# A BIOSOCIAL CASE EVALUATION OF WOOD BIOMASS AVAILABILITY USING SILVICULTURAL SIMULATIONS AND OWNER INTENTIONS ON FAMILY FORESTS IN VIRGINIA AND NORTH CAROLINA

by

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## ABSTRACT

Interest in wood-based bio-energy systems in the United States is increasing and may play a part in future renewable energy initiatives (Dincer 2000). Family forests have potential to play an important role in supplying wood biomass for energy production. However, access depends mostly on the management intentions among family forest owners. Enhanced biomass markets in regions where family forest ownership dominates could increase productivity by reinvigorating the low-value merchandizing required to accomplish silvicultural objectives. Given diverse owner objectives and forest types on family forests, estimates of biomass availability must include both biophysical and social aspects of procurable feedstock. This thesis chronicles a biosocial case study that estimates potential biomass supply from 51 family forests in Virginia and North Carolina.

The study occurred within a woodshed centered on the future site of an impending ethanol plant in Mecklenburg County, Virginia. A survey instrument using the theory of planned behavior was used to measure ownership characteristics and intention to harvest. Forest attributes were collected during property visits to estimate potential yields resulting from silvicultural simulations.

Results reveal that forest cover-type and tree size significantly affect owner intentions to harvest and owner attitudes toward harvesting partially mediate this relationship.  Outputs from silvicultural simulations correspond with those made using Forest Inventory and Analysis data

within the study region. Disproportionality was examined by coupling social and biological drivers of sustainable wood biomass availability. Implications of the research include refined estimates of potential supply and demonstrating a multi-scalar, mixed-method approach for assessing wood biomass availability

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# CHAPTER 1. INTRODUCTION

## 1.1 Background

Costs, climate change, geopolitical instability, and uncertainty about the future of fossil fuel are profoundly influencing energy strategies in the United States (US), and interest in renewable systems is increasing as a result (Duffield and Collins 2006). The use of wood to produce renewable energy has resurfaced and could play an important role in future systems (Dincer 2000). Wood-based renewable energy is popular for several reasons. Using food crops, such as corn, as an energy feedstock is highly controversial (Pimentel 2003). Also, wood has a higher energy return when compared with many other popularized feedstocks, and conversion technologies are well tested and continually improving (Shapouri et al. 2002, Keolian and Volk 2005, Amidon 2006).

Also advantageous is the possibility that associated biomass markets will help improve management operability on much of the nation’s forests. This is particularly germane for family forests which have historically supplied substantial volumes of wood, but are increasingly constrained due to diminishing parcel sizes, mounting numbers of owners, and widespread mismanagement (Munsell et al. 2008). Demand for biomass in regions where family forests predominate could help sustain, or even enhance, productivity by reinvigorating the low-value merchandizing needed to achieve silvicultural objectives. Yet accessing biomass on family forests at rates needed to support multiple large-scale initiatives is likely to be less than straightforward.

Family forest owners are diverse (Butler and Leatherberry 2004). Ownership objectives vary and are increasingly amenity- rather than commodity-oriented (Kendra and Hull 2005). Moreover, exurbanization is shaping a new period defined by smaller parcels and more owners

(Sampson and DeCoster 2000, Butler and Leatherberry 2004). If wood-based renewable production systems are to be appropriately scaled and succeed over the long run in regions dominated by family forests, feedstock estimates will need to consider both the human and biological aspects of sustainable supply. The basic premise is that forest characteristics and owner goals both influence long-term feedstock availability.

This document describes a biosocial case study that measured potential biomass supply from 51 family forests in Virginia and North Carolina. The study occurred within a 30-mile road distance supply woodshed that was centered on the location of a proposed ethanol plant in Mecklenburg County, Virginia. Stand-level timber attributes were collected during property visits. For comparative purposes, US Forest Service (USFS) Forest Inventory Analysis (FIA) data were also collected and aggregated for the woodshed study area. Multi-product silvicultural principles were then used to simulate sustainable, first-wave harvests of biomass on case study stands. FIA plot data were then used in a similar fashion to simulate cutting across the woodshed.

Structured interviews were conducted with owners of the 51 case study forests using a survey instrument designed to measure predictors of intentions, and direct intentions, to commercially harvest timber. Volume outputs from simulated harvests were explicitly coupled with owner intentions to study the disproportionate accessibility of wood biomass brought by the interactive and multiplicative effects of social and biophysical variables on 51 case study forests. Case study results demonstrate that cover type and tree size significantly affect owner intentions and that owner attitudes toward commercial harvesting partially mediate this relationship. Findings also show that case study output corresponds to FIA estimates on a per acre basis, and proximal benefits from harvesting can positively affect intention, which can in turn increase absolute biomass output. Key outcomes are discussed in terms of disproportionality when coupling human and biological drivers of sustainable wood biomass supply. Benefits of this research include demonstrating an integrated, mixed method for estimating supply while controlling for future demand and characterizing insights gained regarding potential first-wave supply from sustainably managed family forests.

### 1.2 Objectives

This study was conducted in light of potential renewable energy initiatives in the southern US. The project occurred in Virginia and North Carolina, where an impending ethanol plant may procure wood biomass for production. The case study had four overarching goals: 1) estimate the probability and magnitude of a sustainable first-wave of biomass output by quantifying the disproportionate, or non-linear, relationship between forest characteristics, owner intentions, and simulated silvicultural treatments across case study stands; 2) measure the affects of social marketing themes on the probability and magnitude of future multi-product harvesting that could render biomass; 3) test whether forest variables affect commercial harvesting intentions and if theoretical psychosocial predictors of intention mediate the affect; and 4) use the results to demonstrate the benefits of biosocial assessments when estimating biomass supply from forests in regions dominated by family ownerships.

Specific case study objectives were as follows: 1) measure the characteristics of case study family forests and simulate multi-product silvicultural treatments following Munsell and Germain (2007) and Munsell et al. (2008); 2) estimate wood biomass output from silvicultural simulations using formulas in Jenkins et al. (2003); 3) compare multi-product biomass output from silvicultural treatments for USFS FIA and case study plot data; 4) design and implement a survey instrument using Ajzen’s (2005) Theory of Planned Behavior (TPB) and a set of social marketing themes to study commercial harvesting intentions among case study family forest owners; 5) couple owner intentions and biomass estimates after Nowak et al. (2006) to reveal disproportionate relationships between biophysical and psychosocial measurements; and 6) use stepwise and multiple linear regression and causal mediation tests after Judd and Kenny (1981) and Baron and Kenny (1986) to study if and to what extent TPB variables mediate affects between forest characteristics and owner intentions.

### 1.3 Thesis Organization

Chapter two reviews literature pertinent to this Thesis. Chapter three covers disproportionality and its affect on biomass supply across case study properties. The chapter also tests the effects of social marketing themes on intention to commercially harvest timber. The fourth chapter models significant affects and mediators of owner intention to commercially harvest timber. The final chapter offers case study conclusions, to include implications, recommendations, and suggestions for future research.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 Renewable Energy in the United States

A growing number of factors including geopolitical instability, concerns about global climate change, uncertainty about fossil fuel, the health of the Unites States (US) economy, and homeland security concerns are influencing energy strategies in the US (Duffield and Collins 2006). Energy supply and demand are highly likely to reach a point very soon that will engender significant economic and environmental challenges for maintaining current ways of life (Lloyd and Sabaubbarao 2009). In light of these challenges, the role of large-scale renewable systems in future US economies and environments is being closely considered (Herzog et al. 2001).

### 2.1.1 Wood to Energy

Wood biomass could potentially play a major role in future renewable energy production (Skog and Rosen 1997, Herzog et al. 2001). Transportation fuel and electricity generation needs account for a large part of US energy dependence upon non-renewable, fossil fuel feedstock. This dependence could be redirected toward domestic sources of biomass, resulting in a more sustainable industrial society while also mitigating environmental damage (Ragauskas et al. 2006). If wood resources in the US are to play a part in large-scale renewable energy production, family forests will likely need to supply substantial volumes of feedstock because these forests are the largest ownership form in the US and greatest source of raw forest products (Smith et al. 2004).

## 2.2 Family Forest Ownership in the United States

Forestland covers 749 million acres, or about one-third of the US (Smith et al. 2004). Over the last 4 decades, the number of US family forest owners and the acreage they possess has steadily increased (Butler and Leatherberry 2004, Birch 1997). Today, there are 10.3 million family forest owners that hold 4 of every 10 acres of US forestland and 9 out of every 10 parcels are located in the eastern US (Butler and Leatherberry 2004). Due to majority control, family forests and owners have been the focus of much research.

According to Butler and Leatherberry (2004), family forest owners in the US are made up of individuals or groups of individuals that are unincorporated or otherwise unrelated to a legal entity and own at least one acre of forestland (land that is considered to be at least 10% stocked by trees or woody shrubs). In concert with the USFS FIA program, which samples on US forestland, Birch (1997) and Butler and Leatherberry (2004) report survey results of forest owners possessing stands where FIA sample points are located. Results from this work, presently known as the National Woodland Owner Survey (NWOS), are summarized below, followed by categorized implications of the findings.

Trends for family forest ownership in the US (Birch 1997, Butler and Leatherberry 2004):

- The number of owners has steadily increased over the last four decades and will likely continue to do so.
- Eighty-nine percent own parcels less than 50 acres in size.
- The majority of owners reside within 1 mile of their forestland.
- The average owner is older and better educated than the general population.
- The most commonly listed reasons for owning forestland are: beauty, to protect nature and biodiversity, for wildlife habitat, as part of a farm or home, for privacy, and to pass the land on to heirs.
- Timber production is not a primary objective for most owners, however roughly half have harvested trees at some point.
- Very few owners seek management advice and even fewer possess a written forest management plan for their forests.

- The likelihood of harvesting, management plan possession, and use of management advice increases with the amount of acres owned.

One of the major regional differences in family forest ownership in the US is the dominance of this owner group in the eastern half of the country. Ninety percent are located in the east, whereas public forestland is most common in the west (Butler and Leatherberry 2004). Within the eastern US, distinctions exist between the North and South. The average family forest is smaller in the North, with 40% falling below 50 acres compared to about 25% in the South (Butler and Leatherberry 2004). Reasons for owning forestland also vary between the two regions, with land investment and family legacy being commonly listed in the South and aesthetic enjoyment being more frequent in the North (Butler and Leatherberry 2004). As for the importance of timber production to family forest owners, only 22% of owners in the North claim that producing timber is a main objective, while the percentage is twice as high in the South (Butler and Leatherberry 2004).

**2.3 Family Forest Management**

Though timber production is not the most common reason for family forest ownership, it is interesting to note that nearly half of NWOS respondents reported that they have harvested timber before (Butler and Leatherberry 2004). For Example, in 2001 63% of all growing stock removals in the US occurred on family forests (Smith et al. 2004). Owners who have harvested timber control 76% of all family forestland, but only 22% of them used professional advice during their most recent harvest (Butler and Leatherberry 2004). Harvesting on family forests is of varying form and intensity and inevitably changes the economic and ecological dynamics of family stands. Understanding these changes is especially important in the South given that harvesting on family forests is relatively more intense when compared with other regions in the US. For instance, between 1986 and 2001 harvesting on southern family forests increased by 46% as demand for wood shifted from forests in the Pacific Northwest to the South (Smith et al. 2004).

While the use of professional forest management and standards are common on industry lands, and often mandated, regulated, and monitored on public lands, professional management advice is less prevalent on family forests. In general, the management of working family forests is not ideal, the legacy of which is tarnished by exploitive cutting practices that neglect silviculture (Ezell 1992, Jones et al. 1995, Fajvan et al. 1998, Pell 1998, Nyland 2000, Munsell and Germain 2007). This is especially true for family forests in the eastern hardwoods, where high-grading or diameter-limit cutting are common (Nyland 1992). On the other hand, sustained yield practices are more common on pine plantations in the South, but not void of challenges given that many family forest owners are hesitant to adequately invest or act in a timely manner to ensure the continued health and productivity of the plantations they own (Arano et al. 2004). The result, in general, is that the post-harvest structure and composition of diverse working family forests largely prevents production of high-quality sawtimber in the next rotation (Nyland 1992, Germain et al. 2007). As a result, there is an increasing need for the rehabilitation of working family forests (Mayfield et al. 2007, Munsell et al. 2009).

### 2.3.1 Silviculture

Silviculture is the foundation of forest management. Silviculture is defined as the science of controlling the establishment, growth, composition, health, and quality of forests to meet the diverse needs and values of people on a sustainable basis (Society of American Foresters 2001). A forest *stand* is a contiguous group of trees uniform enough in characteristics and condition to be a distinctive unit (Smith et al. 1997), also know as a management unit. A key component to silviculture is stand density management. Measures of stand density involve the number, size, spacing, and species composition of a given forest stand. Density management allows the use of selective cutting of trees to alter physical conditions within the stand, giving remaining individual trees access to resources needed to develop (Smith et al. 1997). Density management can be used as a tool to alter the stand characteristics in a way that favors landowner objectives like timber growth, recreation, or aesthetics.

### 2.3.2 Engaging Family Forest Owners

Increasing the extent to which family forest owners engage in silvicultural management has been the focus of much research concerning reforestation, timber supply, and ecosystem sustainability. Federal and state governments have implemented a number of assistance programs such as tax incentives, cost share for certain activities, and professional outreach and technical assistance. Programs have been diverse in design and application and general approaches within the spectrum of these techniques and programs have been examined and are discussed below.

Alig et al. (1990) reviewed a number of studies regarding timber management on family forests, including planting, intermediate treatments, and harvesting activity. The review concludes that cost sharing can increase tree planting and that technical assistance often increases owner revenue, improves the quality of residual stands, and increases harvesting levels. Numerous studies of ownership characteristics and objectives vis-à-vis harvesting have occurred that intend to identify types of owners that are likely to participate in forest management and respond to outreach (e.g., Kurtz et al. 1981, Kuuluvainen et al. 1996). Other studies have gauged owners' intention to commercially harvest timber (Young et al. 1985, Young and Reichenbach

1987, Karpinnen 2005, Munsell et al. 2009). These studies closely evaluated attitudes, beliefs, intentions, and the influence of social groups and used Ajzen's (1980, 2005) Theory of Reasoned Action or Ajzen's TPB. The latter will be discussed in the next section.

### 2.4 The Theory of Planned Behavior

According to TPB, an individual's intention to perform a behavior is a predictor of their actual behavior. The theory is useful in empirical research because it is often costly and impractical to measure behavior. Thus, intention is measured directly in research projects and used as a proxy for actual behavior. In addition, three latent constructs that theoretically affect an individual's intention can be measured: attitude toward the behavior, subjective norm, and perceived behavioral control (Figure 2-1). Stated plainly, an individual's intention to perform a given behavior is affected by their attitude toward doing so, how they think others feel about it, and their perception of factors that may influence their ability to perform the behavior. A final component of the theory is actual behavior control, which is an external intervening variable that can influence an individual's ability to behave in an intended fashion.

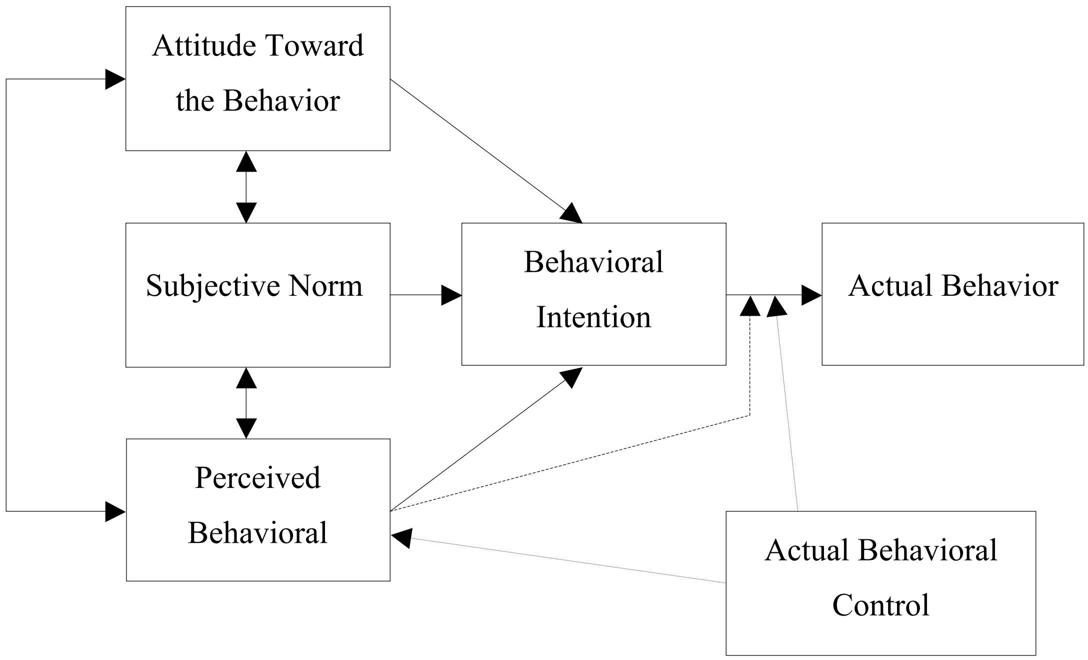


**Figure 2-1. Azjen's (2005) Theory of Planned Behavior.**

The three latent constructs affecting behavioral intention are measured using the product of two measurements. The first measure gauges an individual's belief about performing the behavior and is weighted by the second measure, which seeks to assess the individual's evaluation of the outcome of performing the behavior relative to their belief. To demonstrate, an individual's attitude toward the behavior can be operationalized by measuring how they think timber harvesting affects wildlife weighted by their evaluation of the importance of this affect. Stated differently, an individual may believe that timber harvests negatively impact wildlife, however the negative belief may carry little weight if wildlife is unimportant to the individual. Previous studies that have employed TPB to study timber harvesting on family forests consistently demonstrate that attitude toward harvesting is a significant predictor of harvesting intention (Young and Reichenbach 1987, Karpinnen 2005, Munsell et al. 2009).

**2.5 Owner Attitudes and Management Goals**

Many studies that characterize family forest owners and their actions call for targeted outreach that is more closely aligned with amenity goals (Young et al. 1985, Young and Reichenbach 1987, Karpinnen 2005, Munsell et al. 2009). One such vehicle for carrying out these recommendations is social marketing. This form of marketing involves combining traditional commercial strategies that aim to sell products with targeted messages to promote ideas (Kotler et al. 2002). Social marketing messages that are crafted for specific social groups or segments can be relatively successful in changing individual attitudes, beliefs, and behaviors (Butler et al. 2007).

Social marketing involves three steps: research, implementation, and evaluation. Butler et al. (2007) asserts that this approach could pay huge dividends if applied to family forest owners. The goal of achieving a specific initiative, such as increasing the use of forest management practices relative to timber harvesting in a given region, could be more readily achieved if socially-based, marketing messages are used. To do this, messages must be tested and tailored at proximal levels due to variability in family forest ownership characteristics across regions (Butler and Leatherberry 2004). Personally compelling situations, individual concerns, and locally relevant messages can then be developed to reach family forest owners in a way that maximizes the effect (Butler et al. 2007). Efficacy evaluations are necessary over the course of a campaign if influential marketing is to be sustained.

## 2.6 Disproportionality

Uncovering disproportionality for outcomes within any system requires the examination of multiplicative and interactive effects of social and biophysical variables within a biosocial system. In social sciences, disproportionality is typically associated with between-group variability. For instance, environmental justice researchers often compare racial groups to identify if one group is disproportionately located in areas with environmental problems. Nowak et al. (2006) demonstrates that disproportionality is a helpful tool for studying interrelationships between society and biology by evaluating within-group variability. In other words, a few outliers within one group (either social or biological) may help explain a great deal about aggregated, biosocial outcomes.

Measuring disproportionality on family forests requires that the variability within owner characteristics and their forests be examined simultaneously. For instance, trends indicate that owners of larger parcels are more likely to engage in management, yet family forest parcel size continues to decrease and management objectives are changing (Sampson and DeCoster 2000, Butler and Leatherberry 2004, Kendra and Hull 2005). As such, many forests may be ready for harvesting according to silvicultural guidelines, yet only a small amount of the owners intend to harvest. What is more, those intending to harvest may own various sizes of forests, which would further affect aggregated wood biomass availability and suggest that levels of future supply may differ from estimates gleaned using only generalizations of biological capacity or suppositions derived solely from rational models of harvesting behavior.

Birch (1997) pointed out over a decade ago that 4% of the owners that held 38% of the private forests in the US listed timber production as their primary objective, 45% that possessed 78% had harvesting experience, and 29% holding 60% of the nation's forests planned to harvest within the next 10 years. These examples, however, only capture disproportionality within two dimensions – owner and acreage. The productivity of relative family forest acreage should be included to enhance understanding of the nonlinear, disproportionate relationships on family forests. Relative to this third dimension, investigating the potential type and intensity of timber harvesting would further refine estimates involving the sustainable stream of products, such as wood biomass, that can be realized via timber harvesting on family forests.

# CHAPTER 3. THE EFFECTS OF SOCIAL MARKETING THEMES ON SUSTAINABLE BIOMASS YIELD FROM 51 FAMILY FORESTS IN VIRGINIA AND NORTH CAROLINA

## 3.1 Introduction

Escalating prices, geopolitical instability, climate change, and growing concerns about fossil fuels are affecting energy policy in the United States (US) (Duffield and Collins 2006). Domestic renewable energy is one popular alternative to existing fossil fuel systems and biomass feedstock could play an important role (Dincer 2000). For example, the Energy Independence and Security Act (EISA) of 2007 and American Clean Energy and Security Act (ACES) of 2009 stipulate aggressive bio-energy and bio-fuel production benchmarks (Galik et al. 2009). The EISA, in particular, outlines a Renewable Fuels Standard (RFS) that aims to produce 36 billion gallons of renewable fuel by 2022, at least 60% of which must be sourced from something other than corn. Important to forest stakeholders is the role forest biomass might play in meeting US renewable energy aims.

Forests constitute a potentially significant source of biomass at multiple renewable energy production scales (Galik et al. 2009). Wood biomass has several advantages over other feedstock. For one, using food crops to produce energy or fuel can be controversial (Pimentel 2003). In addition, wood typically has a higher average energy output when compared with most biomass feedstock, its conversion technologies are fairly advanced, and there is a significant amount of standing volume (Shapouri et al. 2002, Keolian and Volk 2005, Amidon 2006, Mayfield et al. 2007). On the other hand, US forests are managed for diverse objectives, some of which could conflict with and thus hinder sourcing of forest biomass for renewable energy production.

Family forests, which are the most prominent and diverse form of forestland in the US, will likely need to supply substantial amounts of wood biomass if initiatives are to succeed. More than 4 out of every 10 acres of US forests are owned by around 10.3 million families, which are a chief supplier of ecosystem goods and services such as timber, recreation, aesthetics, biodiversity, and water quality (Best and Wayburn 2001, Butler and Leatherberry 2004). Forest biomass markets could help enable the sustainability of family forests by causing an increase in management revenue, which in turn could improve the viability of ownership (Munsell and Germain 2007, Munsell et al. 2008, Galik et al. 2009).

It is also important to note that families own their forests for numerous reasons, some of which are to produce commodities and others to preserve amenities (Butler and Leatherberry 2004, Kendra and Hull 2005, Butler 2008). It stands to reason that biomass harvesting may not be compatible with all ownership objectives and thus feedstock accessibility will likely differ from parcel to parcel. In addition, not only do owner objectives and actions vary, but the size and condition of their forests are prone to differ as well. Thus, estimates of the probability and scope of family forests as biomass merchandisers are needed to more accurately project outputs in regions where these forests predominate.

Approximations that do not account for the human and biophysical aspects could depict more or less volume than is actually accessible and adversely affect renewable energy enterprise, politics, and practicability. The assertion is the physical presence of available volumes from family forests do not supplant owner intentions to supply it, and vice versa. Rather, owner intentions and forest characteristics are coupled and should be evaluated simultaneously using disproportionality (after Nowak et al. 2006). In this paper, we present a case study that examines disproportionality between owner intentions and forest conditions as they relate to sustainable biomass output from 51 Virginia and North Carolina family forests. To account for real-world context, the case study was carried out in a woodshed defined using a 30-mile haul distance procurement parameter for an impending ethanol fuel plant.

We conducted timber inventories to measure the size and condition of case study forests, surveyed owner intentions to conduct a commercial timber harvest, and tested the effects of social marketing themes on reported intentions. We used inventory data to prescribe silvicultural treatments that would render an initial, or first-wave, of traditional products (sawtimber, pulpwood) and biomass (tops, limbs, foliage) from case study forests, reported here in oven-dry tons (odt). To characterize landscape-level compatibility, biomass volumes from case study treatments were compared to outputs from replicated silvicultural treatments using Forest Inventory Analysis (FIA) plots located within the case study woodshed. We then used case volumes and owner intentions to model the disproportionate effect of 4 social marketing themes on first-wave biomass accessibility. This chapter describes these elements in greater detail and discusses the relevance of coupled research as it relates to estimating biomass output from family forests and the role of social marketing and disproportionality in realistic and sustainable biomass benchmarks.

### 3.2 Family Forest Management, Social Marketing, and Disproportionality

Family forests have changed significantly in recent years. Urban and suburban residents are undertaking ownership as they migrate to rural areas (Sampson and DeCoster 2000). Meanwhile, the largest intergenerational transfer of US family forests is underway (Pinchot Institute for Conservation 2005). As a result, the number of larger family forests has decreased and, by default, smaller parcels have increased. Another feature of consequence is land use values among younger, exurban owners. Research demonstrates tendencies to favor more acute balances between environmental amenities and commodity provision (Kendra and Hull 2005).

Despite diverse ownership objectives and changing parcel characteristics, US family forests are expected to remain a substantial supplier of forest products. The volume of wood harvested has increased 42% since 1976. In 1997, almost 60% of the volume harvested in the US was derived from family forests. By 2040, removals are projected to swell by about 30% (Smith et al. 2004). Butler and Leatherberry (2004) found timber harvesting to be the most commonly planned activity for family forests in the next 5 years. However, the nature and legacy of family forest harvesting are often not ideal in terms of forest health and productivity (Nyland 1992). Research demonstrates that exploitive cutting is common and silviculture is infrequently used (Ezell 1992, Jones et al. 1995, Fajvan et al. 1998, Pell 1998, Nyland 2000, Munsell and Germain 2007).

The consequence of exploitive, non-silvicultural cutting is that the potential for sustained yields of high-quality products is severely diminished (Germain et al. 2007). As a result, many family forests are in need of rehabilitation (Mayfield et al. 2007, Munsell et al. 2009). Notable exceptions are family plantations associated with diverse product markets and agroecosystem silviculture, but even these forests are experiencing operability and sustainability challenges as pulpwood industries decline (Fox et al. 2007, Munsell et al. 2008). Forest biomass energy markets could provide an additional opportunity for family forest owners to sustain product yields or implement rehabilitative treatments (Aguilar and Garrett 2009). Yet increased consumption of woody biomass for energy production could also exacerbate exploitive practices, such as diameter-limit, premature, and excessive cutting (Munsell and Germain 2007).

Biomass harvesting on family forests will likely need to increase substantially if renewable energy goals are to be achieved. This is particularly so because it is doubtful that forest biomass prices will be high enough in the near future to financially warrant managing solely for its production, the course of which reduces the total potential biomass output from forests in favor of management for higher value products (Sedjo 1997, Munsell and Fox in press). Thus, most family forest owners will need to integrate these removals into conventional, multi-product commercial systems. Research that combines investigations of owners and their forests are needed not only to more accurately estimate accessible yield, but also to increase market participation and improve family forest sustainability.

Social marketing combines traditional commercial techniques that aim to sell a product with the use of targeted messages to promote ideas (Kotler et al. 2002). Butler et al. (2007) suggest that well-crafted social marketing messages could help encourage US family forest owners to manage and retain productive and sustainable forests at greater rates. They argue that personally compelling situations can influence behavior among family forest owners because only small fractions have technical management experience and knowledge. For example, Lindsay et al. (1992) point out that family forest owners are not likely to distinguish between the harvesting of one forest product over another. At the same time, the biological condition of family forests warrants close consideration because the resource will, in many ways, define potential sustainable behaviors.

Disproportionality has been used to assess between-group variability in the social sciences. In natural resources, it can be used to study management outcomes by simultaneously researching non-linear relationships within biosocial couplings (Nowak et al. 2006). Estimating the potential for family forests to sustainably supply wood to meet renewable energy production goals requires that owner and forest variability be considered concurrently. First, it is necessary to evaluate whether owners are likely to conduct harvesting operations that can render forest biomass. It is also important to assess the size of the parcel where such operations may occur and characterize the amount of biomass available from silvicultural operations. This multi-dimensional approach can be used to evaluate the disproportionate output of forest biomass.

### 3.3 Case Study Woodshed

Virginia is similar to other states in the southern US in that well over half of the land is forested and the majority of the acreage is owned by families. This is true for Virginia's Southside, which is generally identified as the area east of the Blue Ridge and south of the James River. The Southside's economic cornerstone has historically been high production agriculture, especially tobacco. In the last two decades, however, tobacco production has steadily declined, in part due to state legislation intended to encourage landowners to transition away from the controversial crop and promote potentially profitable land-use alternatives.

A legislative action of note was the Virginia General Assembly's enactment of the Virginia Tobacco Indemnification and Community Revitalization Commission (VTICRC) in 1999. In 2008, the VTICRC supported the construction of a water main to the site of a proposed ethanol fuel plant in the Southside county of Mecklenburg. The plant aims to use local biomass feedstock to produce 100 million gallons of ethanol annually. Procurement specialists for the company are interested in forest biomass as a potential feedstock because stumpage is plentiful and markets for low value wood are generally needed. We used company recommendations to define our case study woodshed (Figure 3-1) and focused on family forest owners within this sector. Our intent was to conduct a case study using a population of family forest owners that may soon have biomass markets to provide private enterprise with a case example of biosocial projections.

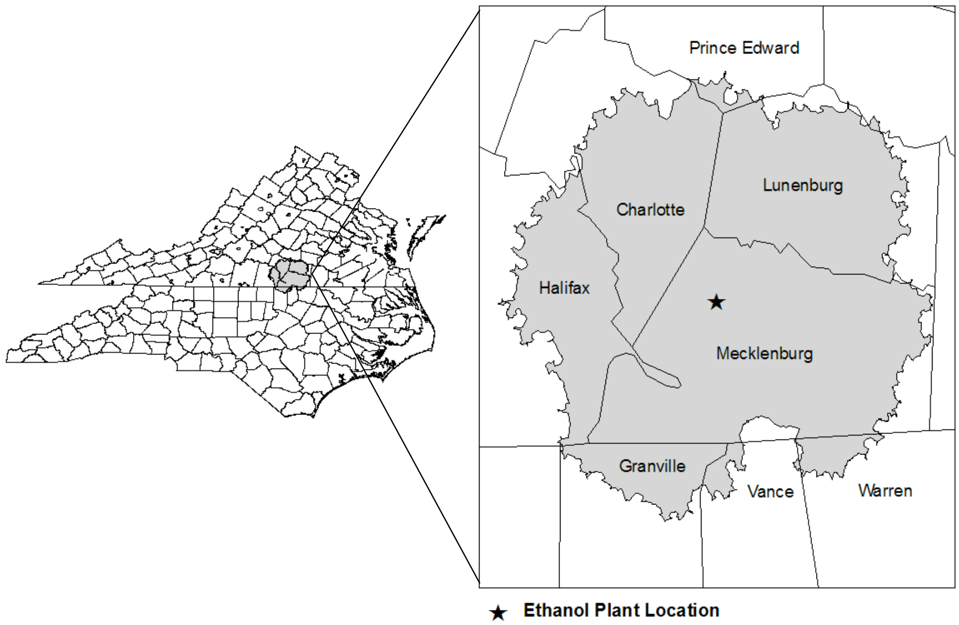


**Figure 3-1. Case study woodshed boundaries are depicted by the grey polygon and were defined using 30 miles of road distance from the centralized location of a future ethanol plant, which is depicted by a black star. The woodshed is 1.02 million acres and covers land in 5 Virginia counties and 3 in North Carolina.**

### 3.4 Methods

The 1.02 million acre study area was created using a 30-mile center point road network analysis. Environmental Systems Research Institute's (ESRI 2009) Street Map USA, Arcmap Network Analyst, and coordinates of the future ethanol plant location were used in the process. About 60% of the study area is forested and covers portions of Mecklenburg, Halifax, Charlotte, Lunenburg, and Prince Edward Counties in Virginia and Warren, Vance, and Granville in North Carolina. We used property tax rolls to draw a sample of 400 parcels that are 10 or more acres, doubly stratified by a county's relative land area contribution to the study area and by parcel size class, from a population of 13,776. A letter describing the study, response card, and business reply envelope were mailed to owners of the sampled parcels. The letter presented study methods and described project relevance and benefits to family forest owner participants (Appendix A). The response card gave recipients the opportunity to indicate whether they possess 10 or more acres of forest on their property and confirm or deny their willingness to participate (Appendix B).

We measured each participating owner's intention to conduct a commercial timber harvest on the sampled parcel. To do this, we measured their baseline intention with a summated, multi-measurement scale that used three 7-point Likert-type scale agreement measurements. We asked whether they intend to: 1) conduct a commercial harvest in the next 5 years; 2) at any point in the future; and 3) in the next 5 years if it were to help supply the impending ethanol plant. Scaled responses ranged from 1, corresponding to strongly disagree, to 7 corresponding to strongly agree, with 4 being neutral. The three responses were averaged to create an overall baseline intention score. We also tested the effects of different social marketing constructs on owner intention by presenting 4 cost-benefit scenarios after measuring the baseline score and asking owners to use a 7-point agreement scale to rate their intention to harvest in the next 5 years if the specific benefit were to be achieved (Table 3-1).

Constructs were selected to test key biomass supply circumstances under which owner intentions may change. The method is based on research activation techniques that prompt a response to germane concepts or goals as a way to study how things like attachment and commitment affect behaviors or perceptions (Green and Campbell 2000, Finkel et al. 2002, Davis et al. 2009). The first constructed scenario accounts for energy independence as a national policy goal defined in legislation such as the EISA. The second speaks to improving the local economy, which has grown in popularity in terms of issues such as local food and could carry over to wood (Feenstra 2009). The third covers government support programs, such as subsidies and cost-share, which have long been included in forest management policy (Alig 1990). The final construct addresses the potential environmental benefits of harvesting to supply renewable energy production (Ragauskas et al. 2006). Overall scenario-based intention scores were calculated by replacing the 5-year ethanol plant baseline score with each scenario measurement. Differences between the average summated baseline and 4 scenario intentions were tested for significance using paired t-tests.

**Table 3-1. Cost-benefit scenario statements used to measure the influence of social marketing themes on owner intentions to commercially harvest timber.**

| |
|---|
| **Scenario:** |
| Supplying the ethanol plant with my wood will help this country become more energy independent. (Energy Independence) |
| Supplying the ethanol plant with my wood will help the local economy. (Local Economy) |
| I could take advantage of renewable energy subsidies and cost-share programs if I supply the ethanol plant with my wood. (Cost-shares/Subsidies) |
| Using wood to produce ethanol has environmental benefits. (Environmental Benefits) |
| **Statement:** (following each scenario) As a result, I intend to commercially harvest timber in the next 5 years. |
| **Response:** Scale of 1 through 7 (1=strongly disagree ; 4=neutral; 7=strongly agree) |

When inventorying case study parcels, we recorded variables needed to project sustainable forest biomass volume from a first-wave of silvicultural treatments. Two-hundred and eighteen 1/10$^{th}$ acre circular plots were installed across 3,952 forested acres on 51 parcels. To achieve landscape-level compatibility between case estimates and those derived from FIA data, case inventories followed elements of FIA protocol. Plot-level measurements included: species, diameter at breast height (dbh), acceptable growing stock (AGS) versus unacceptable growing stock (UGS), number of 16 foot logs in AGS over 12 inches dbh in hardwoods and 10 inches dbh in softwoods, and the number of 8 foot bolts in UGS. Determination of AGS versus UGS was made with an economic objective in mind, using tree form and vigor as criteria. High-resolution satellite imagery and ground-level assessments were used to delineate forest cover types and conditions for all case study acreage.

Managed by the USFS, the FIA program is a continuous, nationwide forest inventory. FIA uses a three phase sampling procedure to achieve standardization. In phase 1, remote sensing imagery is used to classify random grid points as forested or non-forested. Points classified as forested are visited on the ground during phase 2. When a forested condition with 10% or greater stocking based on species composition is confirmed, these points are sampled using fixed area plots. To measure forest cover types and conditions across the case study woodshed, FIA data for the state of Virginia and North Carolina were obtained from the USFS FIA DataMart website. Macro-plot locations for selected inventory years (2002, 2003, 2005-2008 for Virginia; 2003-2006 for North Carolina) were projected into ArcMap (ESRI 2009) and overlaid on the case study woodshed. Phase 2 plots within the case study area were selected and those not identified as privately owned were then eliminated. The 125 remaining phase 2 plots were then used to project forest conditions and simulate silvicultural treatments across the case study woodshed.

Above ground wood biomass (AGB) was calculated within both datasets following Jenkins et al. (2003). Results are reported as total AGB, which includes merchantable bole, tops, limbs, and foliage, and residual AGB, which subtracts wood associated with the merchantable bole. Plot level estimates were then generated and scaled up to represent one acre. To test for similarities between case study and FIA plot data, a K-means cluster analysis using Euclidean distance was used to create clusters, or groups, made up of plots from both datasets with like multi-variable characteristics and acceptable error margins (≤ 20% at the $95^{th}$ percentile). Average dbh, basal area (BA) per acre, trees per acre (TPA), quadratic stand diameter (QSD), ratio of TPA represented by softwoods, and ratio of BA per acre represented by softwoods were calculated for each plot and standardized using z-scores, creating input variables for the cluster analysis.

Plots from both datasets were clustered into nine groups, which resulted in 4 softwood and 5 hardwood forest types with various conditions and levels of stocking (Table 3-3). Clusters were used to prescribe compatible silvicultural simulations for both datasets following an area versus volume control. Silviculture is defined as the practice of controlling growth, composition, health and quality of forests for the benefit of people and involves three interdependent treatments: regeneration, tending, and harvesting (SAF 2001). Appropriate use and timing of treatments should maximize benefits to the landowner, shorten investment periods, minimize costs, improve tree stability and quality, and sustain ecological health and productivity (Nyland 2002).

Two silvicultural techniques were used to simulate area treatments for each group, with the objective of maximizing economic productivity within forest stands. The first was density management and second timber stand improvement (TSI). To manage density, average trees per acre and stem diameter for hardwood groups were plotted on a stocking guide for upland central hardwoods after Roach and Gingrich (1968). The same process was followed for softwood groups using maximum stand density index (SDI) after Dean and Baldwin (1993). Silvicultural thinnings that scaled back stand density to a recommended residual stocking level of 60% were simulated for hardwood clusters which exceeded 80% stocking, while reductions to 30%

maximum SDI were applied to softwood clusters at or exceeding 45%. Clusters that did not meet or exceed these thresholds were left untreated. In TSI, cuts were administered primarily to improve the health and economic viability of the future stand and achieve residual density goals. This was accomplished by thinning from below and above in hardwood stands by first removing UGS, followed by mature AGS if needed. For softwood stands, a row thinning strategy was used that removed interfering hardwoods followed by randomly sized softwood stems to achieve the target residual of maximum SDI.

Residual AGB volumes resulting from silvicultural treatments were tested for significant differences between FIA and case study plots using an independent student t-test. Case plots were then assigned to respective parcels and used to generate a weighted, per acre estimate of biomass yield. Results were used to characterize the potential, absolute, output of case study stands by scaling based on parcel acreage. To achieve biosocial coupling, absolute outputs were factored by the summated baseline and scenario-based intention averages. Percent accumulation in the absolute yield across baseline intention was compared with accumulations across overall scenario-based intentions that differed significantly from the baseline.

### 3.5 Results

Three-hundred and ninety-three letters, cards, and envelopes were successfully delivered using a single mailing. A total of 80 response cards were returned for a single mailing response rate of 20%. Among the 67 respondents that owned 10 or more acres of family forestland and agreed to participate, time constraints allowed surveys and field inventories to be completed for 51. Case study parcels included 3,952 forested acres and ranged in size from 10 to 405 acres. Sampling distribution was fairly even, with 50% of the cases in Mecklenburg, 46% in the remaining Virginia counties and 4% in North Carolina. 1,487 acres were clustered as hardwood and 1,683 as softwood.

Two scenario-based intention measurements differed significantly from the baseline measurement (Table 3-2). Both mean scores were higher and involved scenarios in which harvesting in the next 5 years would be cost-shared and subsidized or improve the local economy. Energy independence and environmental benefits, on the other hand, caused a slight but statistically insignificant increase. The influence of cost-share and subsidies is not surprising given the nature and history of these policies and general decline in management profit margins, particularly on smaller and degraded parcels. Response to improvements in the local economy suggest that a potentially effective social marketing message is one in which supplying forest biomass is tied to improving the well being of surrounding communities.

**Table 3-2. Paired t-test results displaying differences between baseline intention, highlighted in grey, versus four scenario-based scores of a family forest owner's intention to commercially harvest timber on their forest within the case study area. Bold type represents statistically significant differences.**

| Scenario | Mean | Difference | SD | Sig. (2-tailed) |
|---|---|---|---|---|
| Baseline | 4.36 | N/A | 1.98 | N/A |
| Energy Independence | 4.46 | 0.10 | 2.04 | 0.163 |
| **Local Economy** | **4.51** | **0.15** | **2.03** | **0.035*** |
| **Cost-shares/Subsidies** | **4.50** | **0.14** | **2.04** | **0.040*** |
| Environmental Benefits | 4.48 | 0.12 | 2.03 | 0.095 |

*Significant at $P \leq 0.05$

Cluster results are presented in Table 3-3. Most characteristics generally vary, but % BA and TPA in softwood are distinct and used to distinguish whether a cluster is primarily softwood or hardwood. Remaining variables can then be used to characterize whether a softwood or hardwood cluster has, for instance, large-, medium-, or small-sized trees, or the number of trees and total AGB. All clusters achieved acceptable error for variance of BA/ac, with cluster 4 having the lowest margin at 4.7% and cluster 7 the highest at 15.7%. Table 3.4 includes the absolute and per acre total and residual AGB for both the total and simulated treated acreage. Results show that residual AGB harvested from FIA and case study forests did not differ significantly (Table 3-5). Projected forest biomass output from case study simulated harvests resembles woodshed-level estimates derived from compatible FIA treatments, suggesting that case study results provide a degree of insight at the landscape level.

**Table 3-3. Stand characteristics and sample size for 9 stand types resulting from a K-means cluster analysis using plot data from FIA and case study datasets.**

| Cluster (HW = Hardwood) (SW = Softwood) | DBH | BA | TPA | %BA softwood | %TPA softwood | QSD | Total AGB/ac (odt) | FIA Plots | Case Study Plots | BA Mean Error % (α = .05) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 (SW) | 10.1 | 112.5 | 198 | 91.8 | 87.1 | 10.4 | 52.4 | 12 | 39 | 5.51 |
| 2 (SW) | 7 | 65.7 | 228.1 | 82.8 | 82.4 | 7.2 | 28.3 | 26 | 19 | 12.25 |
| 3 (HW) | 14.3 | 149.2 | 118.9 | 0.4 | 1.5 | 15.3 | 135.4 | 1 | 17 | 14.24 |
| 4 (HW) | 8.5 | 110.1 | 251.4 | 16 | 15 | 9 | 74.6 | 29 | 35 | 4.7 |
| 5 (HW) | 9.9 | 97.5 | 157.7 | 4.6 | 5.2 | 10.7 | 75.2 | 18 | 18 | 10.37 |
| 6 (HW) | 11.3 | 160.8 | 197.9 | 7.3 | 6.1 | 12.3 | 131.5 | 8 | 26 | 6.6 |
| 7 (HW) | 7.1 | 42.7 | 143 | 11.1 | 12.4 | 7.4 | 27.1 | 18 | 13 | 15.7 |
| 8 (SW) | 7.8 | 149.9 | 436 | 92 | 91.3 | 8 | 62.5 | 13 | 35 | 6.47 |
| 9 (SW) | 11 | 206.4 | 281.9 | 89.9 | 77.8 | 11.7 | 103.9 | 0 | 16 | 6.7 |

**Table 3-4. Sums and per acre averages for both total AGB and residual AGB extracted during simulated harvests across all 51 case study properties.**

| | Sum | | Per Acre | |
|---|---|---|---|---|
| | Total AGB (odt) | Residual AGB (odt) | Total AGB/ac (odt) | Residual AGB/ac (odt) |
| **Total forested acres (3,952 ac)** | 214,470.31 | 35,158.61 | 54.27 | 8.90 |
| **Forested acres treated (2,665)** | - | - | 80.48 | 17.01 |

**Table 3-5. Independent t-test results and comparing per acre means of AGB extracted during simulated cuttings between case and FIA datasets.**

| Mean (odt) | | SD | | t-test |
|---|---|---|---|---|
| **Case Data** | **FIA Data** | **Case Data** | **FIA Data** | **Sig.** |
| 45.56 | 38.92 | 30.09 | 25.17 | 0.091 |

Intention to commercially harvest timber can be used to gauge the probability of residual AGB output along a disproportionality gradient (Feather 1982, Ajzen 2005). Residual AGB left behind after sorting for traditional products represents a readily available source of biomass that can be captured while removing UGS. From right to left, Figure 3-2 shows how the absolute residual AGB removed during each simulated case study harvest accumulates across associated intentions that owners will commercially harvest sampled parcels. As intention decreases along the horizontal axis the potential absolute residual AGB volume derived from treatment simulations increases to its total.

When comparing baseline and scenario-based intention scores, the disproportionate relationship between owner intentions and absolute residual AGB estimates causes non-linear changes in the probability of biomass feedstock from case study forests (Figure 3-2). These interactive and multiplicative effects of an owner's intention score, the number of acres they own, and the amount of volume being extracted from their forest act to amplify the disproportionate influence of key players within the biosocial system (Figure 3-3). For instance, overall baseline intention score 6 accounts for a larger portion of the total harvested residual AGB than do the overall scores associated with the local economy and subsides/cost-share, yet the residual AGB is much higher in these scenarios when the intention score is 5. To cumulatively address first-wave volume of the highest probability we focus on the upper range of intention scores falling between 5 and 7, wherein harvesting activity is the most likely according to stated owner intentions. Table 3.6 displays the percent harvested residual AGB for the overall baseline intention scores 5 to 7 and the two significantly different scenario scores. Overall scenario-based intentions between 5 and 7 housed between 15 to nearly 17 % more forest biomass than did the baseline score.

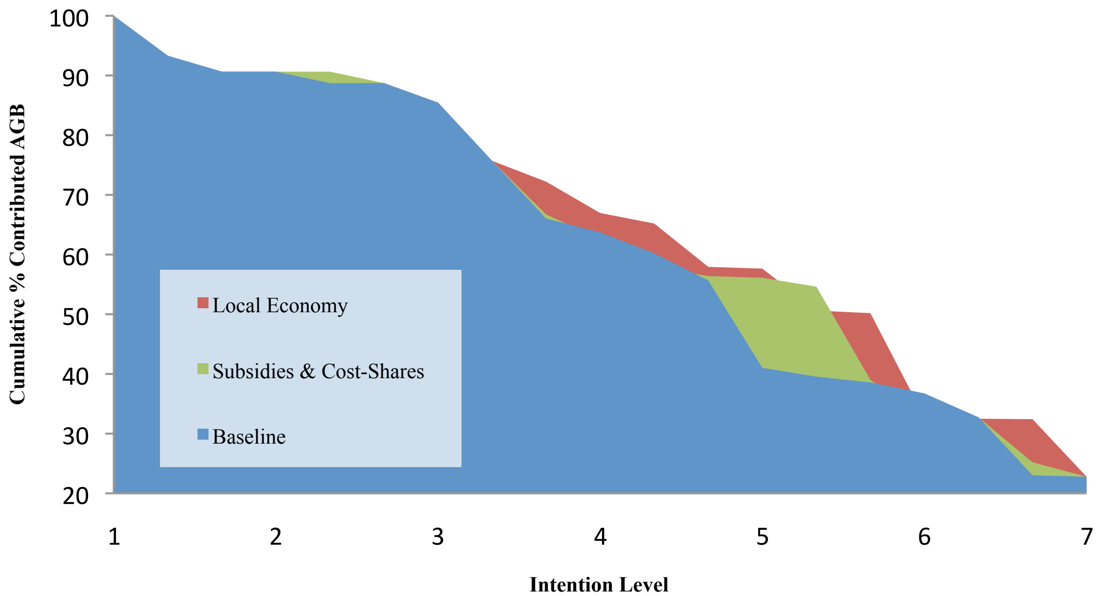


**Figure 3-2. Cumulative percent of residual AGB obtained from simulated thinnings on 51 case study properties with total case study volume accruing as intention decreases. Contribution of AGB is represented by an owner's relative intention score along the X-axis.**

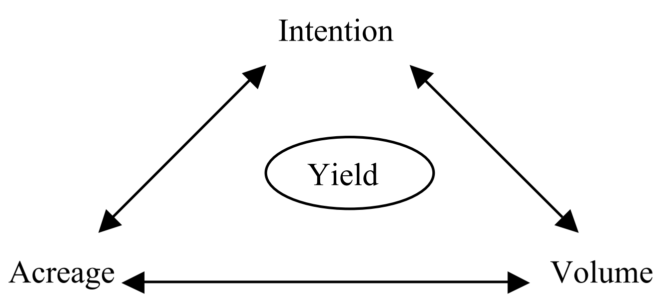


**Figure 3-3. Conceptual depiction of the multiplicative and interactive effects of psychosocial and biophysical variables that lead to actual available biomass within a given biosocial system.**

**Table 3-6. Percent of residual AGB associated with owner intention levels 5 through 7 for their intention to commercially harvest timber on case study properties.**

| | Baseline | Local Economy | Subsidies |
|---|---|---|---|
| | 41.0% | 57.6% | 56.1% |
| **Difference Δ** | n/a | 16.6% | 15.1% |

### 3.6 Discussion

US family forests are a diverse supplier of ecosystem goods and services. When commercial timber harvests are conducted in this role, they are often prohibitive in that forest resources are frequently cut without using silviculture (Nyland 1992, Germain et al. 2007). As a result, the future health and productivity of many family forests is inhibited. Demand for forest biomass to produce renewable energy could help implement sustainable commercial timber harvesting practices at higher rates, but could also aggravate existing trends (Munsell et al. 2007, Aguilar and Garret 2009). To depict the likelihood and extent of first-wave supply from sustainable harvests and test the degree to which social marketing scenarios may increase it, our study coupled owner surveys and forest inventories to measure changes in associated likelihood of biomass accessibility and reveal the disproportionate multiplicative effects of intention to harvest and simulated silvicultural output.

Our case study occurred on family forests in a Virginia and North Carolina woodshed that was defined based on the procurement parameters of an impending bio-fuel plant. Case study forest owners reported a fairly normally distributed range of commercial harvesting intentions, both in terms of the baseline and scenario measurements. We found the percent scoring above 4, or neutral, for all measurements conforms somewhat to Butler (2008), where about 28% of owners reported an intention to harvest in the next five years. This is not surprising given that as far back as the mid-1990s, family forests were providing over 50% of the softwood and about 75% of the hardwood harvested in the US on an annual basis (USDA Forest Service 2001). While owners often report a variety of intentions, research and practical experience suggest that commercial harvests will probably occur at some point on a substantial number of family forests and many owners are personally disconnected from the larger contributions of their harvests (Clawson 1979, Carpenter 1985, Egan and Jones 1993).

The marketing scenarios we tested were constructed to study a set of issues that may affect owner intentions and measure the direction and extent of any change. Results indicate that intentions increased among case study owners when informed that by supplying an impending bio-fuels plant their harvest would help improve the local economy and/or be supported by cost-share and/or subsidies. Less effective were messages involving potential environmental benefits and contributions to US energy independence. Results generally parallel previous research, which suggests that family forest management decisions are motivated almost entirely by individual owner preferences and proximal concerns, rather than larger social and environmental objectives (e.g., Young and Reichenbach 1987, Karpinnen 2005, Munsell et al. 2009). More specifically, some studies suggest that family forest owners are interested in the potential impacts of their management practices on the health of the local economy (Dedrick et al. 2000, Kendra and Hull 2005). Given the current Southside economy, it is not surprising that case study family forest owners responded to the prospect of improving their local economy. This supports Cantrill's (1998) argument that efforts to initiate landscape-level management changes need to align with an owner's sense of personal place, including their natural and social systems.

In our case study, differences between the effects of each scenario that increased intention could likely stem from the proximity of the benefit relating to the scenario. Stated more specifically, supporting the local economy and receiving cost-share payments or subsidies were more appealing than helping to achieve US energy independence and ambient environmental benefits. For the scenario to affect the baseline intention score, the owner needs to believe in its effect on some level, which may have made it more difficult for family forest owners to assess large-scale benefits. In this vein, previous studies have examined the effects of using incentives like cost-share and subsidies to increase family forest management such as reforestation plantings and timber harvesting. Hyberg et al. (1989) found that owner awareness of cost-share programs was positively correlated with an increase in the likelihood of harvesting on family forests. Along the same line, Alig et al. (1990) concluded that subsidized technical assistance is correlated with increased harvesting. Social marketing messages that are fashioned to promote commercial harvesting as a vehicle for supplying feedstock in renewable energy markets would be more effective at stimulating harvesting incentives when they emphasize personal and local benefits rather than larger environmental and energy gains. Wood-based renewable energy initiatives ought to consider these themes, along with silvicultural simulations, in their efforts to initiate and project sustainable, first-wave supplies of forest biomass.

Area-based silvicultural simulations on case study stands resulted in a per acre volume of 45.56 odt/ac total AGB and 8.89 odt/ac residual AGB across all acreage. That is similar to previous assessments (Perlack et al. 2005, Foster et al. 2007). Also, case study volume did not differ significantly from the volume resulting from simultaneous FIA simulations (38.92 odt/ac total AGB across treated acreage). It is additionally important to note that just under one-third of the clusters were left untreated in favor of a more systematic and sustainable management approach. At the case study level, but maybe more importantly the landscape level, this could result in a substantial reduction in the total average residual AGB that is immediately accessible. Yet this could be offset over time if prices for forest biomass were to rise to a point where degraded forests become operational and rehabilitative or conversion treatments feasible. An Oak Ridge National Laboratory study (Perlack et al. 2005) put 2012 US target biomass costs at $47 odt, $37 odt for cutting and hauling, and $10 odt for forest owners. In light of this price, most family forest biomass production will need to be integrated into existing uses rather than supplant them (Butler and Leatherberry 2004; Munsell and Fox in press). One exception might be family forests that are in close proximity to a renewable energy plant because transportation costs associated with logging residues are lower (Becker et al. 2009).

Another important factor that influences owner intentions to commercially harvest timber is scale, and at least three are at play in determining AGB from family forests in our case study. An owner's intention, their acreage, and the potential productivity of their forests are all influential. This multi-scalar, natural resources management construct aligns with Nowak et al.'s (2006) assertion that disproportionality is useful for studying both human and biophysical factors. To explain in terms of our case study, one owner may intend to conduct a commercial harvest on 50 acres that contains low residual AGB, whereas another owner could intend something similar on 25 acres, yet achieve comparable supply when cutting because of higher per acre volume production. However, it could also be that the second owner's intention is not as strong as the first owner's, thereby decreasing the relative probability that the second owner's supply will be accessible. This indicates that singular volume assumptions across family forests could cause estimates of forest biomass to either over or underestimate forest biomass accessibility. Somewhat differently, residual AGB resulting from silvicultural treatments is more adequately balanced when biophysical and social variables are simultaneously studied (Majumdar et al. 2008).

Young and Reichenbach (1987) and Karppinen (2005) suggest that increasing the output of forest products on family forests is best achieved when owners can link preferred choices with individual owner objectives and see that they are compatible with myriad uses and values. Of equal importance is Gramann et al.'s (1985) finding that intention and perceived behavioral control are effective predictors of management behavior on family forests. In light of expected prices and multiple owner objectives, the same likely holds for biomass production on family forests. Cumulative increases in the odt per acre ranged from 10.37 to 10.44, or 15 to 17% respectively, across higher intention levels associated with localized scenarios. From a biological standpoint, these estimates are sustainable in that they are based on area-based, silvicultural simulations over time. Behaviorally speaking, however, past cutting on family forests has left many stands in a degraded state and wood biomass markets may not solve this dilemma (Nyland 1992, Fajvan et al. 1998, Aguilar and Garret 2009, Munsell and Germain 2007, Munsell et al. 2009). Thus, it would also be prudent for forest and renewable energy stakeholders to address that biomass production on family forests is possible without silviculture, but future feedstock would likely be jeopardized because consistent yields could diminish over time due to biological constraints and operational limitations stemming from lower output and revenues associated with future treatments (Germain et al. 2007). For productive and sustainably managed family forests, owners will need to closely consider the biological and economic costs and benefits and overall compatibility of integrating biomass into their management.

Incentivizing wood biomass supply from family forests is one important step. Enhancing awareness and transferring information is equally important. Young and Reichenbach (1987) also found that about three-fourths of the family forest owners in their study were unaware of available assistance programs. Butler et al. (2007) suggest that proactive communication is needed to influence substantial market segments of family forest owners. Encouraging a significant number of US family forest owners to sustainably incorporate biomass production is especially critical in light of the nation's renewable energy goals. Yet such a task is not likely to be simple given the declining operational feasibility of family forest management resulting from trends such as parcelization and intergenerational transfer (Sampson and DeCoster 2000, Butler and Leatherberry 2004). Our case study demonstrates that social marketing centered on local economies and financial assistance could theoretically increase the probability of supply and perhaps lead to a situation where sustainable forest management is implemented at higher rates. One approach that may enhance the sustainable contribution of wood biomass from family forests would be to develop legislation wherein federal taxes are reduced or offset in exchange for contribution of wood biomass for bio-energy and bio-fuel production (Sample 1994).

### 3.7 Conclusion

In reference to family forests, Butler et al. (2007) state: "This private land is perhaps the last frontier for extending sustainability concepts to all forests in the United States; and it is these forests that are most at risk of being fragmented and converted for development". Renewable energy initiatives in the US could offer useful market and management opportunities for family forest owners, but to do so biomass production will likely need to be incorporated into a mixture of broad, long-term merchandizing and amenity objectives. The supply of biomass from family forest owners could play a substantial role in achieving renewable energy objectives, but the process is not necessarily straightforward. Owner intentions vary and directly affect the probability that biomass will be produced at a given price. Marketing targeted messages to sell the idea of biomass production could result in an increase in near-term supply. Strategies to develop and enhance awareness of incentive programs like cost-shares and subsidies for family forest owners should be considered, along with demonstrating explicit ties to improvements in the local economy. At the same time, refined estimates of sustainable supply require gauging forest biomass productivity within a silvicultural framework and incorporating the output into multi-scalar, mixed-method combinations that couple the biophysical and human factors of a disproportionate system. Adequately grasping the role family forests might play in producing wood biomass to meet US renewable energy aims is contingent on such an approach.

# CHAPTER 4. BIOSOCIAL DYNAMICS OF BIOMASS SUPPLY FROM FAMILY FORESTS IN THE TOBACCO REGIONS OF VIRGINIA AND NORTH CAROLINA

## 4.1 Introduction

Forests are a major source of goods and services in the United States (US), and families own the majority at just over 40% (Butler and Leatherberry 2004; Smith et al. 2004). In the South, family ownerships are even more prominent, accounting for 58% of all forestland (Wear and Greis 2002). Interest in producing renewable energy using forest biomass has resurfaced in recent years and could prompt multiple biomass initiatives that will depend in part or entirely on wood supply from family forests. Family forests are an important component of broad, landscape-level forest management systems in the South and will likely play an important role in regional renewable energy efforts.

The cost and source of energy, future of fossil fuels, global climate change, and geopolitical instability are reviving renewable energy interests (Duffield and Collins 2006). Efforts to increase domestic production are becoming more common and wood biomass from family forests is gaining ground in the nation's renewable energy trajectory (Dincer 2000, Munsell and Germain 2007). Yet management objectives among family forest owners differ, with some being more inclined to manage their forests for amenities rather than commodities (Butler and Leatherberry 2004; Kendra and Hull 2005). In addition, past cutting has left many stands in a state of low productivity due to exploitive removals such as high-grading, diameter-limit cutting, and over- and premature-harvesting (Nyland 1992; Fajvan et al. 1998; Germain et al. 2007; Munsell et al. 2008).

It stands to reason that gaining access to biomass from family forests in support of renewable energy initiatives will likely be dynamic. Estimates of wood-based renewable energy production systems in the South will need to consider both the biophysical and social facets of feedstock supply from the region's family forests. This chapter presents the results of a case study that examined both using 51 Virginia and North Carolina family forests located within a supply woodshed that was defined using input from procurement specialists for a future ethanol plant. Case study objectives included testing if forest conditions affect owner intentions to commercially harvest timber, evaluating whether theorized psychosocial predictors of behavioral intention mediate the affect, and discussing changes in silvicultural biomass yield if behavioral intentions are manipulated.

We used Ajzen's (2005) Theory of Planned Behavior (TPB) to study owner intentions to commercially harvest conventional and renewable energy products, forest inventory techniques following Munsell and Germain (2007) and Munsell et al. (2008) to assess the condition of case study forests and prescribe silvicultural treatments, and formulas published in Jenkins et al. (2003) to estimate biomass output in oven-dry tons (odt) from multi-product case study treatments. We used linear regression and steps outlined by Judd and Kenny (1981) and Baron and Kenny (1986) to examine whether and to what extent theorized predictors of owner behavior mediate the affects of forest conditions on harvesting intentions. We then discuss potential modifications in estimated biomass output using model results and cover some considerations regarding biomass sourcing strategies in regions such as the South where family forests are abundant.

### 4.2 Rationale

Family forest owners in the US posses a substantial amount of the nation's forestland and have been the focus of much research (Haymond 1988; Hodgdon and Tyrell 2003). In 1977, about 30% of the 736 million acres of US forestland was owned by families (USDA Forest Service 1982). Fifteen years later, these forests made up almost 40% of the nation's forests and by 2002 they accounted for a little more than 4 out of every 10 acres (Birch 1997, Butler and Leatherberry 2004). At the same time, the body of research concerning family forest owners has grown (Hodgdon and Tyrrell 2003). Some studies focus on demographics and management objectives, both across the US and within specific regions, while others have evaluated motivations and management behaviors (e.g., Binkley 1981, Greene and Blatner 1986, Bliss and Martin 1989, Best and Wayburn 2001, Kendra and Hull 2005, etc.).

The USFS, through its FIA program, periodically surveys family forest owners via the National Woodland Owner Survey (NWOS) (Butler and Leatherberry 2004). Variables recorded by NWOS include owner age, income, education, forest size, ownership tenure, and management activities such as commercial timber harvesting. In addition to NWOS, several family forest owner research projects have empirically studied owner characteristics and commercial timber harvesting during the past three decades (e.g., Kurtz et al. 1981, Carpenter 1985; Young et al. 1985, Young and Reichenbach 1987, Jones et al. 1995, Kuuluvainen et al. 1996, Fajvan et al. 1998, Karpinnen 2005, Munsell et al. 2008). Before then, timber production levels were the primary concern of family forest research (Egan 1997).

More recently, researchers have studied the production of non-timber forest products such as medicinal plant management, preservation of amenities like viewscapes, and provision of environmental services such as clean water and biodiversity, though commercial timber harvesting and wood supply remain important issues (Kluender and Walkingstick 2000, Hodgdon and Tyrell 2003, Workman et al. 2003). Since 1976, the volume of wood harvested on family forests has increased 42% and is not expected to decline. By 2040, removals are projected to increase by about 30% and commercial timber harvesting is one of the most commonly planned activities (Smith et al. 2004, Butler and Leatherberry 2004).

Clawson (1979) stated “The probability is very great that over the life of the timber stand, during which its ownership will often change several times, some owner will accept a good offer, if one is made, for merchantable volumes of timber when these have developed. Over the long run, very little really merchantable timber will go un-harvested.” In addition, Turner et al. (1977) found that changes in family forest ownership eventually led to the removal of most timber stock. Several factors are likely behind this trend and have, for the most part, increased in recent years. For one, worldwide consumption of forest products has dramatically increased, and a steep decline in harvesting on public forestland has shifted procurement to family forests (Shifley 2002, Foster and Mayfield 2007). In addition, divestitures of private industrial forests coupled with parcelization and large-scale intergenerational transfers have led to the expansion of family forest acreage, number of owners, and thus the likelihood the harvesting will continue (Sampson and DeCoster 2000, Pinchot Institute for Conservation 2007).

Confounding these trends are the poor, often exploitive management practices on family forests (e.g., Ezell 1992, Nyland 1992, Jones et al. 1995, Fajvan et al. 1998, Munsell et al. 2008). Silviculture, which sustains the ecological health and productivity of a forest by controlling growth, composition, health and quality, is often neglected (SAF 2001, Nyland 2002). For example, Fajvan et al. (1998) observed silvicultural practices on only 19% of sampled family forest harvests in West Virginia. Similar trends were noted in Pell’s (1998) thesis characterizing harvests across Pennsylvania and Nyland’s (2000) survey of cutting in New York. Egan and

Jones (1993) reported unsustainable practices on working non-industrial private forests (NIPF) in Pennsylvania. Doolittle and Straka (1987) and Arano et al. (2004) found that regeneration occurred only half of the time following a final harvest in Mississippi and Alabama. More recently, Germain et al. (2006) noted widely degraded quality and poor post-harvest stocking conditions on family forests in southeastern New York, and Munsell and Germain (2007) found that many are cut too early and heavily. The result of these trends is that long-term wood merchandizing may be substantially inhibited because future operations are prone to be biologically and financially constrained.

Family forests will likely need to supply substantial amounts of forest biomass over time if multiple large-scale southern US renewable energy initiatives are to thrive. Markets for wood biomass could increase the use of silviculture on southern family forests by providing opportunities to integrate poor quality wood into product sorting associated with high-value commercial operations (Mayfield et al. 2007, Munsell and Fox in press). But it could also be that the additional demand increases the proportional absence of silviculture and sustained yield practices on more family forests (Munsell et al. 2008). While some suggest harvesting on family forests is inevitable, the question of timing and supply is often not broached but critical if sustainable wood-based renewable energy initiatives are to be successful over time (Munsell et al. 2007). From a biosocial perspective, the potential for sustainable biomass harvests on family forests is a product of both the biological condition of a forest and intended behavior of its owner.

Previous research demonstrates that behavioral beliefs are a significant predictor of owner intentions (Young et al. 1985, Young and Reichenbach 1987, Karpinnen 2005, Munsell et al. 2009). Rational assessments of the costs and benefits of forest management behaviors typically correspond to owner plans to implement associated practices. At the same time, intended behaviors may be more or less constrained based on the biological conditions of forests and long-term needs of enterprise that underwrites family forest management (Munsell et al. 2009). We analyzed the predictive and meditative affects of biological and psychosocial factors on owner intentions to conduct commercial timber harvesting for 51 family forests in the potential woodshed for an impending ethanol plant in southern Virginia. We used the results to project multi-product silvicultural output in the case study region and discuss potential feedstock sourcing for wood-based renewable energy initiatives that depend in part or entirely on sustainable supplies of biomass from family forests.

### 4.3 Case Study

Family forest ownership in Virginia and North Carolina is much like other states in the southern US. The land base in both states is more than half forested, with the majority in private ownership. Among private forestland in both states, family forests account for 64% in Virginia and 62% in North Carolina owned by families (Brown et al. 2006, Virginia Department of Forestry 2008). The south-central region of Virginia, known as the Southside, is loosely defined as the area of the state that lies east of the Blue Ridge Mountains and south of the James River and was the setting for the center of our case study area (Figure 4-1). Tobacco production has historically been the dominant economic enterprise. However, tobacco quotas and production have steeply declined over the past decade, leaving local economies in need of profitable alternatives. Selling wood biomass to renewable energy producers is seen by many landowners as one possible option.

The Virginia Tobacco Indemnification and Community Revitalization Commission (VTICRC) was established in 1999 by the Virginia General Assembly to help tobacco communities transition by awarding, among others, grants to support the development of a renewable energy economy in the Southside. VTICRC, along with Virginia Block Grant, recently awarded a grant to support the development of a future ethanol plant in Mecklenburg County, Virginia (Figure 4-1). Our 1.02 million acre case study woodshed was based on a 30-mile road network boundary defined using input from procurement specialists for the ethanol company.

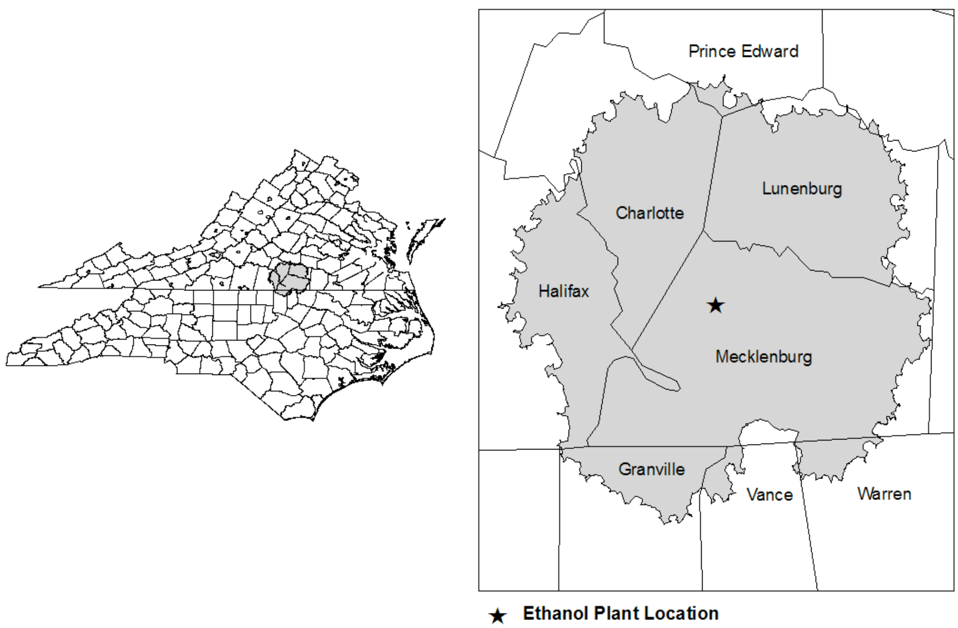


**Figure 4-1. Case study woodshed boundaries are depicted by the grey polygon and were defined using 30 miles of road distance from the centralized location of a future ethanol plant, which is depicted by a black star. The woodshed is 1.02 million acres and covers land in 5 Virginia Counties and 3 in North Carolina.**

### 4.4 Theory of Planned Behavior

TPB states that an individual's behavioral intention is affected by three latent constructs: attitude toward the behavior, subjective norm, and perceived behavioral control. Each construct is a product of beliefs about the behavior and the impact of performing it (Figure 4-2). The three constructs are theorized predictors of behavioral intention, which is a proxy for actual behavior when reconciled with actual controls (Ajzen 2005). In terms of our case study, the theorized constructs codify the affects of an owner's attitude about the behavioral costs and benefits, belief about the importance of norms, and perception about behavioral controls on their intention to conduct a commercial timber harvest. The theory suggests that harvesting intentions are influenced by an owner's attitude about harvesting, belief in the importance of what other people think and feel about harvesting, and perception of possible constraints on the behavior, such as policies, markets, or time. For the purposes of this study, actual behavioral control is defined using silvicultural thinning and timber stand improvement guidelines.

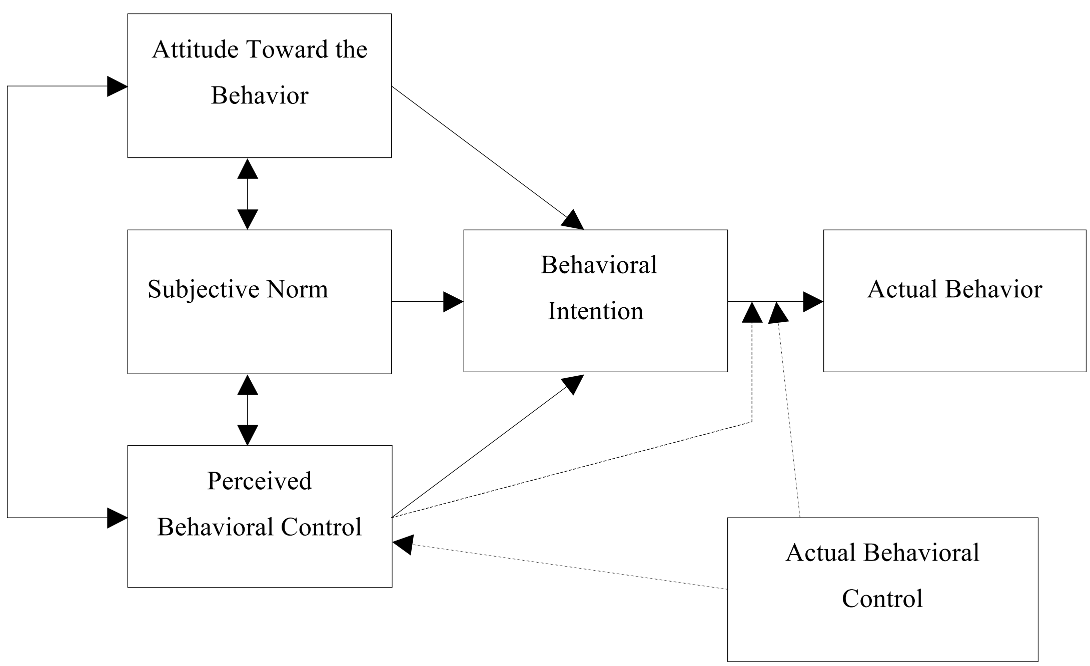


**Figure 4-2. Azjen's (2005) theory of planned behavior.**

Sedjo (1997) and Munsell and Fox (in press) demonstrate that when biomass and pulpwood prices are comparable, supplying aboveground biomass (AGB) is most financially attractive, yet least robust when incorporated into conventional timber harvests that supply more valuable sawtimber, chip-n-saw, and pulpwood products. In unique circumstances, such as when family forests are close to biomass consumers and far away from high-value markets, stumpage prices may be sufficient to support the exclusive production of biomass. For the purposes of our case study, we selected multi-product commercial timber harvesting as the behavioral intention given the existence of higher-value forest product markets, such as sawtimber and chip-n-saw, in the supply woodshed. Thus, trees that were harvested during simulated silvicultural treatments were sorted for multi-product sale. We used Jenkins et al. (2003) to calculate residual AGB by deducting wood in the merchantable portion of each harvested tree.

### 4.5 Silviculture

Silviculture is defined as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis" (SAF 2001). A forest stand serves as the fundamental basis for silviculture and is a contiguous group of trees uniform enough in characteristics and condition to be a distinctive unit (Smith et al. 1997). A key objective of silviculture is stand density management. Measures of stand density involve the number, size, spacing, and species of trees in a given stand (Stout and Nyland 1986). Density management considerations are used to selectively cut trees to alter biological conditions, giving residual trees access to stand resources such as nutrients, water, and light (Nowak and Marquis 1997, Smith et al. 1997). Density management can be used to alter stand characteristics in a way that favors owner objectives.

Nyland (2002) defines stocking as "the number of trees per unit area compared with the desired number for best growth and management". Desirable management can maximize merchantable growth and improve overall stand health. A number of cutting techniques and intensities, which are generally referred to as thinning practices, are available to control competition and maximize stand growth without removing all standing volume (Smith et al. 1997). Biological conditions can be used to determine the economic and operational feasibility of thinning practices, as well as their long-term implications. Quadratic stand diameter (QSD), basal area (BA), and level of acceptable and unacceptable growing stock (AGS; UGS) are all useful metrics. BA is the cross-sectional area of a tree at 4.5' above the ground and QSD is the diameter of the tree of mean BA (Avery and Burkhart 2002). Growing stock acceptability is determined using the health and form of a tree, which both contribute to an average estimate of stand merchantability and vigor.

Young and Reichenbach (1987) found that the absence of merchantable trees, prominence of poor quality trees, overall low standing volume, and high number of immature trees were common reasons used by family forest owners to justify refraining from harvesting. Dennis (1989) found that higher standing volume and the presence of merchantable species were positively correlated with commercial timber harvesting. Also relevant is Carpenter's (1985) notion that tree growth continues regardless of management levels and at some point many family owners will take note and choose to harvest. In the same study, owners commonly listed timber maturity as an important factor in the decision to harvest. Parcel size is also typically related to harvesting intention because larger tracts offer greater economies of scale (Germain et al 2006). Finally, higher percentages of softwoods on a parcel often correspond to, particularly in the southern US, an increased propensity to harvest because of shorter rotations and the likelihood that the species mix is purposive (Alig et al. 2002).

### 4.5 Methods

A single mailing distributed cover letters, response cards, and business reply envelopes to a random sample of 400 family forest owners possessing 10 or more acres in Mecklenburg, Halifax, Prince Edward, Charlotte, and Lunenburg Counties of Virginia and Vance, Granville, and Warren Counties of North Carolina (Figure 4-3). The sampling frame was created using parcel tax records and selected by doubly stratifying by county and parcel size class. 393 mailings were successfully delivered and 80 response cards returned, for an adjusted response rate of 20%. Response cards allowed owners to confirm if they possess 10 or more acres of forests on the sampled parcel and indicate whether they would be willing to participate in an interview and allow a field visit. Out of 67 qualified and willing owners, 51 owners with 3,952 acres ranging from 10 to 405 ultimately participated.

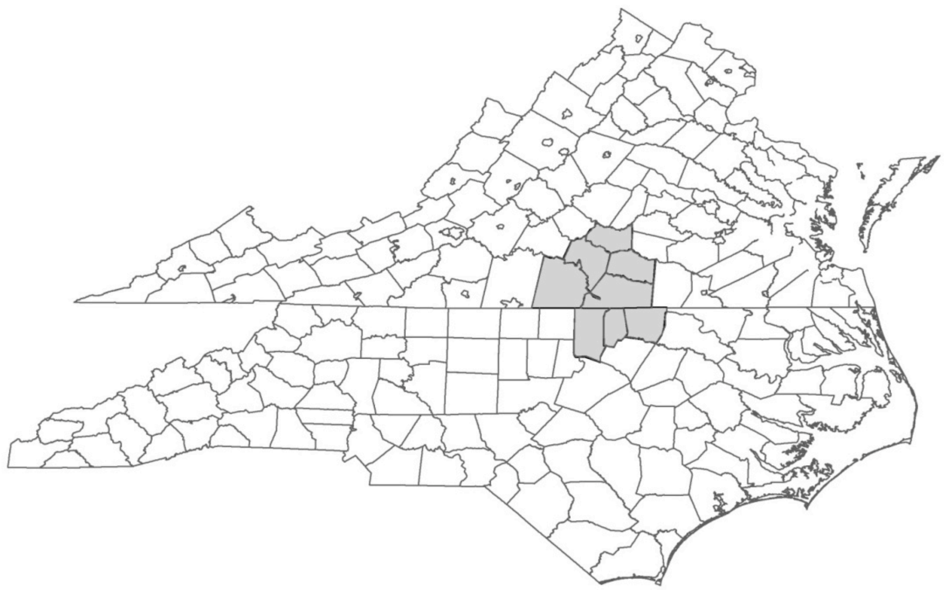

**Figure 4-3. Portions of Mecklenburg, Halifax, Prince Edward, Charlotte, and Lunenburg Counties of Virginia and Vance, Granville, and Warren Counties of North Carolina were included in the case study area; included counties are highlighted in grey.**

Owners were surveyed using a structured instrument. The instrument asked questions about owner characteristics and provided a definition of a commercial timber harvest. Case study owners used Likert-type agreement scales from 1 “Strongly Disagree” to 7 “Strongly Agree”, with 4 representing “Neutral”, to respond to statements about indirect TPB beliefs and behavioral intentions. Using several items to measure a broader concept is referred to as a summated rating scale and can result in more accurate respondent differentiation (Spector 1992). The summated behavioral belief was measured using 3 products, the summated normative belief using 4 products, and summated perceived behavioral control using 3 products (Table 4-1). Behavioral belief components included perceptions of wildlife habitat, forest beauty, and forest health.

Normative beliefs were derived by averaging measurements involving the influence of family members, society, friends, and other forestland owners, and perceived behavioral control was calculated using measurements of confidence in ability to arrange or organize a harvest, and ability to control the outcome of a harvest. Similarly, behavioral intention was measured by summing and averaging responses to 3 intention statements. The first measured if owners intend to commercially harvest timber on the sampled forest within the next 5 years, while the second measured intentions to harvest at any point in the future. The third controlled for case study context and measured intentions to cut in the next 5 years if the harvest were to supply the impending ethanol plant.

We used exploratory principal components factor analysis with varimax rotation and Kaiser normalization to group correlated TPB predictor products into components that exceed an eigen value of 1. Components were used to define scale item groups. The reliability of the groups, or the internal consistency of the components, was measured using Cronbach's α. Acceptable Cronbach's α ranges from 0.60 to 1.00 (Carmines and Zeller 1979; Nunnally 1978; Gagné and Godin 2000). The principal components rotation grouped TPB predictor products into three components using 5 iterations and explained 61.4% of the variance. The 3 attitudinal items grouped into one component, as did the 4 items and 3 items used to measure normative beliefs and perceived behavioral controls, respectively (Table 4-1). Reliability values for inter-item components ranged from 0.62 to 0.73.

**Table 4-1. Attitude, subjective norm, and perceived behavioral control summated latent constructs and results of the varimax principle components factor analysis. The orthogonal rotation grouped items into three components and explained 44% of the variance.**

| **Latent Construct** (Cronbach's α) | **Product Theme** | **Principal Components** | | |
|---|---|---|---|---|
| | | **1** | **2** | **3** |
| **Attitude** (.73) | Wildlife habitat | | **0.79** | |
| | Beauty | | **0.83** | |
| | Forest health | | **0.63** | |
| **Subjective Norms** (.70) | Friends | **0.68** | | |
| | Family members | **0.76** | | |
| | Society | **0.66** | | |
| | Forestland owners | **0.73** | | |
| **Behavioral control** (.62) | Ability | | | **0.61** |
| | Confidence | | | **0.81** |
| | Capability | | | **0.72** |

Two-hundred and eighteen 1/10th acre plots were randomly installed on case study acreage. We recorded the following variables in each plot for all trees 5 inches or greater in diameter at breast height (DBH): species, DBH, stem quality (AGS; UGS), number of 16 foot logs for hardwood AGS greater than 12 inches DBH and softwood AGS greater than 10 inches DBH, number of 8 foot bolts for UGS, hardwood AGS less than 12 inches DBH, and softwood AGS less than 10 inches DBH. To simulate silvicultural treatments, plots were grouped into 9 management cover types using multiple iteration K-means cluster analysis based on Euclidean distance. The following variables were standardized by z-score and used in the K-means analysis: average DBH, average BA per acre, trees per acre (TPA), QSD, ratio of softwood TPA, and per acre ratio of softwood BA. Cluster conditions were used to prescribe unique, multi-product silvicultural thinning for case stands where appropriate and generate associated intention scores by weighting owner responses according to the proportion of their acreage that contributes to the cluster.

To enable uniform application of silviculture across management cover types, we used stocking and maximum stand density index (SDI) as guides to determine the necessity and intensity of simulated thinning. We found this density management approach an acceptable and evenly applicable method to satisfy the assumed objective for all case properties of maximizing financial return while improving the health and productivity of the stand. Simulations for hardwood stands followed timber stand improvement (TSI) and removed undesirable growing stock, which, if needed, was followed by crown thinning where over-story trees dominating the upper canopy were cut to enhance the growth of equally or more desirable, but suppressed crop trees. For softwood stands, a row thinning TSI strategy was simulated to achieve a target residual maximum SDI by first removing all interfering hardwoods, followed by thinning of randomly sized softwood trees.

To select thinning intensity, stands classified as hardwoods were plotted on a stocking guide for upland central hardwoods developed by Roach and Gingrich (1968). We thinned down to 60% full stocking only if observed stocking levels exceeded 80%. Stands classified as softwoods were assessed using a stocking guide for loblolly pine due to the dominance of this species within softwood stands.  Following guidelines in Dean and Baldwin (1993), softwoods were thinned to 30% maximum stand density index (SDI) for stands exceeding 45% maximum SDI. Competing hardwoods were first removed within softwood stands, followed by a simulated row thinning in which trees of various sizes were randomly removed until the desired SDI was reached.

Quality of growing stock (QGS), QSD, and % BA per acre in pine (BAP), and forested parcel acreage (FPA) were tested as forest indicators of intention to harvest. We used stepwise multiple linear regression to explore for significant affects. One component model was tested to identify statistical significance and assess overall change in $R^2$. Final output includes β coefficients, t-values, $F$ values, iterative changes in adjusted $R^2$, final adjusted $R^2$, and model significance. Results were used to identify forest indicators that significantly affect the summated measurement of commercial harvesting intention and can be used to test whether TPB beliefs mediate affects between forest conditions and harvesting intention.

We used steps defined by Judd and Kenny (1981) and Baron and Kenny (1986) to test for causal mediation. In step 1, significant forest indicators were identified using the stepwise results. In step 2, simple linear regression tests were used to identify zero-order affects between significant forest indicators and each TPB belief. To control for the affects of TPB beliefs, the 3$^{rd}$ step entered each measurement, along with significant forest indicators, into a second linear regression. Final output includes β coefficients, t-values, $F$ values, adjusted $R^2$, and model significance. We assumed full mediation if the forest indicator affects an indirect TPB belief in zero-order linear regression, but is no longer significant in the regression model when controlling for the indirect TPB belief it affects. Partial mediation is assumed if the forest indicator is significant in the regression model, but its β is reduced from the stepwise result and less than the TPB belief variable it affects in a zero-order test.

## 4.6 Results

Table 4-2 displays owner characteristics. The average forested acreage and owner age across case study properties is 77.5 and 63, respectively. Owner income is distributed fairly evenly with the majority of owners (61%) earning less than $100,000 annually. All owners are high school graduates with 51% additionally holding college or graduate degrees. Only 16% of owners had obtained a written management plan for their forest at the time of measurement and the majority of owners have harvested once or never during their tenure.

**Table 4-2. Ownership characteristics for 51 case study family forest owners**

| Owner Variables | Categories | Result |
|---|---|---|
| Parcel acreage | 10-24 acres | 13.7% |
| | 25-49 acres | 21.6% |
| | 50-99 acres | 23.5% |
| | 100-149 acres | 19.6% |
| | 150-249 acres | 9.8% |
| | 250+ acres | 11.8% |
| Education Completed | Some High School | 0 |
| | High School Graduate | 27.5% |
| | Technical Degree or Attended College | 21.5% |
| | College Graduate | 41.2% |
| | Graduate Degree | 9.8% |
| Annual Income | <$20,000 | 2.2% |
| | $20,000-39,999 | 6.5% |
| | $40,000-59,999 | 19.6% |
| | $60,000-79,999 | 15.2% |
| | $80,000-99,999 | 17.4% |
| | $100,000-149,999 | 19.6% |
| | $150,000-249,999 | 10.8% |
| | $250,000+ | 8.7% |
| Owner Age (years) | Average | 63 |
| | Minimum | 35 |
| | Maximum | 83 |
| | 1st Quartile | 55 |
| | 3rd Quartile | 73 |
| Management Plan? | Yes | 16% |
| | No | 84% |
| Forested Acreage (acres) | Average | 77.5 |
| | Minimum | 10 |
| | Maximum | 405 |
| | 1st Quartile | 27.5 |
| | 3rd Quartile | 86 |
| Harvesting Experience | Average | 1.76 |
| (# of Previous Harvests) | Minimum | 0 |
| | Maximum | 15 |
| | 1st Quartile | 0 |
| | 3rd Quartile | 3 |

Cluster attributes are presented in Table 4-3. Most attributes vary generally, however % BA and TPA in softwood are distinct and distinguish whether a cluster is primarily softwood or hardwood. Characteristics such as DBH, BA, TPA, QSD, % UGS, and total AGB/ac give insight as to the condition of the stand type throughout the cluster. The weighted intention score reveals the mean intention score for the cluster derived by weighting an owner's intention score by the acreage they control within the cluster. Residual AGB/ac, representing volume left after removing more valuable merchantable products, shows the amount of biomass per acre sustainably available based on the silvicultural guidelines previously discussed, with zeros for clusters 2 and 7 indicating these stand types are not ready for harvest.

**Table 4-3. Mean stand characteristics for 9 forest types derived from a K-means cluster analysis carried out using plot data obtained through a sample of 51 family forests in Southside, VA in 2009.**

| Cluster (HW = Hardwood) (SW = Softwood) | DBH | BA | TPA | %BA softwood | %TPA softwood | % UGS | QSD | Total AGB/ac (odt) | Weighted Intention Score | Acres | Residual AGB/ac (odt) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 (SW) | 10.1 | 112.5 | 198.0 | 91.8 | 87.1 | 17.8 | 10.4 | 52.4 | 6.13 | 766 | 6.1 |
| 2 (SW) | 7.0 | 65.7 | 228.1 | 82.8 | 82.4 | 8.0 | 7.2 | 28.3 | 4.85 | 241 | 0.0 |
| 3 (HW) | 14.3 | 149.2 | 118.9 | 0.4 | 1.5 | 36.3 | 15.3 | 135.4 | 4.56 | 177 | 24.3 |
| 4 (HW) | 8.5 | 110.1 | 251.4 | 16.0 | 15.0 | 32.1 | 9.0 | 74.6 | 3.76 | 312 | 13.2 |
| 5 (HW) | 9.9 | 97.5 | 157.7 | 4.6 | 5.2 | 31.4 | 10.7 | 75.2 | 4.09 | 263 | 15.0 |
| 6 (HW) | 11.3 | 160.8 | 197.9 | 7.3 | 6.1 | 39.7 | 12.3 | 131.5 | 3.88 | 384 | 26.4 |
| 7 (HW) | 7.1 | 42.7 | 143.0 | 11.1 | 12.4 | 13.6 | 7.4 | 27.1 | 3.96 | 493 | 0.0 |
| 8 (SW) | 7.8 | 149.9 | 436.0 | 92.0 | 91.3 | 19.7 | 8.0 | 62.5 | 5.30 | 385 | 12.4 |
| 9 (SW) | 11.0 | 206.4 | 281.9 | 89.9 | 77.8 | 38.8 | 11.7 | 103.9 | 5.70 | 147 | 21.7 |

Of the four indicators tested in the stepwise linear regression, BAP and QSD significantly affected harvesting intention (Table 4-4). BAP explained the most variance and was added in the first model. QSD was added in a second and final model that explained 30% of the variance in the dependent variable. FPA and QGS were not added during the stepwise process. BAP and

QSD were entered separately in a series of zero-order simple linear regression models that test for affects on the TPB beliefs. BAP significantly affected attitudes toward the behavior, but not normative beliefs and perceptions of behavioral control. QSD did not affect any indirect TPB beliefs. BAP and QSD were then entered into a multiple linear regression, along with the summated scores for the three TPB beliefs, to evaluate changes in the variance explained and test for causal mediation (Table 4-5). The model shows that nearly 60% of the variance in the dependent response variable is explained by BAP, QSD, and attitude toward the behavior, and that the $\beta$ for BAP is less than in the stepwise model and is also lower than the attitude toward the behavior.

**Table 4-4. Stepwise multiple regression models of the affects of case study forest conditions on owner intentions to commercially harvest timber.**

| Intention to Harvest | Stepwise Models<br>First Step<br>Beta<br>[Sig.]<br>(t-values) | <br>Final Step<br>Beta<br>[Sig.]<br>(t-values) |
|---|---|---|
| *BAP* (% Basal area per acre in pine) | **0.478**<br>**[0.000]**<br>**(3.805)** | **0.620***<br>**[0.000]**<br>**(4.788)** |
| *QSD* (Average quadratic stand diameter) | 0.349<br>[0.010]<br>(2.693) | **0.349***<br>**[0.010]**<br>**(2.693)** |
| *FPA* (Forested parcel acres cruised) | -0.065<br>[0.626]<br>(-0.491) | 0.032<br>[0.804]<br>(0.249) |
| *QGS* (Quality of growing stock; % basal area in UGS) | 0.130<br>[0.458]<br>(0.748) | 0.023<br>[0.891]<br>(0.137) |
| $F$ | 14.481 | 7.25 |
| Significance level | 0 | 0 |
| Adjusted $R^2$ | 0.212 | 0.301 |

* Significant at $P \leq 0.05$

**Table 4-5. Final regression model of the affects of an owner's intention to commercially harvest timber with forest variables observed within case properties and three variables from the theory of planned behavior (attitude toward the behavior, subjective norm, and perceived behavioral control). BAP, QSD, and AB are all bolded, noting statistical significance.**

| Intention to Harvest | Theory Testing<br>Beta<br>[Sig.]<br>(t-values) |
|---|---|
| *BAP* (% Basal area per acre in pine) | **0.383***<br>**[0.003]**<br>**(3.192)** |
| *QSD* (Average quadratic stand diameter) | **0.226***<br>**[0.047]**<br>**(2.041)** |
| *AB* (Attitude toward the Behavior) | **0.595***<br>**[0.000]**<br>**(4.828)** |
| *SN* (Subjective Norms) | -0.073<br>[0.515]<br>(-0.073) |
| *PBC* (Perceived Behavioral Control) | -0.155<br>[0.158]<br>(-1.434) |
| $F$ | 12.023 |
| Significance level | 0.000 |
| Adjusted $R^2$ | 0.524 |

* Significant at $P \leq 0.05$

### 4.7 Discussion

Age and education among case study owners align with results from previous research in the South, while harvesting experience and management plan use are slightly higher (e.g., Birch 1997, Butler and Leatherberry 2004). Land management income was the most common reason for owning case study forests. However, it is important to note that 11 of 13 owners in this category own forests that are predominately softwood. The amount of softwood forests in the case study may also explain why some owners have harvested several times in the past. Equally interesting is the number of hardwood family forests associated with amenity objectives like privacy, wildlife habitat, and nature, which are not as time-sensitive. Trends support the notion that softwood forests are more commonly viewed as investments with quicker returns and could therefore play a more considerable and consistent role, particularly in the South where softwood plantations are abundant, in supplying biomass for renewable energy production.

Clusters varied in size, species composition, average diameter, quality of growing stock, harvesting intention, and residual AGB output. Species composition was the most distinct, with 5 clusters comprising 1,769 acres of mostly hardwood species and 4 clusters comprising 2,183 acres of mostly softwood. The breakdown is similar to the overall ratio of hardwood to softwood forests within the region in both states (Brown et al. 2006, Virginia Department of Forestry 2008). Two of the 9 clusters were immature and did not contain enough density to prompt thinning according to silvicultural guidelines. Interestingly, one was comprised of juvenile hardwoods and the other pine saplings. The silvicultural acceptability of thinning in both hard and softwood clusters demonstrates opportunities to supply a first-wave of wood biomass from various types of southern family forests. In addition, when thinned, these stands will likely become more healthy and productive and ensure future supplies of residual AGB, while the younger stands come into maturity (Nyland 2002). It should also be noted that weighted intention scores were higher for softwood clusters, suggesting again that softwood family forests in the South are a potentially prominent source of biomass feedstock.

While it is probable that the harvesting intentions for hardwood forests in this case study are lower than for softwood dominated parcels simply due to non-commodity objectives among some owners, it could also be that many of these stands are unproductive due to previous mismanagement, and owners may not believe it is worthwhile to manage them. For example, cluster 6 has 39.7% in UGS, which could likely constrain operations in support of forest management. It may also be that some of these forests are on less-productive sites and not considered capable of generating revenue from management. In any case, many owners may plainly accept that these stands are better suited for low-cost, high-amenity uses. Yet if wood biomass is needed in great quantities for renewable energy production in the South and prices for the feedstock rise, management opportunities on these stands may increase and prompt owners to reconsider (Foster et al. 2007). However, it seems unlikely that wood biomass prices will rise to the point where the rehabilitation of low-productivity degraded hardwood stands is something more than a low- or no-cost operation (Sedjo 1997). Thus biomass supply from southern hardwood family forests is likely to be less probable than it is from more mature and productive softwood stands that make biomass harvesting financially attractive by coupling it with the sale of high-value products.

Our results demonstrate the affect of forest type and maturity on harvesting intention. Results of the stepwise regression show that QSD and BAP significantly affect commercial intentions among case study owners. BAP has the strongest affect on the intentions of case study owners, followed by QSD. In other words, a case study owner's aim to conduct a commercial timber harvest is affected by the percentage of larger softwoods in their stand. On one hand, the affect of softwoods on harvesting intentions likely stems from shorter rotation times, higher uniformity in growing stock quality, and straightforward multi-product possibilities. When compared with hardwood forests, rotation lengths are often much shorter and the product streams more diverse. On the other hand, it is also reasonable to assume that owner beliefs about harvesting vary regardless of forest type and behavior is therefore often more complex than simple cover-type dichotomies. For example, Ribe (1989) demonstrated that harvesting may be prohibitive on family forests with diverse compositions because it can have a negative effect on owner perceptions of visual quality, which is typically highly valued (Butler and Leatherberry 2004).

Casual mediation tests show that a case study owner's attitudes about commercial timber harvesting partially mediate the affects of forest conditions on their intentions. BAP and QSD remain significant, but owner attitudes about commercial timber harvesting are also significant and the adjusted $R^2$ increases from .30 to .52. At the same time, the relative affect of BAP, as expressed by β, decreases from the stepwise model and is lower than attitudes toward the behavior in the integrated biosocial model. Results support previous studies that show attitudes significantly affect intentions among family forest owners and normative perceptions and external controls are not as critical (Young and Reichenbach 1987, Karpinnen 2005, Munsell et al. 2009). Family forest owners do not typically concern themselves with what others think they should do and do not intend to behave according to perceived constraints (Young et al. 1985).

Attitudes toward commercial timber harvesting were measured through the perception of how cutting and merchandizing may affect non-monetized aspects of family forests that owners value, such as habitat, forest health, and aesthetics which are amplified by their perceived importance of achieving these aims. It is possible that perceived changes brought on by harvesting relate to the notion that if an owner greatly values amenities they will be more apt to prefer longer rotation lengths or none at all when compared with the preferences of an owner that places less importance on amenities (Pattanayak et al. 2002). The importance of attitudes is doubly demonstrated through partial mediation of the proportional affects of mature softwood ownership, meaning that owner beliefs, along with cover type and tree size, are also important predictors of commercial harvesting.

One implication for wood biomass sourcing on case study family forests is that stand quality likely influences the profitability of a commercial harvest and thus impacts feedstock supply. In general, numerous hardwood family forests throughout the eastern US have been degraded due to past harvesting practices (Nyland 2002). Distinct differences in growing stock quality between clusters in our case study conform to this supposition. Meanwhile, softwood forests have fairly uniform levels of quality with low levels of defects and higher potential for productivity. Also, because many softwood forests in the South are often prepped and planted, it is likely that owners of these family forests are more apt to harvest and merchandize forest products to begin with.

Conversely, some suggest family forest owners value hardwood and softwood stands in a similar fashion, but that external circumstances, like markets and management infrastructure, enhance or inhibit whether they are managed for sustainable product yields (Munsell et al. 2008). Irrespective of forest type, it could be as Carpenter (1985) found that as the trees grow in diameter, owners eventually become aware of the size of timber, equate it with an economic opportunity, and capitalize by carrying out harvests if favorable markets exist. Renewable energy production in the South that uses wood feedstock could improve the favorability of markets and prompt harvesting, but our case study results suggest it will probably rely in large part on access to softwood volume and owners with favorable attitudes about commercial harvesting.

From a cover type perspective, case study results suggest that boosting softwood acreage could increase feedstock supply, but given that attitudes toward harvesting also partially mediates cover, it seems that increases will also hinge on a supportive and responsive suite of owners. What is also worth noting is that the results imply that improvements in attitudes toward harvesting could separately increase feedstock supply from hardwood forests, which could serve as a basis for restoring forests and sustaining biomass yields if silviculture is applied. It is also possible that owners with less favorable attitudes toward harvesting may be less inclined to cut despite owning softwood stands. For both types, immature stands may be somewhat prohibitive during near-term treatments, but harvests are possible at a later point in time.

Our case study results indicate that positive changes in cover type and attitudes together could lead to noteworthy increases in biomass feedstock output from family forests in the South. For instance, average residual AGB output per acre for the softwood clusters was a little over 10 odt per acre and owner intentions averaged 5.5. Output was notably higher from hardwood stands, increasing to nearly 16 odt per acre but owner intentions averaged 4.1. As a result, incremental increases in the attitudes among owners of hardwood forests would generally need to be less to increase output similar to what would be required for softwood stands. In addition, if attitudes remain constant, boosting supply would require that a portion of the hardwood acreage be converted to softwoods. However, there are potential negative social and biological implications that large-scale conversion from hardwood to pine forests (Carnus et al. 2006). Most appropriate is likely a balanced strategy that assists owners interested in conversion from hardwood to softwood, while also working to improve harvesting attitudes among owners that seek additional opportunities to merchandize lower-value forest products but desire hardwood cover.

Sustainable cover type management strategies could, more specifically, be used as a tool for designing family forest owner outreach in areas of the South where wood-based renewable energy markets exist or could potentially emerge. Efforts could target areas of interest through the use of remote sensing and a framework for assuming management thresholds on softwood acreage. Outreach, technical assistance, and incentive programs for hardwood family forests could be simultaneously set in place to improve the attitudes and perceptions among associated owners. Even if increased timber production is the end goal, outreach efforts to these hardwood owners should be tailored to owner objectives to increase participation and effectiveness (Kendra and Hull 2005). For instance, if an owner can relate to and select various harvesting practices to increase benefits such as the abundance of pertinent wildlife species, the intention to commercially harvest timber may increase.

As demand and prices for traditional low-value products such as pulpwood decline in the South, demand for biomass from southern family forests to support renewable energy production could provide a new lynchpin for facilitating sustainable softwood management. Less clear-cut, but equally important given the sustainable volume possibilities, will be the affect these markets have on hardwood family forests. For these owners, effective programs will likely be those that seek to increase positive associations with harvesting rather than attempting to reverse negative attitudes which could prove much more difficult (Young and Reichenbach 1987). Additional silvicultural efforts will be needed to assist those that may seek to convert to softwood stands, while also working with those that aim to sustain hardwood forests but are inclined to harvest.

### 4.8 Conclusion

Recent renewable energy initiatives in the US could increase market opportunities for family forests in the near future. In our case study, the response to these opportunities will likely correspond with owner attitudes towards harvesting and the cover-type and average size of trees within their forests. With a significant area of forest covered by softwoods in the case study and throughout the southern US, the potential contribution of these forests towards renewable energy aims is promising. While hardwood owners are often more-amenity oriented in their objectives, displaying somewhat less positive attitudes towards harvesting, increases in renewable feedstock markets could prompt more owners to harvest. If past trends continue during this process then the health, productivity, and sustainability of future supplies could be compromised by neglect for proper forest management.

On the other hand, if markets emerge en masse it could be that rehabilitation increases. To hedge these risks while simultaneously attempting to increase favorable harvesting attitudes among family forest owners, outreach intending to increase renewable feedstock from these lands should aim to positively influence owner attitudes with explicit connections to cover-type and owner objectives. As soon as opportunities to do so arise, rehabilitative treatments in hardwood forests should be put in place where possible to expedite future silviculturally available feedstock that will be needed after current first-wave sustainable yields are extracted. The long-term stability of national efforts to increase domestic renewable energy supplies through the use of wood biomass would be bolstered with improvements in owner attitudes towards harvesting and the health and productivity of their forests alike, keeping in mind the need for continued sustainable practices into the future.

# CHAPTER 5. CONCLUSION

## 5.1 Summary

This thesis sought to identify the likelihood and extent of biomass yield from family forests in VA and NC by measuring disproportionate relationships between stand characteristics, owner intentions, and intensity of silvicultural treatments among case study forests. We also attempted to gauge the impact of social marketing messages on owner intentions to harvest and simulated the likelihood and extent of potential future silvicultural treatments that could give way to supply of biomass feedstock. Finally, we tested how forest variables affect commercial timber harvesting intentions among owners and identified mediation of this relationship by theoretical psychosocial predictors of owner intentions. We used the results to demonstrate advantages of biosocial examinations of estimating biomass availability in regions heavily influenced by family ownerships. To do this, we combined commercial timber harvesting intentions among case study owners and silvicultural simulations of potential first-wave sustainable yield on their forests.

The context of the study location is important to reiterate, especially given current nationally relevant issues involving energy, environment and global climate change, geopolitical instability, uncertainty surrounding fossil fuels, recent US renewable energy initiatives, and US economic growth. The study area was located within the rural tobacco region of Virginia and North Carolina and centered upon the future location of an impending ethanol plant. This plant, along with current US renewable energy initiatives, could provide much needed market opportunities for family forest owners that would allow for increased sustainable forest management implementation. In turn, family forests could help achieve US renewable energy objectives, however uncertainty remains surrounding the availability of wood biomass from family forests due to the diversity in landowner harvesting intentions and the size and condition of their forest holdings.

### 5.2 Conclusion

We found, as have previous studies, that an owner's attitude towards timber harvesting is the most powerful attribute influencing their intention to carry out a commercial harvest on their property. In the same model, two biophysical forest variables, BAP and QSD proved to be significant drivers of owner intention to harvest. We also found that an owner's attitudes partially mediates the effect between BAP and their intention to commercially harvest. We also increased owner intentions to harvest using two separate social marketing messages involving improvement of the local economy and receiving subsidies or cost-shares, both geared towards increasing the near-term supply of forest biomass. In comparing biomass yields resulting from silvicultural simulations factored by owner intention scores between the baseline and social marketing scenario-based intention scores, the disproportionate effects of owner intentions on potential AGB availability within the case study were revealed.

Increasing demand for renewable energy feedstock and ongoing need for rehabilitative enhancements bring about an opportunity for a symbiotic relationship. However, to ensure participation and hedge further exploitation and neglect of silviculture across these forests, targeted and relevant outreach must be developed and delivered to family forest owners in areas to be of any significant addition to renewable feedstock supply. Additionally, any estimates made to gauge the feasibility of significant inputs from family forests for renewable energy initiatives within a region need to take into account forest and owner simultaneously.

### 5.3 Recommendations for Future Research

Research that examines family forest ownership characteristics is broad, often in depth, and on-going. The same could be said for research focusing on the forest resource controlled by family forest owners. Both are often regionally specific due to varying biophysical landscapes and diverse social systems that reside within. What is less common is the research on the multi-scalar, inherently coupled relationships of psychosocial ownership characteristics and the biophysical conditions of the forest they control, which begets disproportionate biosocial systems.

Future studies that aim to estimate landscape level resource dynamics should strive to incorporate multi-scalar, mixed-method combinations that couple the biophysical and human factors of a disproportionate system. In this vein, further research examining differences between forest composition and owners' psychosocial characteristics such as timber harvesting attitudes, could lead to a better understanding of implications of family forest management on the broader forest resource, especially in the South where heavy mixtures of ownership and cover-type exists.

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## APPENDIX A. LANDOWNER INVITATION TO PARTICIPATE

VirginiaTech
*College of* Natural Resources

**Department of Forestry**
**Matt Brinckman**
228 Cheatham Hall, 0324
Blacksburg, Virginia 24061
540/449-3665 Fax: 540/231-3330
E-mail: mdbrinck@vt.edu

May 7, 2009

Dear Landowner,

We are contacting you about a research project focusing on private forest management in Charlotte, Lunenburg, Mecklenburg, Halifax, and Prince Edward counties in Virginia and Granville, Vance, and Warren counties in North Carolina. In this study, we're hoping to hear from private landowners with 10 or more acres of forestland to learn about the factors that influence whether or not they plan to harvest trees. The goal of the study is to help improve forestry education and technical assistance policies so that they are more relevant to owners and their forests.

You are receiving this letter because you have been randomly selected from a list of landowners in the study region. If you have 10 or more acres of forestland and are willing to: 1) volunteer for an interview and 2) grant brief access to your forestland for a field assessment, please fill out the enclosed card and mail it using the self-addressed, business-reply envelope. On the other hand, if you do not have 10 or more acres or are not willing to participate, please check the appropriate box on the card, mail it, and we will not contact you again.

For those of you that agree to participate, we will contact you shortly after receiving your response card to: 1) set up a time to talk on the phone or meet in person and 2) coordinate a visit to your forest sometime during the summer of 2009. Please note that the field visit should take no longer than a day and that all information you provide will be kept confidential and not associated with you in any way. You may withdraw from the study at anytime without prejudice.

Your cooperation would be greatly appreciated and, if you wish, we will prepare a report of the field results that will be yours to keep. If you have any questions, please contact Matt Brinckman at 540-449-3665 or mdbrinck@vt.edu. Thank you for your time and consideration. We look forward to hearing from you.

Respectfully,

Matt Brinckman
Graduate Student, Forestry
Virginia Tech

John Munsell
Assistant Professor, Forestry
Virginia Tech

## APPENDIX B. RESPONSE CARD

RESPONSE CARD

❑ **“I own 10 or more acres of forestland and Am Willing to Participate”**

❑ **“I own to or more acres of forestland but Am Not Willing to Participate”**

❑ **“I do not own 10 or more acres of forestland”**

**Please enter your name below and, if participating, your telephone number and the time(s) and day(s) most convenient for you to be contacted.**

**Name:______________________________________________**

**Telephone:__________________________________________**

**Time and Day:_______________________________________**

**e-mail (optional):___________________________________**

# APPENDIX C. SURVEY INSTRUMENT

I feel confident that I could arrange a commercial timber harvest on my forestland if I wanted to.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

A commercial timber harvest would negatively affect the beauty of my forestland.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

A commercial timber harvest would improve the health of my forestland.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

A commercial harvest would improve the growth of timber on my forestland.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

If I were to arrange a commercial timber harvest on my forestland, I could control the outcome.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Society expects me to commercially harvest timber on my forestland.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Even if I was not confident in my ability to arrange a commercial timber harvest on my forestland, I could still do so if I wanted to.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

In general, family members that are important to me would support a commercial timber harvest on my forestland.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Even if I could not control the outcome, I could still commercially harvest timber on my forestland if that is what I wanted to do.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

A commercial timber harvest would improve recreation opportunities on my forestland.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

If I wanted to organize a commercial timber harvest on my forestland, I would feel confident in doing so.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

Friends of mine would say that a commercial timber harvest on my forestland is bad.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

A commercial timber harvest would degrade wildlife habitat on my forestland.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

Even if I were not confident in my ability to organize a commercial timber harvest on my forestland, I could still do so.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

Forestland owners I know would view a commercial timber harvest on my forestland favorably.

| Strongly Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Strongly Agree |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | | | | |

Protecting wildlife habitat in my forestland is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Generally speaking, what my friends think I should do is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Protecting the beauty of my forestland is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Generally speaking, what society thinks I should do is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Protecting the health of my forestland is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Generally speaking, what my family thinks I should do is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Protecting timber growth on my forestland is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Generally speaking, what other forestland owners think I should do is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

Maintaining opportunities for recreation on my forestland is

| Not Important | 1 | 2 | 3 | 4<br>Neutral | 5 | 6 | 7 | Very Important |
|---|---|---|---|---|---|---|---|---|

## Section 3:

We define a **Commercial Timber Harvest** as: the act of harvesting with the objective of producing timber and other forest produce as a personal enterprise or for sale to a business.

**Please circle only one number** for each of the following statements.

I intend to commercially harvest timber on my forestland in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

What are the main factors that influence this decision for you? (Please explain using a few sentences)

________________________________________________

________________________________________________

________________________________________________

If you were to commercially harvest timber on your forestland in the next 5 years, what percent of the acreage in Mecklenburg do you think you would harvest?

________________________________________________

I intend to commercially harvest timber on my forestland at some point in the future.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Is there some portion of your forestland that you would never harvest?

Yes No

If so, how many acres is it?
________________________________

What are the main factors that influence this decision for you? (Please explain using a few sentences)

________________________________________________

________________________________________________

________________________________________________

## Section 4:

We define a **Commercial Timber Harvest** as: the act of harvesting with the objective of producing timber and other forest produce as a personal enterprise or for sale to a business.

**Please assume each of the following underlined statements are true** before circling **only one number** for each.

My wood will supply the ethanol plant.
As a result, I intend to commercially harvest timber in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Supplying the ethanol plant with my wood will help this country become more energy independent.

As a result, I intend to commercially harvest timber in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Supplying the ethanol plant with my wood will help the local economy.
As a result, I intend to commercially harvest timber in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

I could take advantage of renewable energy subsidies and cost-share programs if I supply the ethanol plant with my wood.
As a result, I intend to commercially harvest timber in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Using wood to produce ethanol has environmental benefits.
As a result, I intend to commercially harvest timber in the next 5 years.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree
Neutral

Please describe any other factors that would influence your decision to commercially harvest timber on your forestland:

______________________________________________

______________________________________________

## Section 5:

In this section there are several questions about you and your forestland. Please answer these questions so we can learn about forest landowners as a group. This information will be kept strictly confidential. Thank you for your cooperation.
Please answer all questions to the best of your ability.

How many acres of forestland do you own in total? ___________________________

Do you have a written management plan for any portion of your forestland?

Yes No

If you do have a written management plan, who wrote it? (check all that apply)

State Forester
Private Forest Consultant
Myself
Other:

When did you first acquire forestland?

Within the past 5 years
6 to 10 years ago.
11 to 20 years ago.
21 to 30 years ago.
31 to 50 years ago.
More than 50 years ago.

How did you acquire your forestland?

Bought it
Inherited it
Both bought and inherited
Other _______________________________________________

What are your top three reasons for owning forestland? (**Please rank these items in order of importance**, with 1 being the most important. You may list more than one under "Other", be sure to include a rank)

| Rank | Reason |
|---|---|
| | Land Management Income |
| | Wildlife Habitat/Nature |
| | Recreation |
| | Beauty |
| | Privacy/Home/Farm |
| | Family Legacy |
| | Land Investment |
| | Forest Health |
| | Other: |
| | Other: |
| | Other: |

How often do you visit any portion of your forestland?

| | |
|---|---|
| Once a day. | Once a year. |
| Once a week. | Less than once a year. |
| Once a month. | Never. |

How many times have you harvested timber commercially on your forestland in the past? ______________________________________________________________

If you have commercially harvested before, how many acres have you harvested in total? ______________________________________________________

How much formal education have you completed?

elementary
some high school
high school graduate
technical degree or attended college
college graduate
graduate degree

What year were you born? ________________________

What is your primary occupation? _________________________________________

If retired, what was your primary occupation? _______________________________

What was your approximate 2008 household income before taxes?

| | |
|---|---|
| Less than $19,999 | $80,000 to $99,999 |
| $20,000 to $39,999 | $100,000 to $149,999 |
| $40,000 to $59,999 | $150,000 to $249,999 |
| $60,000 to $79,999 | Over $250,000 |

# APPENDIX D. INSTITUTIONAL REVIEW BOARD PERMISSION LETTER

VirginiaTech

**Office of Research Compliance**
Carmen T. Green, IRB Administrator
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4358 Fax 540/231-0959
e-mail ctgreen@vt.edu
www.irb.vt.edu
FWA00000572( expires 1/20/2010)
IRB # is IRB00000667

DATE: April 6, 2009

MEMORANDUM

TO: John Munsell
Matthew Brinckman

FROM: Carmen Green

SUBJECT: **IRB Exempt Approval:** "Mixed Multi-Scalar Methods to Assess Wood Biomass Availability on Family Forests in Virginia's Southside" , IRB # 09-262

I have reviewed your request to the IRB for exemption for the above referenced project. The research falls within the exempt status. Approval is granted effective as of April 6, 2009.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in the research protocol. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.

2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

cc: File

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