportunity, however, woody bioenergy's profitability, social acceptability, among others are unknown (Gan et al. 2007). Despite the significant share of the forestland managed by private forestland owners and, thus, their stake in the supply of biomass for bioenergy, there is limited research on forestland owners' perception of public programs in the context of woody bioenergy. Such uncertainty may discourage forestland owners from supplying biomass and making other investments to do with woody bioenergy. Under such circumstances, public incentive programs can play a role of encouraging forestland owners to supply biomass for bioenergy by helping cover some of the management cost and guaranteeing prices, among others. Considering how forestland owners may not be fully aware of the economics of woody bioenergy, such programs can also help to correct for information asymmetry and to compensate for the positive externality associated with the relevant forest management. A specialized agency implementing such incentive program also has economy of scale in producing and distributing forest management information and resources, compared to each forestland owner having to do so.

The incentive programs may take the form of direct payments or tax credits to participating landowners (Barber 1989). Tax based programs include property or income tax deferment and abatement, treatment of timber income as capital gain, favorable tax credits and deductions (Greene et al. 2006). Cost sharing programs can cover as high as 75% of the cost for prescribed management practices. The amount of payment to enrollees could also be based on the land rental value, with enrollment durations can last from five to ten years (Conservation Programs 2011; Straka 2011). Moreover, technical assistance to landowners may be provided by the state and federal government and land grant universities. These programs can have practical benefits to enrollees, such as making it possible to afford ownership of their forestland in areas with rising land value and high property taxes (D'Amato et al. 2010). More generally, such programs can reduce forest management costs, increase the production possibility or productivity of the forestland, increase return on the owner's investments, increase welfare by correcting market failure, and increase the intensity and acreage of forestland managed under prescribed practices relative to the absence of the program.

The cost of running such incentive programs, which may be financed by the federal and/or state governments or by the forest industry, may be considered as a public investment in the efficient production and distribution of relevant information and resources. The cost of running such incentive programs may also be considered as a public investment and in ensuring the healthy operation of the timber market along with the economic output, jobs, and tax revenue it supports annually.

Despite these benefits, enrollment rates in public programs are limited, as low as 25% for reforestation tax credit and managed timberland programs (Fortney et al. 2011). Furthermore, trends indicate that the average size of forestlands is decreasing over time (Best 2002). Ownership of smaller tracts of forestlands is associated with lower interest in such programs (Royer 1987a). If this pattern continues, enrollment rates might become even lower in the future.

Furthermore, while some forestland owners routinely practice a prescribed activity without enrolling in a program that aims to encourage that activity, some enrollees may have a limited implementation rate and duration of enrollment, obfuscating what determines enrollment and active implementation (Greene et al. 2004). Given their use of public resources and the important societal objectives the programs aim to achieve, it is important to understand if and how enrollment rates can be improved.

In this paper, we attempt to identify the factors that explain forestland owners' enrolment in financial and technical assistance programs. We also assess how previous experience with such programs affects their perceptions about future programs dealing with woody bioenergy. We also investigate how forestland owners rate public programs that affect others in the supply chain, even though they might not directly benefit from such programs. This research is important because by better understanding the typical attributes of forestland owners less likely to enroll in such programs, we can target them through Extension and outreach programs. Such information may also allow us to adapt existing programs and tailor new ones accordingly, which may lead to higher enrollment and implementation rate, provide for a more effective use of public resources, and lead to a larger forestland acreage covered under such programs. More generally, research in this area allows us to better understand and affect desired changes in management practices and outcomes.

The following sections are organized in four parts. First we introduce findings of previous related studies to provide context for this paper and to highlight the relevant research gaps that this paper intends to bridge. This section is followed by the methods section that describes the study area and statistical methods used. The results section follows and contains a general description of the survey respondents and subsections that provide the results and discussion for the specific objectives. Lastly, a summary conclusion is provided.

4.2 Methods

a. Partitioning analyses

We used recursive partitioning analyses to identify thresholds in explanatory variables. The thresholds are such that they sort observations into two optimal groups that behave statistically differently when compared to each other using t-test. Observations in each cluster exhibit comparable behavior to one another with respect to the explanatory variable. Given that binary variables cannot be partitioned any further, we developed dummy versions of the continuous and multivariate variables, which are presented in Table 4.1 under the columns Reference (Ref.) cluster and Alternative (Alt.) cluster. The odds ratio of enrolling in public programs for respondents in the Alternative group (for example: acreage above the threshold level identified by the partitioning analyses) relative to those in the Reference group (acreage below the threshold level identified by the partitioning analyses) is estimated by taking the exponential of the regression coefficient for forestland acreage. By segmenting observations into such groups, we are better able to profile observations, improving overall prediction capacity of the model, and develop tailored recommendations to the respective segments (Muggeo et al. 2008).

Table 4.1. A description of the variables and corresponding partitions

Variable	**Description**	**Reference**	**Alternative**
Years owning land	Continuous	<26	≥26
How land is acquired	Bought (1), Inherited (2), Inherited+Bought (1.5)	1.5, 2	1
Forestland acreage	Continuous	<42	≥42
Enjoyment of privacy	Ordinal, 1 (not at all important) to 5 (very important)	1,2	3,4, 5
Timber production	Ordinal, 1 (not at all important) to 5 (very important)	1,2, 3	4,5
Production of firewood for own use	Ordinal, 1 (not at all	1,2,	5

	important) to 5 (very important)	3,4	
Level of education	Elementary (1), high school (2), some college (3), and college graduate and above (4)	1,2	3,4,
Residence on forested property	No/Yes	No	Yes
Removed invasive species in the past five years	No/Yes	No	Yes
Built or maintained roads in forested property in the past five years	No/Yes	No	Yes
Developed a forest management plan in the past five years	No/Yes	No	Yes
Wildlife habitat/fisheries improvement projects in the past five years	No/Yes	No	Yes
Gender	Male/ Female	Male	Female
Member of a local forestry/environmental association	No/Yes	No	Yes
Gross annual income in 2013	<$22,000 (1), $22,000 - $49,999 (2), $50,000 - $89,999 (3), >$90,000 (4)	1,2	3,4

b. Logistic regression

Given that whether or not the respondent has enrolled in a public program in the past five years is binomial, we use the binomial logistic regression to analyze the data. For a logistic cumulative distribution, this model can estimate the probability of getting a 'yes' response given the values of the explanatory variables:

$$P(Y = 1|X_1, X_2, X_3, X_4, \ldots X_k). \quad (1)$$

The corresponding logistic function becomes:

$$P(X) = 1/(1+e^{-(\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \cdots)}). \quad (2)$$

For a composite index, z, of all relevant variables it can be summarized as:

$$F(z) = 1/(1+e^{-z}) \quad (3)$$

c. Cochran Armitage trend test

The importance that forestland owners attach to the proposed programs is ordinal while having enrolled in any public program in the past five years is binomial. The Cochran-Armitage test detects a linear trend in the proportion of respondents saying that they have enrollment experience across the ordinal scale relative to those that have not enrolled in such programs. This test accounts for the ordinal nature of the data by treating it as a quantitative instead of nominal scale (Agresti, 2007).

The correlation between two variables, r, can be specified as:

$$r = \frac{\sum_{i,j}(x_i - \overline{x})(y_i - \overline{y})p_{ij}}{\sqrt{\left[\sum_i (x_i - \overline{x})^2 p_i\right]\left[\sum_i \left(y_j - \overline{y}\right)^2 p_j\right]}} \quad (4)$$

where the denominator is the product of the sample standard deviations for the two variables; the numerator weights cross-products of deviation scores by their relative frequency. The test statistics T^2 has a chi-squared distribution with $df = 1$, that is,

$$T^2 = (n-1)r^2 \quad (5)$$

A p value less than α value (significance level) suggest that the slop for the linear trend is not zero (Agresti, 2007).

4.3 Results

a. Respondent attributes

A t-test determining statistical difference between early respondents and late respondents for both states did not yield significant result. The average forestland acreage for private forestland owners in Virginia and Texas are 75 and below 50, respectively (VDoF 2015), while the average values for our survey respondents are 85.4 and 67.7, respectively. This difference results largely from the fact that we targeted forestland owners with at least 20 acres of forestland. Adjusting for this cutoff point, our results are comparable with those of the National Woodland Owner Survey (NWOS), which is based on a larger number of respondents and is done over time for all states including Virginia and Texas (Butler et al. 2015). While 94.8% of the respondents from Virginia and 89.1% from Texas are white, the results from NWOS are 91.4% for Virginia and 92.5% for Texas. While 55.8% of the respondents from Virginia and 43.7% from Texas said the forested property is part of their primary residence, the results from

NWOS are 61.2% for Virginia and 55% for Texas. While 78% of the respondents from Virginia and 82.1% from Texas are male, the results from NWOS are 83.15% for Virginia and 84.3% for Texas.

b. Determinants of enrollment in public programs

Approximately 13.4% of the respondents said they have benefited from a public financial/technical support program in the past five years. Contingency analysis did not result in a statistically different enrollment rate between Texas and Virginia. Odds ratios are computed only for the significant variables in the following table.

Table 4.2. A description of the variables obtained from the survey and the corresponding results calculated using recursive partitioning and logistic regression analyses.

Variable	**Coef.**	**Odds ratio**
Years owning land {≥26 -<26}	1.66***	5.26
How land is acquired {1 -1.5, 2}	-0.04***	0.35
Forestland acreage {≥42 -<42}	3.32***	27.66
Enjoyment of privacy {3,4,5 -1,2}	-0.8	-
Timber production {4,5 -1,2,3}	1.86***	6.42
Production of firewood for own use {5-1,2,3,4}	-1.36	-
Level of education {3,4, -1,2}	2.04**	7.69
Residence on forested property {Yes –No}	-0.36	-
Removed invasive species in the past five years {Yes – No}	0.39	-
Built or maintained roads in forested property in the past five years {Yes –No}	1.11**	3.03

Developed a forest management plan in the past five years {Yes –No}	1.54***	4.66
Wildlife habitat/fisheries improvement projects in the past five years {Yes-No}	0.43	-
Gender {Female –Male}	0.12	-
Member of a local forestry/environmental Association {Yes –No}	1.44***	4.22
Gross annual income in 2013 {3,4 -1,2}	-0.56	-

*** and ** Indicate significance at 0.01 and 0.05 α levels, respectively.

We find mixed results for forestland management objectives as significant predictors of tendency to enroll in public programs. While forest management for timber production is significantly related to program enrollment tendency, land management for the 'enjoyment of privacy' and 'production of firewood for own use' are not significant. Respondents who say timber production is at least a 4 on a scale of 1 to 5, with 5 being a 'very important' reason for owning and managing forestland, had an odds ratio of 6.42 for enrolling in public programs. Forestland owners who do not rate timber production higher than a 3 on the same scale are less likely to enroll in public programs. The statistical insignificance of 'enjoyment of privacy' and 'production of firewood for own use' as forestland management objectives suggests that those enrolled in public programs do not typically attach 'very high' or 'very low' importance to these objectives relative to those not enrolled in any public incentive program. There is no distinct pattern to these objectives with respect to enrollment in public programs.

We find similarly mixed results for socioeconomic attributes in explaining enrollment tendencies. While level of education, how long the forestland owner has owned the land, acreage, the way the forestland was acquired, and membership in forestry/environmental associations significantly explained likelihood to enroll in public programs, we did not find gender, income, or absenteeism to be statistically significant.

Consistent with previous findings (Greene et al. 2004), our results show that enrollees tend to be more educated. Specifically, our data shows that enrollees with at least 'some college' level of education have a 7.69 odds ratio of enrolling in public programs compared to those with just a high school education or less. Respondents who have owned their forestland longer than 26 years are also more likely to enroll in public programs. Long tenure may lead to greater practical experience in managing forestland and knowledge about the resources publicly available to forestland owners.

Consistent with previous findings, our results also show that enrollees tend to have a large size of forestland. Managing a larger forestland area can be demanding in terms of knowledge, capital, and other resources, thus explaining the higher tendency for such forestland owners to take advantage of public programs. Although 42 acres is a relatively small number and below the average forestland size for our respondents, the threshold analyses shows that, for the purpose of enrolling in public programs, it delineates the small from the large forestland. For every 28 enrollees with acreage greater than 42 acres, there is only one owner with forestland less than 42 acres.

If a portion of the land, or if the whole land is acquired by inheritance, the owner is less likely to enroll in public programs, with an odds ratio of 0.35. While intergenerational transfer of forestland leads to changing motivation and management plans (Majumdar et al. 2009), our results suggest that it also leads to lower tendency to enroll in public programs.

Membership in forestry or environmental associations significantly explains enrollment tendencies. Forestland owners that are members of such associations are more likely to enrollment in public programs. This result may be explained by how such associations offer forestland owners opportunities to learn and share practical information relevant to forest management, including information about public resources available for forestland owners.

While some past activities, such as building roads in the forested property and developing forest management plans significantly explain enrollment tendencies, others, such as removing invasive species and conducting wildlife habitat or fisheries improvement projects are not significant. Forestland owners that built roads in their forested property and those that developed forest management plans are more likely to enroll in public programs. Investments in building or maintaining road is a proactive forest management practice that improves access and reduces biomass collection cost while increasing the volume of biomass collected per acre. Such proactive management tendencies associate positively with enrolling in public programs. The significance of forest management plans may be explained by how it can be an eligibility requirement to enroll in the programs.

Absenteeism is associated with inability to attend to the day-to-day management of the forestland while primary residence on the forested property offers more opportunities to be involved in the management and to benefit from prescribed forest management practices. However, we do not find a statistically significant result for this variable. Similarly, we do not find significant results for for gender and income.

In summary, forestland owners less likely to enroll in public programs tend to have a high school or lower level of education, do not belong to a forestry/environmental association, do not have a forest management plan, have not built road in their wooded property in the past five years, do not consider timber production as an important management objective, acquired land in part or as a whole by inheritance, have owned land less than 26 years, and possess less than 42 acres of forestland.

Among the significant variables, developing forest management plans and membership in environmental/forestry associations are more amenable to policy. Both also provide opportunity for forestland owners to learn about public programs and other resources relevant to their objectives and other considerations. Developing forest management plans, for instance, can lead to contact with professionals, defining specific objectives for the forestland, and establishing a timeline for their attainment. The number of enrollees may potentially be improved by encouraging forestland owners to develop management plans that list relevant public programs and a timeframe for submitting program applications. Enrollment in environmental/forestry associations also creates opportunities to share information relevant to forest management and serves to further disseminate information about public incentive programs, eventually leading to the enrollment of more forestland owners in the public incentive programs. Thus, expanding the availability and encouraging enrollment in such associations may prove as a pathway to enrollment in public incentive programs.

c. Program preference

The survey provided a list of potential cost sharing programs that encourage the supply of biomass for bioenergy production and asked respondents to rate the programs' importance in encouraging them to supply biomass from their forestland. The hypothetical programs offer to cover part of the cost incurred for forest management, equipment, hauling, and a price support. We offered two implementing agencies for the forest management cost assistance program, the state and the federal government. By controlling for the type of program, this allows us to test if there is a preference for an implementing agency. Figure 1 presents a visual representation of the rating patterns. The relative width of the columns is based on the number of respondents rating the policies one the ordinal scale from 1 (not at all important) to 5 (very important).

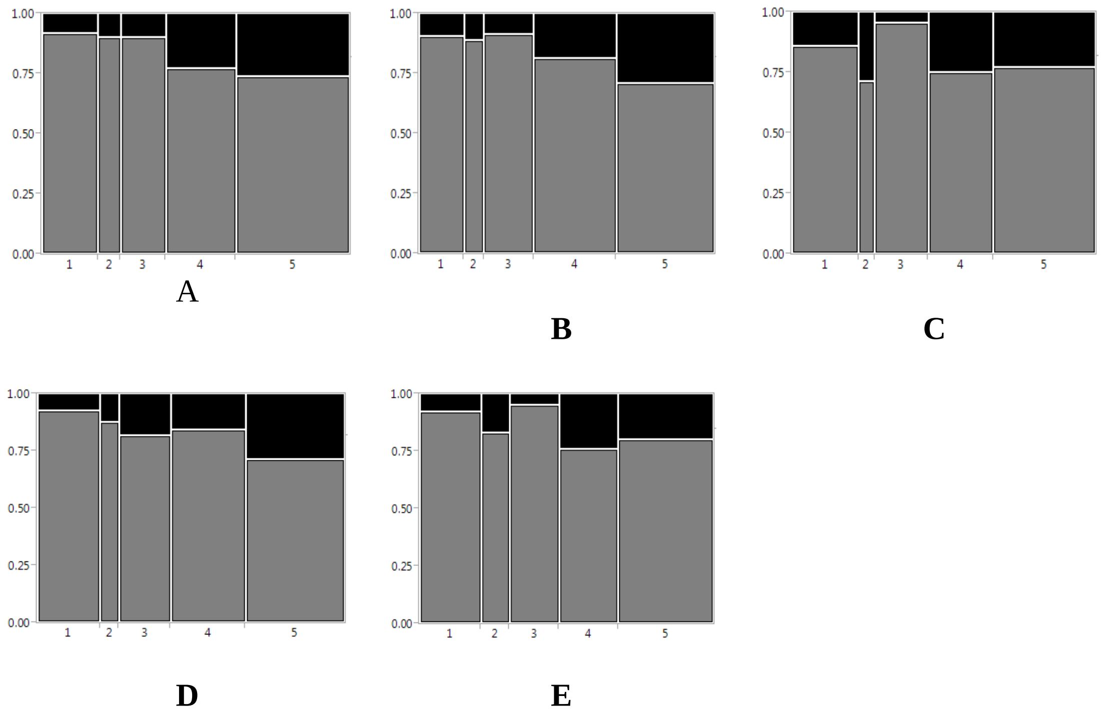

Figure 4.1. Panels represent mosaic plot of the different programs: A [management cost (federal)], B [management cost (state)], C [price support], D [hauling cost], and E [equipment cost]. For a given rating the vertical axis shows the proportion of respondents that have experience with public programs (upper part of the bar, black) relative to those that do not (bottom part of the bar, grey).

The responses corresponding to 4 (important) and 5 (very important), shown by the area in the two right-most columns, for all five programs show that the majority of the respondents rate the programs positively. Even for panels D and E, which directly benefit others in the supply chain, the area taken by 4 and 5 is big. The relative distribution of respondents that have recently enrolled in public programs compared to those that have not across the ordinal scale shows statistically significant pattern for management cost and hauling cost support programs. This result means that forestland owners with public program experience tend to rate the proposed programs as having greater importance than those without similar experience.

Table 4.3. Cochran-Armitage trend test results for the relative distribution of respondents across the ordinal scale.

Policy	**Cochran-Armitage trend statistic**
Federal cost share programs, for example, the type that covers part of the management cost incurred.	-2.21**
State cost share programs, for example, the type that cover part of the management cost incurred.	-2.19**
Price support for biomass program similar to what is available for other agricultural products.	-1.13
Biomass transportation cost support program to help cover hauling cost.	-2.13**
Capital support program such as the type that would help finance the cost of equipment purchased to harvest biomass.	-1.59

** Indicate significance at 0.05 α level.

Although both state and federal government sponsored programs that provide cost sharing opportunities are statistically significant, the federal government sponsored programs have a slightly higher coefficient compared to the state sponsored programs, meaning that the number of forestland owners with public program experience rate that rate it as being important is higher than those that rate the state level program as being important.

Programs dealing with management cost have a slightly higher coefficient compared to programs that deal with hauling costs. This may result from how management cost affects forestland owners more directly than hauling cost does. However, the significance of programs dealing with hauling cost, where more of the owners with public program experience consider it as important, suggests that forestland owners that use public programs also appreciate the importance of programs that benefit others in the supply chain. Even if forestland owners find supplying biomass for bioenergy economically viable or desirable for improving the productivity of forest stands, unless loggers and others along the supply chain cannot viably harvest the biomass, the forestland owner will not realize the economic and other opportunities from the harvest of biomass for bioenergy. Although forestland owners do not primarily benefit from such programs, those that have public program experience consider it important that others along the supply chain have programs that help cover costs. Such experience associates with rating potential programs that benefit them and others in the supply chain more positively than forestland owners without similar experience. More data is needed to determine if they are also more likely to enroll in these programs compared to forestland owners without similar experience, leading to fewer new enrollees at the margin.

We do not find a statistically significant trend for price support and equipment cost support programs, indicating that forestland owner having experience with public programs do not rate these programs in any particular pattern relative to those without experience.

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5 CONCLUSIONS, LIMITATIONS AND FUTURE WORK

5.1 Conclusions

a. Allocation of non-forested land to growing pine for bioenergy purposes

The results of the second chapter suggest that respondents' allocation of non-forested land for pine is affected by several factors that include socioeconomic attributes, forestland management objectives, forestland features, and prior experiences. Higher price offers, a preference for non-timber forest products such as evergreen boughs and grapevine, and lesser dependence on working the land for annual income all have a positive effect on the proportions of non-forested land that respondents are willing to allocate for pine. Prior experience in supplying biomass to pulp/paper industries and prior experience with state/federal financial/technical support programs have the opposite effect. The way some of these factors, such as acreage of existing forestland, affect respondents' land allocation decision for pine is not necessarily consistent with how they are known to affect the likelihood to supply biomass from existing stands. However, market price appears to affect both the allocation of land to pine and the likelihood of supplying pine for biofuel from existing stand. As such, the experience of having supplied wood for chip-n-saw mills in the past five years, large land holding, prior experience with state/federal financial/technical support programs, among other factors, lead to smaller proportion of non-forested land being allocated for pine. However, a higher price offer, stronger preference for producing non-timber forest products such as evergreen boughs and grapevine, and lesser dependence on working the land for annual income lead to larger proportion of non-forested land being allocate for pine.

Our results could assist policy makers in developing and improving land use and energy policies, certification programs, and extension and outreach services including programs such as the biomass crop assistance program (BCAP). Instead of being built around forestland owners' socioeconomic attributes, current land use makeup, forestland features such as stand makeup, and the respective threshold levels of such variables, the programs are designed around eligible feedstock type and land use. Considering the importance of these factors to forestland owners' land use and biomass production decisions, and thus, their reaction to the relevant incentive programs, tailoring the incentive programs to the said attributes and threshold values may be important. This may enhance the programs' ability to reach more forestland owners and affect their land use and biomass production decisions better. Other contributions of this research include the use of threshold analyses to delineate tipping points in variables associated with different response rates and showing the different effect of variables in terms of how they affect the supply of biomass and the supply of land for bioenergy purposes.

b. Residual biomass retention rate

The results of the third chapter suggest that factors such as how long respondents have owned the forestland, the way they acquired the forestland, acreage, and forestland ownership objectives, among others, affect decisions regarding how much biomass to leave unharvested. Specifically, the proportion of residual biomass forestland owners are willing to leave unharvested for environmental purposes is affected by multiple factors that include economic considerations such as dependence on working the land for yearly income, sensitivity to market price, forestland features such as acreage, forestland management objectives, and demographic factors such as household size, tenure, and manner of land acquisition.

Analyses of landowners' sustainability concerns indicate a clustering pattern, where concerns about sufficiency of best management practices and the potential implications of harvest decision on soil and water quality are among the statistical representatives of their respective clusters. Respondents believe that best management practice guidelines dealing with harvest rates of residual biomass for woody bioenergy exist and that they are sufficient. They are also of the opinion that, in general terms, the practice of harvesting residual biomass for bioenergy can be done sustainably. However, forestland owners still have concerns about specific potential impacts of the practice on soil and water quality, timber health and productivity. As such, we cannot conclusively establish if forestland owners have favorable views or concerns about the potential sustainability implications of harvesting residual biomass for bioenergy.

Respondents likely to engage in harvest practices that does not leave any residual biomass on ground have a preference for policies that help cover management cost. Decision makers administering or considering such policy proposals should be aware of the inadvertent effect such cost sharing arrangements can have in encouraging unsustainable practices and the potential need to couple the policies with extension and outreach programs.

c. Enrollment in public incentive programs

The results of the fourth chapter show that enrollment rates are low. No more than 13% of the respondents said they have recently enrolled in public programs. We find mixed results for land management objectives, socioeconomic attributes, and past activities in explaining likelihood to enroll in public programs. The results suggest that forestland owners who are less likely to enroll in such programs have relatively smaller forestland acreage, lower level of education, and shorter land ownership tenure. We also find that forestland owners with experience in public programs tend to rate potential programs, including those that do not directly benefit them, as more important than the forestland owners without such experience do. We also identify threshold values for explanatory variables such as acreage and tenure length. Forestland owners who are likely to engage in harvesting practice that does not leave any residual biomass unharvested show higher interest in policies that help cover management costs. Forestland owners that identify timber production as an important land management objective are more likely to enroll in such programs. The degree of importance placed on ‘enjoyment of privacy’ and ‘production of firewood for own use’ as land management objectives are not significant in explaining likelihood to enroll in public programs. Furthermore, while higher level of education, longer tenure, larger forestland acreage, acquiring the whole or part of the land by purchase, and membership in forestry or environmental associations significantly explained likelihood to enroll in public programs, gender, income, and absenteeism did not. Similarly, while building roads in the forested property and developing forest management plans significantly explain enrollment tendencies, removing invasive species and conducting wildlife habitat or fisheries improvement project are not significant. Having experience with public programs leads to a more favorable assessment of other potential programs. This result holds even for programs that primarily benefit others in the supply chain.

While such policy may help forestland owners reduce harvesting costs and allow them to take advantage of the emerging market for residual biomass, safeguards such as coupling the policy with educational programs may be needed to reduce the chances of inadvertently encouraging the complete harvest of residual biomass.

5.2 Limitations and future work

Given the specific state and tree species focus, the result may not necessarily apply to other states and tree species. Though the economic competitiveness of woody biofuels is assessed, the macroeconomic level, indirect multiplier effects, as well as and interaction impacts of the sector on other industries also need to be researched.

Regarding the land use change decisions of forestland owners, future studies can assess the direction and significance of the variables in other states and determine whether or not the thresholds are generalizable. There is also a need to quantify the biomass that results from such land use change, as well as assess how that change in land use and biomass reflects in the relevant market outcomes. Such studies can also quantify the indirect land use change effects at the regional and national scales, along with the resulting change in ecosystem services.

Future studies dealing with the biomass retention decision of forestland owners can identify if a longer list of specific versus generic sustainability concerns exhibit similar patterns of clustering and frequency distribution. Future research can also assess if the thresholds for partitioning variables and if their significance are generalizable for other states and for other feedstocks such as short rotation energy crops. Such studies can also estimate the resulting quantity and price of biomass from residual biomass harvest as well as simulate the resulting environmental impacts under various policy scenarios.

Instead of asking enrollment decisions in categorically public incentive programs, future studies can use specific public programs and assess if that specificity alters the direction and significance of variables. Future studies can also change the time frame of enrollment by comparing the recent enrollees with others that have not enrolled in such a program for more than five years or by assessing the determinants of longer enrollment durations compared to shorter enrollment durations. Future research can also assess the relevance of the results for other states or at regional levels. Such studies can also assess the composition of program enrollees based on having experience or being new to public programs; assess if forestland owners can suggest programs based on their needs instead of the program design being top-down; what changes they would like to see in the programs, eligibility requirement, or other program features.

Appendix: Summary of survey data

Forest management objectives	1	2	3	4	5
Land investment to generate profit	23.56%	14.90%	26.92%	12.50%	22.12%
For enjoyment of privacy	8.88%	3.74%	14.49%	19.63%	53.27%
To protect nature and biodiversity	7.18%	7.66%	17.23%	27.27%	40.67%
Enjoy natural beauty and scenery	4.72%	5.66%	8.02%	28.30%	53.30%
To pass land to my children or heirs	14.49%	14.02%	12.62%	15.89%	42.99%
Hunting and fishing	25.59%	15.17%	20.85%	14.22%	24.17%
Production and sale of timber products	32.21%	21.64%	18.27%	12.98%	14.90%
Produce non-timber forest products like evergreen boughs, grapevines.	69.71%	16.35%	10.10%	1.44%	2.40%
For production of firewood or biofuels for my own use	40.29%	18.45%	16.99%	12.62%	11.65%
For carbon sequestration payments that can be realized in the future	58.55%	16.58%	12.44%	6.74%	5.70%

Table A.1. respondents' forest management objectives

Motivations for supplying biomass for bioenergy	**1**	**2**	**3**	**4**	**5**
The price offered	13.40%	6.19%	12.89%	13.92%	53.61%
Risk associated with losing timber to	18.14%	13.99%	30.57%	18.65%	18.65%
Improvement in scenic and wildlife	13.78%	11.22%	29.59%	22.96%	22.45%
Contribution to improving energy security of the US	23.08%	8.21%	30.26%	22.56%	15.90%
Contribution to mitigating climate change problems	29.74%	10.77%	23.59%	20.00%	15.90%
My property is too small	38.25%	10.38%	23.50%	8.20%	19.67%

Table A.2. Respondents' motivations for supplying biomass for bioenergy

Educational interest	**No**	**Yes**
Where to get technical assistance (e.g. foresters)	32.96%	67.04%
Type of wood that can be used for energy production	36.87%	63.13%
Market conditions	29.05%	70.95%
Tax implications of biomass sale for energy	29.05%	70.95%
Who to contact for buying/selling of wood (e.g. contractors)	35.20%	64.80%
Impact of harvest on soil/water/recreation/fishing, etc.	40.22%	59.78%
Relevant rules, regulations and government programs	34.08%	65.92%
Forestry-related educational programs offered by university extension service	46.37%	53.63%

Table A.3. Respondents' educational interest

Past-planned forest management activities	Past		future	
	No	Yes	No	Yes
Clear-cutting	85.39%	14.61%	71.43%	25.71%
Partial cutting	65.68%	34.32%	36.74%	63.27%
Harvest fuel wood for sale or own use	58.24%	41.76%	45.26%	53.29%
Remove invasive plant species	67.44%	32.56%	47.58%	52.42%
Harvest/supply wood for saw log or	82.39%	17.61%	55.65%	44.36%
Harvest/supply wood for pulp/paper	80.35%	19.65%	55.20%	44.80%
Harvest/supply wood for chip-n-saw	87.65%	12.35%	60.00%	40.00%
Build or maintain roads	64.00%	36.00%	53.91%	46.09%
Develop a written forest management	81.87%	18.13%	60.80%	39.20%
Wildlife habitat/fisheries improvement	66.86%	33.14%	50.39%	49.61%

Table A.4. Respondents' past-planned forest management activities

Sustainability concerns	Not at all important ---------------Very important				
	1	2	3	4	5
Harvesting forest biomass will affect wildlife negatively	6.06%	27.27 %	39.90 %	18.18 %	8.59%
Harvesting forest biomass affects soil	5.58%	27.92	38.58	20.81	7.11%
Harvesting forest biomass will require	5.21%	15.10	29.69	38.54	11.46
Harvesting residual forest biomass	10.77	41.03	37.95	6.67%	3.59%
Not many landowners have harvested	2.62%	13.61	71.73	8.90%	3.14%
Development of forest biomass based	5.21%	38.02	47.40	6.25%	3.13%
There are sufficient state guidelines	4.66%	8.29%	62.69	20.21	4.15%
When harvesting biomass, soil and	4.59%	4.59%	42.86	38.78	9.18%

Table A.5. Respondents' sustainability concerns

Importance of incentive program in encouraging biomass supply	**Not at all important-----------very important**				
	1	**2**	**3**	**4**	**5**
Federal cost share programs, for example, the type that covers part of the management cost incurred.	18.57%	7.14%	14.29%	22.86%	37.14%
State cost share programs, for	15.11%	6.48	16.55	28.06	33.81%
Price support for biomass program	22.22%	5.19	17.04	21.48	34.07%
Biomass transportation cost	20.90%	5.97	16.42	24.63	32.09%
Capital support program such as	21.26%	9.45	16.54	20.47	32.28%

Table A.6. The importance respondents attach to potential incentive programs in encouraging biomass supply for bioenergy

Forestland features	**Mean**	**Std Dev**
Acreage	191.56	324.93
Number of parcels	3.03	2.83
How long land is owned	25.56	14.49
woodland acreage	121.13	245.92
cropland acreage	19.88	52.20
Pasture/grazing land	61.09	155.10
Other land use acreage	7.09	24.27
Pine	65.40	210.78
Hardwood	32.85	62.16
Pine and hardwood mix	45.38	77.93
planted loblolly pine	78.52	172.40
loblolly pine naturally seeded	17.88	56.47
planted slash pine	1.77	10.40
slash pine naturally established	7.03	19.04

Table A. 7. Respondents' forestland features

Socioeconomic attributes	**No**	**Yes**				
Member of an environmental/forestry association	89.14%	10.86%				
Gender	82.71%	17.29%				
		1	2	3	4	5
Ethnic group	Caucasian (1), Asian or Pacific Islander (2), Hispanic (3), African-American (4), other (5)	92.49%	0.94%	0.94%	4.70%	0.94%
Age	Younger than 30 (1), 31 to 40 (2), 41 to 50 (3), 51 to 65 (4), Older than 65	0.93%	1.86%	7.91%	47.91%	41.40%
Percentage of income generated from working land	none (1), <10% (2), 10-25% (3), 25-50% (4), >50%(5)	47.64%	35.85%	9.43%	3.77%	3.30%
		1	2	3	4	
Level of education	Elementary (1), high school (2), some college (3), and college graduate and above (4)	0.47%	19.25%	22.54%	57.75%	
Gross income	<$22,000 (1), $22,000 - $49,999 (2), $50,000 - $89,999 (3), >$90,000 (4)	4.57%	19.80%	27.41%	48.22%	

Table A.8 Respondents' Socioeconomic attributes