WOODY BIOMASS AVAILABILITY FOR ENERGY: A PERSPECTIVE FROM NON-INDUSTRIAL PRIVATE FOREST LANDOWNERS IN THE U.S. GREAT LAKES STATES

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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Abstract

Non-industrial private forest (NIPF) landowners control 58% of all forests in the U.S. Great Lakes States consisting of Michigan, Minnesota and Wisconsin. A regional assessment of the availability of woody biomass for bioenergy will therefore be incomprehensive without a consideration of supply from the most dominant ownership group. This study aimed to evaluate the social availability of woody biomass for renewable energy in the U.S. Great Lakes States by examining NIPF landowners' willingness-to-harvest (WTH) their woodlands. Following the Tailored Design Method, surveys were mailed to 4,190 NIPF landowners from Michigan, Minnesota and Wisconsin. Results identified two latent factors summarizing landowners' bioenergy perceptions: (a) bioenergy support and (b) environmental degradation and four latent factors behind woodland ownership: (a) amenity, (b) personal use, (c) production and (d) legacy. A two-step cluster analysis approach was used to construct a landowner typology for the region based on landowners' bioenergy views and reasons for woodland ownership. Four types of landowners were consequently identified: *recreationist, indifferent, preservationist* and *multiple-objective*. *Recreationists* were found to own the majority or 51% of the total woodlands reported by sample respondents and were also most willing to harvest their woodlands with an estimated 38% potentially available for timber harvest and 46% for biomass harvest. A comparison of WTH by landowner type and state revealed that the greatest level of acceptance as indicated by potential acreage availability were from *recreationists* owning NIPFs in Michigan. Binary logit regression models were also used to determine significant factors influencing landowners' WTH timber and woody biomass. Findings indicated that non-timber objectives decreased the

odds of harvesting and timber and biomass prices increased those odds. However, marginal probability effects of prices on WTH highlighted the substantial impact that timber price, rather than biomass price had on landowners' choice to harvest. These results suggested that the availability of woody biomass will be contingent upon timber prices.

Chapter 1. Introduction

The United States (U.S.) energy consumption in 2010 was estimated at 98 quadrillion British Thermal Units (Btu) while production was only 75 quadrillion Btu; a staggering 83% of the total consumption came from fossil fuels (coal, natural gas and petroleum) and only 8% from renewable energy consumption (U.S. Energy Information Administration [EIA] 2011). Consumption by the transportation sector alone was 28% of the total (other sector sources include industrial, residential and commercial, electric power) but 26 trillion Btu or 33% of this use was from fossil fuels (EIA 2011). The U.S. Government has recognized the need for displacing fossil fuels with renewable and domestically produced sources with the passage of Renewable Fuel Standards (RFS2) in the Energy Policy Act of 2007 that requires the production of 36 billion gallons of renewable fuels including 16 billion gallons of cellulosic biofuels derived from the conversion of biomass feedstocks by 2022 (P.L. 110-140; U.S. Environmental Protection Agency [EPA] 2010a). Currently biomass used for biofuel is largely sourced from agricultural feedstock but with a goal to achieve energy security, the continued use of this resource may conflict with food supplies (Skipper et al. 2009). Consequently, the combination of forest-derived biomass or woody biomass with agricultural feedstocks can tremendously increase supplies by acquiring feedstock from additional sources (Becker et al. 2009b).

The U.S. Forest Service (2008) has defined woody biomass as “the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the by-products of forest management". The utilization of woody biomass for energy provides a market for traditionally un-marketable materials like slash, debris and poorly formed trees left behind from a commercial timber harvest or removed as part of other forest management activities, including fire hazard reduction. Thus, biomass harvest can provide additional income opportunities to forest landowners and job prospects for local communities (Hall 1997). Also, unlike fossil fuels, woody biomass is a renewable source of energy that, under sound management, can be produced on a sustainable basis to provide a range of environmental benefits (Oregon Department of Forestry 2008; O'Laughlin 2010; Batuska 2010). For instance, harvesting forest biomass can reduce the emissions that would otherwise be released from wildfires in a dense forest stand; nitrogen oxide emissions and particulate matter are reduced by 64% and 97% respectively when non-merchantable forest thinnings are consumed in biomass power boilers instead of being burnt openly in the forest (Oregon Department of Forestry 2008). The use of woody biomass offers significant potential to contribute to the long-term permanent reduction in atmospheric greenhouse gas (GHG) emissions particularly carbon dioxide, compared to the continued use of fossil fuels owing to an on-going carbon cycle where regrowth and surrounding vegetation will absorb previously released carbon dioxide (O'Laughlin 2010).

According to a study sponsored by the U.S. Department of Energy (DOE), forestland and agricultural lands are the two largest potential sources of biomass, capable of supplying at least one billion dry tons per year and representing about 80% of the long-term resource potential (DOE, 2011). Considering that nonindustrial private forest (NIPF) landownership represents nearly 40% of all forestlands in the U.S. (Smith et al. 2009), the estimated availability of woody biomass is constrained by the social factors that need to be considered when evaluating the supply side of this resource. The potential to procure biomass feedstock from Michigan, Minnesota and Wisconsin is significant and even promising (Becker et al. 2009b) but several factors, including the extent of private forest ownership, pose similar constraints as those at the national level. NIPF landownership represents 48% or 25 million acres of all forestlands in the U.S. Great Lakes States consisting of Michigan, Minnesota and Wisconsin (Smith et al. 2009). Thus, in order to comprehensively examine the potential supply from this region, social availability must be addressed as one critical facet of woody biomass availability. According to Butler et al. (2010, p 151) social factors "determine the desirability of the potential goods and services and the propensity for those who control a resource, such as wood, to use it themselves, allow others to do so, or do nothing with it".

1.1. Study Aim and Objectives

This study aimed to evaluate the social availability of woody biomass for renewable energy in the U.S. Great Lakes States of Michigan, Minnesota and Wisconsin by examining NIPF landowners' willingness-to-harvest (WTH) their woodlands. Since landowners commonly refer to their forested property as woodlands (Butler 2011), this term was used synonymously with forests throughout this study. The findings from this research contribute to a better understanding of the complexity to estimating the availability of woody biomass for energy by considering the social factors that may influence NIPF landowners' decision to harvest. An evaluation and analysis of survey responses will allow for an examination of several land characteristics, landowner attributes and external factors that may influence their decision to harvest timber and woody biomass. The specific objectives for this thesis were to:

1. Describe land characteristics and landowner attributes such as acreage owned and demographics of NIPF landowners of the U.S. Great Lakes States and identify latent factors behind woodland ownership and landowners' views towards bioenergy from woody biomass.
2. Identify a typology for NIPF landowners of the U.S. Great Lakes States based on their ownership reasons and bioenergy views and determine timber and biomass harvesting preferences from each group.
3. Determine significant factors affecting NIPF landowners' WTH their woodlands and probability of harvesting timber and woody biomass at specific price offers.

1.2. Conceptual Framework

This research was motivated by a need to conduct a comprehensive estimation of woody biomass for bioenergy in the U.S. Great Lakes States by assessing the social availability of woody biomass from the most dominant ownership group in the region, NIPF landowners. Past studies (e.g. Kluender and Walkingstick 2000; Kendra and Hull 2005; Finley and Kittredge Jr. 2006; Ross-Davis and Broussard 2007; Majumdar et al. 2008) have demonstrated that NIPF landowners represent a diverse group of individuals with different ownership objectives, motivations and views towards forest management. Thus, it is expected that WTH would not be exhibited as a consensus but rather vary by different segments of landowners. Surveys administered to NIPF landowners of the U.S.

Great Lakes States served to gather information on landowners' woodland characteristics, forest management experience and future plans, cost share enrollment, bioenergy views, harvesting and price preferences, ownership objectives, public tax preferences and demographic attributes. Responses were analyzed to understand NIPF landowners within the context of the survey and identify WTH by groups of landowners sharing similar attitudes towards woodland ownership and bioenergy. Furthermore, numerous studies have demonstrated significant effects of most of these variables on landowners WTH timber and woody biomass. Row (1978) and Binkley (1981) found an increase in WTH timber to be associated with an increase in the number of acres owned and Kurtz and Lewis (1981) regarded physical resource availability as a potential constraint to participation in forest management. Road accessibility to forest property was hypothesized to decrease timber availability (Conway et al. 2003; Butler et al. 2010) and Conway et al. 2003 found that residence on woodlands and the increase in harvest price offers positively influenced NIPF landowners' choice to harvest timber. Vokoun et al. (2005) identified that an increase in the number of children in a household increased the probability of harvesting timber. On the other hand, an increase in age negatively affected both timber and woody biomass harvesting decisions (Becker et al. 2010; Joshi and Mehmood 2011; Gruchy et al. 2011). Education represents another demographic variable that was previously found to be a determinant of harvesting; an increase in education led to increasing probabilities of harvesting timber (Greene and Blatner 1986) and woody biomass (Becker et al. 2010; Joshi and Mehmood 2011; Gruchy et al. 2011). Other characteristics positively affecting landowners' harvesting decisions include having harvesting experience, increase in the number of years of forest ownership and cost share enrollment (Vokoun et al. 2005; Butler 2007). Additionally, the association between forest management objectives and harvesting decisions were also examined; timber and non-timber objectives were found to influence landowners' choice to harvest timber (e.g. Young and Reichenbach 1987; Bliss and Martin 1989; Vokoun et al. 2006) and woody biomass (Joshi and Mehmood 2011; Gruchy et al. 2011; G.C. and Mehmood 2012). The influence of bioenergy views on harvesting woody biomass have also been published (Becker et al. 2010; Markowski-Lindsay et al. 2012).

Based on past literature, the associated theoretical framework for this study was based upon the utility maximization and random utility theory where landowners will choose to harvest based on the utility received from doing so and therefore not harvest if this would not increase their utility. Thus, landowners' decisions to harvest their woodlands will be based on those factors that maximize their utility so the utility model can be summarized as:

$U_i = f\,(L, LO, E) + \varepsilon$

where U_i is the utility received by the *i*th landowner from harvesting (or not) their woodlands. L is a vector of land characteristics consisting of number of forested acres owned, volume of commercial timber representing physical availability and road accessibility, LO is a vector of landowner characteristics including residence on woodlands, land tenureship, bioenergy views, reasons for woodland ownership, harvesting experience and future plans to harvest, demographic information (age, education, income, number of children in household), organization membership and ownership of a forest management plan, E is representative of timber and biomass price offered and ε is a random error term. Consequently, this study assumed that landowners' WTH will likely be a function of L, LO and E; expressed as:

$$WTH = f\,(L, LO, E)$$

The literature review conducted to develop this framework is presented in Chapter 2. Chapter 3 explains the methods employed for carrying out this research, including the selection of counties for the study and survey development. The fourth chapter features a profile of respondents owning woodlands in the U.S. Great Lakes States, the latent factors behind woodland ownership and NIPF landowners' bioenergy views and a typology for the region. Chapter 5 examines the factors influencing NIPF landowners' WTH timber and woody biomass from their woodlands, their predicted probability of harvesting at various price offers and marginal effects of prices. The final (sixth) chapter serves to conclude this study and propose recommendations for future research. Additional figures and tables presenting descriptive statistics and comparisons with the National Woodland Owner Survey (NWOS) are included under Appendix A. The survey instrument used to gather information for analysis is presented under Appendix B.

Chapter 2. Literature Review

2.1. Forest Resources of Michigan, Minnesota and Wisconsin

Timberland is defined as "forest land, excluding reserved forests that is producing or capable of producing in excess of 20 cubic feet (ft^3) per acre per year of wood at culmination of mean annual increment" (U.S. Forest Service 2006). This production capability differentiates timberland from other forestlands that have lower productivity due to adverse growing conditions or other site conditions that do not support timber production above 20 ft^3 (U.S. Forest Service 2006). Timberlands therefore include those forestlands that are not reserved from harvest and can most likely be managed for sustainable production of commercial timber. Forests occupy 19.5 million acres or 54% of the land base in Michigan, 16.4 million acres or 32% of land base in Minnesota and 16.3 million acres or 47% of Wisconsin's total land base (Smith et al. 2009). Nearly half or 49% of productive forests or timberland in the three states combined is owned by NIPF landowners; 9.4 of 19 million acres in Michigan, 5.8 of 15 million acres in Minnesota and 9.6 of 16 million acres in Wisconsin (Smith et al. 2009). Average annual net growth of wood on Michigan, Minnesota and Wisconsin timberlands is 750.2 million cubic feet, 409.3 million cubic feet and 637.6 million cubic feet for trees at least 5 inches diameter at breast height [d.b.h.], respectively (Miles 2012). Meanwhile, average annual removals total 357.5 million cubic feet, 271.3 million cubic feet and 352.4 million of live trees on Michigan, Minnesota and Wisconsin's timberlands respectively (Miles 2012). Consequently, unutilized wood volume equates to 52% of the annual growth in Michigan, 34% for Minnesota and 45% for Wisconsin timberlands. The Lake States therefore exhibit a national trend of growth that significantly exceeds harvest resulting in increased timber inventory over the years but this also presents an opportunity for sourcing biomass feedstocks that are not being utilized by other industries.

A subset of total estimates representing only private timberlands, account for the majority of growth and associated removals: 69% of the average net growth of live trees and 64% of the removals for Michigan, 60% of net growth and 58% of the removals for Minnesota and 60% of annual net growth and 69% of removals for Wisconsin. Thus, physical estimates of growth on private timberlands demonstrate the capacity for procuring woody biomass feedstock from both the harvesting debris of trees annually removed and materials from the additional volume that can be potentially harvested. Becker et al. (2009a) estimated that there are nearly seven million dry tons of additional biomass from public and private lands in the region that could be used for energy production and not interfere with pulp and paper production. Additionally, there is room for an increase in timber production that can generate more feedstock since a significant portion of the growing stock in is not currently being utilized. Actual availability is inevitably constrained by a number of factors; considering only price offered it is projected that 4.1 million dry tons of biomass could be available at a price of $36 per dry ton (Becker at al. 2009b).

2.2. Physical Availability of Woody Biomass

Forests cover about 33% or 751 acres of land in the United States and of this total 514 million acres are classified as timberland, 75 million acres are deemed reserved for non-timber uses and 162 million acres fall other the category of other forestlands that are not harvested but are crucial for providing watershed services, wildlife habitat and other vital forest values (Perlack et al. 2005; Smith et al. 2009). About 56% of the total acreage of forestlands is under private ownership but most of this, about two-thirds accounting for nearly 40% of all forestlands or 285 million acres is owned by non-industrial private landowners (NIPF) (Smith et al. 2009). Private lands account for 355 million acres or 69% of all timberland while 49% of U.S. timberlands are owned only by NIPF landowners (Smith et al. 2009).

Perlack et al. (2005) determined that an estimated total of 278 million dry tons (short tons) of forestland-derived biomass can be extracted from the conterminous U.S. on an annual basis. A more recent study by the DOE (2011) estimated that an increased value, up to 370 million dry tons (short tons) of forestland-derived biomass can be available under conditions of high-yield and extensive establishment of perennial grasses and tree crops. While a myriad of factors will inevitably affect the amount of biomass actually available for bioenergy, biomass derived directly from forests, from logging, site clearing operations and fuel treatments represent the largest biomass feedstock source (DOE 2011). Furthermore, since forest growth on timberland has been exceeding harvest since the 1950's (Smith et al. 2009), there is tremendous potential for sourcing biomass from forests. The volume of timber removed from forests is indicative of forest health and sustainability. Removals that exceed net growth may suggest that timberlands are being over-harvested which will pose a threat to the sustainability or perpetuity of forest resources while removals that are much lower than growth may imply that forests are overstocked and as such vulnerable to insect and disease outbreaks, wildfires and an overall decline in forest health (Munsell and Germain 2007). According to Shifley (2006), there should be a balance between harvest and consumption at the national level for achieving globally sustainable forests. Harvest inventories indicate that the U.S. does not meet sustainability standards from a global perspective since forest growth exceeds harvest nationally and forest per capita surpasses the global average even though the country is a net importer of wood (Shifley 2006). For instance, estimates from the year 1996 indicate that only 1% or 15.5 billion cubic feet of the growing stock inventory was harvested (Smith et al. 2009). Notably 92% of the total removals came from NIPF and other privately owned forests (Smith et al. 2009). Thus, under-utilized forest resources can contribute a sizable amount of woody biomass for conversion to biofuels.

2.3. Legislation Promoting the Use of Woody Biomass for Renewable Energy

2.3.1. Biomass Policy Instruments

Various public policies and standards have been developed to encourage and promote the sustainable development of a bio-based energy industry. A recent step towards the promotion of research and development of biomass for energy and specifically to promote the production of liquid vehicle fuels is the Biomass Research and Development Act of 2000 (P.L. 106–224 2000) which was later amended by the Food, Conservation and Energy Act of 2008 (P.L. 110-246 2008). This Act outlines the economic and environmental benefits in accordance with national interests and specifies the need to develop efficient conversion technologies for cellulosic biomass and other types of feedstocks that would help meet future energy needs (P.L. 106–224 2000). The Biomass Research and Development Act also facilitated the establishment of the Biomass

Research and Development (R&D) Board that serves to "maximize the benefits deriving from Federal grants and assistance and bring coherence to Federal strategic planning" (P.L. 106–224 2000). A Biomass R&D Technical Advisory Committee also established in the year 2000 provides input to the board and is guided by the same goals as the Biomass R&D Board while the DOE and U.S. Department of Agriculture (USDA) provide the funding for operations carried out by the board and committee (P.L. 110-246 2008). These departments along with the Environmental Protection Agency provide technical support in areas of biofuels and bio-based products development, feedstocks development and biofuels development and analysis where the latter is concerned with addressing sustainability, environmental impact and assessment of potential federal land to increase biomass feedstock production (P.L. 110-246 2008).

The Biomass R&D technical advisory committee created a Vision for Bioenergy and Biobased Products for the U.S. in 2002 and this was updated and approved in 2006 by both Biomass R&D technical advisory committee and Biomass R&D Board with goals and targets geared towards achieving a well-established bio-based and bioenergy industry by 2030 (Biomass Research and Development Initiative [BR&Di] 2006). One of the vision goals targeted for the year 2030 included the production of 20% of the transportation fuels consumption from biomass or a projected equivalent of 85 billion gallons of ethanol (BR&Di 2006). The Healthy Forest Restoration Act of 2003 is an example of one law that encourages the removal of woody biomass from forests to reduce hazardous fuel and restore forest ecosystems while at the same time encouraging the creation of market incentives for using the removed materials for energy production (P.L. 108–148 2003).

A mandate for seeking proposals for development of cellulosic biorefinery demonstration projects was endorsed in the Energy Policy Act of 2005 (P.L. 109-58 2005) and this has resulted in several integrated biorefinery (IBR) projects, some of which can be found in Michigan and Wisconsin (DOE 2012). One commercial-scale project set up in Michigan and one commercial-scale and one demonstration-scale project deployed in Wisconsin use forest residues as their primary feedstock for producing biofuels (DOE 2012). While pilot-scale projects serve to validate the use of conversion technologies and produce a minimum of 50 dry metric tons (mt) of feedstock daily, commercial-scale projects are designed to utilize 700 mt of feedstock daily to produce biofuels, biopower and bioproducts (DOE 2012). These IBR projects are part of the Biomass Program supported by the DOE. The Biomass Program works closely with the previously discussed Biomass R&D board, DOE and other federal agencies to accomplish the "Biomass Program Multi-Year Program Plan" (DOE 2010). This plan seeks to develop cost-competitive biomass technology for producing high performance fuels including cellulosic ethanol from biomass while working towards meeting the goals set out by the DOE Strategic Plan and U.S. Energy Independence and Security Act (EISA) of 2007.

EISA of 2007 revised the Renewable Fuel Standard (RFS) that was first established by the Energy Policy Act of 2005 that required 250 million gallons of fuel from cellulosic ethanol by 2013 (P.L. 109-58 2005). The new Renewable Fuel Standard (RFS2) now requires 1 billion gallons of cellulosic biofuel by 2013 and a total amount of renewable fuel of 36 billion gallons by 2022 that includes 16 billion gallons from cellulosic biofuels (P.L. 110-140 2007).

2.3.2. USDA Biomass Crop Assistance Program

The Biomass Crop Assistance Program (BCAP) was established by the Food, Conservation and Energy Act of 2008 (2008 Farm Bill) under the USDA (P.L. 110-246 2008). Funding was allocated for BCAP from its initiation in 2008 and continued until the program's expiration in 2012 (U.S. Senate Committee on Agriculture, Nutrition and Forestry 2012). BCAP provided financial assistance for landowners who established, harvested, stored and transported eligible materials to be used for energy. While subjected to funding availability, financial assistance included matching payments to eligible owners at a rate of $1 for every $1 per dry ton paid by a qualified biomass conversion facility for a maximum amount of $45 per dry ton and for a total period of two years (USDA 2010). Eligible materials included by-products from forest harvesting, restoration and other forest management activities as well as certain types of renewable organic matter such as wood residues, non-edible food processing wastes and grasses (Farm Service Agency 2009). The BCAP program served to enhance the economic feasibility of harvesting woody biomass to consequently increase the availability and supply for supporting a bioenergy market. The program implemented sustainability standards by allowing only biomass feedstock that was harvested in compliance with sound management and practice of good land stewardship. Additionally, existing markets such as paper and pulpwood were protected since materials that were used for pre-existing markets did not qualify for assistance through BCAP.

2.3.3. State Initiatives

Mandatory Renewable Portfolio Standards (RPS) have been introduced in 31 U.S. states (Aguilar and Saunders 2010). The passage of RPS in the U.S. Great Lakes States is an important driving force for the development of a bioenergy market from woody biomass. Michigan, Minnesota and Wisconsin have each implemented RPS that state woody biomass as an eligible feedstock with considerable potential for energy production. Michigan's RPS was established in 2008 and requires electric companies to provide at least 10% of their electric sales from renewable sources by 2015 (Public Service Commission of Michigan 2011). Wisconsin created a similar target of 10% by the year 2015 while Minnesota included one renewable standard that requires an energy provider, Xcel Energy, to supply 30% of their energy from renewable sources by the year 2020 and then a separate RPS for other utilities to generate 25% by the year 2025 (DSIRE 2011a; DSIRE 2011b).

The passage of various state legislatures and development of biomass initiatives have fostered growth in bioenergy research from woody biomass. The Minnesota Next Generation Act of 2007 sets a target to meet its energy production from renewable sources to 25% of by the year 2025 (Minnesota House of Representatives 2011). The Minnesota Department of Natural Resources (Minnesota DNR) also developed its own Biomass Program that functions to provide up-to-date information on biomass resources, facilities, incentives, harvesting guidelines and other relevant information to enhance outreach and promote participation and development of a viable energy market from woody biomass (Minnesota DNR 2011).

Through $1.4 million in funding from the United States Department of Energy, the Michigan Economic Development Corporation created the Forestry Biofuel Statewide Collaborative Center (FBSCC) in 2009 that serves to boost Michigan's research on biofuels specifically from woody biomass and increase resource supplies (LaCourt et al. 2011; Mueller et al. 2011). Wisconsin also created its own Bioenergy Initiative in 2007 (University of Wisconsin-Madison 2012). The Wisconsin Bioenergy Initiative was created by the University of Wisconsin-Madison to conduct research that would help create and promote a viable bio-industry for the state (University of Wisconsin-Madison 2012). Additionally Wisconsin enacted a Woody Biomass and Harvesting Tax credit (personal tax credit) in 2010 that allows individual taxpayers to claim a tax credit from income of 10% of the cost of equipment used to harvest or process woody biomass for fuel usage or a component of fuel (State of Wisconsin 2010).

2.4. Woody Biomass Harvesting Guidelines

Regardless of the forest resource being utilized or extracted, guidelines must be put in place to ensure its sustainability and prevent degradation of the forest ecosystem and its services such as carbon storage, watershed resources, aesthetics and habitat for wildlife. Although many states have implemented timber harvesting guidelines to reduce the environmental impacts from forest harvesting, these may not be sufficient to cover the impacts from woody biomass harvests (Janowiak and Webster 2010). An example may be the cutting limits that are set by some guidelines or the way in which coarse woody debris (CWD) are addressed since the latter may be extracted in woody biomass harvests. As the bioenergy industry for woody biomass continues to grow, woody biomass harvesting guidelines in collaboration with forest management guidelines will represent an indispensable component of ensuring sustainable production of biomass resources. Biomass harvesting guidelines have been developed in Michigan, Minnesota and Wisconsin to minimize the potential negative environmental impacts of woody biomass removal (Minnesota Forest Resources Council [MFRC] 2007; Michigan Department of Natural Resources and Environment [DNRE] 2010b; Wisconsin Council on Forestry 2008).

Minnesota was the first state in the region to adopt Biomass Harvesting Guidelines. These guidelines were completed in 2007 by the MFRC and approved by the Minnesota DNR as part of the state's legislation for energy production (MFRC 2007). Guidelines for forest management sites have been dealt with separately from those developed for brushlands and openlands. The Biomass Harvesting Guidelines for forest management sites indicate that biomass for utilization includes tops and limbs of trees from roundwood harvesting, non-merchantable vegetation such as small diameter trees and other dead woody materials and brush (MFRC 2007). These guidelines provide safeguards to minimize environmental damage during the collection and removal process of woody biomass harvests (MFRC 2007).

Issues addressed in Minnesota's guidelines include the potential impacts on biodiversity, water quality, riparian zones, soil productivity as well as harvesting on sites deemed sensitive for the presence of "endangered, threatened and special concern species (ETS), sensitive plant communities or cultural resource" (MFRC 2007). Some of the guidelines include a maintaining a 25-feet distance from dry wash banks, retaining about one-third of fine woody debris (FWD) on harvested sites, leaving 20% of harvesting brush, small trees, tops and branches that were leftover from previous timber harvest and avoiding erosion prone slopes greater than or equal to 35% (MFRC 2007).

Michigan follows similar guidelines in their Woody Biomass Harvesting Guidance (Michigan DNRE 2010b). The Michigan Woody Biomass Harvesting Guidance (WBHG) was developed by a group consisting of personnel from Michigan the DNRE and stakeholders. The final document was approved in 2010 by the chief of the Forest Management Division of the Michigan DNRE (Michigan DNRE 2010b). Although voluntary and not included in any state legislature, Michigan's WBHG have generally been adopted by certification programs supporting sustainable management practices (Michigan DNRE 2010a). Michigan's WBHG was designed to be used in compliance with Michigan's existing federal and state statues and Best Management Practices (BMPs) (Michigan DNRE 2010a). Michigan's WBHG relies on the same principle as Minnesota's harvesting guidelines, that is, to ensure sustainable production of forest resources. Retaining one-sixth or one-third of harvested tree residues is advised in Michigan's WBGH along with guidelines for various sites such as riparian zones and shallow soils with examples that show how the guidelines can be modified and implemented to ensure the benefits of sustainable management (Michigan DNRE 2010b).

Wisconsin’s Forestland Woody Biomass Harvesting Guidelines were approved by the Wisconsin Council on Forestry in 2008 after receiving technical support from the Wisconsin Department of Natural Resources (WDNR) staff, stakeholder review by an advisory committee and comments from the public (Wisconsin Council on Forestry 2008). Similar to Michigan’s guidance, Wisconsin’s recommendations are voluntary but are important for the sustainability of woody biomass and other resources that may be affected by its removal. The document is also one that must be used in conjunction with other forest management manuals such as BMPs. Michigan, Minnesota and Wisconsin all recommend leaving forest floor litter and root systems.

2.5. Social Dimensions of Woody Biomass Availability

According to Butler (2008) about 423 million acres of forestland are under private ownership. Family forests are defined as “lands that are at least 1 acre in size, 10% stocked and owned by individuals, married couples from estates and trusts or other groups of individuals who are not incorporated or otherwise associated as a legal entity” (Butler and Leatherberry 2004). Family forest ownership is a constituent of the group referred to as nonindustrial private forest (NIPF) owners that are differentiated from other types of private landowners (e.g. industry owners) for the absence of ownership and operation of a primary wood-processing facility (Butler 2008). NIPF landownership represents the most dominant ownership group of forests in the U.S., including productive forests. In the U.S. Great Lakes States, NIPF landowners alone, own nearly half of all productive forestlands in the three states combined and are consequently responsible for providing important public benefits such as carbon storage, aesthetics and watershed services along with important economic opportunities. The extent of privately owned forests in the U.S. and specifically the U.S. Great Lakes States therefore translates to a potential for landowners to collectively impact forest ecosystems and influence the supply of goods and services (Butler et al. 2007). For instance, Butler et al. (2010) revealed that social constraints, specifically owners' attitudes and parcel size reduced wood availability from family forest owners in the northern U.S. by 60% compared to an 8% cumulative reduction from biophysical constraints such as slope. Furthermore, financial incentives may constitute only a minor contribution to forest management decisions rather than being the main driver as one would expect. D'Amato et al. (2010) examined the influence of various financial incentives that can encourage forest management and found that despite the potential for timber management combined with a tax program and conservation easement to reduce the burden of property taxes, enrollment in these programs are low due to eligibility requirements, non-timber objectives and lack of awareness of these resources (D'Amato et al. 2010). Similar barriers of adoption may be foreseen for a bioenergy market if effective policies are not developed and periodically revised to promote production from NIPFs. This was demonstrated in previous studies, where even though 40 states have introduced financial incentives for encouraging sustainable use of woody biomass for bioenergy (Aguilar and Saunders 2010), landowners seem to be unfamiliar and skeptical over the use of woody biomass to generate energy (Joshi and Mehmood 2011; Monroe and Oxarart 2011).

Landowners' decision to engage in any forest management activity including biomass harvesting would represent a reflection of their ownership objectives, motivations and constraints (Kurtz and Lewis 1981). Consequently, the absence of knowledge of the utilization of woody biomass for energy or unfamiliarity about financial incentives would represent personal constraints that may result in the reluctance to harvest woody biomass.

2.5.1. Ownership Trends and Potential Constraints Affecting Woody Biomass Availability

Fragmentation of private forestlands in the U.S. or the loss of forest to development has been identified as a major challenge affecting forests (Smith et al. 2009). Forestlands are on the verge of being further modified where there is projected net decrease of forestlands by approximately 23 million acres between 1997 and 2050 (Alig et al. 2003). Timberland area specifically is also expected to decrease by 4% by the year 2040 and this will most likely take place by private land owners from the conversion of forestlands to developed uses (Erickson et al. 2002). To further complicate the issue of fragmentation, there has been an increase in NIPF ownership that does not equate to new forest lands being purchased but rather a subdivision or parcelization of the forest into smaller tracts of forest lands resulting in a decrease in holding size but still an increase in landowners (Butler and Leatherberry 2004). The number of family forest owners increased from 9.3 million in 1993 to 10.3 million in 2003 (11%) (Butler and Leatherberry 2004). An estimated 6.2 million or 61% of family forest owners in the United States owned less than 10 acres of forest land in the year 2006 (Butler 2008). Factors that have been attributed to the increasing trend of parcelization include personal constraints such as the age of landowners, changing lifestyles and taxes including property, income and estate taxes (MFRC 2010). Parcelized forestlands poses a greater challenge for sustainable forest management as new landowners will possess different management objectives and motivations as well as resources to invest in forest management activities (D'Amato et al. 2010). Furthermore, previous studies have demonstrated that due to economies of scale, landowners owning less than 20 acres are less likely to participate in forest management (Row 1978; Butler and Leatherberry 2004) such as timber harvesting or seeking advice from public agencies, if they decide to modify current land-use. Also, Butler and Leatherberry (2004) reported that new landowners of smaller parcels will be less aware of the necessity of sound forest management. The average parcel size at the national level is 25 acres (Butler 2008).

Developed areas in Michigan, Minnesota and Wisconsin increased by 0.8 million acres, 0.5 million acres and 0.4 million acres respectively from 1982 to 1997 (Alig et al. 2003). Meanwhile forestlands in the region decreased by 3.2 million acres from the 1950's to 1997 and 4.6 million acres of forestland in the region is expected to be lost by the year 2030 (Alig et al., 2003; Mauldin et al. 1999). Forestlands in Michigan alone is projected to decline by 1.4 million acres by 2050 and 93% of this estimate is from NIPFs; Minnesota, 1.0 million acres of forest loss is projected by 2050 with 60% of this decline on NIPFs and Wisconsin, 2.2 million acres of forest loss is projected with 64% of loss coming from its NIPFs (Mauldin et al. 1999). Given that forest management decisions can be viewed as an expression of landowners' beliefs, motivations and attitudes toward their land (Kurtz and Lewis 1981; Butler et al. 2007) it is important to examine these factors and others that may affect landowner management objectives. This understanding will help determine how landowners may contribute to the projected changes to forestland that can affect both the physical and social availability of woody biomass feedstock and thus the supply of this resource.

In the state of Michigan, an estimated 498,000 individuals own about 11 million acres of NIPFs with a mean holding size of 20 acres (Butler 2008; Butler and Ma 2011). A glance at family forest ownership shows that nearly 8.9 million acres of forestlands contribute to this ownership group amounting to 88% of NIPF ownership and 80% of the private ownership category (Butler 2008). Michigan's forests are at risk of becoming increasingly fragmented as populations increase and parcel sizes are also being reduced (Leefers et al. 2007). The mean parcel size for the state, by itself, presents a challenge for encouraging active forest management among NIPF owners. Erickson et al. (2002) found that Michigan NIPF landowners cite non-timber values such as aesthetics and environmental protection as the most important reasons for land ownership.

Parcelization has been identified as a top concern for the state of Minnesota and one affecting the sustainability of its forests (MFRC 2010). Statewide 202, 000 NIPF landowners own 6.5 million acres of forestlands (Butler, 2008). The mean parcel size owned by NIPF landowners decreased from 57 acres in the 1980's (Carpenter at al. 1986) to 48 acres in 2005 (Donnay et al. 2005) while the average size of parcels sold decreased from 72 acres in 1989 to 57 acres in 2002 (Kilgore and MacKay 2007). Significant changes to ownership are also noteworthy where an estimated 5.4 million acres of forestland in Minnesota are owned by 194,000 family forest owners or 96% of all NIPF landowners and 15% of these owners have changed between the years of 2005 to 2010 (Butler 2008; MFRC 2010). New landowners translate to different ownership objectives and attitudes. Changes to forest ownership, increase in land values other than those that include traditional forest management and federal tax changes have encouraged the trend toward parcelization and conversion to other types of land-use (Donnay et al. 2005). Median forestland prices increased by 13% from 1989 to 2003 (Kilgore and MacKay 2007) indicating that landowners may be more inclined to sell their forestlands rather than continue to own them (Donnay et al. 2005). NIPF landowners who have kept their forestlands and new landowners purchasing the same have largely indicated recreation as their primary reason for ownership; this is a growing trend in the region (Donnay et al. 2005). As with other parts of the U.S., Minnesota's NIPF landowners are indicating non-timber uses as important reasons for owning land such as aesthetics and privacy (Butler 2008).

An estimated 10.4 million acres of Wisconsin's forestlands are under NIPF ownership and family forest owners, a total of 352,000 individuals, hold the majority of this acreage; an estimated 87% (Butler 2008). A population increase of 14.8% or by 725,702 individuals from 1990 to 2008 in Wisconsin resulted in an increase in the interest of owning woodland for recreational uses which in turn raised the sale price of forestlands (Wisconsin DNR 2012b). The average forestland values for the state increased from $311 per acre in the year 1993 to $2,438 in 2010 (Wisconsin DNR 2012b). This increase in forestland values escalated a trend of forest parcelization where many landowners chose to divest their holdings rather than to invest in forest management. As a result, there was a 68% change (positive) from 1997 to 2006 in the number of forest landowners owning less than 20 acres (Wisconsin DNR 2012b). Additionally, an increasingly number of owners are “absentee, wealthier and less engaged in managing their forests” (Willyard and Tikalsky 2006, p.2). Wisconsin’s NIPF landowners in this state also expressed an interest in non-timber objectives particularly beauty and recreation (hunting and fishing) (Butler 2008).

Chapter 3. Methods

Research methods first involved the selection of counties from Michigan, Minnesota and Wisconsin to be included in a forest landowner survey. This was done randomly from a list of eligible counties where eligibility was determined based on the physical availability of forest resources. A mailing database consisting of 4,190 landowners was subsequently developed. A survey developed for the region was then pre-tested among a sample of respondents randomly chosen from the database and deployed following Dillman's Tailored Design Method (Dillman 2000) from February to March, 2012. Responses were entered, physical availability estimates were incorporated and data were analyzed in accordance with research objectives. The following sections describe each step in greater detail.

3.1. County Selection and Data Collection

The study area consisted of Michigan, Minnesota and Wisconsin. A mail-based survey was chosen to gather data for meeting the objectives of the study due to the cost effectiveness of this option versus an online survey. A list of counties with a considerable amount of total tree biomass on private lands from each state was developed, so that a random selection of eligible counties to potentially participate in the survey could then be made. This was an important consideration so that a reasonable sample of private landowners owning forests could be derived. An ad hoc value of 7 million dry tons of total tree biomass on private forests was the minimum quantity target for considering counties to be included. The U.S. Forest Service's Forest Inventory and Analysis (FIA) data and tools in AcrMap were used to select counties based on this criterion. Eight counties from each state were than randomly selected using a randomization tool in Microsoft Excel for a total of twenty-four counties for potential participation in the survey (Table 3.1).

Table 3.1. List of counties randomly selected for potential participation in U.S. Great Lakes States landowner survey.

Michigan	Minnesota	Wisconsin
Houghton	St. Louis	Ashland
Antrim	Beltrami	Iron
Dickinson	Itasca	Burnett
Chippewa	Aitkin	Chippewa
Otsego	Ottertail	Menominee
Newaygo	Pine	Sauk
Keweenaw	Houston	Crawford
Kent	Winona	Grant

An e-mail was sent to each of the above county's tax assessor requesting the name, mailing address, acres owned and assessed value of forest property for those landowners owning more than 20 acres of forest. Twenty acres was used as the minimum number of acres owned for inclusion in the study since landowners owning less than 20 acres are considered less likely to engage in forest management practices (Row 1978; Butler and Leatherberry 2004). Each county's tax assessor was also contacted via phone to follow-up on email requests. The procedure used to develop the final mailing database varied by state and also county due to the availability of the information requested and the format in which it was received.

A forest landowner database for Michigan was not readily available from tax roll data or local governments so various sources were sought develop a mailing list for this state. Michigan Commercial Forest (CF) Program offers a property tax reduction to enrolled landowners who are required to “retain and manage their forestland for long term timber production” (Michigan DNRE 2011). A list of landowners enrolled in Michigan Commercial Forest were obtained from the department’s website for Houghton, Dickinson, Chippewa and Otsego counties after contacting each county assessor to inquiry about the availability of other options including use of a geographic information system (GIS) database for acquiring the data. Following data collection for these counties, 127 landowners were listed for Houghton County, 58 landowners for Dickinson County, 15 forest landowners for Chippewa County and 11 landowners for Otsego County. A list of forest landowners was sent by Keweenaw County’s tax assessor and after summarizing the data using Microsoft Structured Query Language (SQL) Server 2008 Management Studio Express to manage for duplicated names, 240 landowners were listed as potential survey participants. Additional landowner information was derived from the CF list for the county resulting in a mailing database of 250 landowners for Keweenaw County. A list of landowners owning agricultural land was requested for Antrim County, Newaygo County, Kent County since a GIS database was available on each county’s website. Using a list of parcels (with acreage information) classified as agricultural lands for Antrim County, parcel searches were carried out to view each parcel on an aerial map to estimate which ones were at least 20 acres (Antrim County Community Center 2011). At the end of this process, 105 landowners were listed. Additional landowners were obtained from the CF listing for Antrim County, resulting in a total of 129 landowners (name, address and acres of forest owned) for the county. This procedure was also followed for Kent County (Kent County, MI 2011) resulting in a total of 129 potential survey participants listed from visual inspection and from the CF listing for the county. A list of landowners owning at least 20 acres of forested agricultural parcels for Antrim County was sent by the county's land use educator; 250 landowners were randomly chosen from this list.

Based on responses from Minnesota county assessors, data were sought from a combination of tax data and state programs for forest landowners. Landowners enrolled in the Sustainable Forest Incentive Act (SFIA) receive incentive payments for the sustainable management of their forestlands. This program is administered by the Minnesota Department of Revenue (St. Louis County 2012). Landowners' information was derived from the SFIA for Beltrami, Ottertail, Houston and Pine Counties in Microsoft Excel Format. A list of forest landowners was bought from St. Louis County, Aitkin and Winona Counties for $310.01, $50 and $25 respectively while list a of forest landowners for Itasca County was sent free-of-charge by the county assessor. A random selection of landowners was done for Aitkin, Houston, Itasca and St. Louis counties since there were more than 250 forest landowners available for these counties. There were 56 landowners listed for Beltrami County, 198 for Ottertail County, 190 landowners for Pine County and 15 for Winona.

Wisconsin's tax assessment codes include designations for productive forest lands and agricultural forest and forestry codes for landowners enrolled in Wisconsin's Managed Forest Law (MFL) and Forest Crop Law (FCL). Both programs encourage landowners to manage their woodlands in a sustainable manner in exchange for lowered property taxes (Wisconsin DNR 2012a). Consequently, tax roll data provided the information necessary to develop a mailing list of forest landowners for Wisconsin counties. Tax roll data were sent by county assessors from Ashland County, Crawford County, Grant County, and Iron and Sauk Counties upon purchase payments of $50 to each county. The data were sent in either text or Microsoft Excel format, but the final mailing list was prepared in Microsoft Excel for consistency. Microsoft SQL Server 2008 Management Studio Express was used to execute a series of T-SQL queries to filter, group and summarize tax data by landowner so that each landowner's name appeared once in the listing and only those landowners owning parcel sizes at least 20 acres were retained. A sample of 250 landowners (names, addresses, acres, and assessed values) per county was then randomly selected as potential survey participants. Data for Burnett and Chippewa counties was available on the county's website; a Geographic Information Web Server was utilized to retrieve assessment records for Burnett County (Burnett County, WI 2011) and a parcel search of landowners owning forest land using landowners names sent by the tax assessor, was carried out for Chippewa County (Chippewa County, WI 2011). In order to obtain additional names to meet the 250 target, queries were also submitted for landowners owning agricultural forest and also for landowners enrolled in MFL. A list of forest landowners from Menominee County were sent by the county's tax assessor. Menominee has a small tax base as most of the forested areas are part of the Menominee Indian Reservation that is managed by Menominee Tribal Enterprises. After compilation, there were 14 landowners listed for Menominee County and 250 landowners were listed for every other included Wisconsin county.

3.2. Survey Instrument

A survey devised by Daniel (2012) for Missouri NIPF landowners was used as an initial template for the development of questionnaires for the U.S. Great Lakes States. This instrument served to gather information on NIPF landowners' views towards the harvesting of woody biomass for bioenergy and identify potential constraints to supply. It was also designed to capture landowners' price preferences for carrying out a timber and woody biomass harvest. Following research on each of the three states' to gather data on their forest resources, timber markets, available forest landowner enrollment programs, feedback from the states' Department of Natural Resources (DNR) and assistance from faculty members at University of Missouri, University of Minnesota and University of Wisconsin, a survey instrument was developed and pre-tested from October to December 2011. The pre-testing phase involved a mail survey, sent to 48 randomly selected landowners; two from each of the twenty-four counties. A cover letter requesting landowners' comments and responses accompanied each survey and a reminder postcard was mailed two weeks later. A $20 gift card was offered for landowners' time and participation for the return of completed surveys. A total of 17 surveys were returned for a response rate of 35%. Only few comments were received from this process that resulted in changes to stand volume and associated price offers for hypothetical harvesting scenarios in the final questionnaire.

The final survey instrument contained 21 questions and was divided into five parts to gain insight into landowners' forestland management experience and intentions, their perceptions on harvesting biomass for bioenergy, price preferences for carrying out a harvest, reasons of woodland ownership, interest in public incentives, and demographic information. Questions were formatted to include discrete choices (Yes/No/Do not know), open-ended questions, closed questions with ordered choices and partially closed questions. A questionnaire was developed for each of the three states and four versions were generated by state to incorporate 16 timber and biomass harvesting scenarios. The Tailored Design Method by Dillman (2000) was employed to carry out a mail-out-mail-back survey from March to May of 2012 (Figure 3.1). Landowners were given the chance to enter a raffle for ten $30 gift cards; this served as an incentive for the return of completed surveys to increase the response rate. Return envelopes were also included with the surveys to reduce the cost to landowners who participated in the study.

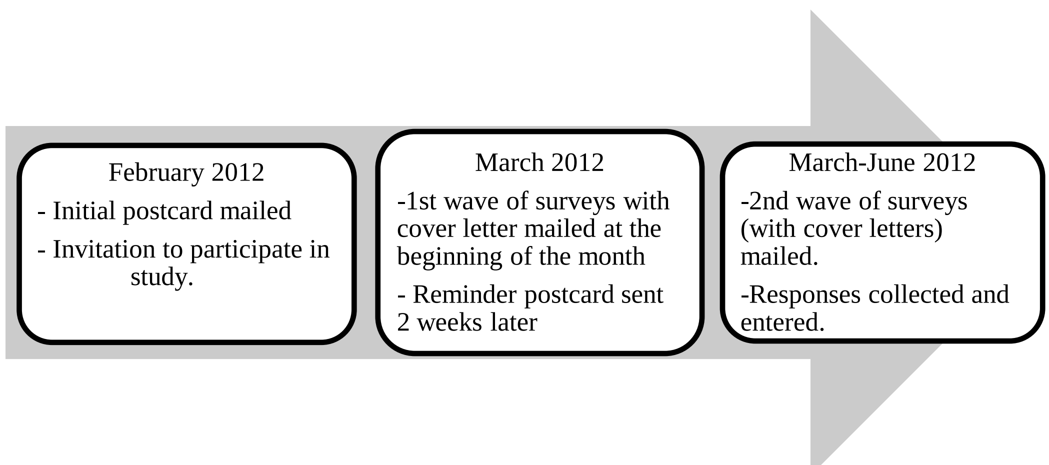

Figure 3.1.Timeline of survey instrument deployment to NIPF landowners in MI, MN and WI

3.2.1. Forestland Characteristics, Landowners' Management Experience and Perceptions on Harvesting Woody Biomass for Bioenergy

The first section of the questionnaire served to capture information on acres owned, location of forest property relative to permanent residence, tenureship, previous harvesting experience and future harvesting plans, forest landowner program enrollment, road accessibility and involvement in an environmental organization. These factors were previously found to affect landowners' forest management decisions (e.g. Kurtz and Lewis 1981; Young and Reichenbach 1987; Amacher et al. 2003; Vokoun et al. 2005; Butler 2007). Forest landowner programs listed were unique to each state and represented options offered by state governments to encourage and promote sustainable forest management in exchange for lowered property taxes. All surveys included questions on enrollment in American Tree Farm program which also promotes sustainable forest management, a cost share program such as EQIP and conservation easement that prevents forest conversion or development to other uses. These questions were close-ended with options of "yes", "no" or "do not know" but were later recoded to binary variables for data analysis.

Woody biomass was defined in the survey as "small diameter trees less than 5 inches dbh traditionally used for firewood as well as portions of trees and wood waste not useable in the traditional wood products industry". This description was based on the U.S. Forest Service's definition of woody biomass (U.S. Forest Service 2008) and edited after comments received from the U.S. Great Lakes States DNR personnel. A Likert scale was utilized to indicate the level of agreement (1= strongly disagree, 3= neither agree nor disagree, 5= strongly agree) on statements about the utilization of woody biomass for generating energy (Daniel 2012). Statements pertaining to advantages of utilizing woody biomass for energy generation support of woody biomass harvesting for energy, environmental concerns that are likely to result from overharvesting or in the absence of sustainable management practices were incorporated in this section (Daniel 2012).

3.2.2. Forestland Management and Woodland Harvesting

A question on landowners' level of agreement to harvest timber or biomass was presented and questions on landowner's WTH a hypothetical forest stand for timber and woody biomass were then proposed. Price offers were derived by estimating commercial timber, biomass volumes and species composition and using current market prices to determine average stand value by state. Data from the FIA database via the EVALIDator software (Miles 2011) was used to derive estimations for the amount of biomass, commercial timber volumes and species composition for the U.S. Great Lakes States. Calculations were carried out to adjust values to reflect typical stand volumes on a per acre basis by state. The survey period selected for all retrievals in FIA was 2004 to 2008 and only values under private ownership of timberland for the selected counties were used. Forest assessments in the FIA program designate private ownership from other types of ownership but private ownership includes non-industrial private, timber management organizations, real estate trusts, industrial forests and tribal lands which resulted in an incorporation of estimates for industrial forest ownership as well (U.S. Forest Service 2006). Additionally, retrievals were filtered to include estimates for only the counties involved in the study instead of statewide estimates for describing "an average acre of woodland" in Michigan, Minnesota and Wisconsin; this was done to localize typical stand volumes and associated price values as much as possible. All retrievals focused on sawtimber size stands so that values would closely match those from a stand where a commercial timber harvest would most likely be carried out. For the purposes of this study, a commercial timber harvest referred to a traditional harvest consisting of the removal of sawlogs and pulpwood. The following retrievals were executed for each state for the development of harvesting scenarios:

1. <u>Area of timberland in acres</u>: The value from this retrieval was used as the divisor for deriving per acre estimates.

2. <u>Net volume of growing-stock on timberland in cubic feet (cuft)</u>: Growing-stock and cull trees are subsets of the classification of live trees (U.S. Forest Service 2006). Growing-stock trees are "live trees of commercial species except rough and rotten trees" and growing stock volume refers to the net volume, in cubic feet (cuft) of growing-stock trees at least 5 inches dbh (U.S. Forest Service 2006). According to Leefers and Vasievich (2011), growing-stock volume represents "the main stem of the tree that is used traditionally for timber products (e.g., sawlogs, pulpwood, etc.)". The result from this retrieval represented the volume of commercial timber. For this study, 79.2 was used as the conversion factor for converting values in cuft to cords (cds).

3. <u>Net volume of sawtimber on timberland in board feet (bdft)</u>: Sawtimber trees are "live trees of commercial species at least 9 inches dbh for softwoods and 11 inches for hardwoods" (U.S. Forest Service 2006). Sawtimber volume is the net volume of sawlogs in sawtimber trees (U.S. Forest Service 2006). This value, divided by the area of timberland was used to report the volume of sawtimber per acre.

4. Net volume of saw-log portion on timberland (cuft): This retrieval reported the volume of the saw-log portion of a sawtimber tree in cuft. According to FIA (U.S. Forest Service 2006), the saw-log portion is the “part of the bole of a sawtimber tree between the stump and the saw-log top”. The volume of pulpwood was calculated by subtracting the result of this retrieval from the net growing-stock volume.

3. All live top and limb biomass on timberland in oven-dry short tons (ODT): Top and limb biomass include the tops and branches of timber species that measure at least 5” in dbh (Woudenberg et al. 2010). Results were limited to growing-stock trees since it was assumed that growing stock trees will be harvested at some point and as such, will produce logging slash that can be used for bioenergy.

4. All live tree and sapling aboveground biomass on timberland in ODT: Results were limited to biomass in only rough and rotten cull trees (saplings were not included) and therefore non-growing stock trees.

5. All live stump (ground to 12 inches) biomass on timberland in ODT: Results were limited to rough and rotten cull trees so that values from this attribute could be subtracted from the previous values from step 4 to remove stumps from the estimates. The result from this retrieval was added to the value obtained from step 3 to determine the total amount of biomass.

6. All live tree and sapling aboveground biomass on timberland in (ODT) by forest type and diameter distribution: Results were divided into pulpwood and sawtimber; it was assumed that trees from 5” to 12.9” dbh would be used for pulpwood and the remaining volume greater than 13”, as sawlogs. Using the values for pulpwood and sawlogs and associated species information, stand composition was weighted by species and the

weighted averages were multiplied by stumpage prices to derive the weighted average price per cord for pulpwood and weighted average price per thousand board-feet (MBF) for sawtimber.

Stumpage price data are consistently reported from State and National forest by states' Department of Natural Resources but may not be readily available for private lands. Timber Mart North (TMN) is published by a private consulting firm, Prentiss & Carlisle (2011a-c), and the publication includes a summary of statewide timber prices from all ownerships for the U.S. Great Lakes States. As a result, copies of these reports were requested from the firm and the most recent publications (October 2010 to March 2011) for Michigan, Minnesota and Wisconsin were acquired free-of-charge. Prices from this report were used to calculate the average price of pulpwood and sawtimber (in combination with FIA estimates).

The average percent of commercial timber volume removed for each state was determined by contacting each of the three states' DNR. Since both clearcut and partial harvest operations are popular in the region, an average percent removal was recommended based on the most prevalent type of harvest for the counties involved in the study. An average of 30% was applied as the volume harvested in Michigan, 80% for Minnesota and 33% for Wisconsin (Table 3.2). An average price offer for each state was determined by associating the average stumpage price of pulpwood and sawtimber with the timber estimates acquired from the FIA retrievals and then adjusting these values based on the percentage removals. Four price offers for a commercial timber harvest were derived by decreasing the average price offer by 20%, increasing the average price by 20% and then finally by 40%. Four options were presented to capture landowners' preferences towards several price offers for harvesting timber and woody biomass.

For the state of Michigan, applying volume estimates and average prices, total stand value was calculated:

150.54	(7.16)	+	25.06	(11.12)	= $1356.08
$/MBF	MBF/acre		$/cd	cds/acre	$/acre
Weighted average price	Volume of sawtimber		Weighted average price	Volume of pulpwood	Total average stand value

Assuming that one acre had 26 cds of commercial timber and the average stand value was $1356.08, the approximate value of 1 cd of commercial timber encompassing both sawtimber and pulpwood was therefore $52.75 and the recommended 30% removal would be valued at $406.82 per acre.

Repeating this procedure for Minnesota yielded:

74.08	(5.54)	+	18.01	(8.32) =	$560.21
$/MBF	MBF/acre		$/cd	cds/acre	$/acre
Weighted average price	Volume of sawtimber		Weighted average price	Volume of pulpwood	Total average stand value

Assuming then that one acre had 20 cds of commercial timber and the average stand value was $560.21, the approximate value of 1 cd of commercial timber was therefore $28.57 and 80% removal would be valued at $448.17 per acre.

For the state of Wisconsin:

170.67	(7.77)	+	33.12	(9.67) =	$1646.42
$/MBF	MBF/acre		$/cd	cds/acre	$/acre
Weighted average price	Volume of sawtimber		Weighted average price	Volume of pulpwood	Total average stand value

Assuming that one acre had 25 cds of commercial timber and the average stand value was $1646.42, the approximate value of 1 cd of commercial timber was therefore $65.02 and the recommended 33% removal would be valued at $536.42.

A minimum retention level of 33% for biomass harvest was outlined in Minnesota's Biomass Harvesting Guidelines for protection of harvest sites from degradation and to ensure the sustainability of forest resources (MFRC 2007). A one-third retention rate was also advised in the Michigan Biomass Harvesting Guidance (Michigan DNRE 2010b) so this level was considered for determining the volume of biomass that may be removed in conjunction with timber harvesting on a per acre basis in the U.S. Great Lakes States. Minnesota's average bio-stumpage values in 2010 for logging slash from all ownerships was $1.50 per green ton (gt) and ranged from $1 to $2 per gt or $2 to $4 per dry ton (dt) following that 1gt is equivalent to about 0.5 dt, assuming 50% moisture content (Donald

Deckard, pers. comm., Aug. 17, 2011). Based on feedback from the Wisconsin DNR, it was determined that the same rates could also be applied in the Wisconsin's version of the survey. Also, considering the newness factor of the bioenergy market in the region, the average biomass price offers were based on the value of Minnesota's bio-stumpage rate ($1.50/gt). Four biomass price offers were developed to match the four timber price offers in the construction of harvesting profiles so as to create a balanced research design. The lowest price offer was set at $0 per acre to determine whether landowners would have biomass removed in the absence of a price offer; values were then increased by $1 at each level to encompass current bio-stumpage rates (Table 3.2).

Table 3.2. Summary of price offers for harvesting timber and biomass. Price values were rounded-off to the nearest tenth.

Attribute	Units	Michigan	Minnesota	Wisconsin
Volume of commercial timber	cds/acre	26	20	25
Volume removed in a commercial timber harvest	cds/acre	8	16	8
Price offers for a commercial timber harvest:	$/acre			
*20% decrease		330	360	430
Average		410	450	540
*20% increase		490	540	650
*40% increase		570	630	760
Total amount of biomass- tops, limbs, rough and rotten cull trees	ODT/acre	13	15	15
Total amount of biomass- tops, limbs, rough and rotten cull trees	gt/acre	27	30	29
Biomass harvested (66% removal)	gt/acre	18	20	19
Price offers for woody biomass harvest:	$/acre			
$0/gt		0	0	0
$1/gt		20	20	20
$2/gt		40	40	40
$3/gt		60	60	60

cds, cords; ODT, oven-dry short tons; gt, green tons.

*Increase/decrease from the average price value

Harvesting scenarios were then introduced. A harvesting scenario consisting of two questions, aimed to identify the lowest price that landowners would be willing to accept to harvest timber and woody biomass. A timber price offer was presented in the first question and a biomass price offer was presented in the second question. The biomass price represented an additional price offer to harvest woody biomass following a timber harvest. For each state, twelve harvesting scenarios with each consisting of one timber price offer and one biomass price offer were constructed using the Bretton-Clark orthogonal design (Bretton-Clark 1988). The responses to the hypothetical harvesting scenarios were binary in nature; either "yes" or "no" according to whether respondents decided to accept the offer and harvest or reject the offer. Scenarios were divided among four versions of the survey per state; in this way, survey length was minimized but all price offers were incorporated for subsequent data analyses. Consequently, each instrument contained four harvesting scenarios and each version presented a different set of scenarios. Survey versions were randomly assigned to potential survey participants in the mailing database.

3.2.3. Reasons Owning Land, Incentive Preference and Demographic Information

A 5-point rating scale (1= not important, 3= moderately important, 5= extremely important) was utilized for landowners to indicate their level of importance for sixteen different reasons for owning their woodlands. Fifteen of these ownership reasons were taken from the National Woodland Owner Survey (NWOS) (U.S. Forest Service 2012) and an additional statement was included to capture landowners' response on harvesting specifically for commercial bioenergy production. One close ended question on landowners' intention to pass on their land was also incorporated in this section of the survey was well (Daniel 2012). Demographic questions presented served to gather information on the respondent's age, gender, race, income and education level. Answer options to most of these questions were also derived from the NWOS for validation and comparison purposes (Table 3.3).

Table 3.3. List of questions and response variables adapted from the U.S. Forest Service National Woodland Owner Survey (NWOS) included in the survey of NIPF landowners of the U.S. Great Lakes States.

Question	**Response options**
1. Demographics - How old are you?	- "Under 25 years", "25 to 34 years", "35 to 44 years", "45 to 54 years", "55 to 64 years", "65 to 74 years" and 7= "75 years or older"
- "What is your race?"	- "American Indian" "Asian", "Black or African-American", "Native Hawaiian or Pacific Islander" and "White"
- What is the highest level of education you have completed?	- "Less than 12th grade", "High school graduate or GED", "Some college", "Associate or technical degree", "Bachelor's degree", "Graduate degree"
- What is your annual household income range?	- "Less than \$25,000", "\$25,000-\$49,999", "\$50,000-\$99,999", "\$100,000 to \$199,999", and "\$100,000 or more".
2. Importance of woodland ownership reasons "To enjoy beauty or scenery" "To protect nature or biological diversity" "For land investment" "As part of my home or vacation home" "As part of my farm or ranch" "For privacy" "To pass land on to my children or other heirs" "For cultivation or collection of non-timber forest products (maple syrup, berries)" For production of firewood for personal use "For production of sawlogs, pulpwood or other timber products" "For hunting or fishing" "To protect land from development (housing)" "To leave land unmanaged and let nature take its course" "As part of my inheritance" "Other (please specify)"	Rating scale (1= not important , 3= moderately important to 5= extremely important).

Statements in quotations were directly taken from the NWOS (U.S. Forest Service 2012).

3.3. Timberland Bio-physical Estimates for Data Analyses

Following the entry of survey responses, values on the physical availability of timber in the study area were derived from the FIA database (Miles 2012). Physical availability represented an additional explanatory variable used in regression analyses to determine the effect of this variable of the choice to harvest. Values for growing stock on private timberland (in cuft and for trees at least 5 inches dbh) for only those counties that responded to the survey were retrieved from the FIA database to denote physical availability. As previously mentioned, it was assumed that trees of commercial species above 5 inches would be harvested as sawlogs and pulpwood.

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Chapter 4. Application of Multivariate Techniques for Understanding NIPF Landowners of Michigan, Minnesota and Wisconsin and their Willingness-to-Harvest Timber and Woody Biomass for Bioenergy

Abstract: Bio-physical estimates on woody biomass and regional developments such as state-level Renewable Portfolio Standards (RPS) and woody biomass harvesting guidelines demonstrate the capacity of Michigan, Minnesota and Wisconsin to create a viable wood-based bioenergy market. This study aimed to examine non-industrial private forest landowners' willingness-to-harvest (WTH) timber and woody biomass for energy. Results identified two latent factors summarizing landowners' bioenergy perceptions: (a) bioenergy support and (b) environmental degradation; and four latent factors behind woodland ownership: (a) amenity, (b) personal use, (c) production and (d) legacy. Responses to both bioenergy views and woodland ownership were used to construct a landowner typology for the region. Findings indicate four types of landowners: *recreationist, indifferent, preservationist* and *multiple-objective*. *Recreationists* were found to own the majority of woodlands and were also most willing to harvest timber and woody biomass. Analysis of landowners' price preferences from the three states found greatest potential from Michigan NIPFs; *recreationists* owning 46% of the woodlands in Michigan could potentially be available for timber harvest and 61% of Michigan's woodlands for biomass harvest.

Keywords: Woody biomass, bioenergy, typology, non-industrial private forest landowners, U.S. Great Lakes States

4.1 Introduction

Non-industrial private forest (NIPF) landowners own 48% of all forestlands in the United States (U.S.) Great Lakes States of Michigan, Minnesota and Wisconsin (Smith et al. 2009). At the state level, 48% or 9.5 million acres of the total forestland acreage in Michigan are owned by NIPF landowners; the corresponding values are 36% or 5.9 million acres in Minnesota and 59% or 9.7 million acres in Wisconsin (Smith et al. 2009). The decisions of NIPF landowners on how they choose to manage their lands are therefore instrumental in shaping the future of forests and the availability of wood resources, including woody biomass. The utilization of woody biomass for energy creates a market for traditionally unusable materials, introduces job opportunities and reduces forest fire hazards, thereby rendering this resource as a key source of renewable energy (Hall 1997; U.S. Forest Service 2008; DOE 2010). Given the national energy goal of producing 36 billion gallons of renewable fuels by 2022 (P.L. 110-140 2007), it is important to assess potential availability of woody biomass for bioenergy.

In the U.S. Great Lakes States, the utilization of woody biomass for bioenergy has received considerable attention as exemplified by the establishment of states' Renewable Portfolio Standards (RPS) which include woody biomass as an eligible feedstock for energy production (Public Service Commission of Michigan 2011; DSIRE 2012a; DSIRE 2012b). RPS serve to meet state-level renewable energy goals by specifying electricity supply targets from renewable sources (EPA 2012). Michigan and Wisconsin's RPS each require electric companies to provide at least 10% of their electric sales from renewable sources by 2015 while Minnesota has a 25% target by 2025 (Public Service Commission of Michigan 2011; DSIRE 2012a; DSIRE 2012b). Additionally, each of the three states has adopted their own woody biomass harvesting guidelines in an effort to minimize environmental impacts from biomass harvesting. The development of biomass harvesting guidelines is indicative of the U.S. Great Lakes States commitment to promoting the harvest of woody biomass in a sustainable manner. Thus, availability findings will contribute towards an evaluation of the potential for consistent supply of woody biomass for energy. Given the extent of NIPF ownership, accomplishing this task will require an understanding of NIPF landowners' decisions to harvest their woodlands.

The aim of this study was to determine NIPF landowners' willingness-to-harvest (WTH) timber and woody biomass in the U.S. Great Lakes States of Michigan, Minnesota and Wisconsin. Consequently, the objectives of this study involved an identification of NIPF landowners' ownership attributes, incentive and price preferences for harvesting timber and woody biomass; latent factors behind the reasons for woodland ownership; and views towards woody biomass utilization for energy. In order to better understand the heterogeneity of NIPF landowners' attitudes and views towards woodland ownership and bioenergy, the final objective of this study served to identify landowner topology. The result facilitated the identification of responsive groups with regards to the WTH timber and woody biomass.

4.2. Literature Review

NIPF landowners in the U.S. Great Lakes States account for nearly half or 24.9 million acres of productive forests regionally (Smith et al. 2009). Landowners' decisions can therefore affect the resource base for commercial timber, woody biomass and other forest resources. Many studies have been dedicated to understanding NIPF landowners forest management decisions (e.g. Kurtz and Lewis 1981; Young and Reichenbach 1987; Conway et al. 2003; Amacher et al. 2003; Vokoun et al. 2005), and the results of these studies represent useful sources of information in the development of effective strategies for encouraging the sustainable management of forests. At the national level, the National Woodland Owner Survey (NWOS) conducted by the Forest Inventory and Analysis (FIA) program of the U.S. Forest Service since 2001 serves to contribute towards the comprehensive assessment of forest resources. This is accomplished by examining the social constituent of forest resources through annualized surveys of private forest landowners (Butler et al. 2005). For instance, recent findings from the NWOS indicate that at the national level, landowners deem non-commodity values such as aesthetics and family legacy, as the most important reasons for owning land while only 9% have indicated timber production as an important reason (Butler and Leatherberry 2004). This finding can have important implications for woody biomass availability. For instance, Minnesota and Mississippi forest landowners were predicted to be less likely to harvest woody biomass if they owned forestland for aesthetic purposes (Becker et al. 2010; Gruchy et al. 2011). Other factors such as demographic attributes (e.g. age, education and income) and past harvest experience affecting biomass harvesting decisions were previously found to influence timber harvesting decisions (Young and Reichenbach 1987; Amacher et al. 2003; Becker et al. 2010; Gruchy et al. 2011; Joshi and Mehmood 2011; Markowski-Lindsay 2012). Participation in an emerging bioenergy market for woody biomass will require increasing the involvement in existing wood production as woody biomass harvesting must be done in conjunction with a timber harvest in order to be economically feasible (Hubbard et al. 2007; Saunders et al. 2012). This in turn, will require effective strategies such as policies and services that are designed to appeal to landowners and encourage their participation in active forest management. The development of NIPF landowner typology is one method that can be used to guide the design of such strategies by considering the different attitudes of a diverse group of landowners rather than viewing these owners as a single homogenous group (Butler et al. 2007). By grouping landowners with similar objectives and attitudes towards their forest land, communication modes can be streamlined based on the targeted audience (landowner type).

The grouping or classification of forest landowners on the basis of shared attributes is not a new concept, literature dates back to the 1980's in the U.S. for Missouri and Wisconsin NIPF landowners (Kurtz and Lewis 1981; Marty et al. 1988). A number of studies have since followed (e.g. Kluender and Walkingstick 2000; Kendra and Hull 2005; Finley and Kittredge Jr. 2006; Ross-Davis and Broussard 2007; Majumdar et al. 2008). Butler et al. (2007) also demonstrated the application of hierarchical clustering using NWOS data to group family forest owners of the United States into four attitudinal segments; *woodland retreat owners*, *working the land owners*, *supplemental income owners*, and *ready to sell owners*. Comparisons of landowner typology from previous studies revealed many similarities among group attributes or segments. In North Central Indiana a typology constructed for *forest managers* was comparable to characteristics of *supplemental income owners* by Butler et al. (2007), *resource conservationists* in Wisconsin as well as *timber conservationists* in Missouri for their participation in active forest management and timber production objectives (Marty et al. 1988; Ross-Davis and Broussard 2007). These landowner groups were most likely to engage in activities that yielded financial benefits. *Woodland retreat owners* possessed characteristics common to *forest environmentalists* in Missouri *and forest recreationists* in Wisconsin in that they were most likely to choose non-timber, amenity benefits as their ownership motivations (Marty et al. 1988). The typology for *passive forest owners* in North Central Indiana was comparable to *ready to sell owners* by Butler et al. (2007) for their lack of motivation in both timber and non-timber values and this was attributed to their agedness, as these groups consisted of the oldest age class of landowners (Butler et al., 2007; Ross-Davis and Broussard 2007). According to Butler et al. (2007), the most common type of NIPF landowner in the U.S. is the *woodland retreat landowner*.

With the exception of Missouri, the inclusion of bioenergy views in the development of landowner typology is relatively new but this type of market segmentation can be very useful for the growth a bioenergy market by targeting responsive groups or tailoring programs that appeal to a specific audience. Aguilar et al. (unpublished) analyzed Missouri NIPF landowners' responses to woodland ownership reasons and bioenergy views for generating landowner types for Missouri that represent a revision to the previously developed typology by Kurtz and Lewis (1981). Results revealed four types of landowners; *forest enthusiasts, woodland retreat landowners, woodland preservationists* and *passive landowners*. Examination of these groups' willingness to harvest revealed that *passive landowners*, characterized by having neutral views towards bioenergy and woodland ownership, would be most likely to harvest timber and woody biomass as they were found to be more willing to harvest at every price offer as well as more sensitive to price changes (Aguilar et al. unpublished). Thus, while price may positively influence landowners' WTH, the effect may vary considerably by landowner type resulting in a substantial portion of woodlands restricted from harvests. To exemplify, among landowner types identified for the state of Missouri, the least responsive group to price offers, the *preservationist*, controlled 43% of woodlands (Aguilar et al. unpublished).

4.3. Methods

4.3.1. Study Area

The study area consisted of the U.S. Great Lakes States of Michigan, Minnesota and Wisconsin. An estimated 54% of Michigan's land area, 32% of Minnesota's land area and 47% of Wisconsin's land area are occupied by forests (Smith et al. 2009). Non-industrial private forest ownership accounts for 9.5 million acres (48%) of all forestland in Michigan, 5.9 million acres (36%) of Minnesota's forestland and 9.7 million acres (59%) in Wisconsin; 48% regionally (Smith et al. 2009). According to recent FIA estimates, a majority of average annual removal of live trees came from private forests; 60% or 940 million cubic feet for the three states combined (Miles 2012). However, the volume of unutilized wood volume on private timberlands indicates that forest growth have been exceeding harvest in each state; the approximate unutilized annual growth in Michigan is 50%, 41% in Minnesota and 54% in Wisconsin (Miles 2012). This demonstrates significant potential from a physical perspective, for increasing timber harvest and procuring woody biomass.

4.3.2. Data

A mail survey was chosen to collect data for this study due to the cost effectiveness of this option versus an online survey. Only counties with relatively high amounts of total tree biomass (an indication of being forested) were considered for potential participation; 7 million dry tons of total tree biomass per county was chosen ad hoc as the minimum limit for county inclusion using FIA data and tools in ArcMap 9.3. A total of eight counties per state were randomly selected from the list of the eligible counties and a mailing database of 4,190 forest landowners whose names, addresses and acres owned were gathered by contacting each county's tax assessor office was developed. Landowners owning less than 20 acres were excluded since previous literature demonstrated a decreased likelihood in landowners' participation in active forest management for parcel sizes less than 20 acres (Row, 1978; Butler and Leatherberry, 2004).

A survey developed for Missouri by Daniel (2012) was used as an initial template. Research of each state's timber markets and timber resources and comments and suggestions from each of the three states' Department of Natural Resources (DNR), forestry faculty members from University of Missouri, University of Minnesota and University of Wisconsin were used for development of the final instrument. Pre-testing of 48 randomly selected landowners (16 per state) also led to additional fine tuning to ensure the survey's appropriateness. The final survey instrument consisted of questions on landowners' forest management experience and future plans to harvest, land characteristics, cost share enrollment, bioenergy views, harvesting preferences, ownership objectives, public tax preferences and demographics. Demographic questions included age, gender, income, education level; these questions were taken directly from the NWOS (U.S. Forest Service 2012) for comparison and validation purposes. Similarly, fifteen of the 16 ownership reasons were taken from NWOS; a statement on the importance of owning forests for bioenergy production was incorporated to ascertain whether this was important to landowners (Table 4.1).

Survey mailing took place from February to April 2012. Following Dillman's Tailored Design Method (Dillman 2000), an initial postcard was mailed to landowners at least one week before the mailing of the first wave of surveys with cover letters enclosed. Thank you and reminder postcards were sent one week later and a second mailing of surveys were carried out the following month to those not responding to the first wave. In an attempt to increase response rate, an incentive offer was included; landowners were given the chance to enter a raffle of ten $30 gift cards.

Table 4.1. List of survey variables used in examining U.S. Great Lakes States NIPF landowners' ownership attributes, enrollment in public programs, incentive preferences, bioenergy views and ownership reasons.

Variables	**Scale**
1. Number of woodland acres owned	Continuous variable (acres)
2. Demographic information - Age - Education - Children under 18 years of age live in the household - Annual household income range in dollars per year	 - Ordered categories: 1= "Under 25 years", 2= "25 to 34 years", 3= "35 to 44 years", 4= "45 to 54 years", 5= "55 to 64 years", 6= "65 to 74 years" and 7= "75 years or older" - Categorical: 1= "Less than 12th grade", 2= "High school graduate or GED", 3= "Some college", 4= "Associate or technical degree", 5= "Bachelor's degree", 6= "Graduate degree" Binary variable ("yes"=1, "no"=0). - Ordered categories: 1= "Less than \$25,000", 2= "\$25,000-\$49,999", 3= "\$50,000-\$99,999", 4= "\$100,000 to \$199,999", 5= "\$100,000 or more".
3. Public programs enrollment "Is enrolled in Michigan's Commercial Forest (CF) Program" "Is enrolled in Minnesota's Class 2c Managed Forest Land" "Is enrolled in Minnesota's Green Acres Program" "Is enrolled in Minnesota's Sustainable Forest Incentive Act" "Is enrolled in Wisconsin's Managed Forest Law" Has a forest management plan written by a professional forester "Is enrolled in American Tree Farm Program" "Is enrolled in a cost share program for management activities (e.g. CRP or EQIP)" "Has had a timber sale organized by a professional forester since you owned it" "Is under a conservation easement prohibiting future development"	Binary variables; coded 1=yes or 0=no Statements that specifically included the name of the state were presented only to NIPF landowners owning forests in that state.
4. "What is your 1st choice for the type of payment you would prefer?"	Categorical variable; options were "Incentive or reimbursement payment", "Tax reduction", "Don't know" and "Neither".

5. Bioenergy views “Woody biomass is a viable alternative to fossil energy (e.g. coal/oil/gasoline/diesel)” “National security can be enhanced by using woody biomass for energy rather than relying heavily on fossil fuels” “Utilization of woody biomass for energy could positively impact United States' energy independence” “Waste wood from forest harvests should be used for energy/fuel generation” “Commercial harvesting of woody biomass is likely to limit the regrowth of forests” “Harvesting woody biomass for energy/fuel is likely to benefit local economies” “Forest health is likely to be improved by harvesting woody biomass” “Harvesting woody biomass is likely to degrade wildlife habitat” “Harvesting woody biomass is likely to result in soil erosion” “Harvesting woody biomass is likely to result in water pollution” “Harvesting woody biomass can create competition for raw materials used in other wood product industries (lumber, pulp and paper composites, etc.)” “I support harvesting woody biomass for energy” “The opinions of family members and/or other landowners play an important role in how I choose to manage my woodland”	Likert rating scale (1= strongly disagree, 3= neither agree nor disagree, 5= strongly agree) was used to measure the level of agreement to each statement.
6. Woodland ownership reasons “To enjoy beauty or scenery” “To protect nature or biological diversity” “For land investment” “As part of my home or vacation home” “As part of my farm or ranch” “For privacy” “To pass land on to my children or other heirs” "For cultivation or collection of non-timber forest products (maple syrup, berries)" “For production of firewood for personal use” “For production of woody biomass for commercial bioenergy production” “For production of sawlogs, pulpwood or other timber products” “For hunting or fishing” “To protect land from development (housing)” “To leave land unmanaged and let nature take its course” “As part of my inheritance” “Other”	A 5-point rating scale (1= not important, 3= moderately important, 5= extremely important) was used to measure importance rating of each statement. With the exception of bioenergy production, reasons were taken from the NWOS.

Statements in quotations were directly taken from National Woodland Owner Survey (U.S. Forest Service, 2012).

4.3.3. Data Analysis

Survey responses were entered into a Microsoft Excel spreadsheet and later uploaded to Stata 10 to carry out all analyses. Landowners owning less than 20 acres were excluded from analyses. Summary statistics were carried out for all variables involved in the study and *t*-tests were performed on variables representing ownership reasons and bioenergy views to determine whether means were statistically significantly different from a rating of “3” (moderately important rating for ownership reasons and neutral rating for bioenergy views).

Exploratory factor analysis using the principal component analysis model and Varimax orthogonal rotation, was applied to forest ownership reasons at the regional level to reduce groups of correlated variables into a smaller set of uncorrelated variables while retaining the original variables’ character (Hair et al. 1998; Majumdar et al. 2008). Varimax is the default rotation in Stata and this produces orthogonal factors. According to Hair et al. (1998) an orthogonal rotation is best suited if the goal is to derive a reduced number of variables. Also, rotation of the factor matrix is necessary to redistribute the variances to get to “a more even distribution” of the explanatory power (Hair et al. 1998, p. 125) rather than having the largest amount of variance on the first factor generated. The factor analysis procedure was repeated for bioenergy views. Since the ownership reason “Other” was not included in analyses due to only 9% of landowners responding to this statement, 15 ownership reasons and 11 bioenergy views were used in factor analysis (Tables 4.2-4.3). The result of this technique served to identify the latent factors behind forest ownership and views towards the harvesting of woody biomass for bioenergy.

Cluster analyses were carried on the dataset using variables for reasons for forest ownership and bioenergy views; responses to ownership reasons were measured on a 5-point importance rating scale (1= not important, 3= moderately important, 5= extremely important) and bioenergy views, on a 5-point Likert rating scale (1= strongly disagree, 3= neither agree nor disagree, 5= strongly agree). A two-step cluster analysis approach was used to derive clusters based on landowners' responses to thirteen bioenergy statements and fifteen ownership motivations (Tables 4.4-4.5). Nonhierarchical methods were first applied to decide on an appropriate number of clusters and generate seed points and nonhierarchical methods were then used to refine the partitioning process of deriving clusters. According to Punj and Stewart (1983) and Hair et al. (1998), the selection of cluster seeds is problematic with non-hierarchical procedures so a two-step approach can be more beneficial. Also, an appropriate number of clusters can be determined from the hierarchical cluster approach and then this value may be specified for the non-hierarchical step.

Ward's hierarchical method of clustering was performed since this method is less affected by outliers while squared Euclidean distance was selected as the distance measure of similarity for grouping objects similar objects into clusters (Sharma 1996; Hair et al. 1998). A *k*-means clustering was then carried out using the initial seed points from the previous step; these represent the cluster centroids on the clustering variables (Hair et al. 1998). Results were interpreted and cluster labels were determined based on the characteristics of each variate. The interpretation stage involved calculation of *F* statistics to determine whether at least one group (cluster) mean differed significantly from the others and *t*-tests were then calculated to determine whether group means were statistically different from each other (two-sample *t*-tests). Statistical significance between two group means was tested at an alpha of 0.05 and results tabulated. Responses to questions on timber and biomass harvesting preferences were then used to estimate the availability of woodlands for harvesting from the different types of landowners identified and also to further differentiate among groups. This step was carried out at the state-level since price offers for timber and woody biomass varied by state.

4.4. Results

The adjusted response rate, after accounting for non-deliverables, non-responses and removing feedback from landowners owning less than 20 acres, was 32%. Following the same criteria, there were 268 returned questionnaires from Michigan, 579 for Minnesota and 501 for Wisconsin; representing a 31% response rate from Michigan landowners, 45% for Minnesota and 32% for Wisconsin. With the exception of Menominee, Wisconsin, respondents indicated owning land in counties that were listed for potential participation in the survey. For the state of Michigan, 98% of respondents owned woodlands in the eight counties listed for this study; this value was 98% for Minnesota and 87% for Wisconsin.

4.4.1. Acreage, Residence and Demographic Attributes

The average number of woodland acres owned for the three states combined was 168 acres. Average number of acres owned in Michigan alone was 343 acres, 133 acres for Minnesota and 114 acres for Wisconsin. Approximately 63% of all respondents were found to own from 20 to 99 acres of woodland and 22% owned 100 to 199 acres. An estimated 65% of Michigan's NIPF landowners owned between 20 and 100 acres, this value for 55% for Minnesota and towards the upper end, 71% in Wisconsin. NWOS findings for U.S. Great Lakes States found that the second largest percentage of all NIPF landowners possessed between 20 and 100 acres; 23%, 29% and 31% of Michigan, Minnesota and Wisconsin's NIPF landowners (Butler 2008). Meanwhile, an estimated 73%, 62% and 61% of NIPF landowners from Michigan, Minnesota and Wisconsin respectively owned less than 20 acres of woodland (Butler 2008). The NWOS also reported Michigan's NIPF landowners owning comparatively larger acreages; 21% owned more than 499 acres, compared to 14% and 12% of all Minnesota's and Wisconsin's NIPF landowners respectively.

85% of all respondents were males who controlled 91% of the total number of woodland acres reported. Findings indicated that 70% of landowners were at least 55 years of age and owned 79% of the woodlands. At the state level, 76% of Michigan NIPF landowners were at least 55 years old; for Minnesota, this value was 71% (of Minnesota NIPF landowners) and for Wisconsin, 65%. Only 7% of all respondents were less than 44 years of age and controlled a mere 4% of the total woodland acres owned by all respondents while 35% were at least 65 years of age and this group was responsible for nearly half or 49% of total forested acres regionally. An overwhelming majority of respondents, 81%, indicated having no children under 18 living in the household.

The average respondent possessed an Associate or technical degree, and this result was consistent for each individual state. Average income earned per household was also the median income level; between $50,000 and $99,000 which is comparable to the current median state income for each state (U.S. Census Bureau 2012).

4.4.2. Public Programs Enrollment

Regionally, 43% of respondents indicated having a forest management plan that was written by a forester but at the state level, 31% of Michigan's NIPF landowners had one compared to 59% of Minnesota's NIPF landowners and 31% of Wisconsin's NIPF landowners. The lowest participation rates were associated with enrollment in American Tree Farm Program where only 6% of all respondents reported being involved; 4% of Michigan's NIPF landowners, 8% of Minnesota's NIPF landowners and 5% of Wisconsin's NIPF landowners. On average, 31% of all respondents reported having had a timber sale since ownership of their woodlands; state-level estimates for this variable were comparable, 38% of Michigan's NIPF landowners, 32% of Minnesota's NIPF landowners and 26% of Wisconsin's NIPF landowners. Cost-share program involvement was highest among Minnesota's NIPF landowners but this value was only 13%.

4.4.3. Incentive and Price Preferences

Landowners' responses to the type of payment they would prefer to harvest woody biomass served to indicate whether Government initiatives for promoting woody biomass would be an effective tool for promoting supplies. Results indicate that while responses were divided between an incentive payment option and tax reduction, 24% of all respondents could not decide on a payment option. An examination of the results from individual states revealed that an even higher percentage of Michigan's NIPF landowners indicated not knowing what type of payment they would prefer. While incentive payment and tax reduction options constituted 47% of the Michigan sample, 31% of Michigan's NIPF landowners selected "Don't know" as their response. The highest percentage of landowners not interested in any of the incentive options was also for Michigan at 18%. Minnesota and Wisconsin results closely resembled the regional statistics with 68% and 56% of each state's respondents respectively indicating a preference for one of the incentive payment options. Furthermore, an estimated 74% of all respondents indicating a preference for either an incentive payment of tax reduction owned woodlands in Minnesota.

A consideration of the uniqueness of the "average" woodland acre in each of the three states led to different timber price offers but in surveys for each state, biomass per ton was valued the same for all three states. An estimated 42% of Michigan's NIPF landowners were willing to accept one of the four price offers presented in the survey for harvesting timber; 9% of the Michigan's NIPF respondents would accept $330 per acre and 12% at $570 per acre. However, most of the landowners were either not willing to harvest at any price offered or did not answer the question; 44% of Michigan's NIPF landowners controlling 30% of woodlands in the state met these criteria.

Almost one-quarter or 22% of Minnesota's NIPF landowners owning 14% of woodlands within the state indicated that they would not harvest timber regardless of the price offered while 58% of Minnesota respondents would harvest at one of the four timber price offers presented. The latter group controlled 68% of NIPF lands in Minnesota. While 14% of Minnesota's NIPF landowners were willing to harvest timber at a lowest price of $630 per acre, 17% indicated $540 per acre as their lowest price for harvesting. Similarly, 22% of Wisconsin's NIPF landowners indicated that they would not harvest timber regardless of price offered while 52% of the state's respondents would harvest at one of the four price offers. The latter group of landowners controlled 63% of woodlands in the state and every price offer increase led to an increased proportion of landowners willing to harvest timber; 8% were willing to harvest for $430 per acre and 17% for $760 per acre.

Regionally, 53% of NIPF landowners from the U.S. Great Lakes States in possession of 63% of the total acreage in the sample indicated that they would accept one of the given price offers to harvest timber. A comparison of the states revealed that the greatest number of acres of woodland potentially available for a commercial timber harvest was from the state of Michigan (24% of the total reported acreage or 54,476 acres) followed by Minnesota (23% or 51,558) and finally Wisconsin (16% or 35,299).

Biomass price offers were $0, $20, $40 and $60 per acre. The survey's answer option to not harvest regardless of price was most popular in the region, with 25% of respondents in possession of 38,231.67 acres or 17% of total NIPF lands in the sample indicating this option. However, landowners willing to accept one of three price offers (non-zero) to carry out an integrated harvest, controlled 62% of the woodlands while 8% of all respondents owning 5% of the total woodlands indicated that they would harvest for no additional revenue. The median price indicated by all landowners for harvesting at some other additional amount was $100 per acre.

Responses from each individual state were comparable with 24% to 26% of respondents not being willing to harvest woody biomass with timber and 18% of Michigan's NIPF landowners and 18% of Minnesota's NIPF landowners willing to harvest at $60 per acre while 25% of Wisconsin's NIPF respondents would consider $60 as the lowest offer to accept for harvesting. In terms of absolute acreage values, the greatest number of acres potentially available for harvesting woody biomass was in the state of Michigan; 63,689 acres or 29% of the total acreage reported regionally could potentially be available, followed by Minnesota (23% of the total acreage) and Wisconsin (16% of the total acreage).

4.4.4. Bioenergy Views and Woodland Ownership Objectives

Regional results indicated that with the exception of the view that woody biomass harvest would degrade wildlife habitat, all views were statistically different from rating of 3 (neither agree nor disagree) (Figure 4.1). State-level estimates revealed that Minnesota's responses mirrored the regional trend, both in terms of mean rankings and significance while both Michigan and Wisconsin NIPF landowners expressed additional views not statistically different from 3; that the opinions of others matter and that harvesting is likely to result in soil erosion respectively. Thus, all other mean ratings of bioenergy perception statements were truly different from neutrality. The highest mean ratings were attributed to the belief that waste wood should be used for fuel, that its use could benefit local economies and agreement to having overall support for its utilization. An average of 63% of all respondents in control of 61% of the NIPF forest acreage was in agreement or strong agreement with these statements.

Regionally, the view that woody biomass harvesting would likely degrade wildlife habitat had a mean rating of 2.96 that was not found to be statistically significantly different from the neutral rating (3) so there was some level of uncertainty about the landowners' opinion of the effects on wildlife. The statement pertaining to raw material competition resulting from woody biomass harvesting had a mean rating of 3.27 that was significantly greater than 3. This statement therefore represented the only negative view towards bioenergy, both regional and at the state level that was found to be closer to agreement by landowners than other opposing views towards bioenergy. Statements pertaining to harvesting being harmful to the forest and resulting in water pollution had the lowest mean ratings of 2.73 and 2.64 respectively.

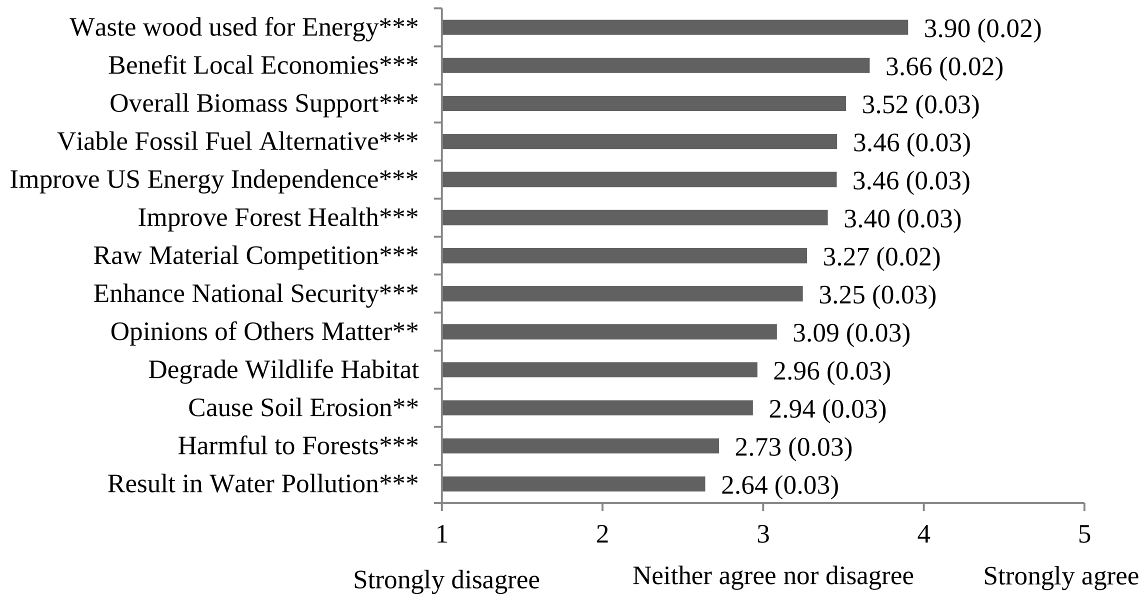

Figure 4.1. U.S. Great Lakes States NIPF landowners' mean responses to bioenergy perception statements. All statements were measured on a 5-point Likert scale (1 = strongly disagree, 3 = neither agree nor disagree and 5 = strongly agree).Standard errors associated with mean ratings are in parenthesis. **Statistical significant difference from 3 at α = 0.05, ***Statistical significant difference from 3 at α = 0.001

At both the state and regional levels, all 16 woodland ownership variables were found to be statistically significantly different from the mid-level rating of 3 that corresponded to a "moderately important" rating (Figure 4.2). Regionally, landowners responses to the level of importance of reasons for owning woodland indicated highest mean ratings for non-timber values like beauty and for hunting, which were both 3.96 ("very important"). An average of 66% of all respondents representing 29% of NIPFs indicated owning woodlands for beauty, to protect nature, to hunt and for privacy at least very important while 93% of woodlands were controlled by landowners finding at least one of these reasons at least very important. "Other" was the third most important reason for woodland ownership but this variable had the least number of observations (n = 119) and consequently represented a very or extremely important reason by only 7% of all respondents.

The least important reasons for forest ownership were attributed to owning forests for the production of woody biomass for bioenergy production; this was considered “slightly important” to landowners. Variables associated with a similar average level of importance were for the cultivation of non-timber forest products, production of timber products like sawlogs and to leave unmanaged. Forest ownership for the production of timber products was very or extremely important to 23% of respondents who controlled 57% of the NIPFs and on average, owned 375 acres forest compared to the overall average of 168 acres. This ownership objective was considered at least very important by 29% of Michigan’s NIPF landowners controlling 76% of the state’s reported NIPF acreage, 20% of Minnesota’s NIPF landowners representing 37% of the state’s NIPFs and 22% of Wisconsin’s NIPF landowners or 51% of reported NIPFs.

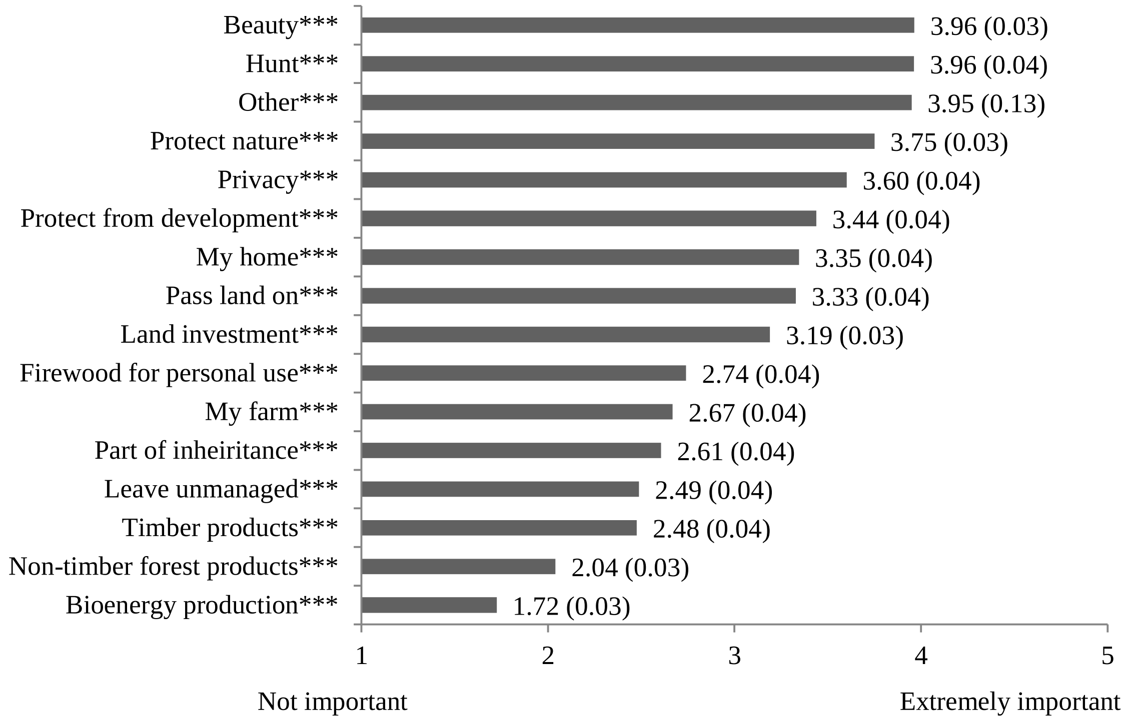

Figure 4.2. U.S. Great Lakes States NIPF landowners' mean responses to reasons for owning woodlands. Statements that were measured on a 5-point Likert scale (1 = Not important, 3 = moderately important and 5 = extremely important). Standard errors associated with mean ratings are in parenthesis. ***Statistical significant difference from 3 at $\alpha = 0.001$

4.4.5. Latent Factors Behind Forest Ownership and Bioenergy Views

4.4.5.1. Bioenergy Views

The original rotated factor solution resulted in 3 factors where these factors accounted for 62.2% of the total variance. However, upon closer examination and trial analysis it was determined that three factors did not well-summarize the data. The third factor possessed only two significant factor loadings associated with variables that were poorly correlated with each other compared to five significant loadings associated with each of the two remaining factors. The two variables associated with the third factor reported on the level of agreement to the importance of opinions of other landowners and competition for raw materials resulting from woody biomass harvesting. Since these variables also exhibited weak correlations with every other variable (highest coefficients were 0.127 and 0.158 respectively), they were removed and the procedure was repeated. The final rotated factor solution for bioenergy views generated two factors that accounted for 63.20% of the total variance in the responses. Six variables associated with bioenergy support were loaded on factor 1 with five variables associated with environmental degradation representing factor 2; factors were therefore labeled the same and significant factor loadings for each variable were underlined (Table 4.2). Given that loadings at least ±.50 are considered "practically significant" (Hair et al. 1998, p. 111), the first factor had all six positive significant loadings that met this criterion; variables were woody biomass as a viable alternative, enhancement of natural security from utilizing woody biomass, potential to positively impact U.S. energy independence, utilizing waste wood for energy, potential to benefit local economies and overall support for harvesting. The environmental degradation factor comprised of five significant factor loadings regarded as practically significant; statements alluded to woody biomass harvest limiting forest regrowth, degrading wildlife habitat, resulting in water pollution and soil erosion and improving forest health. The statement on improving forest health or "harvesting would likely improve forest health" had a negative loading (-0.54) thus, as agreement to statement on the negative impacts of harvesting woody biomass on the environment increase, agreement to the statement that harvesting would likely improve forest health would decrease. Bioenergy support and believing that harvesting woody biomass would result in environmental degradation therefore represented the two latent factors behind U.S. Great Lakes States NIPF landowners' bioenergy perceptions.

Table 4.2. Latent factors and loadings on U.S. Great Lakes States landowners' perceptions towards the utilization of woody biomass for bioenergy.

Variable	Bioenergy Support	Environmental Degradation	Uniqueness
Viable alternative to fossil energy	0.84	-0.10	0.28
Enhance national security	0.84	-0.08	0.28
Positively impact US energy independence	0.87	-0.10	0.23
Waste wood should be used for energy generation	0.69	-0.14	0.50
Harvesting is likely to benefit local economies	0.68	-0.23	0.49
Support for harvesting woody biomass	0.75	-0.38	0.30
Harvesting is likely to limit forest regrowth	-0.16	0.73	0.45
Harvesting would likely improve forest health	0.40	-0.54	0.55
Harvesting is likely to degrade wildlife habitat	-0.13	0.78	0.37
Harvesting is likely to result in soil erosion	-0.12	0.84	0.28
Harvesting is likely to result in water pollution	-0.12	0.82	0.32

4.4.5.2. Reasons for Forest Ownership

Factor analysis revealed four latent factors behind woodland ownership by NIPF landowners in the U.S. Great Lakes States; these factors represented 55.42% of the variance of the 15 forest ownership variables. Considering the sample size (*n* = 1202), factor loadings of .30 were considered to be significant (Hair 2008). The final (rotated) factor solution for variables for ownership reasons indicated a well-defined separation of ownership motivations; for amenity values, personal use, production and legacy. Statistically significant factor loadings for each were underlined (Table 4.3). Loadings of practical significance for the amenity factor were ownership for beauty, protection of nature, for privacy, hunting or fishing, and to protect land from development. Following the same criterion, the personal use factor consisted of reasons pertaining to ownership as part of a home, farm or ranch, cultivation of non-timber forest products and production of firewood for personal use. The production factor consisted of statements on ownership for bioenergy and timber production while for legacy, owning as part of one's inheritance and passing on to heirs were most significant.

Table 4.3. Latent factors and loadings on the importance of forest ownership among NIPF landowners of the U.S. Great Lakes States.

Variable	Amenity	Personal Use	Production	Legacy	Uniqueness
"To enjoy beauty or scenery"	0.79	0.15	-0.15	0.06	0.33
"To protect nature and biological diversity"	0.73	0.08	-0.09	0.27	0.38
"For privacy"	0.65	0.44	0.04	-0.04	0.39
"For hunting or fishing"	0.53	-0.15	0.37	-0.02	0.56
"To protect land from development (housing)"	0.61	0.13	-0.06	0.38	0.46
"As part of my home or vacation home"	0.43	0.65	-0.08	-0.11	0.38
"As part of my farm or ranch"	0.10	0.72	0.16	0.09	0.44
"For cultivation or collection of non-timber forest products (maple syrup, berries)"	0.15	0.56	0.16	0.28	0.55
"For production of firewood for personal use"	0.03	0.67	0.16	0.16	0.49
"For land investment"	0.11	0.28	0.41	-0.05	0.75
"For production of woody biomass for commercial bioenergy production"	0.01	0.04	0.75	0.16	0.42
"For production of sawlogs, pulpwood or other timber products"	-0.15	0.16	0.82	0.03	0.28
"To pass land on to my children or other heirs"	0.24	0.06	0.17	0.68	0.44
"To leave land unmanaged and let nature take its course"	0.34	0.03	-0.41	0.47	0.50
"As part of my inheritance"	0.03	0.08	0.06	0.82	0.32

4.4.6. Landowner Typology

A combination of results obtained from the hierarchical cluster analysis procedure and personal judgment, were considered for deciding on an appropriate number of clusters. The agglomeration coefficient derived from the hierarchical procedure is the "within-cluster sum of squares" (Hair et al. 1998, p. 503) and the percentage change in coefficients allow for identifying when the greatest change in coefficients occur. Small changes indicate that similar clusters are being formed while large changes indicate that more diverse cluster groups are being generated (Hair et al. 1998). The largest percentage change in the agglomeration coefficient obtained from hierarchical cluster analysis was going from 2 to 1 cluster, followed by 3 to 2 and 4 to 3 clusters. The four-cluster solution was both sufficient for identifying distinct groups of landowners (versus three-cluster solution), manageable to interpret and the number of cases in the four cluster solution was also well-distributed among the four groups. Consequently, four groups were specified as the cluster number for the *k*-means procedure.

The four clusters were labeled to communicate the characteristics of each variate according to responses on landowners' bioenergy perceptions and ownership reasons: *recreationist, indifferent, preservationist* and *multiple-objective* (Tables 4.4-4.5). Approximately 30% of respondents constituted the *recreationist* cluster group, followed by 25% in the *multiple-objective* cluster, 23% in the *indifferent* cluster and 21% in the *preservationist* cluster. With regards to forest ownership *recreationists* controlled the majority; 95,912.4 acres or 51% of the total acreage accounted for by the four landowner types. *Indifferent* and *multiple-objective* landowners each represented 19% of acreage owned while *preservationists*, 12% (Table 4.6). Representing one indicator of active forest management, the percent of landowners with a forest management plan from each group was estimated. The percent of landowners with a forest management was similar for *recreationists* and *multiple-objective* landowner with 48% and 51% having one respectively, while values were similar between *indifferent* landowners and *preservationists*; 40% and 37% respectively. Support for the harvesting of woody biomass for bioenergy was greatest from *recreationists* (81%) and *multiple-objective landowners* (82%) while only 14% of *preservationists* expressed support.

Bioenergy views were found to be positive among landowners belonging to the cluster group labeled “recreationist”. *Recreationists* were in agreement with statements that support the harvest of woody biomass for bioenergy including that waste wood should be used for bioenergy (Mean value= 4.2) and that its utilization can benefit local economies (Mean value= 3.9). The *recreationist* placed high importance on owning land for recreational outdoor activities like hunting and fishing (Mean value= 4.0), enjoying beauty (Mean value= 3.8) and privacy (Mean value= 3.7), regarding these ownership reasons as “very important”. Ownership for timber production was rated as being moderately important by this cluster group. Variables found to be only slightly important to these landowners included owning as part of one’s inheritance (Mean value= 1.7) and to leave unmanaged (Mean value= 1.8).

Indifferent landowners expressed generally neutral views towards bioenergy and forest ownership and were found to be statistically significantly different from all other groups for 12 of the 15 ownership reasons and 11 of the 13 bioenergy views. The highest rating on forest ownership was associated with the statement on owning for hunting or fishing (Mean value= 3.4) but this was only found to be moderately important. Although statistically different from all other cluster groups, the bioenergy views of highest ratings were the same as those of the *recreationist* (“Agree”); that waste wood should be used for bioenergy (Mean value= 3.7) and that harvesting is likely to benefit local economies

(Mean value= 3.5). The bioenergy view that harvesting woody biomass can create competition for raw materials was the only variable that did not appear to have significant differences across most groups but *indifferent* landowners (Mean value= 3.2) were different from *preservationists* (Mean value= 3.4) in this regard even though the rating translated to the same meaning.

The highest ratings on negative views towards the utilization of woody biomass were attributed the *preservationist* group. *Preservationists* were in agreement with two negative environmental effects of biomass harvest; the degradation of wildlife habitat (Mean value= 3.8) and soil erosion (Mean value= 3.7). All other bioenergy views were found to be neutral by this group. High mean ratings on non-timber woodland ownership objectives were identified, particularly for owning for beauty (Mean value= 4.5), for privacy (Mean value= 4.3) and to protect nature (Mean value= 4.3). There were no statistical mean differences from the *multiple-objective* group for the latter two variables. Unimportant to the *preservationist* was forest ownership for commercial bioenergy production (Mean value= 1.1) and second to this was timber production (Mean value= 1.7).

The *multiple-objective* cluster group was in agreement with all positive views on the utilization of woody biomass for bioenergy. The view that the opinions of others are important in the decision-making process of land management, possessed a neutral mean rating (Mean value= 3.4) similar to other groups but its mean still differed significantly from every other group. The *multiple-objective* cluster consisted of landowners who, with the exception for bioenergy production, rendered both timber and non-timber forest uses as being very important. The lowest mean ratings on ownership reasons were still classified as “slightly important” and the *multiple-objective* landowner was significantly different from every other group on all ownership reasons except for owning to protect nature (Mean value= 4.3) and to protect land from development (Mean value= 4.3) and for privacy (Mean value= 4.2) where there were no statistical differences from the *preservationist*.

Table 4.4. Mean comparison of U.S. Great Lakes States NIPF landowners' ratings to statements regarding bioenergy views classified by cluster groups.

Bioenergy Characteristic	a. Recreationist 30%		b. Indifferent 23%		c. Preservationist 21%		d. Multiple-objective 25%	
	M	Std. Err.	M	Std. Err.	M	Std. Err.	M	Std. Err.
Viable Fossil Fuel Alternative	3.78 (b,c,d)	0.05	3.10 (a,c,d)	0.07	2.83 (a,b,d)	0.06	3.97 (a,b,c)	0.05
Enhance National Security	3.54 (b,c,d)	0.05	2.88 (a,c,d)	0.06	2.61 (a,b,d)	0.06	3.78 (a,b,c)	0.05
Energy independence	3.82 (b,c,d)	0.04	3.11 (a,c,d)	0.06	2.77 (a,b,d)	0.06	3.95 (a,b,c)	0.05
Wastewood used for Energy	4.15 (b,c,d)	0.04	3.68 (a,c,d)	0.06	3.43 (a,b,d)	0.07	4.28 (a,b,c)	0.04
Harmful to Forests	2.33 (b,c)	0.05	2.81 (a,c,d)	0.06	3.39 (a,b,d)	0.07	2.46 (b,c)	0.05
Benefit Local Economies	3.92 (b,c)	0.04	3.49 (a,c,d)	0.05	3.18 (a,b,d)	0.06	3.97 (b,c)	0.04
Improve Forest Health	3.69 (b,c)	0.05	3.27 (a,c,d)	0.06	2.78 (a,b,d)	0.06	3.71 (b,c)	0.05
Will Degrade Wildlife Habitat	2.53 (b,c,d)	0.05	3.02 (a,c,d)	0.06	3.78 (a,b,d)	0.06	2.70 (a,b,c)	0.06
Instigate Soil Erosion	2.47 (b,c,d)	0.04	2.93 (a,c,d)	0.05	3.74 (a,b,d)	0.05	2.70 (a,b,c)	0.05
Result in Water Pollution	2.24 (b,c,d)	0.04	2.64 (a,c,d)	0.05	3.35 (a,b,d)	0.06	2.44 (a,b,c)	0.05
Create Competition	3.27	0.05	3.17 (c)	0.06	3.41 (b)	0.05	3.28	0.05
Overall Biomass Support	3.93 (b,c)	0.04	3.30 (a,c,d)	0.05	2.67 (a,b,d)	0.06	3.96 (b,c)	0.04
Opinions of family members matter	2.89 (d)	0.07	2.93 (d)	0.07	3.10 (d)	0.09	3.43 (a,b,c)	0.07

Likert rating scale (1= strongly disagree, 3= neither agree nor disagree, 5= strongly agree) was used to measure the level of agreement to each statement. Based on *F*-tests and with the exception of the statement that harvesting woody biomass will create competition, all variables used to create typology exhibited group means where at least one differed significantly from the others at $\alpha = 0.05$. Statistical significance difference between two group means were tested at an alpha of 0.05 and results indicated in parentheses. There were 313 observations in group a (Recreationist), 243 in group b (Indifferent), 223 in group c (Preservationist) and 260 in group d (Multiple-objective). M = mean; Std. Err. = standard error.

Table 4.5. Mean comparison of U.S. Great Lakes States NIPF landowners' ratings to statements on woodland ownership reasons classified by cluster groups.

Reasons for Owning Land	a. Recreationist 30%		b. Indifferent 23%		c. Preservationist 21%		d. Multiple-objective 25%	
	M	**Std. Err.**	**M**	**Std. Err.**	**M**	**Std. Err.**	**M**	**Std. Err.**
To enjoy beauty or scenery	3.80 (b,c,d)	0.05	3.28 (a,c,d)	0.07	4.47 (a,b,d)	0.05	4.33 (a,b,c)	0.04
To protect nature	3.44 (b,c,d)	0.05	3.06 (a,c,d)	0.07	4.26 (a,b)	0.06	4.33 (a,b)	0.04
For land investment	3.29 (b,c,d)	0.06	2.79 (a,d)	0.07	2.94 (a,d)	0.09	3.70 (a,b,c)	0.07
As part of my home	3.37 (b,c,d)	0.07	2.00 (a,c,d)	0.08	3.90 (a,b,d)	0.08	4.12 (a,b,c)	0.06
As part of my farm	2.61 (b,d)	0.08	1.54 (a,c,d)	0.06	2.78 (b,d)	0.10	3.65 (a,b,c)	0.08
For privacy	3.74 (b,c,d)	0.06	2.08 (a,c,d)	0.07	4.30 (a,b)	0.05	4.22 (a,b)	0.05
To pass land on to my heirs	2.71 (c,d)	0.07	2.79 (c,d)	0.08	3.55 (a,b,d)	0.09	4.24 (a,b,c)	0.06
For collection of non-timber forest products	1.88 (b,c,d)	0.05	1.41 (a,c,d)	0.04	2.19 (a,b,d)	0.08	2.77 (a,b,c)	0.08
For production of firewood	2.67 (b,d)	0.07	1.88 (a,c,d)	0.07	2.82 (b,d)	0.09	3.44 (a,b,c)	0.08
For commercial bio-fuel production	1.89 (b,c,d)	0.06	1.44 (a,c,d)	0.05	1.14 (a,b,d)	0.03	2.32 (a,b,c)	0.07
For production of timber products	2.74 (b,c,d)	0.07	2.26 (a,c,d)	0.08	1.71 (a,b,d)	0.07	3.05 (a,b,c)	0.07
For hunting or fishing	4.04 (b,d)	0.06	3.38 (a,c,d)	0.09	4.10 (b,d)	0.08	4.38 (a,b,c)	0.06
To protect land from development	2.85 (b,c,d)	0.07	2.42 (a,c,d)	0.09	4.23 (a,b)	0.07	4.30 (a,b)	0.05
To leave land unmanaged	1.76 (b,c,d)	0.05	2.21 (a,c,d)	0.08	3.46 (a,b,d)	0.08	2.70 (a,b,c)	0.08
As part of my inheritance	1.73 (b,c,d)	0.06	2.44 (a,d)	0.08	2.59 (a,d)	0.11	3.65 (a,b,c)	0.08

A 5-point rating scale (1= not important, 3= moderately important, 5= extremely important) was used to measure importance rating of each statement. Based on *F*-tests, all variables used to create typology exhibited group means where at least one differed significantly from the others at α= 0.05. Statistical significance difference between two group means were tested at α= 0.05 and results indicated in parentheses. There were 313 observations in group a (Recreationist), 243 in group b (Indifferent), 223 in group c (Preservationist) and 260 in group d (Multiple-objective). M = mean; Std. Err. = standard error.

Table 4.6. Description of cluster groups based on responses to selected survey variables.

Attribute	**Recreationist 30%**	**Indifferent 23%**	**Preservationist 21%**	**Multiple-objective 25%**
Percent of woodlands	51%	19%	12%	19%
Primary residence on woodlands	75%	82%	65%	65%
Has a forest management plan	48%	40%	37%	51%
In support of bioenergy	81%	47%	14%	82%

4.4.6.1. Price Preferences for Timber and Woody Biomass Harvesting

Further examination of the landowner typology revealed differences in landowners' price preferences to harvest timber and woody biomass. For the state of Michigan, 44% of respondents in ownership of a total of 62% of the reported acreage controlled by all four groups in the state indicated their willingness to harvest timber at one of the four prices offered (Figures 4.3-4.4). An estimated 18% of respondents were *recreationists* and only 4% *preservationists* while *multiple-objective* landowners represented just 10% of the total. The greatest percentage of woodlands available for harvest was owned by *recreationists* (46%) while indifferent landowners were far behind but second in place representing 8% of the woodlands. Availability of woodlands for woody biomass harvesting was comparable to that available for timber harvest for all other groups except from *preservationists*; this value was only 0.4%. *Preservationists* also did not respond differently when the timber price offer increased from $410 to $490. Cumulatively, 49% of Michigan NIPF respondents from the four cluster groups were willing to accept one of the four biomass price offers where this translated to 74% of woodlands for the state. The percentage of respondents responding to biomass price offers was highest from *recreationists*; 22% of respondents who controlled 61% of the state's total acreage in the sample. *Indifferent* landowners were again second in place resulting in 8% of the woodlands also available for biomass harvesting.

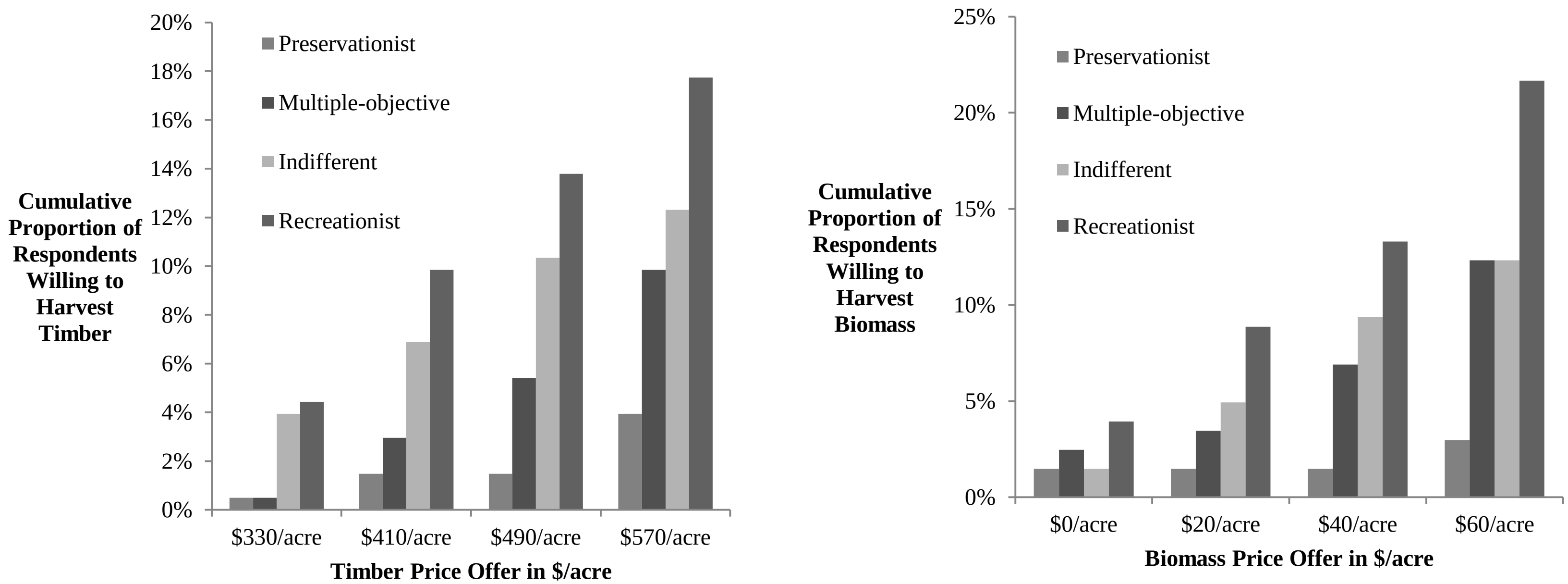

Figure 4.3. Cumulative proportion of Michigan's NIPF landowners willing to harvest commercial timber and woody biomass at specific price levels. Statewide total number of respondents belonging to cluster groups: 203 landowners.

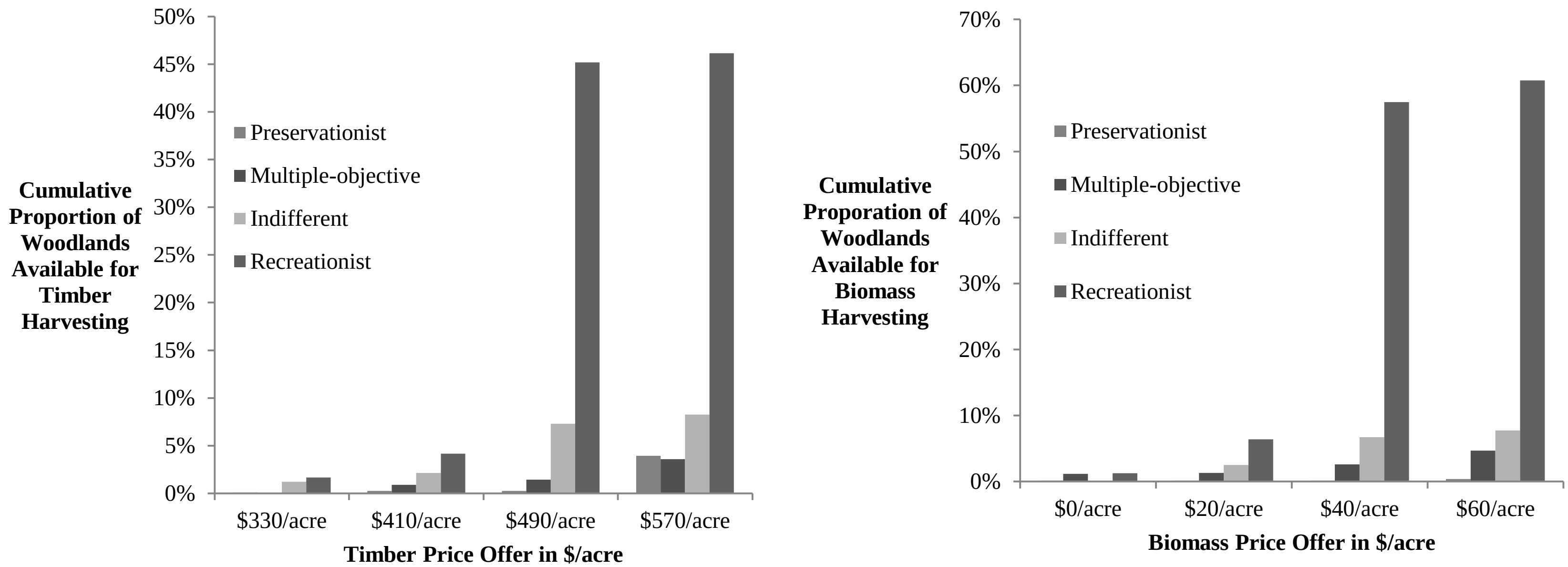

Figure 4.4. Cumulative proportion of Michigan's NIPFs available for commercial timber woody biomass harvest at specific price levels. Total acreage accounted for by the four cluster groups in the state: 79,822.5 acres.

Minnesota's NIPF landowners were found to follow a trend similar to that of Michigan's landowners. An estimated 62% of Minnesota's NIPF sample respondents were willing to accept one of the four timber price offers; representing 73% of the total acreage for the state (Figures 4.5-4.6). Meanwhile, 59% of respondents owning 70% of the woodlands accepted one of the four biomass price offers. With regards to a timber harvest, the cumulative percentage of respondents and availability of woodlands consistently increased with increasing timber and biomass price offers across all groups. As before, *recreationists* were most willing to harvest both timber and woody biomass while *multiple-objective* landowners constituted the second most willing group. 20% of respondents willing to accept timber price offers were *recreationists* who owned 29% of the woodlands, while 18% were *multiple-objective* landowners controlling 22%. Acceptance of woody biomass harvest offers was highest from *recreationists*; 22% of respondents owning 31% of the woodlands. Meanwhile values were the same as those for timber harvesting by the *multiple-objective* landowners. *Preservationists* were less responsive to both timber and harvest offers, representing less than 10% of the sample respondents and woodlands owned by these respondents.

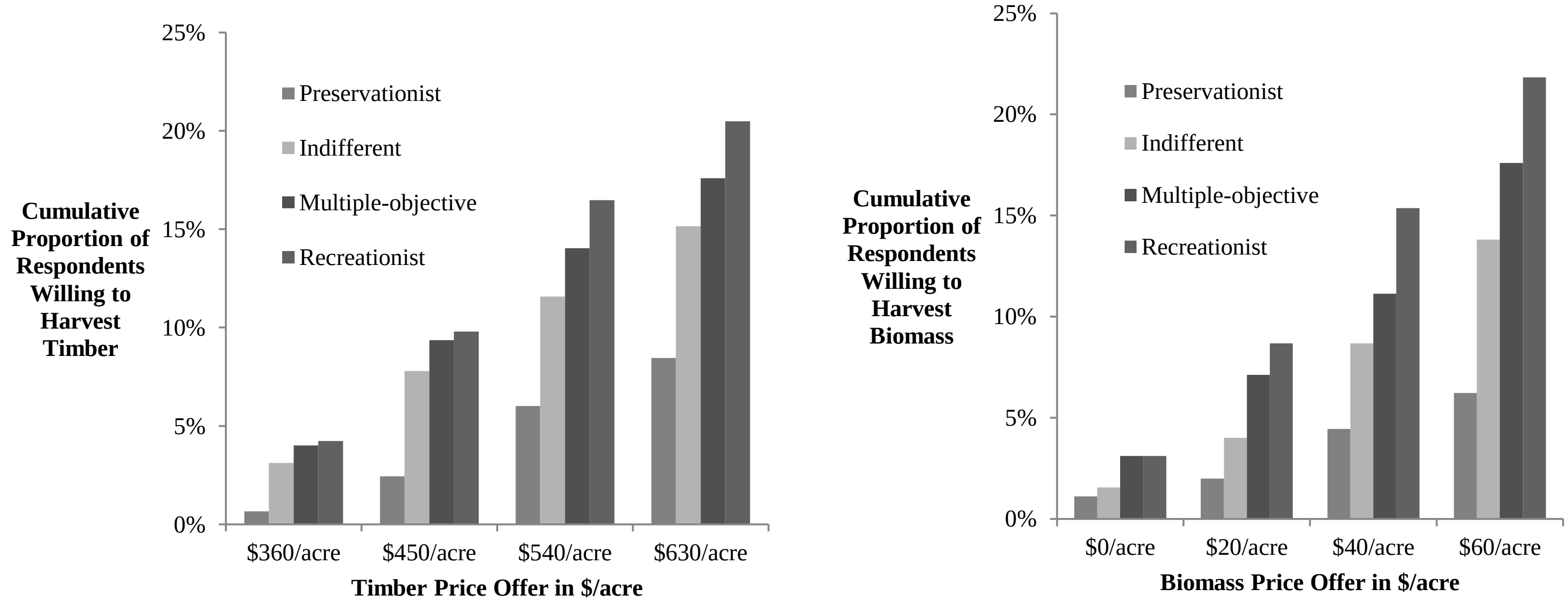

Figure 4.5. Cumulative proportion of Minnesota's NIPF landowners willing to harvest commercial timber and woody biomass at specific timber price levels. Statewide total number of respondents belonging to cluster groups: 449 landowners.

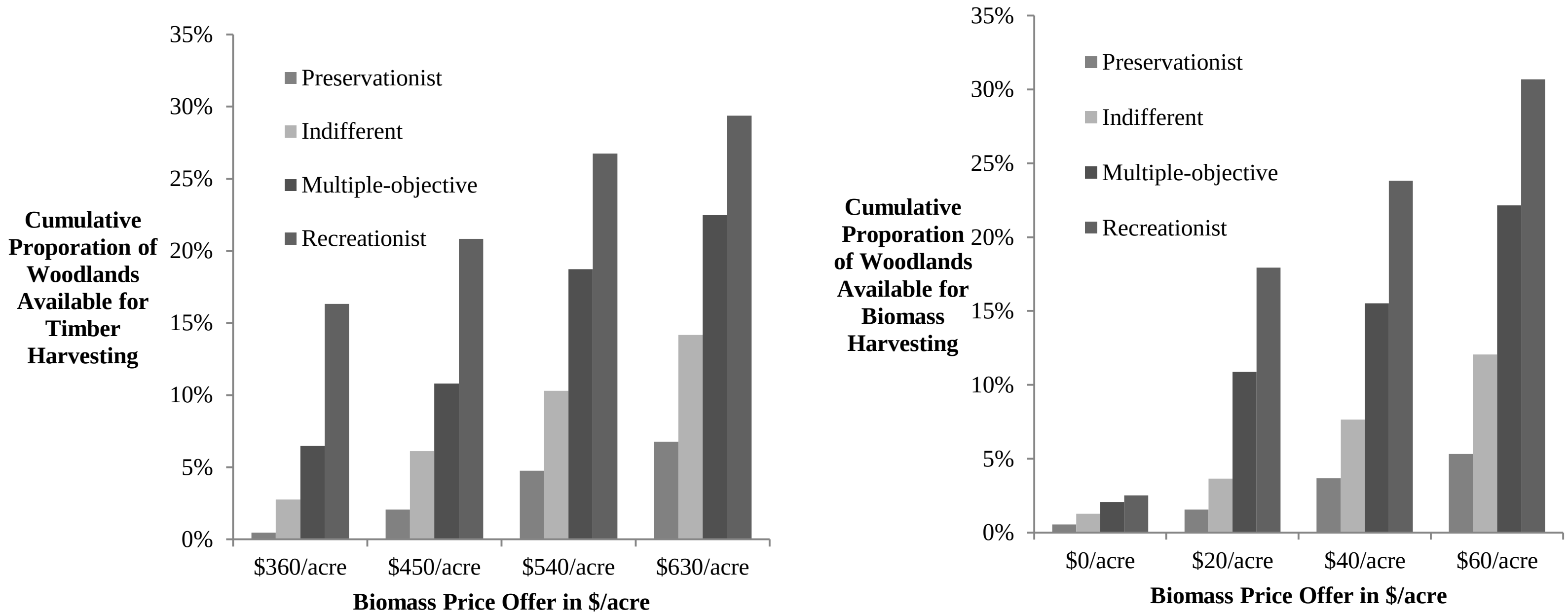

Figure 4.6. Cumulative proportion of Minnesota's NIPFs available for commercial timber and woody biomass harvest at specific price levels. Total acreage accounted for by the four cluster groups in the state: 61,142.42 acres.

Wisconsin's NIPFs available for timber harvesting was estimated at 68% of the total acreage accounted for by 56% of survey respondents for the state (Figure 4.7-4.8). *Recreationists* surpassed other groups in their acceptance of both timber and woody biomass price offers to harvest which translated to far more woodlands available statewide for harvest than from any other group. 19% of NIPF landowners owning 37% of the woodlands were *recreationists* who accepted one of the four timber price offers from this group. Similar to Minnesota, *multiple-objective* landowners were the second most popular group; 15% of respondents in control of 13% of the forest acreage were willing to harvest timber. As with other states in the region, *preservationists* were found to be least responsive to timber offers. In total, 55% of Wisconsin's NIPF landowners who cumulatively owned 68% of woodlands statewide indicated that they would accept one of the four biomass price offers proposed. Again, the most responsive group was the recreationists, followed by *multiple-objective* landowners, *indifferent* and lastly, *preservationists*. A total of 42% of woodlands in Wisconsin could potentially be available for biomass harvest by only the *recreationists* followed by 12% from *multiple-objective* landowners.

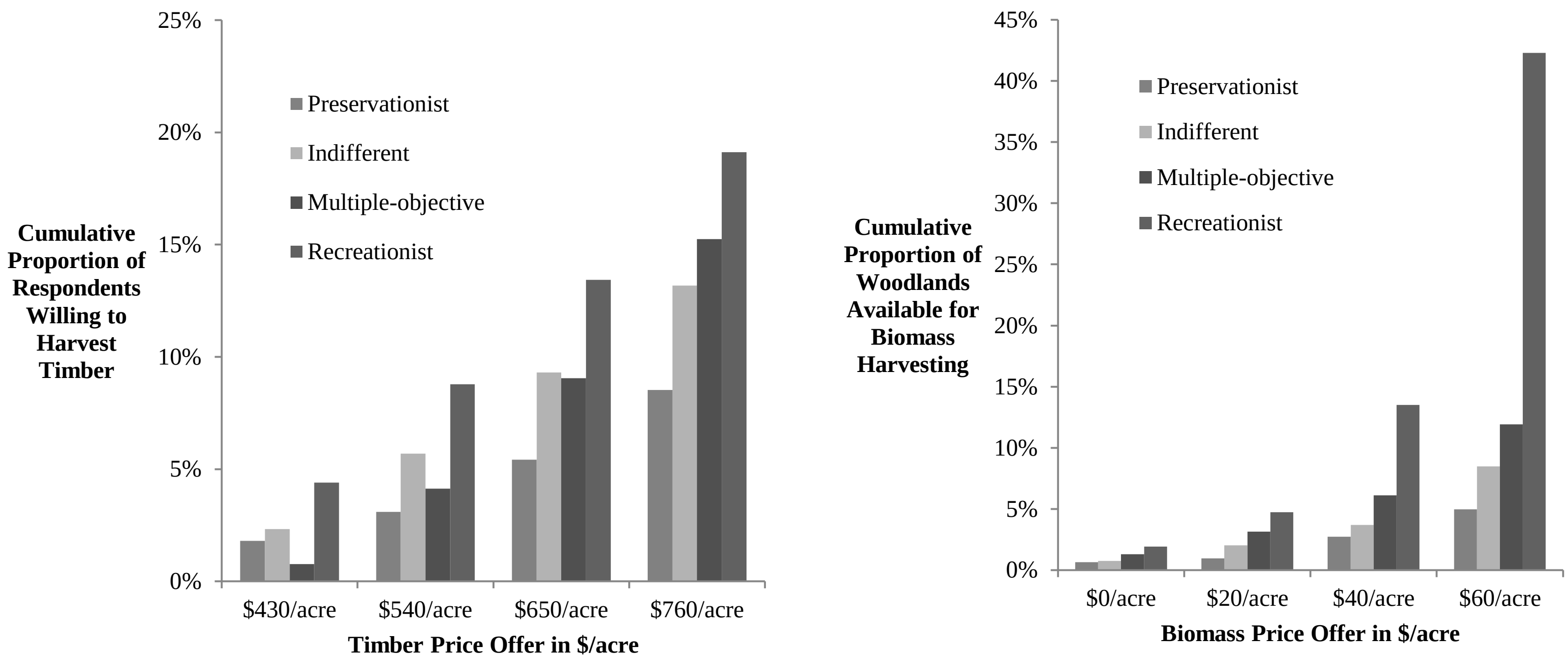

Figure 4.7. Cumulative proportion of Wisconsin's NIPF landowners willing to harvest commercial timber and woody biomass at specific price levels. Statewide total number of respondents belonging to cluster groups: 387 landowners.

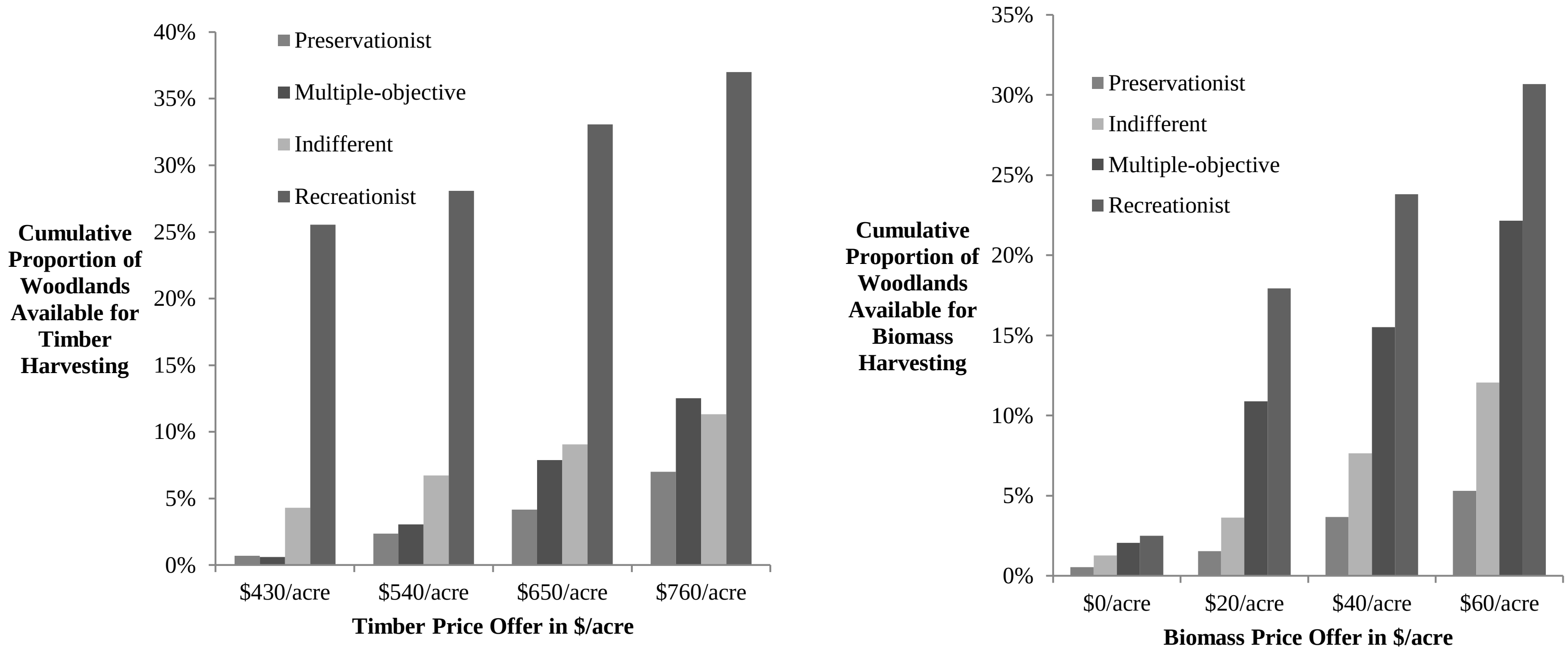

Figure 4.8. Cumulative proportion of Wisconsin's NIPFs available for commercial timber and woody biomass harvest at specific price levels. Total acreage accounted for by the four cluster groups in the state: 46,778.85 acres.

4.5. Discussion

Just over one-third of all respondents was at least 65 years of age and controlled nearly 50% of NIPF woodlands in the region. Considering that past literature found an increase in age associated with a decrease in willingness to harvest timber (Romm et al. 1987) and woody biomass (Becker et al. 2010; Gruchy 2011; Joshi and Mehmood 2011), a considerable portion of NIPF lands was expected to be restricted from harvest. However, a substantial proportion of respondents indicated a willingness to harvest both timber and woody biomass and expressed supportive views towards bioenergy. Regionally, 63% of woodlands could potentially be available for a timber harvest as indicated by responses to price offers, while 62% of woodlands were found to be potentially available for woody biomass harvest. Furthermore, given that 60% of landowners indicated a preference for either a tax reduction or incentive payment to harvest woody biomass, there is potential for promoting biomass supplies from financial initiatives by the public sector.

A comparison of state estimates revealed that even though the least number of respondents were those owning woodlands in Michigan, the largest reported acreage was from this state. Thus, even though the lowest percentage of acceptance of timber and biomass price offers were attributed to Michigan NIPF landowners, the largest number of acres potentially available for an integrated harvest were from this state. An estimated 24% and 29% of the total acreage were found to potentially be available for timber and biomass harvest respectively, in Michigan. Minnesota followed with 23% of woodland acreage potentially available for timber and again 23% for woody biomass harvest.

On average, landowners' views towards bioenergy were found to be positive while mean ratings to forest ownership reasons indicated that non-timber objectives particularly aesthetic and recreational reasons were very important to NIPF landowners from both the state and regional levels. Landowners indicating timber production as at least an important reason for forest ownership owned, on average, 375 acres compared to the overall average of 168 acres. Thus, larger acreages were associated with timber production objectives. Past literature have also indicated positive statistical significance between acres owned and willingness-to-harvest both timber and woody biomass (e.g. Binkley 1981; Vokoun et al 2005; Joshi and Mehmood 2011).

In an attempt to further understand the structure and dimensionality of the several ownership reasons and bioenergy perceptions presented, factor analyses were applied. Results identified two latent factors behind landowners' bioenergy perceptions and four factors associated with woodland ownership. NIPF landowners from the U.S. Great Lakes States were found to own woodland for amenity values, personal use, production and legacy and these landowners' views on bioenergy were summarized as having support for bioenergy and believing that woody biomass utilization for bioenergy would lead to environmental degradation. Findings were consistent with Aguilar et al. (unpublished) who identified bioenergy support and environmental effects from the same set of bioenergy statements presented to Missouri NIPF landowners. Markowski-Lindsay (2012) also identified two factors for Massachusetts landowners; concern about negative impact and belief of a positive impact, thus exhibiting a similar underlying structure on landowners' bioenergy views. Factor analysis results for Missouri also identified four latent factors behind NIPF forest ownership that closely resembled those derived for the U.S. Great Lakes States; protection, privacy, production and legacy (Aguilar et al. unpublished).

Using cluster analysis on responses to bioenergy statements and ownership reasons, NIPF landowners were classified into four groups: *recreationist*, *indifferent*, *preservationist* and *multiple-objective*.

The *recreationist* was characterized by owning mainly for recreational and aesthetic purposes. *Recreationists* expressed positive views towards bioenergy with an estimated 81% of these landowners indicating support. This type of landowner possessed similar traits as *woodland retreat landowners* of Missouri (Aguilar et al. unpublished) and *woodland retreat owners* identified at the national level by Butler et al. (2007). *Recreationists* represented one-half of the total acreage accounted for by all four groups, so their decisions will be instrumental in predicting biomass supplies. Surprisingly, even though timber production was found to be only "moderately important" for the average *recreationist,* this type of landowner will be most willing to harvest their woodlands. This finding represents a contradiction to the initial examination where the *multiple-objective* group was determined to be the most willing to harvest than the other three groups due to their indicated importance of forest production. According to results of groups' price preferences, the greatest potential availability of woodlands for harvesting was from *recreationists* who owned woodlands in Michigan; approximately 36,831 acres or 46% of Michigan's NIPFs owned by landowner groups could potentially be available for timber harvest and 48,499 acres or 61% for biomass harvest. Regionally, *recreationists* willing to harvest timber and woody biomass controlled an estimated 38% and 46% respectively, of the total acreage accounted for by the four landowner types. Off course, the gap between the acreage available for timber and biomass would need to be reduced for an integrated harvest.

Indifferent landowners were comparable to *passive* landowners of Missouri (Aguilar et al. unpublished) due to their overall neutral ratings towards bioenergy and forest ownership reasons and the *Jane Doe* group of Massachusetts for their lack of prominent identifiable characteristics (Finley and Kittredge Jr. 2006). This group of landowners indicated timber and bioenergy production as being only "slightly important" and "not important" but expressed general agreement that the utilization of woody biomass could benefit local economies and that waste wood should be used for bioenergy. These landowners, however, were more responsive than *preservationists* in their acceptance of timber and biomass price offers to harvest their woodlands. Given that *indifferent* landowners controlled 19% of the total acreage, their WTH translates to significant potential for procuring woody biomass feedstock. With regards to the greatest potential availability by state, Minnesota's *indifferent* landowners were most responsive to timber and biomass price offers resulting in the potential availability of 8,665 acres or 14% of its acreage for timber harvest and 7,375 acres or 12% for woody biomass harvests. Regionally, the percent of the total acreage accounted for by landowner groups that were potentially available for timber and biomass harvest from *indifferent* landowners was 11% and 9% respectively. Thus, values are still very low when compared when those from the *recreationist* group.

Similar to the *indifferent* group, *Multiple-objective* landowners owned 19% of woodlands regionally. As the label suggests, these landowners possessed both timber and non-timber objectives for woodland ownership had positive views towards the utilization of woody biomass for bioenergy. *Multiple-objective* landowners were the second most willing group to harvest timber and woody biomass in Minnesota and Wisconsin but with regards to the cumulative availability of woodlands by state, the greatest potential availability for timber harvest was in Minnesota. An estimated 13,737 acres or 22% of the state's sample acreage could potentially be available for a timber harvest and the same percentage was also found available for woody biomass harvesting. Regionally, indifferent landowners represented an estimated 12% of the total acreage accounted for by the cluster groups that could potentially be available for timber harvesting and 12% for biomass harvesting.

Preservationists owned the least number of woodland acres regionally (11%) and were least willing to harvest their lands for both timber and biomass. This was expected since these landowners were in agreement with biomass harvesting resulting in environmental damage and possessed mainly non-timber ownership reasons. *Preservationists* were found to be comparable to *woodland preservationists* of Missouri (Daniel 2012) and *preservationists* of Virginia (Kendra and Hull 2005). *Preservationists'* unwillingness to harvest resulted in small acreages available for harvesting and very low sensitivity to both timber and biomass price changes.

4.6. Conclusions

The availability of woody biomass is highly contingent upon NIPF landowners' willingness to harvest their woodlands for both commercial timber and biomass feedstock. While landowners have positive views towards the utilization of woody biomass and two-thirds of woodlands regionally are potentially available for harvesting, the dominant age group suggests that estimations will change in the near future as new owners take control of these lands. Furthermore, it is important to realize that landowners in the U.S. Great Lakes States possess very different views towards forest ownership and bioenergy, giving rise to distinct types of landowners that will respond differently to harvesting. This study found that *recreationists* would be the most likely group of landowners to harvest their woodlands while preservationists would be the least regardless of the price offered. *Recreationists* controlled 51% of the total woodlands reported by sample respondents and were most responsive to harvest offers so there is potential for integrated harvests from this group across the three states. This group of landowners' WTH translated to potential availability of 38% of woodlands available for timber harvesting and 46% for biomass harvesting with the majority coming from Michigan's NIPFs. Ultimately, policy initiatives that can appeal to the specific landowner types, particularly the most responsive groups, will be essential for the promotion of woody biomass availability.

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Chapter 5. Econometric Examination of Michigan, Minnesota and Wisconsin Non-Industrial Private Forest Landowners' Willingness to Harvest Timber and Woody Biomass

Abstract: While there is expected to be significant growth in demand for woody biomass for energy in the U.S. Great Lakes States, the supply side needs to be comprehensively examined for the social availability of the resource since social factors affect the volume that can be harvested. Nearly 60% of forestland in the region is owned by private forestland owners and non-industrial private forest landowners (NIPF) represent 92% of this total. Analysis of responses to a mail survey of 4,190 NIPF landowners from Michigan, Minnesota and Wisconsin revealed that while non-timber objectives significantly decreased landowners' willingness-to-harvest (WTH) timber and woody biomass, prices significantly increased the odds of harvesting. However, the effects of timber and woody biomass price offers on WTH were not found to be equal. Marginal probability analyses of timber and woody biomass prices suggests that timber price rather than biomass price drive the decision to harvest both timber and woody biomass. While this finding was consistent across states, a comparison of state-level results revealed that respondents owning woodlands in Minnesota would be most willing to harvest timber and woody biomass from their woodlands.

Keywords: Woody biomass, social availability, non-industrial private forest landowners, bioenergy, Lake States

5.1. Introduction

Woody biomass may be defined as "the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the by-products of forest management"(U.S. Forest Service 2008). Woody biomass is an abundant and locally available renewable energy resource and biofuel generation from biomass is seen as a way to decrease carbon emissions, reduce dependence on and importation of coal and liquid natural gas and create new markets for an otherwise disposal problem for farmers and forest landowners (Bartuska 2010). In recognition of the potential to displace fossil fuels with a renewable, reliable and domestically produced fuel along with the environmental and economic benefits associated with its use, the United States (U.S.) has set a goal for transportation fuels to contain 36 billion gallons of renewable fuels including at least 16 billion gallons of cellulosic biofuels such as woody biomass by 2022 (P.L. 110-140 2007; EPA 2010). Currently biomass used for biofuel is largely sourced from agricultural feedstock but with a goal to achieve energy security, the continued use of food for ethanol may conflict with food supplies (Skipper et al. 2009). The combination of agricultural feedstocks with woody biomass can significantly increase supplies (Becker et al. 2010) to help meet national renewable energy goals.

Forests cover about 33% or 751 million acres of land in the United States where about 56% of this total are under private ownership but most of this, about two-thirds accounting for nearly 40% of all forestlands or 285 million acres are owned by nonindustrial private forest (NIPF) landowners (Butler 2008; Smith et al. 2009). There are 52.2 million acres of forests in the U.S. Great Lakes States of Michigan, Minnesota and Wisconsin combined and 30.3 million acres or 58% of this total are privately owned (Smith et al. 2009). Non-industrial private forests account for 27.9 million acres which equates to 92% of all private forest lands in the region (Butler 2008). This translates to NIPF ownership representing 48% of forestlands or 9.5 million acres in Michigan, 36% or 5.9 million acres in Minnesota and 59% or 9.7 million acres in Wisconsin. The extent of forest ownership by NIPF landowners indicates a necessity for understanding these landowners in order to capture a realistic estimation of woody biomass supplies to support a bioenergy market. While physical estimates on woody biomass can be derived from the U.S. Forest Service's resource inventory (e.g. Goerndt et al. 2012) availability is also constrained by social factors. Social factors need to be considered when evaluating the supply side of the woody biomass resource.

The aim of this study was to portray a comprehensive representation of the availability of woody biomass from NIPF landowners in the U.S. Great Lakes States of Michigan, Minnesota and Wisconsin for proposing a viable bioenergy market from woody biomass in the region. The objectives of this study included a determination of significant factors influencing landowners' WTH timber and woody biomass from their woodlands in Michigan, Minnesota and Wisconsin and an examination of the marginal effects of timber and biomass prices on the choice to harvest woody biomass for bioenergy in each of the three states.

5.2 Theoretical Framework

Factors affecting NIPF landowners' WTH timber have been extensively studied over the years (Kurtz and Lewis 1981; Young and Reichenbach 1987; Amacher et al. 2003; Vokoun et al. 2005; Tonisson 2012) but with recent interest in woody biomass usage for energy production, social availability studies on woody biomass have become crucial for predicting supplies. The harvest of woody biomass must be done in conjunction with a timber harvest as past reports suggest this activity will not be economically feasible if done alone (Hubbard et al. 2007, Saunders et al. 2012) and by-products of a timber harvest can be used as woody biomass feedstock. It is therefore crucial to incorporate the same factors previously found to affect timber harvesting as potential factors that may affect woody biomass harvesting decisions.

Landowners' decision to engage in forest management activities is a reflection of their ownership objectives, motivations and constraints (Kurtz and Lewis 1981). Specific factors that have been found to affect landowners' decisions to harvest timber include stumpage price, technical assistance, ownership objectives, membership in an organization and demographics like age, income and education (Binkley 1981; Young and Reichenbach 1987; Amacher et al. 2003). Kurtz and Lewis (1981) found that a lack of previous timber harvesting experience, low timber prices, absence of incentives, physical resource availability and lack of technical assistance constrained participation in forest management. Other factors such as land tenureship, has been shown to positively correlate with timber harvesting intensity and landowners who have owned their land for a longer time (ten years or more) have been found to be more involved in active forest management versus new landowners (less than ten years) (Vokoun et al. 2005; Butler 2007).

A study of NIPF landowners' WTH woody biomass for bioenergy in Arkansas, Florida and Virginia revealed similar findings with timber studies where an increase in acreage owned was positively associated with an increase in landowners' willingness to supply biomass (Joshi and Mehmood 2011). However, another study of NIPF landowners in Mississippi found that an increase in ownership size was associated with a decrease in WTH woody biomass since these landowners were more interested in timber production (Gruchy et al. 2011). The effect of acreage must be analyzed to determine their impact on landowners' decisions from the U.S. Great Lakes States as results evidently vary across regions. Demographics like landowners' age and education influence ownership objectives since older landowners are more likely to transfer or bequeath their forestland in the near future and would be less interested in harvesting their forest (Butler and Leatherberry 2004). Consequently, older landowners were found to be less likely to engage in both timber and woody biomass harvesting (Becker et al. 2010; Joshi and Mehmood 2011; Gruchy et al. 2011). Unlike age, education positively influenced decisions to harvest woody biomass in the southern U.S. and Minnesota (Becker et al. 2010; Joshi and Mehmood 2011; Gruchy et al. 2011). According to a study of Minnesota forest landowners by Becker et al. (2010), those who were more likely to harvest woody biomass were landowners who chose the highest price offers for harvesting. Significant negative influences on WTH were indicated by landowners who did not believe that woody biomass could improve U.S. energy independence and absentee landowners who did not reside on their woodlands (Becker et al. 2010).

Since landowners' decisions to harvest their woodlands will be based on those factors that maximize utility, the utility model can be summarized as: $U_i = f\,(L, LO, E) + \varepsilon$, where U_i is the utility received by the ith landowner from harvesting (or not), L is a vector of land characteristics of forest owned by the landowner, LO is representative of all the landowner attributes, E stands for external factors and ε is a random error term (Figure 5.1).

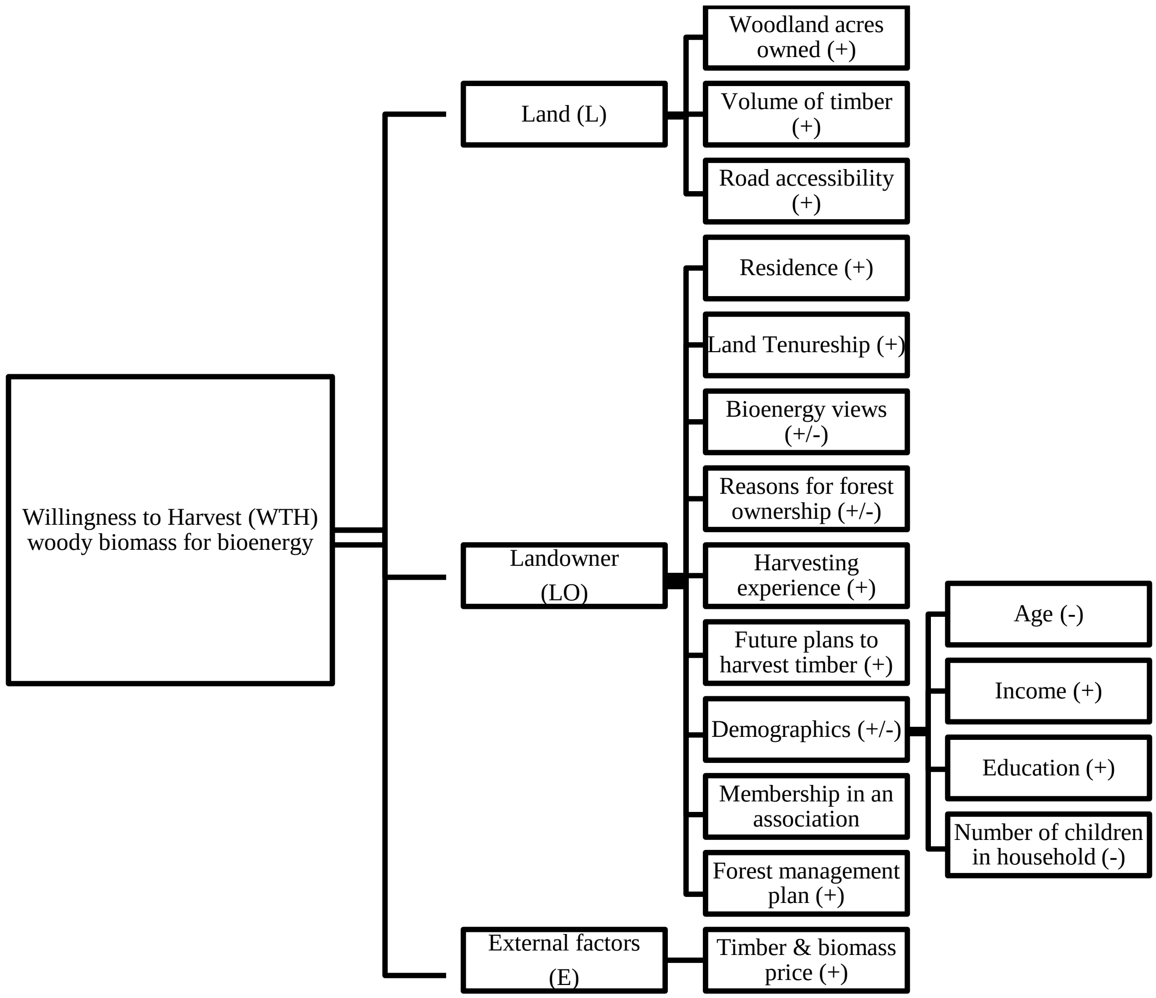

Figure 5.1. Expected effects, indicated by positive/negative signs, of explanatory variables (land characteristics, landowner attributes and external factors) on landowners' choice to harvest timber and woody biomass.

Gruchy et al. (2011) found no difference in the coefficient signs obtained from ordered logit, binary logit and tobit regression models used for measuring WTH in a conjoint analysis so the logit model was selected for assessing landowners' WTH in this study. Thus, in order to assess the theoretical utility associated with WTH, a binary logit model generated as a latent-variable model was used. According to Greene (2011), the latent variable y^* is unobserved and related to the observed independent variables by the equation: y_i^*= $x_i \beta + \varepsilon_i$ where i indicates the observation, y^* is the latent unobserved utility derived from harvesting $x_i \beta$ stands for a vector of explanatory variables (L, LO and E) and associated coefficients and ε is the random error. The relationship between the latent y^* and observed y, representing WTH (Greene 2011) is:

$$y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \; if \; y_i^* \leq 0 \end{cases}$$

Consequently, positive values of y^* (where $U_i > 0$) translate to an observed state where $y = 1$, which would mean that the landowner would accept the offer to harvest while negative or zero values of y^* would be observed as $y = 0$ would equate to an unwillingness to accept at the proposed harvest offer.

5.3. Methods

5.3.1. Data

A survey developed by Daniel (2012) for Missouri NIPF landowners was used as an initial template for the development of questionnaires for the study area consisting of Michigan, Minnesota and Wisconsin. This instrument served to gather information on landowners' views towards the harvesting of woody biomass for bioenergy and potential constraints to supply as well as landowners' price preferences for carrying out a harvest. Following research of the region's timber markets and resource inventory, reviews from each of the three states' Department of Natural Resources (DNR) and forestry faculty members from University of Missouri, University of Minnesota and University of Wisconsin, a survey instrument was developed and pretested among a sample of forest landowners from the study area via mail. The final survey instrument was divided into five parts; the first section served to gain insight into landowners' forestland management experience, intentions and road accessibility, the second part, to determine perceptions on harvesting woody biomass for bioenergy the third, to determine landowners' price preferences for harvesting and interest in incentives, fourth, reasons of land ownership and finally the fifth section aimed to capture respondents' demographic information. Questions were formatted to include discrete choices (Yes/No/Do not know), open-ended questions, closed questions with ordered choices and partially closed questions. Most of the reasons for forest ownership and response options for demographic variables and were taken directly from the U.S. Forest Service's National Woodland Owner Survey (NWOS) (2012) for validation and comparison purposes. The NWOS is sent to forest landowners nationwide and the information derived serves to compliment the physical forest resource inventory administered by the U.S. Forest Service (U.S. Forest Service 2012). Growing stock estimates, representing physical availability of commercial timber, were gathered from the U.S. Forest Service's Forest Inventory and Analysis (FIA) program using the EVALIDator software (Miles 2012). Conjoint analysis was used in the third part of the survey to ascertain landowners' price preferences for harvesting woody biomass; four timber price offers determined from a combination of data from FIA and Timber Mart North (Prentiss & Carlisle 2011a-c) and four woody biomass price offers based on the average bio-stumpage rate for the region, were used to construct harvesting scenarios. All price offers were on a per acre basis; the methods applied for the development of price offers are detailed in Chapter 3. Each scenario consisted of one timber price offer and one biomass offer that was at least $0. Combinations of timber and biomass price offers, in the form of profiles, were derived randomly using the Bretton-Clark orthogonal design (Bretton-Clark 1988). Twelve harvesting scenarios were constructed and divided among four versions of the survey per state. The responses to the hypothetical harvesting scenarios were binary in nature; either "yes" or "no" according to whether respondents chose to accept the offer and harvest or reject the offer. Except for price offers for timber and forest landowner programs, the final survey instrument was the same for the three states.

A mail-based survey was chosen to administer the survey due to the cost effectiveness of this option. Consequently, a mailing database was generated by randomly selecting eight counties from each state, resulting in a total of twenty-four counties; selection was made from a list generated using FIA data and tools in ArcMap to derive only those counties with relatively considerable amounts of total tree biomass (at least 7 million dry tons of total tree biomass) on private lands. The mailing database was then developed by gathering landowner data (names, addresses, acres owned) from the respective county tax assessors and online parcel maps where available. The mailing database consisted of 4,190 landowners' names and corresponding addresses for potential participation in the survey.

Survey mailing was carried out from March to April 2012 following Dillman's Tailored Design Method (Dillman 2000). The first round of surveys with cover letters was mailed one week following the mailing of initial postcards that invited potential respondents to participate in the bioenergy study. Thank you and reminder postcards were sent at least two weeks later followed by a final mailing of the surveys with cover letters (second wave).

5.3.2. Econometric analysis

All responses were entered into Microsoft Excel 2010; data from the conjoint analysis section of the survey were recorded in a separate spreadsheet from the rest of the survey since there were multiple responses per respondent (one per harvest scenario) and a single response per question per respondent for the rest of the survey. Following data entry, unique respondent identification numbers were assigned to each respondent to facilitate merging of the two datasets for complete records of responses from each respondent. Datasets were imported into Stata 10.0 and merged into a single one to carry out econometric analyses. All analyses were carried out using Stata version 10.0. Analyses were also limited to only those observations in total acreage of forest owned were at least 20 acres. Twenty acres was used as the minimum number of acres owned for inclusion in the study since landowners owning less than 20 acres are considered less likely to engage in forest management practices (Row 1978; Butler and Leatherberry 2004).

Descriptive statistics were generated for all variables involved in subsequent regression analyses. The dependent variable (DV) was “choice” which was dichotomous; coded “1” for yes and “0” for no and represented landowners’ decision to harvest their woodlands. Binary logistic regression models of “choice” on the independent variables were carried out to determine the factors that significantly influenced landowners’ decisions to harvest. According to Hill et al. (2001), in the logit model, the probability (p) that the observed binary y (0, 1) has a value of 1 is modeled as:

$$p = \frac{1}{1+e^{-(\beta_1 + \beta_2 x)}} ,$$

where β refers to the regression coefficients resulting from the maximum likelihood estimation of the logit model, x is an explanatory variable and multiple explanatory variables may be included in the model. Cluster robust standard errors were estimated for all regression models as there were multiple responses per respondent in the dataset so these values would be more reliable than non-robust standard errors (Maas and Hox 2004). Furthermore, since coefficients of logit regression models are in log-odd units, odds ratios were computed in Stata by taking the exponential of the coefficients, to create a more natural scale for interpretation of results.

Two regression models were generated for each state (Michigan, Minnesota and Wisconsin) to determine the effects of only prices on WTH, followed by an observation of the effects of all other explanatory variables (Table 5.1). Since these two models consisted of the same variables across states, results were presented as “Model 1” and “Model 2” for each of the three states. Model 1 involved a regression of “choice” on timber price, biomass price and option to harvest biomass. Results were used to calculate cumulative probabilities associated with landowners WTH to harvest timber and biomass at each price level. The subtraction of two consecutive cumulative or predicted probabilities resulted in the marginal probability or marginal change that was interpreted as the change in probability associated with an increase in a biomass price offer for a given timber price. Marginal probability analyses of timber and woody biomass prices therefore served to examine the effect of changes in price offers on the probability of harvesting timber and woody biomass.

Model 2 involved a regression of “choice” on all of the explanatory variables involved in the study (Table 5.1). As previously discussed, WTH as measured by “choice” was assumed to be a function of L or land characteristics for the forest owned by the landowner, LO or landowner attributes and E; external factors.

Table 5.1. List and description of explanatory variables used in the examination of social availability of woody biomass for bioenergy among NIPF landowners of Michigan, Minnesota and Wisconsin.

Explanatory variable	Description
Land Characteristics	
1. Number of woodland acres owned	Continuous variable (acres)
2. Volume of commercial timber in cubic feet, by county	Continuous variable. Estimates were divided by 100,000 to downscale figures.
3.Whether woodlands have direct access to county road or highway	Binary variable (1= “yes”, 0= “no”).
Landowner Attributes	
4. Whether the landowner resides on his/her woodland	Binary variable (“yes/ some of it is”=1, “no”= 0).
5. Total number of years landowner has owned his/her woodland	Continuous variable representing tenureship.
6. Bioenergy views	
- “Harvesting woody biomass is likely to result in soil erosion”	Binary variable (“Agree”= 1 and “Disagree” = 0)
- “I support harvesting woody biomass for energy”	Binary variable (“Agree”=1 and “Disagree”=0)
7. Reasons for owning land - “To enjoy beauty or scenery” -“For production of firewood for personal use” - “To leave land unmanaged and let nature take its course”	Likert rating scale (1= not important to 5= extremely important) was used to measure importance rating of each statement.
8. Have sold timber since ownership of woodlands	Binary variable (“yes”= 1, “no”= 0).
9. Have sold timber in the past and plans to sell timber	Binary variable (“yes”= 1, “no”= 0).
10. No plans to harvest timber or biomass regardless of price	Binary variable (“Agree”= 1, “Disagree”= 0).
11. Demographic information	
- Age	- Ordered categories: 1= “Under 25 years”, 2= “25 to 34 years”, 3= “35 to 44 years”, 4= “45 to 54 years”, 5= “55 to 64 years”, 6= “65 to 74 years” and 7= “75 years or older”
- Education	- Categorical: 1= “Less than 12th grade”, 2= “High school graduate or GED”, 3= “Some college”, 4= “Associate or technical degree”, 5= “Bachelor’s degree”, 6= “Graduate degree”
- Children under 18 years of age live in the household	Binary variable (“yes”=1, “no”=0).
- Annual household income range in dollars per year	Binary variable (Income ≥ \$50,000 = 1, Income ≤ \$50,000 = 0).
13. Membership in a forest landowner group or environmental organization	Binary variable (“yes”=1, “no”=0).
14. Has a professionally written forest management plan	Binary variable (“yes”=1, “no”=0).
External Factors	
15. Timber price in dollars per acre (\$/ac)	Continuous variable
16. Biomass price in \$/ac	Continuous variable
17. Option offered to sell woody biomass	Binary variable (1=both timber and biomass offers proposed and 0= Only timber offer proposed)

5.4. Results

5.4.1. Descriptive Statistics

The adjusted response rate, after accounting for non-deliverables, non-responses and removing returned questionnaires from landowners owning less than 20 acres, was 32%. This response rate was comparable to that of a recent survey of Missouri NIPF landowners, where this was 34% and also for a survey of Mississippi NIPF landowners (28.8%) (Gruchy et al. 2011; Daniel 2012). At the state level, the highest response rate was from the state of Minnesota (45%), followed by Wisconsin (32%) and finally from Michigan (31%). Regionally, an average of 85% of sample respondents were male and the average age group of a respondent and education level was between 55 and 64 years old and Associate or technical degree respectively. Landowners at least 55 years of age represented the majority of respondents from each state; 76% of Michigan's NIPF landowners, 71% of Minnesota's NIPF landowners and 65% of Wisconsin's NIPF landowners. Only 15% of respondents regionally had children under the age of 18 years living in the household and 67% earned at least $50,000 per year per household.

An estimated 75% of landowners indicated that their woodlands had direct access to roads and landowners on average, owned 168 acres of forestland and were found to be in possession of their land for about 25 years. The percent of landowners possessing woodlands with road access were comparable for the three states; 83% of Michigan landowners, 76% of Minnesota landowners and 69% of Wisconsin landowners. A similar trend was observed for tenureship that ranged between 24 and 29 years of woodland possession for the average landowner.

An average of 58% of all respondents supported the harvest of woody biomass for bioenergy by indicating their agreement to this statement but nearly a quarter or 23% had no future plans to sell timber regardless of the price offered. State estimates were comparable with the largest percent of respondents indicating support owned NIPFs in Minnesota; an average of 61% supported the harvest of woody biomass for energy but 20% indicated having no plans to harvest. An average of 58% and 56% of Michigan's and Wisconsin's respondents indicated support and 25% per state had no plans to harvest. Woodland ownership for enjoyment of beauty was found to have the highest mean rating of all ownership objectives where it was deemed very important by NIPF landowners (respondents) from each state. Forest ownership for firewood was rated as being moderately important in each state and leaving woodlands unmanaged was only found to be slightly important by Michigan and Minnesota's NIPF landowners and moderately important to Wisconsin's NIPF landowners. Regionally, less than half or 44% of landowners indicated having a management plan written by a professional forester indicating that 56% of landowners are either not managing their woodlands in a sustainable manner or are not interested in actively managing their woodlands. With regards to state-level estimates this value was 32%, 61% and 31% for Michigan, Minnesota and Wisconsin respectively. Only 10% of landowners regionally were found to be involved in a forest or environmental organization; 7%, 13% and 8% of Michigan, Minnesota and Wisconsin's respondents respectively answered "yes" to this question.

Table 5.2. Descriptive statistics for model examining landowners' willingness-to-harvest (WTH) their woodlands (Model 2) in the state of Michigan.

Variable	*n*	Mean	Std. Dev.	Min	Max
Dependent Variable					
Choice	1733	0.39	0.49	0	1
Land Characteristics					
Number of woodland acres owned	2096	344.59	2063.68	20	32000
Volume of commercial timber in cubic feet, by county*	2120	3239.47	1365.20	1352	6075
Whether woodlands have direct access to county road or highway	2136	0.83	0.37	0	1
Landowner Attributes					
Whether the landowner resides on his/her woodland	2128	0.71	0.46	0	1
Total number of years landowner has owned his/her woodland	2040	29.83	19.09	1	175
"Harvesting woody biomass is likely to result in soil erosion"	1960	0.29	0.45	0	1
Support for harvesting woody biomass for energy	1984	0.58	0.49	0	1
"To enjoy beauty or scenery"	2104	3.88	1.05	1	5
"For production of firewood for personal use"	2080	2.82	1.35	1	5
"To leave land unmanaged and let nature take its course"	2072	2.42	1.40	1	5
Have sold timber since ownership of woodlands	2136	0.57	0.49	0	1
Have sold timber in the past and plans to sell timber	2136	0.39	0.49	0	1
No plans to harvest timber or biomass regardless of price	2008	0.25	0.44	0	1
Age	2104	5.33	1.14	2	7
Education	2096	3.92	1.59	1	6
Children under 18 years of age live in the household	2080	0.12	0.32	0	1
Income (≥$50,000/year)	1888	0.61	0.49	0	1
Membership in a forest landowner group or environmental organization	2128	0.07	0.25	0	1
Has a professionally written forest management plan	2112	0.32	0.47	0	1
External Factors					
Timber price in dollars per acre ($/ac)	2136	452.85	88.41	330.00	570.00
Biomass price in $/ac	2136	14.72	21.47	0.00	60.00
Option offered to sell woody biomass	2136	0.50	0.50	0	1

* Commercial timber volume expressed in 100,000 cubic feet units.
See Table 5.1. for definition of variables.

Table 5.3. Descriptive statistics for model examining landowners’ willingness-to-harvest (WTH) their woodlands (Model 2) in the state of Minnesota.

Variable	***n***	**Mean**	**Std. Dev.**	**Min**	**Max**
Dependent Variable					
Choice	4060	0.46	0.50	0	1
Land Characteristics					
Number of woodland acres owned	4551	133.63	304.93	20	6400
Volume of commercial timber in cubic feet, by county*	4575	3628.06	1951.50	716	7733
Whether woodlands have direct access to county road or highway	4599	0.76	0.43	0	1
Landowner Attributes					
Whether the landowner resides on his/her woodland	4607	0.76	0.43	0	1
Total number of years landowner has owned his/her woodland	4479	23.83	14.13	0	118
“Harvesting woody biomass is likely to result in soil erosion”	4319	0.24	0.43	0	1
Support for harvesting woody biomass for energy	4335	0.61	0.49	0	1
“To enjoy beauty or scenery”	4559	4.03	0.94	1	5
“For production of firewood for personal use”	4391	2.57	1.28	1	5
“To leave land unmanaged and let nature take its course”	4535	2.47	1.27	1	5
Have sold timber since ownership of woodlands	4599	0.61	0.49	0	1
Have sold timber in the past and plans to sell timber	4591	0.38	0.49	0	1
No plans to harvest timber or biomass regardless of price	4511	0.20	0.40	0	1
Age	4551	5.14	1.15	1	7
Education	4575	4.04	1.40	1	6
Children under 18 years of age live in the household	4511	0.15	0.35	0	1
Income (≥$50,000/year)	4279	0.72	0.45	0	1
Membership in a forest landowner group or environmental organization	4583	0.13	0.34	0	1
Has a professionally written forest management plan	4439	0.61	0.49	0	1
External Factors					
Timber price in dollars per acre ($/ac)	4623	490.85	101.38	360.00	760.00
Biomass price in $/ac	4623	14.80	21.74	0.00	60.00
Option offered to sell woody biomass	4623	0.50	0.50	0	1

* Commercial timber volume expressed in 100,000 cubic feet units
See Table 5.1. for definition of variables.

Table 5.4. Descriptive statistics for model examining landowners' willingness-to-harvest (WTH) their woodlands (Model 2) in the state of Wisconsin.

Variable	*n*	Mean	Std. Dev.	Min	Max
Dependent Variable					
Choice	3264	0.40	0.49	0	1
Land Characteristics					
Number of woodland acres owned	3953	113.73	376.52	20	7500
Volume of commercial timber in cubic feet, by county*	3945	2481.74	251.28	1745	4054
Whether woodlands have direct access to county road or highway	3961	0.69	0.46	0	1
Landowner Attributes					
Whether the landowner resides on his/her woodland	3977	0.67	0.47	0	1
Total number of years landowner has owned his/her woodland	3833	24.12	13.11	2	67
"Harvesting woody biomass is likely to result in soil erosion"	3721	0.30	0.46	0	1
Support for harvesting woody biomass for energy	3729	0.56	0.50	0	1
"To enjoy beauty or scenery"	3897	3.94	0.95	1	5
"For production of firewood for personal use"	3889	2.90	1.37	1	5
"To leave land unmanaged and let nature take its course"	3913	2.55	1.32	1	5
Have sold timber since ownership of woodlands	3961	0.55	0.50	0	1
Have sold timber in the past and plans to sell timber	3953	0.33	0.47	0	1
No plans to harvest timber or biomass regardless of price	3809	0.25	0.43	0	1
Age	3944	4.96	1.15	2	7
Education	3952	3.88	1.47	1	6
Children under 18 years of age live in the household	3816	0.18	0.38	0	1
Income (≥$50,000/year)	3600	0.64	0.48	0	1
Membership in a forest landowner group or environmental organization	3969	0.08	0.27	0	1
Has a professionally written forest management plan	3929	0.31	0.46	0	1
External Factors					
Timber price in dollars per acre ($/ac)	4000	596.76	123.38	430.00	760.00
Biomass price in $/ac	4000	14.88	21.72	0.00	60.00
Option offered to sell woody biomass	4000	0.50	0.50	0	1

* Commercial timber volume expressed in 100,000 cubic feet units
See Table 5.1. for definition of variables.

5.4.2. Logistic Regression and Probability Findings

5.4.2.1. Michigan

Results for Model 1 indicated significant effects of timber price and having the option to sell woody biomass, with the latter possessing a negative effect on WTH (Table 5.5). Biomass price was not significant in this model. According to regression results from Model 2 for Michigan, the significant factors positively affecting WTH were timber price, biomass price and support for the harvesting of woody biomass for bioenergy (Table 5.5). The greatest magnitude on WTH was attributed to an owner attitude supportive of bioenergy; the odds of harvesting were 1.31 times greater for landowners who indicated such support (p-value < 0.05). Biomass price (p-value < 0.05) and timber price (p-value < 0.001) both significantly increased the odds or harvesting by 1% and 0.5% respectively for each dollar increase per acre controlling for all other explanatory variables. The greatest negative effect on WTH was for landowners who indicated that they had no plans to harvest (p-value < 0.05); this was associated with a 70% decrease in the odds of harvesting, while holding all other variables constant. Greater importance of owning woodland for firewood production and being given the option to have woody biomass harvest significantly decreased the odds of harvesting by 29% and 28% respectively at 0.05 type-I error level.

Table 5.5. Logistic regression results for landowners' willingness-to-harvest (WTH) woody biomass for bioenergy in the state of Michigan.

	Model 1				Model 2			
Variable	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**
Timber price	0.004	0.001	<0.001	1.004	0.005	0.001	<0.001	1.005
Biomass price	0.004	0.003	0.139	1.004	0.006	0.003	0.057	1.006
Option offered to sell woody biomass	-0.234	0.102	0.022	0.791	-0.334	0.150	0.026	0.716
Land Characteristics								
Total acres of woodland owned					-0.0002	0.0002	0.399	0.9998
Volume of commercial timber in 100,000 cubic feet units					0.0002	0.0001	0.143	1.0002
Access to county road/highway					-0.382	0.477	0.423	0.682
Landowner Attributes								
Residence on woodland					0.208	0.404	0.606	1.231
Total years of ownership					-0.006	0.008	0.486	0.995
"Harvesting woody biomass is likely to result in soil erosion"					-0.107	0.415	0.797	0.899
Support for harvesting woody biomass for bioenergy					0.838	0.363	0.021	2.313
"To enjoy beauty"					-0.150	0.182	0.408	0.860
"For production of firewood for personal use"					-0.338	0.137	0.014	0.713
"To leave land unmanaged"					-0.071	0.143	0.621	0.932
Have sold timber since ownership of woodlands					0.235	0.518	0.650	1.265
Have sold timber in the past and plans to sell timber					-0.063	0.526	0.905	0.939
No plans to harvest timber or biomass in the future regardless of price					-1.202	0.512	0.019	0.300
Age					-0.185	0.206	0.371	0.831
Education					-0.049	0.119	0.681	0.952
Children under 18 years of age live in the household					-0.097	0.619	0.876	0.908
Income (≥$50,000/year)					0.382	0.363	0.292	1.466
Forest/environmental organization membership					0.171	0.592	0.772	1.187
Has a forest management plan					-0.042	0.452	0.925	0.958
Constant	-2.209	0.391	<0.001		-0.730	1.674	0.663	
Wald chi^2	32.21				67.41			
Prob > chi^2	<0.001				<0.001			
Log pseudo-likelihood	-1129.559				-681.228			
n	1733				1239			

Following Model 1, cumulative probability estimates for WTH were determined using regression coefficients associated with timber price, biomass price and option offered to sell woody biomass by applying the cumulative distribution function for the logit model. For all estimates (across states), the variable representing the option offered to sell woody biomass was set to “1” and timber and biomass price were manipulated to examine the effects of different price levels on WTH.

Results for Michigan indicated increasing probabilities for landowners being willing to accept an offer to harvest timber and woody biomass that were associated with increasing price offers (Figure 5.2). For an offer of $330 per acre to harvest timber and $20 to harvest woody biomass, the probability of harvesting was 0.26. However, if a landowner was offered $570 and $20 to harvest timber and woody biomass respectively, the probability was much higher, at 0.47. While the increase in biomass price offered consistently increased the probability of harvesting, the increase in timber price resulted in larger effects. The predicted probability of harvesting at each level increase in the timber price offer coupled with a biomass offer of $0 per acre were always higher than those associated with the preceding (lower) timber price offer at the maximum biomass price of $60 per acre.

An examination of marginal probabilities associated with price changes detected apparent differences between lower and higher timber prices versus changes in biomass price offers. For instance, for a landowner offered $330 to harvest timber and $20 to harvest woody biomass, an additional offer of $20 to harvest woody biomass would increase the probability of harvesting by 0.014 or 1.4% while another increase of $20 for a total of $60 to harvest woody biomass would be associated with a marginal change of 1.5%. An increased timber price offer of $570 per acre and change from $20 to $40 per acre was found to be associated with a marginal probability of 0.019 while increasing the latter offer to $60 would still be associated with a marginal change of 0.019.

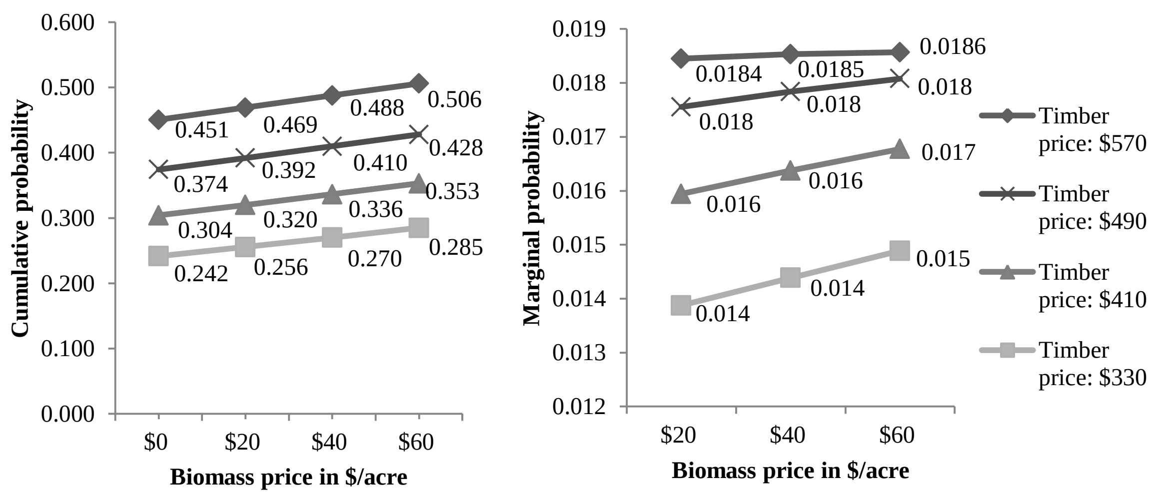

Figure 5.2. Predicted (cumulative) and marginal probabilities associated with landowners' WTH their woodlands in Michigan at timber price levels of $330, $410, $490 and $570 per acre and biomass price levels of $0, $20, $40 and $60 per acre.
Marginal probabilities are associated with changes in biomass price offers for each timber price level. All predicted probability estimates were significant at a Type-I error level of 0.001.

5.4.2.2. Minnesota

According to Model 1 for the state of Minnesota, timber and biomass price positively and significantly influenced WTH and like Michigan's Model 1, biomass offer had a negative effect on WTH (Table 5.6). Looking at the coefficients from Model 2, the largest significant and positive effect on WTH was attributed to landowners involved in a forest or environmental organization (p-value < 0.05); the odds of harvesting were 1.2 times greater for these landowners. At 0.05 type-I error level, residence on woodland exhibited the second highest magnitude on WTH; controlling for other explanatory variables, the odds of harvesting were 76% higher for landowners residing on or on land adjoining their woodlands. Positive and significant effects were also attributed to both timber and biomass prices at magnitudes comparable to Michigan's model. Also similar to Michigan was the greater significance attributed to timber price (p-value < 0.001) than for biomass price (p-value < 0.05).

In order of greatest magnitude, variables that were found to have negative and significant effects on WTH were agreement to the statement that harvesting woody biomass would likely result in soil erosion (p-value < 0.001), having no plans to harvest regardless of price (p-value < 0.05), being given the option to sell woody biomass (p-value < 0.001) and owning woodlands to leave it unmanaged (p-value < 0.1). Biomass offer and having no plans to harvest were also significant in Michigan's model, but the odds associated with a biomass offer was 1.5 times that of Michigan and having no plans to harvest was not the greatest effect negatively affecting WTH. Instead, agreement to the statement that harvest would result in soil erosion decreased the odds of harvesting by 68% while having no plans to harvest decreased the odds of harvesting by 59%.

Table 5.6. Logistic regression results for landowners' willingness-to-harvest (WTH) woody biomass for bioenergy in the state of Minnesota.

	Model 1				Model 2			
Variable	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**
Timber price	0.005	0.0005	<0.001	1.005	0.006	0.001	<0.001	1.006
Biomass price	0.008	0.002	0.001	1.008	0.010	0.003	0.001	1.010
Option offered to sell woody biomass	-0.474	0.084	<0.001	0.623	-0.585	0.112	<0.001	0.557
Land Characteristics								
Total acres of woodland owned					0.0001	0.0002	0.675	1.0001
Volume of commercial timber in 100,000 cubic feet units					0.00002	0.00005	0.695	1.00002
Access to county road/highway					-0.347	0.213	0.104	0.707
Landowner Attributes								
Residence on woodland					0.562	0.228	0.014	1.755
Total years of ownership					0.012	0.008	0.123	1.012
"Harvesting woody biomass is likely to result in soil erosion"					-1.148	0.262	<0.001	0.317
Support for harvesting woody biomass for bioenergy					0.439	0.222	0.048	1.552
"To enjoy beauty"					-0.222	0.111	0.046	0.801
"For production of firewood for personal use"					-0.095	0.080	0.237	0.910
"To leave land unmanaged"					-0.151	0.089	0.091	0.860
Have sold timber since ownership of woodlands					-0.171	0.282	0.544	0.843
Have sold timber in the past and plans to sell timber					0.294	0.290	0.311	1.342
No plans to harvest timber or biomass in the future regardless of price					-0.892	0.296	0.003	0.410
Age					0.012	0.111	0.913	1.012
Education					0.057	0.077	0.459	1.058
Children under 18 years of age live in the household					0.464	0.286	0.105	1.590
Income (≥$50,000/year)					0.284	0.249	0.253	1.329
Forest/environmental organization membership					0.776	0.305	0.011	2.173
Has a forest management plan					0.139	0.221	0.530	1.149
Constant	-2.474	0.245	<0.001		-2.768	0.955	0.004	
Wald chi^2	136.93				232.78			
Prob > chi^2	<0.001				<0.001			
Log pseudo-likelihood	-2665.979				-1720.495			
n	4060				3170			

The trend associated with the probability of harvesting at various timber and biomass prices was similar to that of Michigan (Figure 5.3). The highest probability, 0.649, was predicted to be the result of a timber price offer of $630 and $60 to harvest woody biomass; the highest price offers proposed. At a timber price offer of $360 and $60 to harvest commercial timber and woody biomass respectively, the probability of harvesting was 0.330. While landowners' predicted probability of harvesting was higher for Minnesota than for Michigan landowners, timber price offers were greater for the former state.

Marginal effects associated with prices detected pronounced differences at lower timber price offers while these changes became less evident as the timber price increased. The marginal change associated with timber price offer of $360 to harvest timber and an increase of $20 to harvest woody biomass for a total biomass offer of $40, was 0.032. An additional increase of $20 for a total of $60 to harvest woody biomass was associated with a marginal change of 0.035. At the highest timber price offer of $630 per acre, a change in the biomass price offer from $20 to $40 per acre was associated with a marginal probability of 0.039 while increasing the latter offer to $60 resulted in a lower marginal probability of 0.038.

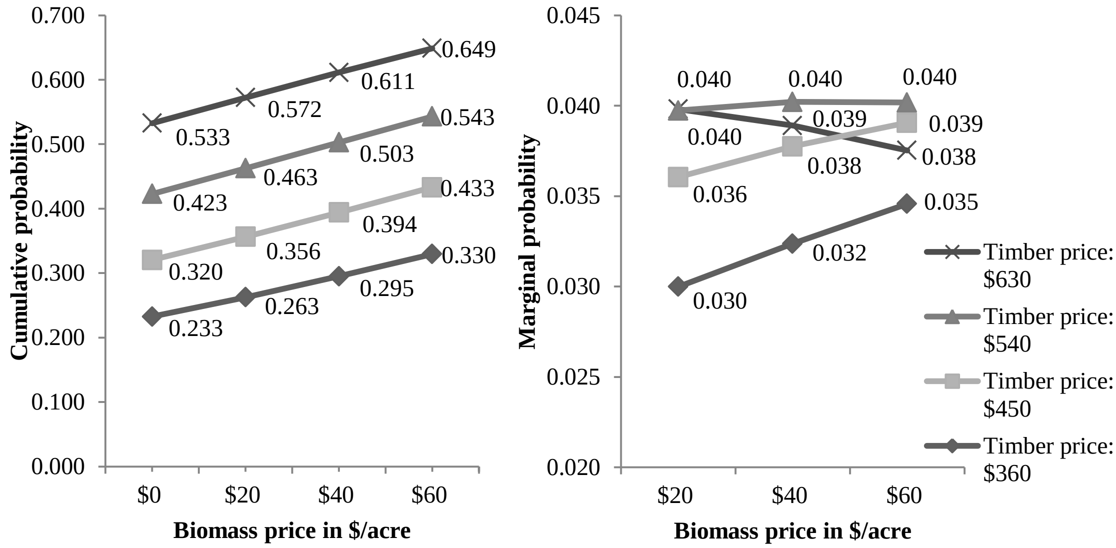

Figure 5.3. Predicted (cumulative) and marginal probabilities associated with landowners' WTH their woodlands in Minnesota at timber price levels of $360, $450, $540 and $630 per acre and biomass price levels of $0, $20, $40 and $60 per acre.
Marginal probabilities are associated with changes in biomass price offers for each timber price level. All predicted probability estimates were significant at a Type-I error level of 0.001.

5.4.2.3. Wisconsin

Results for Wisconsin's Model 1 were similar to those of Minnesota with all three explanatory variables exhibiting significant effects on WTH. Timber price had the highest level of significance (p-value < 0.001) in terms of positive effects, followed by biomass price (p-value < 0.05) (Table 5.7). Being offered the option to sell woody biomass was again found to negatively influence WTH. Findings for Model 2 indicated that Wisconsin NIPF landowners' choice to harvest were influenced by prices, being given an offer to sell woody biomass, having support for the harvesting of woody biomass for bioenergy, having past harvesting experience, having future plans to sell with previous experience and having no plans to harvest regardless of price offered. Similar to Michigan's respondents, the choice to harvest by Wisconsin's respondents was found to be positively influenced by having support for bioenergy and negatively influenced by owning woodlands for firewood production. The odds of harvesting were 96% greater for landowners in support of the harvesting of woody biomass for bioenergy (p-value < 0.05) and were 20% less as the importance of owning woodlands for firewood production increased (p-value < 0.05). Having past harvesting experience was found to increase the odds of harvesting by 90% (p-value < 0.001) and was second to support in terms of the magnitude of factors positively affecting WTH. Similar to findings for Michigan and Minnesota, having no plans to harvest regardless of price negatively influenced WTH; at a Type-I error level of 0.001, the odds of harvesting decreased by 85% for this group of landowners. Furthermore, even with future plans to harvest, landowners who harvested in the past were found to be less likely to harvest their woodlands; the odds of harvesting were 55% less than for landowners who did not meet these criteria.

Table 5.7. Logistic regression results for landowners' willingness-to-harvest (WTH) woody biomass for bioenergy in the state of Wisconsin.

	Model 1				**Model 2**			
Variable	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**	**Coef.**	**Robust Std. Error**	***p*-value**	**Odds Ratio**
Timber price	0.004	0.0004	<0.001	1.004	0.004	0.001	<0.001	1.004
Biomass price	0.006	0.002	0.003	1.006	0.008	0.003	0.002	1.008
Option offered to sell woody biomass	-0.428	0.087	<0.001	0.652	-0.538	0.108	0.000	0.584
Land Characteristics								
Total acres of woodland owned					0.0002	0.0003	0.622	1.0002
Volume of commercial timber in 100,000 cubic feet units					0.001	0.0005	0.048	1.001
Access to county road/highway					-0.067	0.229	0.771	0.936
Landowner Attributes								
Residence on woodland					0.202	0.227	0.373	1.224
Total years of ownership					-0.006	0.010	0.566	0.994
"Harvesting woody biomass is likely to result in soil erosion"					-0.326	0.253	0.198	0.722
Support for harvesting woody biomass for bioenergy					0.671	0.227	0.003	1.957
"To enjoy beauty"					-0.075	0.121	0.537	0.928
"For production of firewood for personal use"					-0.222	0.086	0.010	0.801
"To leave land unmanaged"					0.084	0.100	0.401	1.088
Have sold timber since ownership of woodlands					0.642	0.291	0.027	1.900
Have sold timber in the past and plans to sell timber					-0.789	0.300	0.009	0.454
No plans to harvest timber or biomass in the future regardless of price					-1.888	0.336	<0.001	0.151
Age					0.001	0.127	0.993	1.001
Education					0.110	0.080	0.17	1.117
Children under 18 years of age live in the household					-0.024	0.294	0.936	0.977
Income (≥$50,000/year)					0.107	0.259	0.679	1.113
Forest/environmental organization membership					-0.266	0.442	0.547	0.766
Has a forest management plan					0.079	0.234	0.735	1.082
Constant	-2.514	0.254	<0.001		-4.795	1.467	0.001	
Wald chi^2 (22)	136.86				157.62			
Prob > chi^2	<0.001				<0.001			
Log pseudo-likelihood	-2108.732				-1399.689			
n	3264				2476			

Predicted and marginal probability trends for Michigan and Minnesota were also found to be applicable to Wisconsin's NIPF landowners (Figure 5.4). The lowest predicted probability was associated with a timber price offer of $430 per acre and a biomass price offer of $0 per acre and the highest probability, a timber price offer of $760 and biomass price offer of $60 per acre. Increase in timber price offers substantially increased the probability of harvesting while estimates increased gradually across biomass price offers. Marginal probability findings were also similar to the other states in that landowners were more sensitive to biomass price offers at lower timber prices resulting in larger marginal changes at the lowest price offers and smaller and more inconspicuous differences at higher timber price offers. For a landowner who is offered the lowest timber price offer of $430 per acre to harvest timber and $20 per acre to harvest woody biomass, an additional biomass offer of $20 was predicted to increase the probability of harvesting by 0.023 and a further increase to $60 per acre, by 0.025. However, if the timber price offer is $760 instead of $430, the additional $20 per acre for a total of $40 for woody biomass would increase the probability of harvesting by 0.032 and this value will remain unchanged if $60 is offered for woody biomass. Marginal effects at the highest timber price offer of $760 revealed that increasing the biomass price from $0 to $20, $40 and $60 per acre were associated with the same marginal probability estimates. This trend was also observed when the timber price offered to Minnesota's NIPF landowners was kept at $540 per acre.

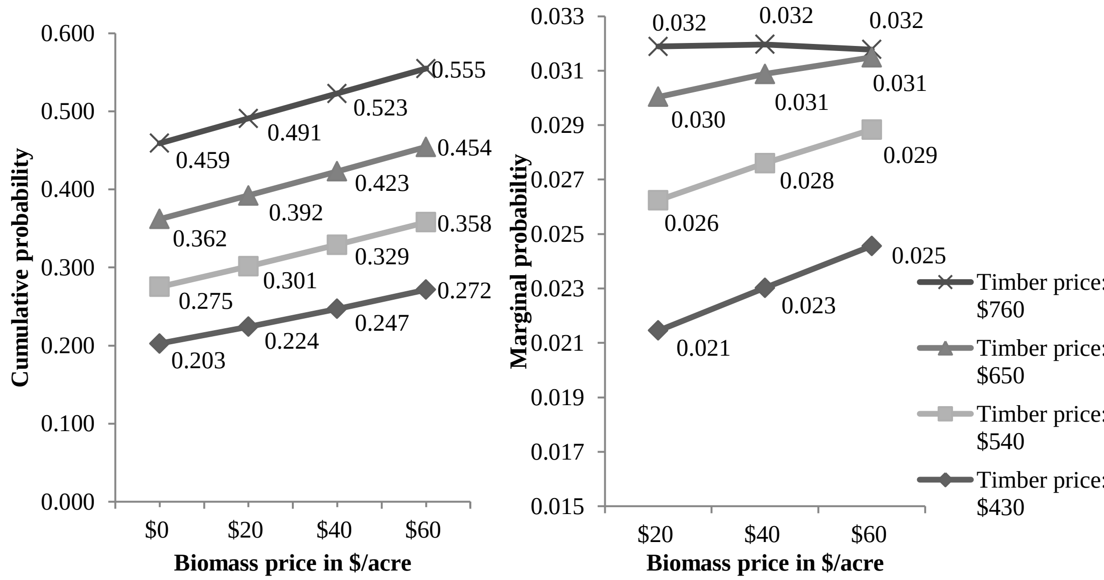

Figure 5.4. Predicted (cumulative) and marginal probabilities associated with landowners' WTH their woodlands in Wisconsin at timber price levels of $430, $540, $650 and $760 per acre and biomass price levels of $0, $20, $40 and $60 per acre.
Marginal probabilities are associated with changes in biomass price offers for each timber price level. All predicted probability estimates were significant at a Type-I error level of 0.001.

5.5. Discussion and Conclusions

Timber price exhibited the highest level of significance for Model 1 across the three states and was found to positively influence WTH. Biomass price was significant for Minnesota's and Wisconsin's Model 1; this variable positively influence WTH at 0.05 type-I error level in both states. Even though the coefficient for biomass price was greater, in absolute terms, an increase in the timber price offer would substantially increase the odds of harvesting. Furthermore, the significance of timber price was consistent across states and shared similar effects on WTH; the odds of harvesting increased by 0.4% to 0.5% for each dollar per acre increase in timber price. The option to sell woody biomass also exhibited comparable effects on landowners' WTH from

Michigan, Minnesota and Wisconsin. Holding other variables constant, this variable negatively influenced the choice to harvest.

The trend in probabilities associated with WTH harvest timber and woody biomass was also consistent across states; timber and biomass price offers increased the probability of landowners' WTH. However, the effects of timber price were much greater than those of biomass price suggesting that timber price rather than biomass price drive the decision to harvest both timber and woody biomass. Marginal probability results reinforce this point; marginal probabilities increased at an increasing rate at lower timber prices and increased at a decreasing rate at higher timber prices.

A comparison of predicted probabilities revealed that Minnesota's NIPF landowners would be most likely to harvest their woodlands. To demonstrate, a predicted probability of 0.572 from Minnesota's NIPF landowners was associated with a timber price offer of $540 and biomass price offer of $20 per acre while the highest probability between the two other states was 0.555, which was associated with a timber price of $760 and biomass price of $60 per acre. Thus, even though timber price offers for Wisconsin were highest for the three states, the probability of landowners being willing to harvest was highest from Minnesota's landowners. Also, the regression results from each state's Model 1 found that the odds of harvesting based solely on timber price were greatest from Minnesota respondents; a 0.5% increase for each dollar per acre offered.

Regression findings (Model 2) for each the three U.S. Great Lakes States revealed common factors influencing landowners WTH. Prices (timber and woody biomass) positively influenced landowners' choice to harvest but being given the option to sell woody biomass negatively affected this decision (holding all other variables constant). The odds of harvesting were 28%, 44% and 42% less for Michigan, Minnesota and Wisconsin respondents respectively when given an offer to harvest woody biomass from their woodlands. Respondents indicating having no plans to harvest timber regardless of price offered were also less likely to harvest regionally; the odds of harvesting were 70%, 59% and 85% less for Michigan, Minnesota and Wisconsin respondents respectively. This group of landowners represented 25%, 20% and 25% of sample respondents from Michigan, Minnesota and Wisconsin respectively. Non-timber ownership objectives were also found to negatively influence landowners' choice to harvest from their woodlands across states; these included owning for the production of firewood for personal use and to leave woodlands unmanaged. Negative effects on WTH were expected for these variables since these indicated that landowners were interested in either utilizing wood for their personal use or had no interest in harvesting and deriving monetary benefits from their woodlands.

Having support for the harvesting of woody biomass for bioenergy had significantly positive effects on WTH from Michigan and Wisconsin's respondents and were attributed to having the greatest magnitude on the choice to harvest from both states. Michigan's NIPF landowners were 1.31 more likely to harvest if they indicated support while Wisconsin's NIPF landowners were 96% more likely to accept an offer. An estimated 58% and 56% of landowners from Michigan and Wisconsin, respectively, supported the harvest of woody biomass which translates to considerable potential for procuring future biomass supplies.

In Minnesota, it is noteworthy that the involvement in a forest landowner group or environmental association had the greatest impact on WTH; the odds of harvesting were 1.2 times greater for landowners involved in one but only an average of 13% of Minnesota's respondents indicated their involvement. Landowners involved in an environmental or forest organization may likely be more informed about bioenergy from woody biomass and multiple-use of forests through networking and consequently more inclined to harvest woody biomass. Second to organization membership, residing on woodlands increased the odds of harvesting by 76%. The significance of this variable coincides with a previous study for this state where Becker et al. (2010) found absentee ownership to negatively predict landowners' WTH woody biomass.

A number of variables were not found to be statistically significant resulting in a contradiction of past findings and expected relationships. For instance, none of the demographic variables had significant influences on WTH woody biomass. Recent woody biomass studies for Minnesota found age to have a negative effect on WTH (Becker et al. 2010). An opposite relationship was found in this study for Minnesota, but the effect was not significant at least at type-I error level of 0.1. Similarly, tenureship, acres owned and aesthetics were expected to have significant effects on WTH woody biomass.

This study found both promising possibilities and constraints to woody biomass availability. Based on state-level findings, strategies that serve to promote support for the harvest and utilization of woody biomass for energy in Michigan and Wisconsin could be effective in increasing landowners' involvement in harvesting their woodlands. Since involvement in an environmental or forest organization represent an educational platform where landowners would more likely be informed about multiple use and active management of their woodlands, extensive research and planning efforts could be invested into the development of effective education and outreach programs to enhance WTH among Minnesota's NIPF landowners. Regionally, prices, particularly timber price, had positive effects on WTH. A combination of regression results and probability estimates indicate that the viability of a bioenergy market rests upon flourishing timber markets since timber prices rather than biomass prices drive landowners' decision to harvest both timber and woody biomass from their woodlands.

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Chapter 6. Conclusions and Recommendations

6.1. Conclusions

The analysis of survey responses from NIPF landowners of the U.S. Great Lakes States resulted in a better understanding of these landowners and an identification of the potential for procuring woody biomass for bioenergy. First, findings indicated that a majority of NIPF landowners were at least 55 years of age, but landowners owning nearly 50% of the total woodland acreage reported were at least 65 years of age. The social availability of forest resources is therefore likely to change in the near future, either as a result of new landowners with a different set of attitudes towards forest management taking control or from older landowners possessing different ownership objectives and motivations.

Since the availability of woody biomass is contingent upon NIPF landowners' willingness to harvest their woodlands for both commercial timber and biomass feedstock, landowners WTH their woodlands for both resources were examined. Descriptive statistics of survey variables that captured landowners' timber and biomass price preferences indicated that Michigan sample respondents in control of 24% of the total acreage reported (regionally) were willing to accept one of the four minimum price offers to harvest timber and Minnesota's respondents in control of 23% of the total acreage were willing accept of its four timber price offers to harvest. Wisconsin's sample respondents were least responsive to price offers with respondents owning 16% of the total acreage indicating their WTH. The potential for harvesting woody biomass was also greatest from Michigan NIPFs where an estimated 29% of woodlands could potentially be available for harvest. Notably, even though the highest number of woodland acres potentially available for an integrated harvest was from Michigan, the largest number of respondents indicating WTH was from Minnesota, followed by Wisconsin and lastly, Michigan.

Mean ratings to bioenergy statements and woodland ownership reasons indicated that overall, NIPF landowners supported the utilization of woody biomass for bioenergy and landowners possessed mainly non-timber ownership objectives. However, factor analysis revealed two latent factors behind landowners' bioenergy views: (a) bioenergy support and (b) environmental degradation and four latent factors behind woodland ownership: (a) amenity, (b) personal use, (c) production and (d) legacy. These findings coupled with previous estimates on landowners' WTH at various price offers clearly indicate a substantial number of landowners would not be willing to harvest or even support harvesting on their woodland. Thus, the development of a landowner typology using cluster analysis highlighted the heterogeneity of NIPF landowners with regards to bioenergy views and ownership objectives, both of which have been found to influence WTH. The four types of landowners identified were labeled to communicate the characteristics of each cluster group: *recreationist, indifferent, preservationist* and *multiple-objective*. As the name suggests, *recreationists* placed high importance on owning land for recreational purposes, *indifferent* landowners expressed neutral views towards forest ownership, *preservationists* were disinclined to production values and placed high importance on aesthetic and protective reasons for forest ownership and *multiple-objective* landowners indicated importance of multiple uses of forests, both timber and non-timber. Support for the harvesting of woody biomass for bioenergy was greatest from the *multiple-objective* group (82% indicated support) and the *recreationist* cluster followed close behind (81%). Nearly one-half of landowners belonging to the *indifferent* were supportive of harvesting for bioenergy (47%) and as expected, support was lowest from the *preservationist* segment (14%).

Recreationists controlled 51% of the total woodland acreage reported by sample respondents regionally and were also most responsive to harvest offers so there is potential for integrated harvests from this group across the three states (Michigan, Minnesota and Wisconsin). Findings on WTH from each landowner group revealed that not only does Michigan possess enormous potential for the harvesting of timber and procuring woody biomass supplies, Michigan NIPF landowners belonging to the *recreationist* group were largely responsible for this potential. While regional estimates revealed that *recreationists* willing to harvest timber and woody biomass controlled an estimated 38% and 46% respectively of the total acreage accounted for by the four landowner types, *recreationists* owning woodlands in Michigan alone were responsible for 20% and 26% of the total regional acreage potentially available for timber and biomass harvesting respectively.

Results from the application of binary logit regression models to determine significant factors influencing landowners' WTH confirmed that both monetary and non-monetary variables affect landowners' choice to harvest in the U.S. Great Lakes States. Having support for the harvesting of woody biomass for bioenergy positively influenced WTH in Michigan and Wisconsin; Michigan landowners were 1.31 times more likely to harvest if they had support and for Wisconsin, landowners were 96% more likely to harvest. A comparative level of magnitude among Minnesota's NIPF landowners was associated with involvement in an environmental or forest organization; these landowners were 1.21 times more likely to harvest. Landowners involved in an environmental or forest organization are likely to be more informed about bioenergy from woody biomass and multiple-use of forests through networking and consequently more inclined to harvest woody biomass. Involvement in an environmental or forest organization may therefore represent an educational platform, so the positive effect of this variable may also suggest that education and outreach programs could be useful for increasing landowners' knowledge and promote awareness on the harvesting of woody biomass for bioenergy. Awareness may also increase support for biomass harvesting which, in turn, would increase the likelihood of harvesting.

An examination of the effect of timber and biomass prices found that while both increase the probability of harvesting, marginal effects associated with price changes revealed that timber price rather than biomass price, was the primary driver behind WTH. This finding was evident across states and suggests that woody biomass availability will depend on the performance of the commercial timber market.

6.2. Recommendations

Alterations that could be made to future projects focusing on NIPF landowners were noted following the completion of various parts of this study. First, the development of a mailing database for survey dissemination involved gathering information from multiple sources and the availability of information varied by both county and state. For instance, for the state of Michigan, NIPF landownership data were not readily available for all counties and were consequently sourced from the Michigan CF program, GIS online maps and tax assessors. An alternative to this process would be to obtain lists of NIPF landowners from a commercial vendor, if available and funding permits. In this way, a random selection of an equal number of NIPF landowners could then be made from each state. Second, holding focus group meetings with NIPF landowners in addition to pre-testing via mail may be useful. Face-to-face meetings with NIPF landowners may have allowed for additional improvements or revisions to the questionnaire.

Results from this study translate to important considerations for examining the comprehensive availability of woody biomass for energy and the development of effective strategies to promote bioenergy production from woody biomass. Interested groups of landowners can be targeted to capitalize on resources where biophysical availability matches its social counterpart and public policies can be tailored to promote availability based on knowledge of landowner types regionally. Specific segments of the NIPF population that were not strongly averse to harvesting and can consequently be targeted included *recreationist*, *indifferent* and *multiple-objective* landowners; these groups cumulatively represented 79% of sample respondents and 89% of the total woodland acreage reported by landowner groups. These values represent a positive indicator of U.S. Great Lakes States' capacity to develop its bioenergy market from woody biomass. Furthermore, a consideration of the factors influencing WTH and marginal effects of prices can be used to contribute towards the development of state-level models or framework representing landowners' decision-making process. Such models can enhance the predictive ability for determining landowners' WTH decisions given a set of land characteristics, landowner attributes and price information.

Finally, it is recommended that this study be updated to reflect the latest motivations and objectives of landowners and to capture any associated changes to resource availability. Findings from this study are based upon the decisions of a sample of the present NIPF landowners but changes in land ownership may be unavoidable and changes to landowners' woodland ownership attitudes are possible. While this study hopes to contribute towards the comprehensive evaluation of woody biomass availability, a reliable assessment requires up-to-date knowledge that is possible through future research.

Appendix A. Additional tables and figures

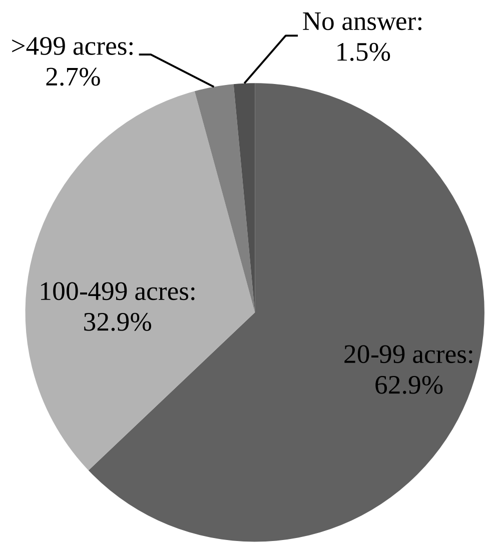

Figure A.1. Percent distribution of sample respondents by size of woodland acres owned in the U.S. Great Lakes States (Total acreage = 222,668.9 acres)

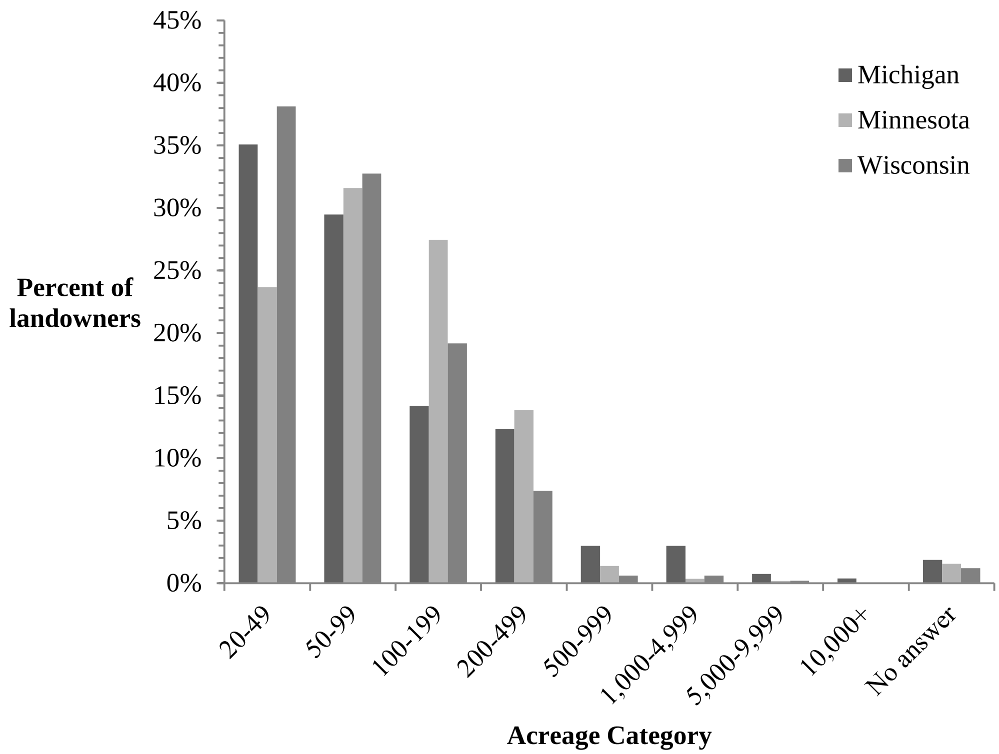

Figure A.2. Percent of sample respondents in Michigan, Minnesota and Wisconsin by woodland acres owned. (Total acreage: Michigan = 90,302.5 acres; Minnesota = 76,063.09 acres; Wisconsin = 56,303.3 acres)

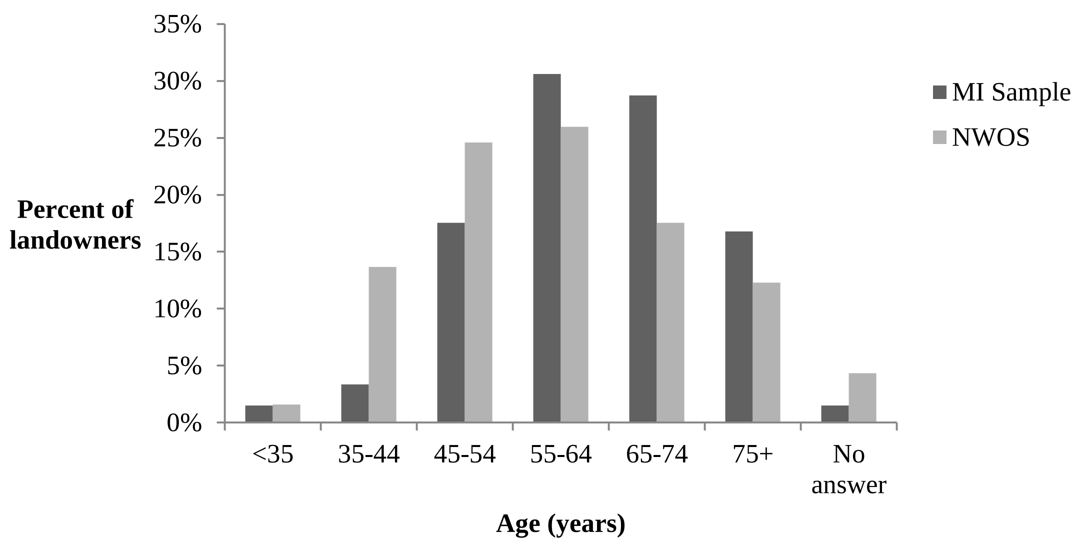

Figure A.3.Age distribution of Michigan sample respondents and NWOS respondents.

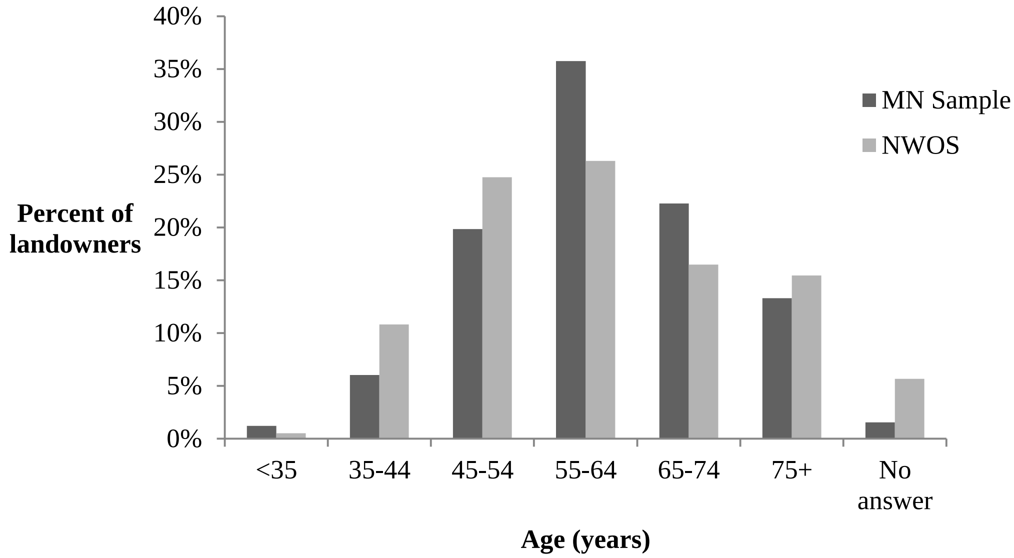

Figure A.4. Age distribution of Minnesota sample respondents and NWOS respondents.

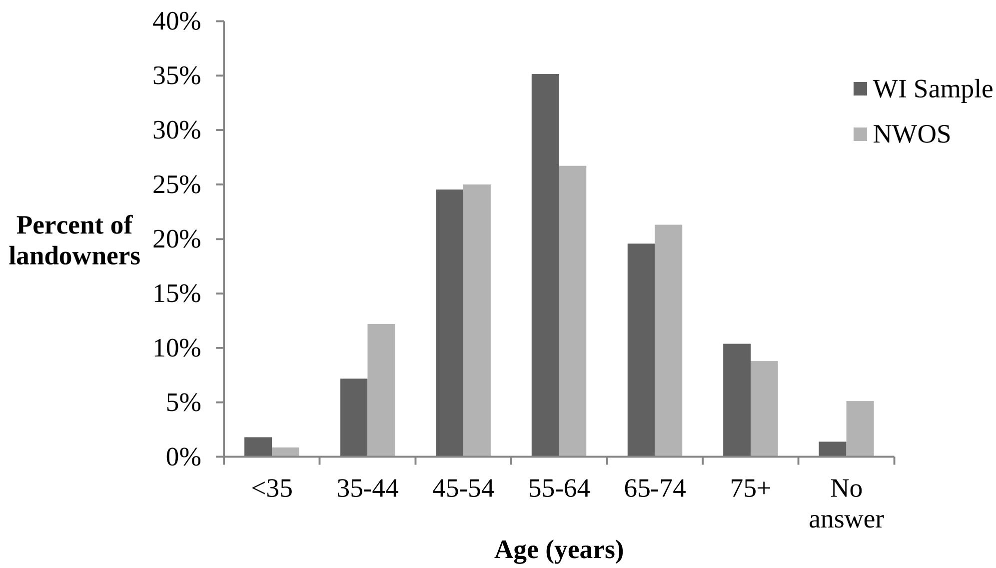

Figure A.5. Age distribution of Wisconsin sample respondents and NWOS respondents.

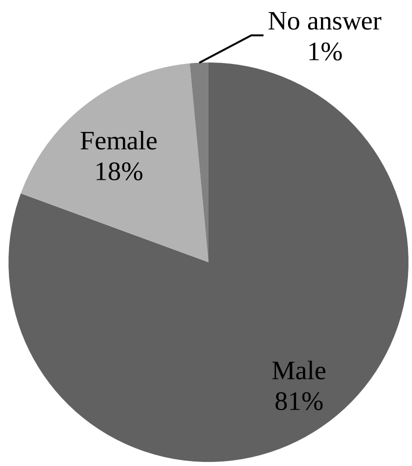

Figure A.6. Gender of Michigan's respondents.

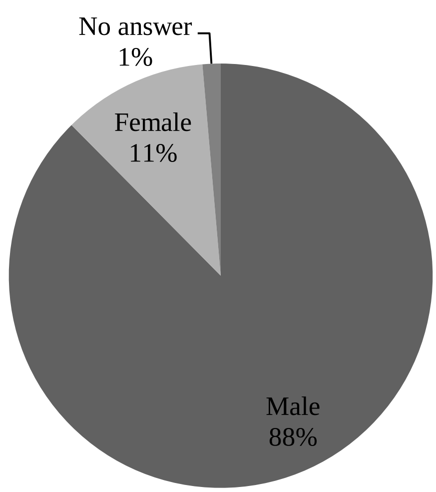

Figure A.7. Gender of Minnesota's respondents.

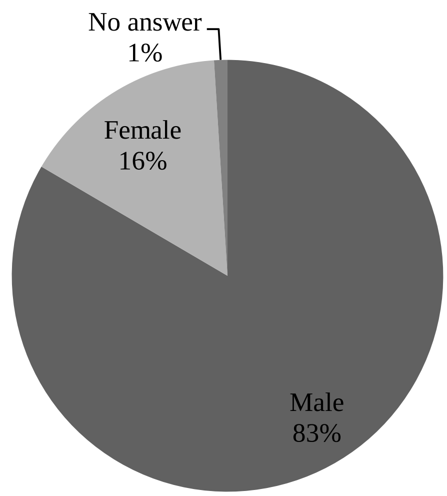

Figure A.8. Gender of Wisconsin’s respondents.

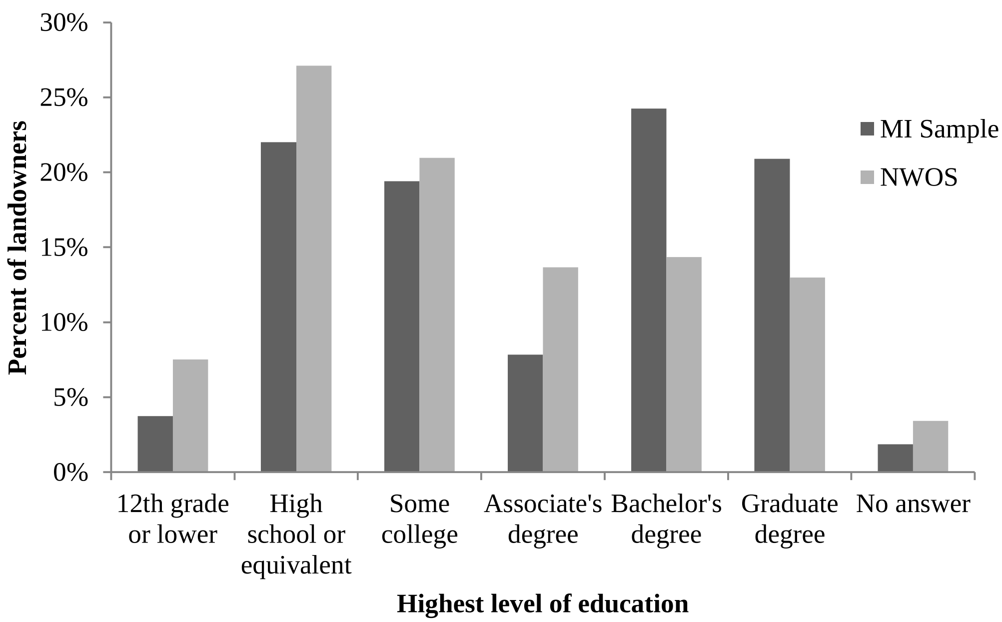

Figure A.9. Highest level of education completed by Michigan sample respondents and NWOS respondents.

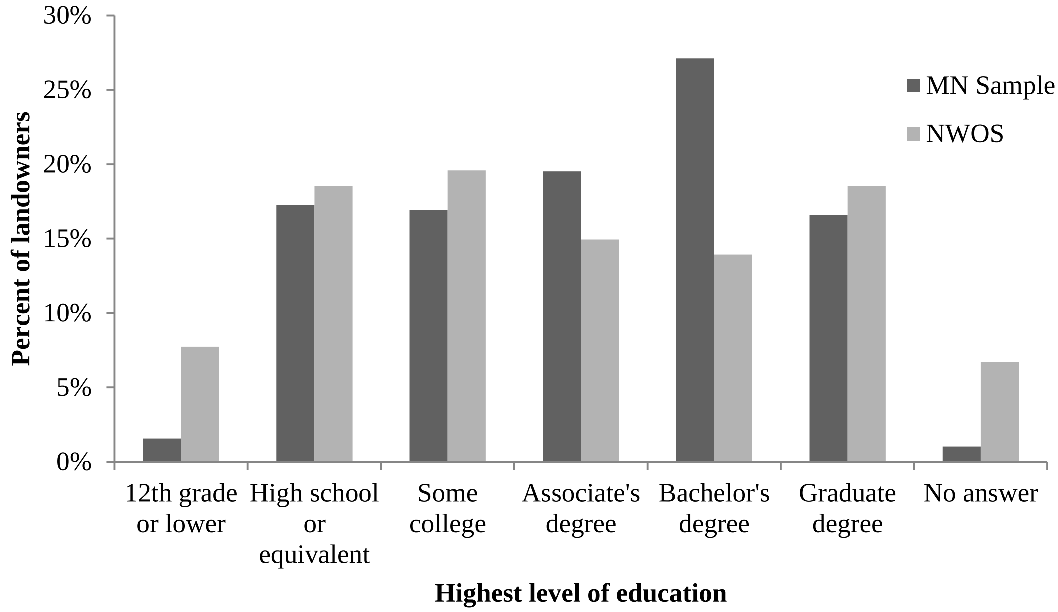

Figure A.10. Highest level of education completed by Minnesota sample respondents and NWOS respondents.

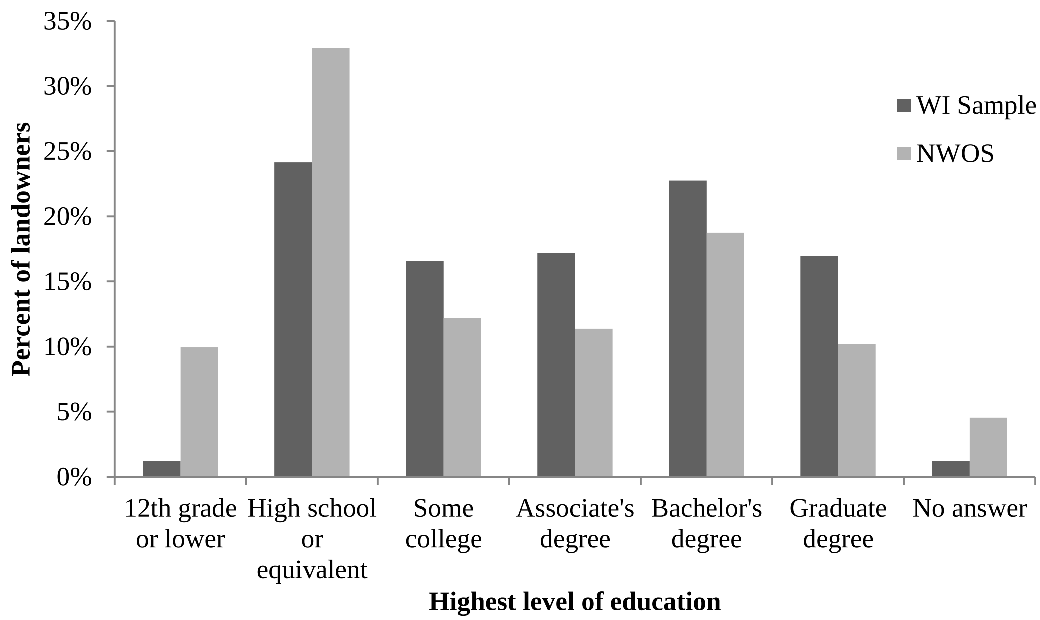

Figure A.11. Highest level of education completed by Wisconsin sample respondents and NWOS respondents.

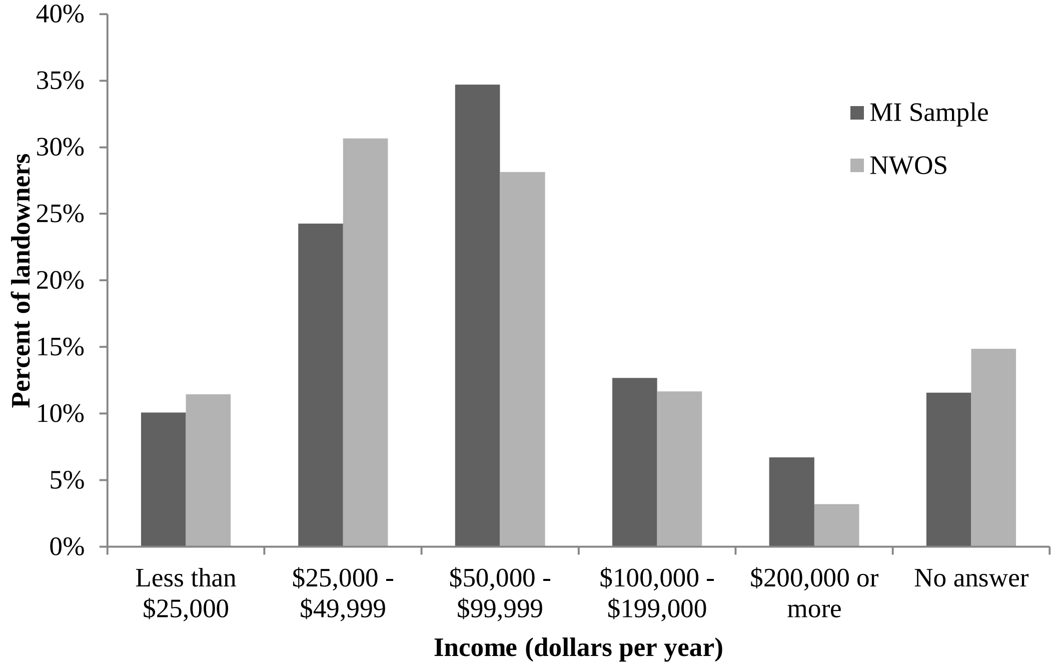

Figure A.12. Annual household income of Michigan sample respondents and NWOS respondents.

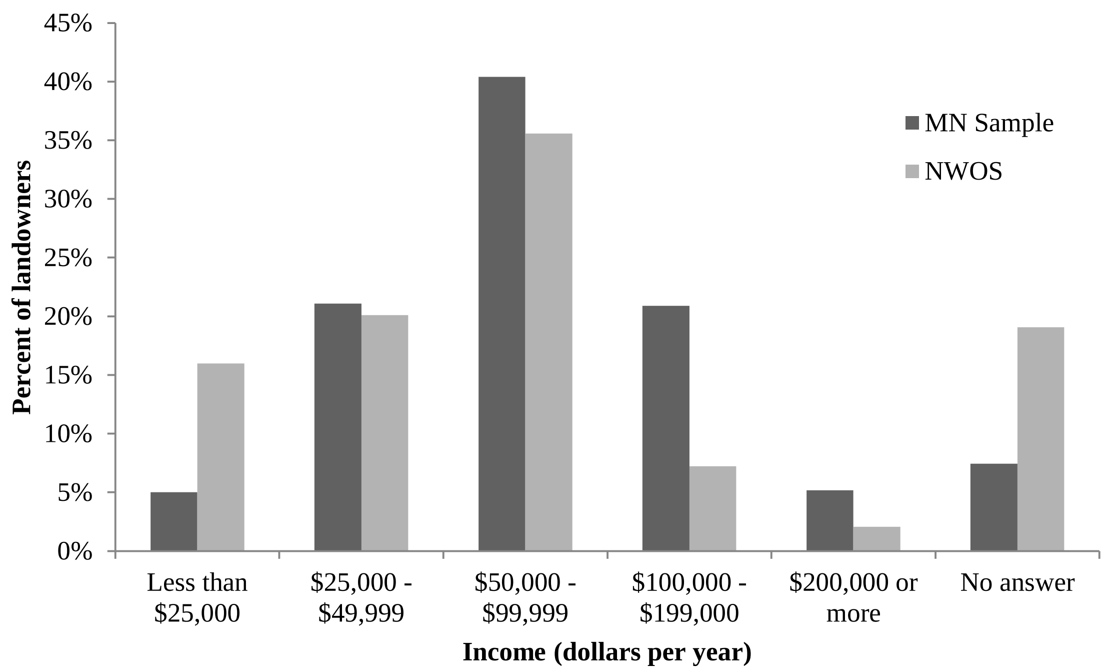

Figure A.13. Annual household income of Minnesota sample respondents and NWOS respondents.

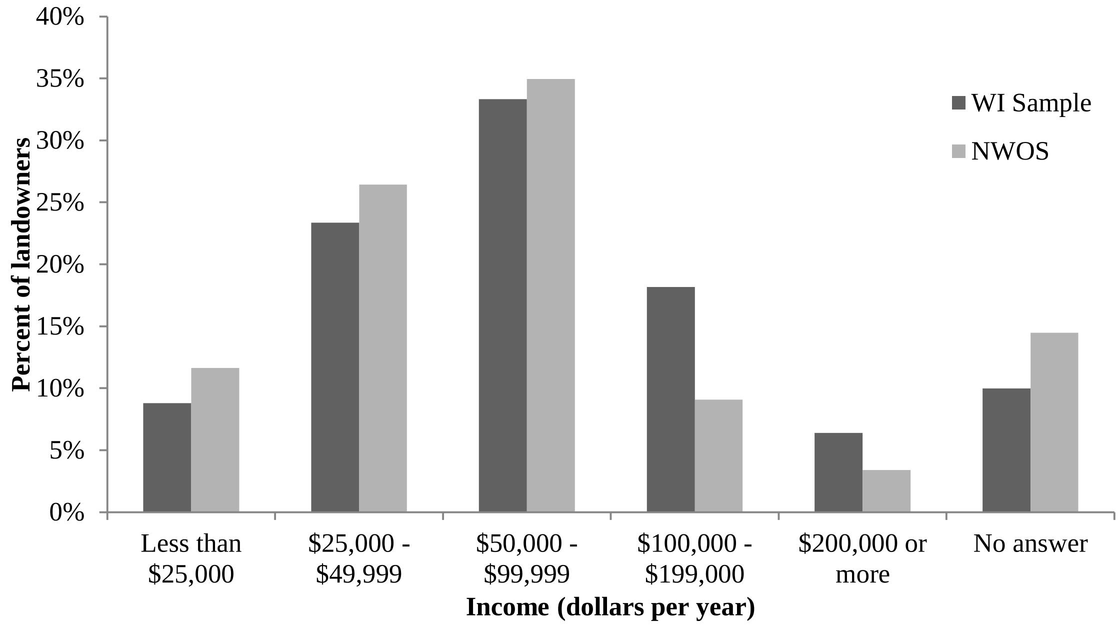

Figure A.14. Annual household income of Wisconsin sample respondents and NWOS respondents.

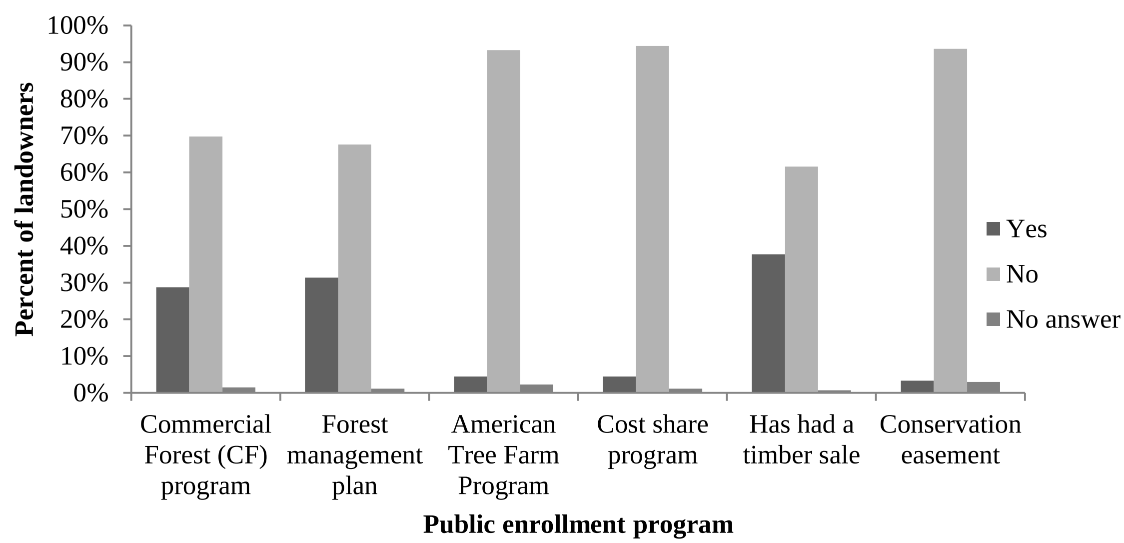

Figure A.15. Michigan sample respondents' participation in public incentive programs and forest management activities.

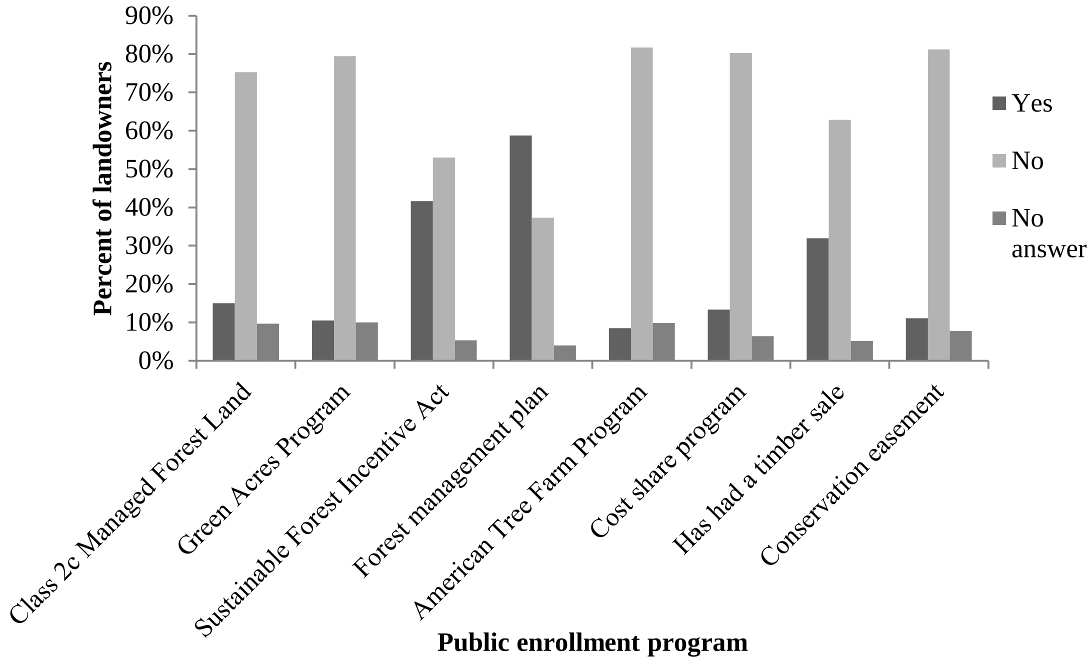

Figure A.16. Minnesota sample respondents’ participation in public incentive programs and forest management activities.

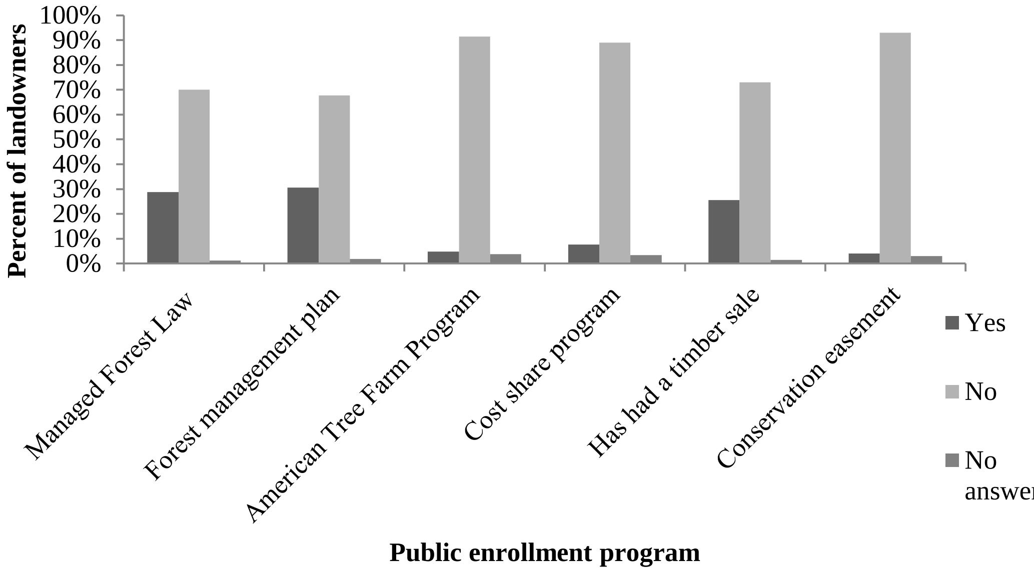

Figure A.17. Wisconsin sample respondents' participation in public incentive programs and forest management activities.

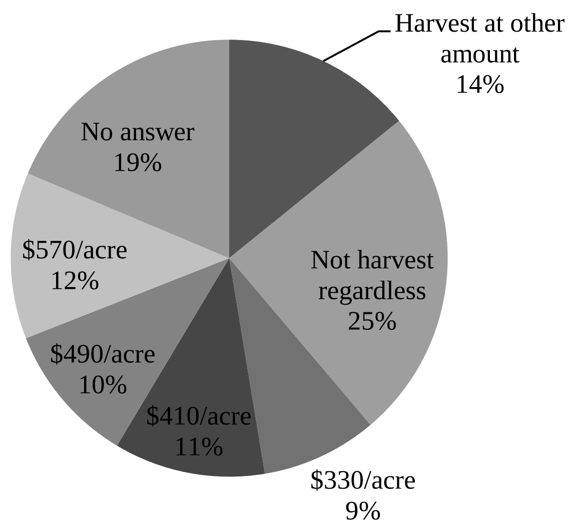

Figure A.18. Timber price preferences for harvesting commercial timber from Michigan NIPFs.

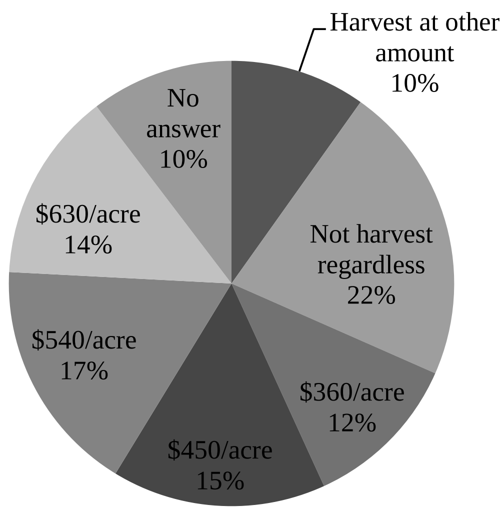

Figure A.19. Timber price preferences for harvesting commercial timber from Minnesota NIPFs.

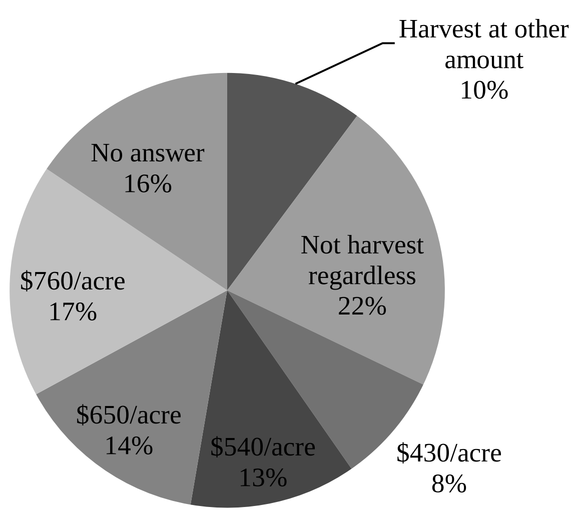

Figure A.20. Timber price preferences for harvesting commercial timber from Wisconsin NIPFs.

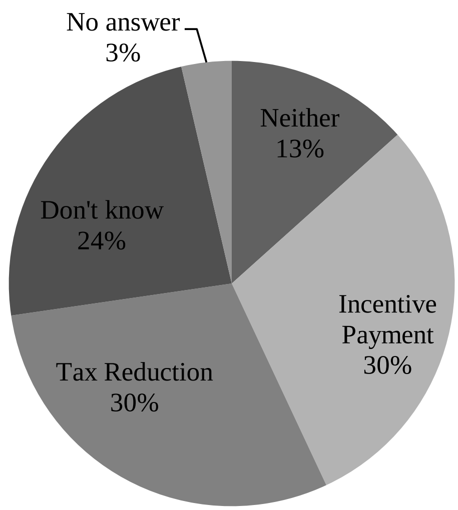

Figure A.21. Tax incentive preferences of sample respondents from the U.S. Great Lakes States.

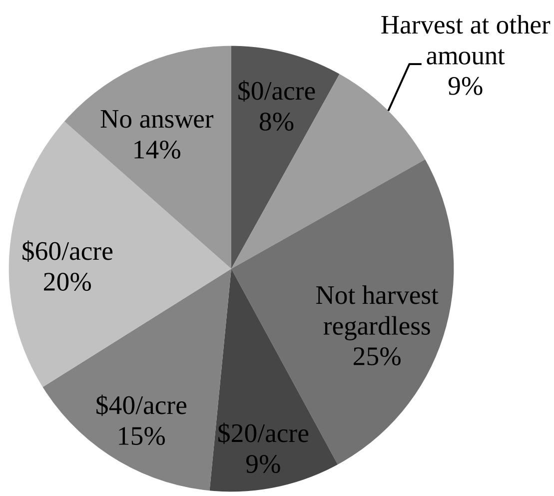

Figure A.22. Percent of U.S. Great Lakes States sample respondents' willing to harvest woody biomass at various price offers.

Table A.1. Agglomeration coefficient for hierarchical cluster analysis using Ward method.

Number of Clusters	Agglomeration Coefficient	% change in coefficient to next level
8	29811.17	2.0%
7	30421.12	2.3%
6	31122.83	2.3%
5	31846.43	2.6%
4	32666.46	3.4%
3	33785.78	4.5%
2	35293.16	10.5%
1	38996.41	

Appendix B. Survey Instrument (Michigan, Version 1)

Woodland Management, Bio-energy and Your Views

I. Your Land

1. In what counties in Michigan do you own land? _______________________

2. How many total acres of land do you own in Michigan? __________________ acres

3. How much of the total acreage is woodland? _____________________ acres
(Excluding: Christmas tree farms, nurseries, and fruit/nut orchards?)

4. In what year did you personally acquire/purchase/inherit your first parcel of woodland in Michigan?_______________

5. Is your woodland located on a separate, non-adjoining, parcel of land from your home (primary residence)?
□ Yes □ No □ Some of it is

6. Do your woodlands have direct access to a county road or highway?
□ Yes □ No

7. Have you sold timber from your land since you have owned it?
□ Yes □ No

8. Do you plan to sell timber from your land in the future?
□ Yes □ No □ Do not know

9. As long as you own it, what percentage of your woodland do you think will **never** be cut for an income-generating purpose?(0 to 100%) ______________ % □ Do not know

10. Which of the following applies to some or all of your woodland? (check one box for each line)

	Yes	No	Don't know
Is currently enrolled in Michigan's Commercial Forest (CF) program	□	□	□
Has a forest management plan written by a professional forester	□	□	□
Is enrolled in the American Tree Farm Program	□	□	□
Is enrolled in a cost share program for management activities (e.g CRP or EQIP)	□	□	□
Has had a timber sale organized by a professional forester since you owned it	□	□	□
Is under a conservation easement prohibiting future development	□	□	□

11. Are you a member of a forest landowner group, association or an environmental organization?
□ Yes → a. IF Yes, what is the name of the organization? ________________
□ No

12. Have you ever paid someone to conduct a timber stand improvement (e.g., thinning, pruning, cull tree or weed tree removal) on your property?
□ Yes → a. IF Yes, how much did you pay? $________________/acre

□ No → b. IF No, would you be willing to pay for a timber stand improvement?

□ Yes □ No □ I don’t know

Bio-Energy: In the following pages, we would like to gather your opinion on harvesting of your woodlands and in particular, woody biomass harvesting and uses. Let’s start with specifying a few concepts.

What is woody biomass? Woody biomass includes small-diameter trees (less than 5 inches) traditionally used for firewood as well as portions of trees (tree limbs, tree tops, needles, leaves) and wood waste not useable in the traditional wood products industry. Woody biomass can be used to generate heat or electricity, or to produce fuel substitutes for cars and trucks (ethanol or biodiesel).

Harvest types:
- Commercial timber harvest: This harvest includes removal of trees at least 5 inches in diameter for **sawlogs** that are used for making solid wood products and **pulpwood** used by the pulp and paper industry.
- Commercial timber harvest and woody biomass harvest: This activity includes the removal of **sawlogs** and **pulpwood for traditional products** and **woody biomass** for energy use.

For purposes of this study, both commercial harvests are to be conducted by professional loggers and follow sustainable management practices such as implementing Best Management Practices (BMPs).

Please rate your level of agreement/disagreement with each of the following statements (please circle one per statement).

	Strongly Disagree	*Disagree*	*Neither Agree nor Disagree*	*Agree*	*Strongly Agree*
Woody biomass is a viable alternative to fossil energy (e.g. coal/oil/gasoline/diesel)	1	2	3	4	5
National security can be enhanced by using woody biomass for energy rather than relying heavily on fossil fuels	1	2	3	4	5
Utilization of woody biomass for energy could positively impact United States’ energy independence	1	2	3	4	5
Waste wood from forest harvests should be used for energy/fuel generation	1	2	3	4	5
Commercial harvesting of woody biomass is likely to limit the regrowth of forests	1	2	3	4	5
Harvesting woody biomass for energy/fuel is likely to benefit local economies	1	2	3	4	5
Forest health is likely to be improved by harvesting woody biomass	1	2	3	4	5
Harvesting woody biomass is likely to degrade wildlife habitat	1	2	3	4	5
Harvesting woody biomass is likely to result in soil erosion	1	2	3	4	5
Harvesting woody biomass is likely to result in water pollution	1	2	3	4	5
Harvesting woody biomass can create competition for raw materials used in other wood product industries (lumber, pulp and paper composites, etc.)	1	2	3	4	5
I support harvesting woody biomass for energy	1	2	3	4	5
The opinions of family members and/or other landowners play an important role in how I choose to manage my woodland	1	2	3	4	5

Management Information: Now we would like to introduce examples of timber and woody biomass harvesting options in Michigan woodlands. Please read each description and answer accordingly.

An average acre of woodland in Michigan might look like the photo to your left. It has a mixture of hardwood (e.g. aspen and birch) and softwood species (e.g. pine and spruce) and a total estimated 26 cords of commercial timber and 27 tons of biomass (small trees, tops, limbs, needles, etc.).

Please rate your level of agreement/disagreement with the following statement:

Regardless of price, I prefer not to have my woodlands harvested for timber or biomass

□ Strongly Disagree	□ Disagree	□ Neither Agree nor Disagree	□ Agree	□ Strongly Agree

A harvest of **commercial timber only**, would harvest on average 8 cords per acre and leave woody biomass on the ground as shown in the photo to your left.

Please select the option that best reflects your opinion:

What is the lowest price you would consider being paid to have your woodlands harvested for timber?

□ $330/acre □ $410/acre □ $490/acre □ $570/acre

□ I would not harvest regardless of how much money I am offered

□ I would harvest at a higher/lower amount (Please specify: $______per acre)

A combined **commercial timber and woody biomass** harvest would remove 8 cords per acre of timber and pulpwood and an average of 18 tons per acre of biomass (see photo to your left). Please select an option that best reflects your opinion:

If you have already been paid for the timber harvest, what is the <u>lowest additional price</u> you need to also have your woodlands harvested for biomass?

□ $0/acre □ $20/acre □ $40/acre □ $60/acre

□ I would harvest at a higher/lower amount
Please specify: $__________________ for biomass per acre

□ I would not harvest woody biomass regardless of how much money I am offered

□ I would have woody biomass harvested and expect no extra payment

II. Harvesting Your Woodlands

Now we will ask for your opinion about four potential harvest scenarios. Answer each scenario as though the previous one had not occurred. Scenarios describe price offers for harvesting 8 cords of timber and 18 tons of biomass. *All harvesting scenarios follow Best Management Practices (BMPs) including Michigan's voluntary Woody Biomass Harvesting Guidance (WBHG) aimed at protecting soil, water and other natural resources.*

SCENARIO 1*: You are approached by a professional logger to harvest pulpwood and sawlogs from your woodlands for* **$570 an acre**. *Would you seriously consider this offer?*
□ Yes---IF Yes, what percent of your woodlands would you harvest? __________ %
□ No---IF No, please explain why____

Y*ou are also offered an additional* **$60 per acre** *to harvest woody biomass from the same area. Would you still seriously consider this offer of $630 per acre to harvest pulpwood, sawlogs and woody biomass?*
□ Yes
□ No---IF No, please explain why____

SCENARIO 2*: You are approached by a professional logger to harvest pulpwood and sawlogs from your woodlands for* **$330 an acre**. *Would you seriously consider this offer?*
□ Yes---IF Yes, what percent of your woodlands would you harvest? __________ %
□ No---IF No, please explain why____

You are also offered an additional **$40 per acre** *to harvest woody biomass from the same area. Would you still seriously consider this offer of $370 per acre to harvest pulpwood, sawlogs and woody biomass?*
□ Yes
□ No---IF No, please explain why____

SCENARIO 3*: You are approached by a professional logger to harvest pulpwood and sawlogs from your woodlands for* **$410 an acre**. *Would you seriously consider this offer?*
□ Yes---IF Yes, what percent of your woodlands would you harvest? __________ %
□ No---IF No, please explain why____

You are ***not*** *offered an additional payment to harvest woody biomass from the same area. Would you still seriously consider this offer of $410 per acre to harvest pulpwood, sawlogs and woody biomass?*
□ Yes
□ No---IF No, please explain why____

SCENARIO 4*: You are approached by a professional logger to harvest pulpwood and sawlogs from your woodlands for* **$330 an acre**. *Would you seriously consider this offer?*
□ Yes---IF Yes, what percent of your woodlands would you harvest? __________ %
□ No---IF No, please explain why____

You are also offered an additional **$60 per acre** *to harvest woody biomass from the same area. Would you still seriously consider this offer of $390 per acre to harvest pulpwood, sawlogs and woody biomass?*
□ Yes
□ No-----IF No, please explain why____

III. You and Your Woodlands

13. Are you planning to pass on all or part of your woodland to your children or heirs? (please check one)
□Yes □ No □ Maybe □ I don't know

14. People own woodlands for many reasons. How important are the following as reasons for why you own woodlands in Michigan? *Please circle **one number** for **each** item.*

	Not important	Slightly important	Moderately important	Very important	Extremely important
a) To enjoy beauty or scenery	1	2	3	4	5
b) To protect nature and biological diversity	1	2	3	4	5
c) For land investment	1	2	3	4	5
d) As a part of my home or vacation home	1	2	3	4	5
e) As a part of my farm or ranch	1	2	3	4	5
f) For privacy	1	2	3	4	5
g) To pass land on to my children or other heirs	1	2	3	4	5
h) For cultivation or collection of non-timber forest products (maple syrup, berries)	1	2	3	4	5
i) For production of firewood for personal use	1	2	3	4	5
j) For production of woody biomass for commercial bioenergy production	1	2	3	4	5
k) For production of sawlogs, pulp-wood or other timber products	1	2	3	4	5
l) For hunting or fishing	1	2	3	4	5
m) To protect land from development (housing)	1	2	3	4	5
n) To leave land unmanaged and let nature take its course	1	2	3	4	5
o) As a part of my inheritance	1	2	3	4	5
p) Other (please specify) ____________________	1	2	3	4	5

IV. Public Incentives

15. Imagine that you could receive either a tax reduction or an incentive payment when you harvest woody biomass for commercial bioenergy production. To qualify for either an incentive payment or a tax reduction, a landowner must have a forest management plan in place. A forest management plan is a document prepared by a professional forester to aid you, the landowner, in meeting your objectives for the property.

What is your 1st choice for the type of payment you would prefer?
□ Incentive or re-imbursement payment □ Tax Reduction □ Don't know □ Neither

V. Demographics

Please remember your responses will be kept in strict confidentiality and will in no way be tied back to you personally. The final section simply helps our understanding of potential availability of woody biomass in Michigan.

16. How old are you?
□ Under 25 □ 25 to 34 □ 35 to 44 □ 45 to 54
□ 55 to 64 □ 65 to 74 □ 75 or older

17. What is your gender?
□ Male □ Female

18. What is your race?
(Please select one or more)
□ American Indian □ Asian □ Black or African-American
□ Native Hawaiian or Pacific Islander □ White

19. What is the highest level of education you have completed?
□ Less than 12th grade □ High school graduate or GED □ Some college
□ Associate or technical degree □ Bachelor's degree □Graduate degree

20. How many children under 18 live in your household? _________

21. What is your annual household income range?
□ Less than $25,000 □ $25,000 - $49,999 □ $50,000 - $99,999
□ $100,000 - $199,999 □ $200,000 or more

FINAL COMMENTS: Do you have any final questions or comments for us?

You are done! Please return this survey by placing it in the postage paid envelope and dropping it in the nearest mailbox. THANKS FOR YOUR TIME!