The Timber Harvesting Behavior of Family Forest Owners

by

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Phillip Sollins

To increase our understanding of the timber harvesting behavior of family forest owners, I developed theoretical and empirical timber harvesting models for family forest owners in the southeastern United States. An individual-choice model was the basis for the models. Family forest owners were modeled as utility-maximizers who made harvesting decisions by balancing amenity and profit values. The relative weights of these values were determined by owners' personal preferences (e.g., forest ownership objectives). Harvesting was modeled as a function of these weightings and biophysical and socioeconomic variables. The three owner groups identified in the theoretical model – profit, multiple-objective, and amenity – were incorporated in the empirical models. Data from forest inventories and forest owner surveys conducted by the USDA Forest Service, Forest Inventory and Analysis program were used in logistic regression harvesting models. Separate models were generated for all family forest owners and each of the family forest owner groups. Among the owner groups, harvesting propensity was highest for the profit group and lowest for the amenity group. Using information collected from on-the-ground forest surveys, stand structure variables, such as basal area and volume, were the most significant predictors of timber harvesting among the biophysical and socioeconomic variables tested. Other significant variables were stumpage values, the importance of timber production as an ownership objective, and whether owners lived within one mile of their forestland. Softwood sawtimber stumpage value, whether owners lived within one mile of their forestland, their incomes, whether they had management plans, and whether their forestland was managed by a professional forester were significant variables in the harvesting model for the profit group. Basal area, softwood sawtimber stumpage value, the importance of timber production as an ownership objective, whether owners lived within one mile of their forestland, and slope were significant for the multiple-objective group model. For the amenity group model, softwood pulpwood stumpage value and owners' incomes were significant variables. The results of the models were aggregated and implications for the region's timber supply were assessed for different scenarios. Continued shifts away from strong timber ownership objectives will likely decrease the flow of timber from family forestlands.

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In loving memory of Bubbie

The Timber Harvesting Behavior of Family Forest Owners

1. Introduction

To exist as a nation, to prosper as a state, and to live as a people, we must have trees.

- Theodore Roosevelt

Forests are essential to the existence and survival of our race. Many of our most basic life necessities – air, water, food, and shelter – are supplied, at least in part, by forests. The fates of countless civilizations have been irreparably altered by the state of their forests (Perlin 1989). Beyond supplying materials for meeting our physical needs, forests provide intangible benefits that allow us to attain higher levels on our hierarchy of needs (Maslow 1970). From fiber for producing the materials for communicating the tenets of our culture to conceptual ideals that provide mental solace, forests are a pillar of human society. To continue to improve our standard of living without irreparably harming the environment for future generations, requires, among other things, the sustainable stewardship of our forest resources.

The largest disturbance force affecting the fate of contemporary forest ecosystems is people. Timber harvesting and land clearing activities cause 72 percent (16 billion ft^3/year) of the tree mortality in the United States (Smith et al. 2004). The remaining 28 percent of the trees killed by natural agents and the forests that are left undisturbed are also influenced by people. People have widespread impacts on natural disturbance regimes through land use decisions, forest management practices, and the dispersal of pathogens. Successional patterns are affected by humans' influences on the growth rates and competitive advantages of selected tree species through passive and active methods of stand initiation and regeneration, forest management practices, and our impacts on local, regional, and global biogeoclimatic cycles.

Federal, State, and local governments have a vested interest in seeing that forests are maintained for "the greatest good, for the greatest number" (Pinchot 1947). Although individual forest owners may be optimizing management decisions based on their specific needs and desires, these decisions, aggregated across many owners, may not be socially optimal. To formulate informed opinions and craft effective policies to foster socially desirable conditions, it is imperative to understand the dynamics of the forest resources and the people who own and control these resources. The U.S. Congress recognized this need by enacting the Forest and Range Land Renewable Resources of Act of 1978 (Pub. L. 95-307) and mandating the U.S. Department of Agriculture to "obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting, managing, and utilizing forest and rangeland, renewable resources." As part of this mandate, significant effort has been placed in modeling the harvesting behavior of forest owners – primarily in the context of timber supply.

1.1. Forest Sustainability

Forest sustainability has many facets and definitions (Gale and Cordray 1991). Numerous initiatives have been formed to assess and foster forest sustainability at scales ranging from individual forest owners (e.g., Forest Stewardship Council) to nations (e.g., Montreal Process) (Holvoet and Muys 2004).

The United States is party to the Montreal Process. This process is designed to assess forest sustainability through monitoring of 67 indicators that are categorized into seven broad categories (U.S. Forest Service 2004):

1. Conservation of biological diversity;
2. Maintenance of the productive capacity of forest ecosystem;
3. Maintenance of forest ecosystem health;
4. Conservation and maintenance of soil and water resources;
5. Maintenance of forest contributions to global carbon cycles;
6. Maintenance and enhancement of long-term, multiple socioeconomic benefits to meet society's needs; and

7. Legal, institutional, and economic frameworks for forest conservation and sustainable management.

One factor that the Montreal Process and other national assessment systems attempt to quantify is the supply and demand of forest goods and services, with a particular emphasis on timber. Indicator 2.a of the Montreal Process is intended to quantify timberland availability – the "area of forestland and net area of forestland available for timber production." There are many factors that affect the supply of timber (e.g., intensity of forest management), but having forestland available for production is one of the most basic aspects of timber supply and is the focus of my policy analyses.

The southern United States produces more timber than any country other than the United States (Prestemon and Abt 2002b), but the United States is still a net importer of wood products (Haynes 2003). In the mid-1980s, urbanization surpassed reversion and conversion of agricultural lands as the primary reason for loss of forestland in the southern United States (Conner and Hartsell 2002). In addition to the land use changes, social processes are changing the attributes and attitudes of the remaining forest owners (Wear et al. 1999, Egan and Luloff 2000). These social pressures are felt most strongly by the 10.3 million family forest owners who control 42 percent of the forestland in the United States (Butler and Leatherberry 2004), with much of this land located in or near the wildland-urban interface (Macie and Hermansen 2002).

The harvesting behaviors of forest owners have consequences far beyond timber supply. Forest structure is positively and negatively impacted by harvesting. The retention of older trees can create environments that provide more aesthetic appeal (to some individuals) and more closely resemble old-growth habitat. Harvesting activities also can be used to mimic natural disturbance patterns and create early successional habitats that are favored by some wildlife species, such as some neo-tropical migrant birds.

1.2. Dissertation Overview

The timber harvesting behavior of family forest owners in the southeastern United States was analyzed to gain insights into the behavior of family forest owners and the availability of forestland for timber production. After reviewing the available literature on timber harvesting behavior (Chapter 2), I present a theoretical model based on the economic principle of utility maximization that incorporates amenity and profit objectives using an individual-choice framework (Chapter 3). Empirical models using logistic regression are presented that incorporate biophysical and socioeconomic variables to test their relationships with the timber harvesting behavior of family forest owners (Chapter 4).

Timber availability is assessed by examining the current propensity for harvesting and how this propensity is likely to change under scenarios reflecting social and economic perturbations (Chapter 5). In the discussion and conclusions chapters (Chapters 6 and 7, respectively), I address the implications of the theoretical and empirical models and make suggestions for future research.

The robust dataset, combining previous ideas and concepts in novel ways, and the explicit examination of timber availability make this dissertation unique. The greatest weakness of previous studies of forest owner behavior was a lack of adequate data. By combining data from extensive forest and forest owner surveys, this shortcoming was substantially mitigated. As a result of the data and techniques used, the results can be aggregated to make observations over broad areas. The inability to aggregate individual-choice models has been a major weakness of previous research (Prestemon and Wear 2000).

2. Literature Review

Using different theoretical and empirical approaches, researchers have studied the timber harvesting behavior of private forest owners (Jennings and Matysek 2000). In this chapter, I discuss the strengths, weaknesses, and conclusions of these studies.

2.1. Theories of Timber Harvesting Behavior

Economic theories are the most common underpinning of the theoretical approaches that have been used to understand timber harvesting behavior. The objectives of most timber harvesting studies have centered around the interrelated issues of timber supply and optimal rotation lengths. The owners' objectives included in the theoretical models are a major distinguishing feature.

Traditionally, theoretical timber harvesting models have focused on the profit or financial motivations that influence forest owner behavior. This approach is appropriate for forest owners with strong profit-maximization motivations (Newman and Wear 1993), but there are numerous amenities produced by forests and valued by forest owners that are not captured in market-based transactions. Most forest owners, particularly family forest owners, value, at varying levels, both the amenities and profits provided by forests. The most vexing problem for modeling timber harvesting behavior is how to incorporate both profit and amenity values.

The Faustmann Model

The foundation of most economic timber supply models is the Faustmann model. Faustmann (1849) posited that the optimal timber harvest rotation length or harvesting age is a function of the benefits generated from revenues, costs incurred in future investments (e.g., planting), and opportunity costs. Opportunity costs are the profits that could be gained if resources (e.g., capital) are invested in alternative ventures (e.g., stocks or bonds) and are commonly accounted for by including discount factors (e.g., interest rates) in the timber harvesting models. There have been many alternatives developed (e.g., maximization of gross yield), but under most conditions they are inferior to the Faustmann model for estimating financially optimal rotation lengths (Newman 1988).

Solving the land expectation value equation proposed by Faustmann (Equation 2.1), the financially optimal rotation length is the point at which the value of the marginal revenue product (MRP) equals the value of the marginal input costs (MIC) (Equation 2.2). The MRP is the value earned by waiting one more time period and the MIC is the opportunity cost associated with retaining the trees, $rV(t)$, and the land, $rLEV$. One result of this model is that as stumpage prices increase, the financially optimal harvest rotation length decreases. Stumpage price is the value of standing trees (e.g., dollars per thousand board feet) sold for forest products. By referencing standing trees, it is implied that the harvesting and hauling costs to be incurred by the buyer are factored into the price offered to the forest owner.

(Equation 2.1)
$$LEV = \frac{p(t)q(t) - c}{e^{rt} - 1}$$

where LEV = land expectation value, $p(t)$ = stumpage price at time t, $q(t)$ = volume harvested at time t, c = regeneration costs, t = time (e.g., years), and r = discount rate.

(Equation 2.2)
$$\frac{\partial V(t)}{\partial t} = rV(t) + rLEV$$

where $V(t) = p(t)q(t)$ and the other variables are as defined above.

The Hartman Model

The Faustmann model is limited by inclusion of only financial considerations. One of the first, and most widely cited, models to incorporate amenity values (e.g., the value of standing trees) was proposed by Hartman (1976). With the additional consideration of non-timber values, the optimal rotation length is affected by the shape of the amenity curve [i.e., the value of the amenities at varying levels of the stand attributes (e.g., volume or age)] in addition to the variables in the Faustmann model. As long as the amenity curve has a positive slope, inclusion of amenity values increases the optimal rotation lengths and can cause harvesting to be uneconomical.

The total utility or satisfaction that forest owners derive from their forests can be mathematically optimized by combining profit and amenity values (Equation 2.3) and solving the equation for first- and second-order optimization criteria. Although we have a reasonable understanding of the variables influencing profits, we have only cursory understandings of the shape of the amenity curve and how to combine the profit and amenity components. The theory of time allocation (Becker 1965) provides the theoretical basis for combining profit and amenity values, but not a specific functional or mathematical form.

(Equation 2.3) $$U = \int_0^{t_h} e^{-rt} A(t)\partial t + e^{-rt_h} P(t_h)$$

where U = utility, A = amenities, P = profits, t_h = harvest or rotation length in years, t = time in years, and r = discount rate.

To improve theoretical timber harvesting models, we need to improve the methods for estimating amenity values and combining them with profit values. Maybe we should not be searching for one amenity curve or combinatorial method, but a set of amenity curves and combinatorial methods that are unique for each owner or owner group based on their personal preferences.

Capital Constraints and Planning Horizons

The constraints placed on the capital or inputs of production, such as the area of land devoted to forests, obviously, influence timber harvesting models. In long-run timber supply models, "enough time [is] available for the inventory level to adjust to economically optimal levels" (Binkley 1987) and forest owners maximize net present value over, theoretically, an infinite time horizon. In short-run timber supply models, the inputs of production are held essentially constant – "demand is fixed and supply is determined by rotation age, management intensity, and land area" (Binkley 1987). Short-run supply models can be transformed into long-run supply models by jointly modeling the supply of timber and forestland (Binkley 1981), but this is rarely done.

Many forest owners, particularly family forest owners, have planning horizons that are less than a harvest rotation length and, consequently, short-run supply models are more appropriate when modeling the timber harvesting behavior of these forest owners. This implies that when forest owners make harvesting decisions, they hold inputs constant and make their decisions based on their immediate needs and desires and the current state of the forest.

Conclusions

Theoretical timber harvesting models can maximize profit or utility. Profit-maximization models assume that market forces cause forest owners to make harvesting decisions and that their primary or sole ownership objective is financial gain. These models are useful because they are easier to test/implement and, as expected, do a good job of describing forest owner behavior where profit-maximization is the dominant ownership objective (Newman and Wear 1993). These models are consistent with the traditional Faustmann model based on stumpage prices, stand characteristics, establishment costs, and discount rates.

When non-financial values are included in timber harvesting models, utility is the appropriate objective to maximize. Utility is the total amount of pleasure or satisfaction that forest owners derive from owning forestland. These models are more appropriate for describing the behavior of family forest owners than profit-maximization models, but they are also more difficult to construct due to our insufficient understanding of the underlying processes. The greatest weaknesses of the utility-maximization models are estimation of the amenity values and methods for combining the profit and amenity components. The inability of researchers to empirically test these models is a major obstacle and is, primarily, due to insufficient data.

2.2. Observed Timber Harvesting Behavior

To test theoretical models and further increase our understanding of timber harvesting behavior, many different empirical approaches have been used. The objectives of these studies included descriptive statistics, increased understanding of harvesting behavior, modeling the impact of forest policies, and projecting timber supply. The owner groups, geographic scope, level of aggregation, statistical models, and variables tested differ appreciably among the studies.

Owner Groups

To increase the accuracy of harvesting models or to focus on a specific question, forest owners are commonly differentiated into groups. At the broadest level, owners are frequently separated into private and public groups. The private category is often subdivided into forest industry and non-industrial private forest owner groups. Family forest owners, non-industrial corporations, nongovernmental conservation organizations, non-industrial Native American tribes, and unincorporated clubs and associations are subsets of the non-industrial private category. Less commonly, groupings are made within the family forest owner category.

The selection of owner groups has a large influence on the construction and conclusions of timber harvesting models. For example, a financial model may be satisfactory for understanding the behavior of forest industry owners (e.g., Newman and Wear 1993), but is inappropriate for family or public ownerships because owners in these groups commonly assign high values to standing trees. A limited number of timber harvesting models have been developed for public owners (e.g., Adams and Haynes 1989, Alavalapati and Luckert 1997); most timber harvesting studies have been for private and, in particular, family forest owners.

The purpose of most ownership categorization systems is to group forest owners who behave similarly. The management objectives of forest owners within the public and forest industry groups are relatively homogenous compared to the management objectives of family forest owners, which have long been considered "complex, fluid, and ill-defined" (Barraclough 1949). Further refinement of owner groups within the family forest owner category can be accomplished by subdividing the owners into groups based on their beliefs or actions. The idea of owner typing dates back to at least the 1950s (Webster and Stoltenberg 1959) and numerous approaches have been proposed to accomplish this task. Q-sort psychological testing (Kurtz and Lewis 1981, Marty et al. 1988), factor analysis (Walkingstick et al. 2001), k-means clustering (Kuuluvainen et al. 1996), and differentiation by forest tract size (Thompson and Jones 1981) have been used to segment family forest owners into groups.

Some common groupings have emerged. Using varying terms, a minimum of three family forest owner groups have been identified: profit, multiple-objective, and amenity. Kurtz and Lewis (1981) identified timber agriculturist, timber conservationist, forest environmentalist, and range pragmatist owner groups in Missouri. In Wisconsin, Marty et al. (1988) classified family forest owners into resource conservation, forest recreation, and forest utilization groups. Environment/recreation, nursery, timber, farm, and residence groups were identified in Arkansas by Walkingstick et al. (2001). In western Oregon and Washington, Kline et al. (2000) identified timber production, multiple-objective, recreation, and passive owner groups. Kuuluvainen et al. (1996) identified multiple-objective, recreation, self-employed, and investor owner groups in Finland. Grouping family forest owners into at least three categories should improve our understanding of their timber harvesting behavior.

Level of Aggregation

Timber harvesting models have traditionally represented either individual forest owners or broad, aggregated owner groups. The choice of aggregation level is, at least partially, tied to the modeling objectives. Aggregate or market-level models (e.g., Adams and Haynes 1996, Abt et al. 2000) are commonly used for broad-scale projections of timber supply and, as such, have fairly specific data requirements. These models are often applied across multiple owner groups.

As the name implies, individual-choice or household-production models describe the behavior of individual forest owners (Binkley 1981). These models are more common than aggregate models because "the forest holding is not only a productive enterprise, but may also be a consumption good for its owner, in which case the theory of the household is as important as the theory of the firm when analyzing forest holdings" (Barraclough 1949). Individual-choice models are generally confined to relatively small geographic areas due to data limitations and are hampered by problems in translating theoretical models into empirical models, again largely due to data limitations. Although theoretically feasible, few studies have attempted to aggregate the results of individual-choice models to facilitate broad conclusions (Prestemon and Wear 2000).

The appropriate level of aggregation depends, in part, on the objectives of the study and data availability. For modeling the timber harvesting behavior of family forest owners, the individual level is more appropriate and, ideally, the data would be robust enough to allow aggregation. I used the individual-choice approach in my theoretical and empirical model presented below and, consequently, most of the following discussion focuses on studies that also used such models.

Geographic Extent and Sampling Intensity

The geographic extent of a study refers to the land area that is covered and the sampling intensity refers to the number of observations within the area. Both of these attributes vary appreciably among studies. For individual-choice models, the extents of the studies have ranged from multiple counties to entire countries (Table 2.1). Most of these studies were conducted in areas with prominent forest industries and relatively high concentrations of private and, in particular, family forest owners (e.g., United States and Scandinavia). Aggregate timber supply models are usually conducted at the national or multi-state level (e.g., Adams and Haynes 1996, Abt et al. 2000).

Table 2.1. The study areas and sample sizes of selected individual-choice, timber harvesting behavior studies by nation and region

Nation, region	Study	Study area	Sample size (n)
Canada			
	Jamnick and Beckett 1988	New Brunswick	8,790
Finland			
	Kuuluvainen and Salo 1991	Southern Finland	370
	Kuuluvainen et al. 1996	Southern Finland	146
Norway			
	Løyland et al. 1995	Norway	41,500
Sweden			
	Lonnstedt 1989	Sweden	2,500
United States			
North Central			
	Kurtz and Lewis 1981	Ozarks of Missouri	72
	Carpenter 1985	Upper Peninsula of Michigan	271
	Young and Reichenbach 1987	Illinois	621
	Marty et al. 1988	Missouri and Wisconsin	n/a
	Bliss and Martin 1989	Wisconsin	16
Northeast			
	Larsen and Gasner 1973	Pennsylvania	394
	Binkley 1981	New Hampshire	97
	Dennis 1989	New Hampshire	68
South			
	Boyd 1984	North Carolina	420
	Greene and Blatner 1986	Arkansas	1,335 [a]
	Blatner and Greene 1989	Arkansas	200
	Hyberg and Holthausen 1989	Georgia	n/a [b]
	Prestemon and Wear 2000	Coastal Plain of North Carolina	921
	Pattanayak et al. 2003	North Carolina	n/a [c]
West			
	Romm et al. 1987	Northern California	299 [a]

[a] Estimated
[b] n/a = not available
[c] 4,400 trees were analyzed, but the number of plots analyzed was not reported

The sample sizes and sampling intensities are influenced by the available data sources and analytical methods. In some countries, such as Norway (Løyland et al. 1995), censuses are conducted of landowners and provide a rich dataset. If censuses are not conducted, sampling frames (i.e., lists) of all forest owners are sometimes available [e.g., New Brunswick, Canada (Jamnick and Beckett 1988)] which provide a comparably rich data source. In the absence of these sources, sampling is required. Random sampling is the least likely method to introduce sampling biases, but some studies have used non-random sampling techniques (e.g., Bliss and Martin 1989).

The data required will influence the data source(s) selected. Many individual-choice models primarily rely on forest owner survey data. Alternative data sources are required if biophysical variables are to be examined. In the United States, the USDA Forest Service's Forest Inventory and Analysis program is an extensive survey of forest biophysical attributes. This data source has been used for aggregate timber harvesting models (e.g., Adams and Haynes 1996, Abt et al. 2000) and, less frequently, for individual-choice models (e.g., Prestemon and Wear 2000).

Ideally, socioeconomic and biophysical data would be collected in tandem, but this is rarely done. When this has been done (e.g., Kuuluvainen et al. 1996, Dennis 1989), the sample sizes have been relatively small.

A shortcoming of many individual-choice harvesting studies has been limited geographic scopes, often only a state or sub-state region. Extrapolation of findings to larger areas is always desired, but the accuracy and implications of such an exercise are rarely considered. Although some meta-analyses have been conducted (e.g., Alig et al. 1990), few studies have explicitly examined differences among geographic areas. Greene and Blatner (1986) and Marty et al. (1988) found differences across geographic areas. More individual-choice studies are needed that cover broader geographic areas and use more comparable data and methods to facilitate comparisons.

Greene and Blatner (1986) found differences in forest management practices across Arkansas. Twenty-five percent of the owners in the Coastal Plain region were classified as active managers, compared to 10 percent in the Delta and Ouachita regions, and 7 percent in the Ozark region. Models predicting forest management practices among regions within Arkansas had some commonalities (e.g., number of acres of forestland owned was significant in all models), but also showed many differences. For example, timber production as a primary objective, "wage earner" as the owner's principal occupation, and farmer as the owner's principal occupation were significant variables retained in only the model for the combined Ozark and Ouachita regions. Percent of forestland in an undivided estate, owner had sold forestland, owner's formal education, and real estate speculation as a primary ownership objective were significant only in the Coastal Plain model.

Marty et al. (1988) found general agreement among the forest owner groups identified in Missouri and Wisconsin, but the relative distributions of the groups varied appreciably between the states. In Missouri, a plurality of the private nonindustrial forestland was owned by profit oriented owners – timber agriculturalists and timber conservationists. In Wisconsin, a plurality of the private nonindustrial forestland was owned by people with amenity and multiple-use objectives – forest recreationists and forest utilitarians.

Analytical Approaches

The appropriate analytical approach is dependent on the objectives of the study and data availability. Most quantitative, individual-choice studies treat harvesting as a discrete choice, making ordinary linear regression inappropriate. A logistic transformation of the binary variable is commonly performed using either a logit (Romm et al. 1987, Jamnick and Beckett 1988, Hyberg and Holthausen 1989) or probit (Dennis 1990, Prestemon and Wear 2000, Pattanayak et al. 2003) function. For studies that model harvesting intensity or the amount of timber removed, ordinary linear regression is inappropriate because of the large number of zero (no harvest) values. Here a censored regression approach, such as Tobit (Dennis 1989, Kuuluvainen et al. 1996), is appropriate. No published individual-choice models have explicitly modeled stochastic events, but Provencher (1995) proposed the use of dynamic programming to model stochastic processes, such as random revenue shocks, at least for aggregate timber harvesting models.

Other analytical approaches to studying harvesting behavior have included three-stage least squares analysis (Pattanayak et al. 2002), discriminant analysis (Greene and Blatner 1986), Q-sort (Kurtz and Lewis 1981), paired comparisons (Blatner and Greene 1989), automatic interaction detection (Larsen and Gansner 1973), unstructured interviews (Bliss and Martin 1989), decision theory and goal structures (Lonnstedt 1989), and correlation coefficients (Straka et al. 1984). Qualitative methods allow deeper insights into topics, such as forest owners' motivations, than most quantitative methods, but the conclusions of the qualitative analyses are difficult to quantify and extrapolate. In addition, it is often time and cost prohibitive to collect qualitative data for large sample sizes and, consequently, most qualitative research is limited to case studies.

Empirical Results of Previous Studies

Published studies present a lot of information about the determinants of, or at least correlates to, harvesting behavior, but differences in approaches make drawing overarching conclusions difficult (Alig et al. 1990). Much of the discussion above on empirical studies was presented to understand the diversity of approaches used and provide background and justification for the empirical approaches that I used below (Chapter 4). Here I present a summary of the results of selected empirical timber harvesting models.

Aggregate timber supply models are more consistent in the approaches and variables used than individual-choice models. The relative homogeneity of the aggregate models is related to common theoretical foundations and the use of similar, if not identical, data sources. Stumpage prices, inventory levels, and management intensities have proven effective for modeling aggregate timber supply (Adams and Haynes 1980, Abt 1989). Pattanayak et al. (2002) also found the skewness of stand age classes to be significant.

Individual-choice models have used a variety of approaches because of varying theoretical underpinnings and data sources. In assessing the conclusions of the quantitative individual-choice timber harvesting models, it is necessary to consider the statistical power of the models. If a variable is found to be non-significant was it because it was not significant, it was not investigated, or did a Type I error occur? A Type I error occurs when the null hypothesis is rejected, but is true (Fisher and van Belle 1993). A Type II error occurs when the null hypothesis is not rejected when it is false.

Stand inventory, forest acreage owned, occupation, and having received management advice or having a written management plan consistently increased the probability of timber harvesting in individual-choice models (Table 2.2). Increased total or non-timber (exogenous) income decreased harvesting probabilities, but timber (endogenous) income had the opposite effect. Owners' ages were also negatively related to harvesting. Stumpage prices produced mixed results, but most studies found a positive relationship.

Table 2.2. Relationships between the probability of timber harvesting and common variables tested in selected individual-choice, timber harvesting behavior studies of family forest owners

	Variable tested[a]						
Study	Stand inventory	Stumpage prices	Forest-land acreage	Income	Occupation	Owner age	Manag. advice or plan
Binkley (1981)		+	+	-[c]	+[e]	o	
Dennis (1989)	+	o		-[c]	+[f]		
Hyberg and Holthausen (1989)		-	+	-[c]	+[e]		+
Jamnick and Beckett (1988)			+	-[c], +[d]	+[e]	-	+
Kuuluvainen et al. (1996)	+	+		-[c]		-	
Larsen and Gasner (1973)			+		+[e], +[f]		+
Løyland et al. (1995)	+	+	+	+[d]	-[g]	-	+
Prestemon and Wear (2000)	+, -[b]	o					
Pattanayak et al. (2003)	+	+					

[a] + = positive, significant relationship; - = negative, significant relationship; and o = no significant relationship
[b] Positive relationship with plot volume, but negative relationship with square root of plot volume
[c] Total or non-timber (exogenous) income
[d] Timber (endogenous) income
[e] Farmer
[f] White collar worker
[g] Work off of property

Many other variables were included in only one or a few studies. Variables that were positively related to timber harvesting included participation in cost-share programs (Hyberg and Holthausen 1989), species composition (Dennis 1989), and land tenure (Jamnick and Beckett 1988). Road density was positively related to harvesting

(Løyland et al. 1995) and road distance was non-significant (Prestemon and Wear 2000). Negative relationships with harvesting were found for absentee owners (Løyland et al. 1995, Jamnick and Beckett 1988) and subsidy rates (Løyland et al. 1995). Education had a negative (Dennis 1989) or non-significant (Binkley 1981) impact. Kuuluvainen et al. (1996) found family forest owner groups – multiple-objective, self-employed, investors, and recreationists – to be significant predictors of harvesting probabilities. Pattanayak et al. (2003) found a "predicted nontimber index" based on tree species diversity, scenic beauty, deer habitat, and bird habitat to be negatively related to harvesting.

The results of qualitative studies provide additional insights related to the timber harvesting behavior of private forest owners. Results from the qualitative studies are useful, but due to the methods and sample sizes used, the results need to be assessed differently than the results of robust, quantitative studies. The smaller sample sizes and, where applicable, non-random sampling designs make the extrapolation of the results more tenuous. External (e.g., market forces) and internal (e.g., personal financial needs) motivational factors were important determinants of forest owner behavior (Blatner and Greene 1989), but qualitative studies have tended to focus on the latter set of factors. Bliss and Martin (1989) summarized the motivations of a group of Wisconsin forest owners as ethnicity, family legacy, personal identity, and forest conservation. In a study of Swedish forest owners, family legacy was one of the most prominent motivational factors due, at least in part, to legal and cultural values

(Lonnstedt 1989). This study also noted financial need as a key element in making timber harvesting decisions.

Conclusions

The diversity of approaches and limited datasets used to empirically study the timber harvesting behavior of family forest owners hinders our ability to make broad conclusions. Robust datasets need to be developed that incorporate biophysical and socioeconomic variables and allow for the conclusions of individual-choice models to be aggregated. Individual-choice models should be made for broader areas and comparable methods should be used to facilitate inter-regional comparisons.

Given the above limitations, some trends in variables that are significantly correlated with timber harvesting behavior are discernable. Stand inventory, stumpage price, forest acreage owned, occupation, and having received management advice are positively correlated with harvesting. Increased incomes and owners' ages are negatively correlated. These correlations, in general, seem to be reasonable, but the causal relationships are not always clear. As the size, volume, quality, and value of trees increase, we would expect harvesting propensities to increase. Having received management advice can be interpreted as a causal factor or as the manifestation of owners' prior intentions. Income, and in particular non-timber income, is negatively related to harvesting because owners with higher incomes may be relying less on their forestland for the generation of income, they may assign higher amenity values to their forests, or both.

2.3. Summary of Theoretical and Empirical Studies

Theoretical and empirical models of timber harvesting behavior have provided many new insights, but substantial improvements are still needed. Utility-maximization is the most appropriate theoretical approach for modeling the timber harvesting behavior of family forest owners. "Any study that purports to model the behavior of NIPF forest owners must address the specific ownership objectives of the individuals under consideration" (Max and Lehman 1988) and this requires the incorporation of non-timber values. In theoretical models, non-timber values are easy to insert, but determining the specific forms of these functions has proven to be very difficult (Max and Lehman 1988). Most theoretical models assume that non-timber values increase monotonically with stand age, but there have yet to be empirical tests of this assumption.

No published harvesting studies have directly estimated the values of amenities, but some have used indirect measures to quantify relevant attributes. Lee (1997) quantified tree species diversity, scenic beauty, deer habitat, and bird habitat to estimate amenity attributes of forests in North Carolina. These attributes were used by

Pattanayak et al. (2003) to quantify amenity values in their joint production modeling of timber and non-timber forest amenities values.

Using primarily logistic and censored regression approaches, stand inventory, stumpage price, size of forestland holdings, income, occupation, owner age, and receipt of management advice/plan variables have proven to be highly correlated with the timber harvesting behavior of family forest owners. These studies have not effectively incorporated both biophysical and socioeconomic variables, due, in large part, to insufficient data. Examination of sub-populations of family forest owners warrants additional research. Timber supply models can be improved if individual-choice models are aggregated (Wear and Parks 1994, Prestemon and Wear 2000). The aggregation of individual-choice models, versus the traditional aggregate models, allow for greater insight into ownership behavior and better incorporation of variability among forest owners.

Many aspects of timber harvesting studies depend on the research objectives, the data availability, or both. In this dissertation, I present theoretical and empirical models to increase our understanding of the timber harvesting behavior of family forest owners. Building on the Hartman model, I present a utility-maximization model that combines profit and amenity components and assumes a planning horizon that does not allow for inputs of production to vary (Chapter 3).

The empirical models that I present use logistic regression to model the timber harvesting behavior of family forest owners in the southeastern United States (Chapter 4). The owners are divided into profit, multiple-objective, and amenity groups. The predictor variables include biophysical and socioeconomic variables. The results of the individual-choice harvesting models are then aggregated to assess forest sustainability (i.e., timberland availability) over a broad region (Chapter 5).

3. Theoretical Model

Building upon the research summarized in Chapter 2, I developed a theoretical model of the timber harvesting behavior of family forest owners. It is an individual-choice model that maximizes the short-run utility of forest owners and is the basis for the empirical models presented in the next chapter. In this chapter (Chapter 3), I discuss specification of the utility, profit, and amenity functions, optimization of the utility function, and the implications of this model for understanding forest owners' harvesting behaviors.

3.1. Form of the Utility Function

A forest owner's utility is the sum of the financial (profit) and non-financial (amenity) values the owner derives from forest ownership. The owner makes harvesting decisions to maximize the profit and amenity benefits received. How forest owners balance profits and amenities is analogous to how individuals balance their time between work and leisure. The theory of time allocation states that individuals balance their time between work and leisure to maximize their personal satisfaction or utility, subject to internal and external constraints (Becker 1965).

There is no consensus on the proper specification of the form of the utility function for combining family forest owners' profit and amenity values. The form adopted here is that of perfect substitutes, $U(X,Y) = \alpha X + \beta Y$, as proposed by Kuuluvainen et al. (1996). This formulation facilitates the combining of the profit and amenity components based on a forest owner's relative preferences for these benefits (Equation 3.1). Forest owners can choose to concentrate completely on profits, $\alpha = 1$, or amenities, $\alpha = 0$, but most forest owners value both, $0 < \alpha < 1$, to varying degrees. Cobbs-Douglas, $U(X,Y) = X^{\alpha} Y^{\beta}$, and log-linear, $U(X,Y) = \alpha \ln(X) + \beta \ln(Y)$, are alternative forms that have been proposed (Binkley 1981, Max and Lehman 1988).

(Equation 3.1) $$U = \alpha P + (1 - \alpha) A$$

where U = utility, P = profit derived from the forest, A = amenities derived from the forest, and α = relative importance of profits subject to $0 \leq \alpha \leq 1$.

Forest owners can be classified according to the relative weights they assign to profit and amenity values. Although owners are arrayed along a continuum, I used arbitrary breakpoints to facilitate comprehension, analysis, and discussion of the model. Family forest owners can be categorized as profit, multiple-objective, or amenity maximizers based on the relative importances they assign to profits and amenities (Table 3.1).

Table 3.1. Theoretical weights given to benefits derived from profits and amenities by owner group

Owner group	Weight (α)
Profit	$0.75 \leq \alpha \leq 1.0$
Multiple-objective	$0.25 < \alpha < 0.75$
Amenity	$0.0 \leq \alpha \leq 0.25$

3.2. Specification of the Profit Function

The profit generated from a forest is a function of the stumpage value of the harvested timber, revenue generated from non-timber activities (e.g., hunting leases), and the costs of intermediate stand treatments, establishing the next stand, and holding the land (Equation 3.2). Stumpage prices incorporate timber quality, harvesting and delivery costs, and other variables captured in market-based transactions. Stumpage values observed by forest owners are a function of stumpage prices and stand and forest owner characteristics. Although the establishment cost directly affects the subsequent stand, the income generated from harvesting the preceding (current) stand is commonly used to pay for it. Other non-timber revenue generating activities would be treated similarly to leasing and, to simplify the discussion, were not included. Opportunity costs (e.g., discount rates) are not included in the profit function because this function represents the profits received from a forest over a given period of time (e.g., one rotation); opportunity costs are included when the optimal profit and amenity levels are discussed (Section 3.6).

(Equation 3.2) $$P = (p_s v + p_l a_l) - (c_i a_i + c_e a_e + t_h v + t_p a)$$

where P = profits; p_s = stumpage price; v = volume harvested; p_l = lease fee; a, a_l, a_i, a_e = amount of forestland owned, leased, receiving intermediate treatments, and treated for establishment of the next stand; c_i, c_e = intermediate treatment and stand establishment costs; and t_h, t_p = harvesting and property tax rates.

3.3. Specification of the Amenities Function

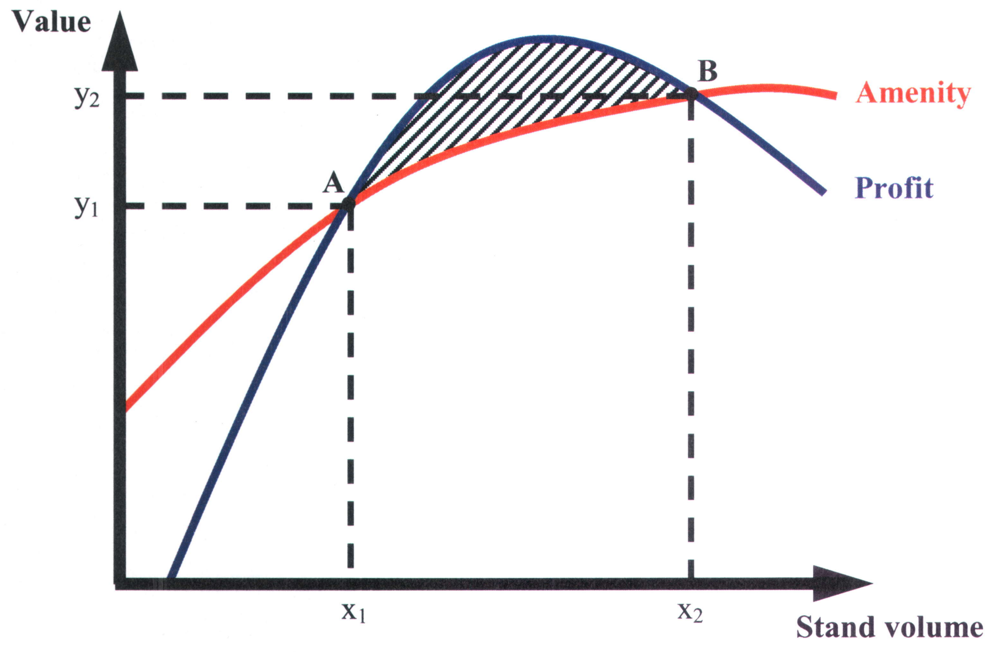
Factors influencing amenity values are poorly understood, complex, and vary among forest owners. Previous researchers (e.g., Kuuluvainen et al. 1996) have suggested that forest owner characteristics, such as ownership objectives, and forest characteristics, such as stand structure, affect amenity values. Forest owners' objectives are influenced by factors ranging from financial needs to social norms. Forest characteristics are a function of stand age, species composition, stand productivity, and stand history. These forest characteristics directly influence stand attributes such as aesthetics and wildlife habitat (Lee 1997).

Although an obvious oversimplification, amenity values have been represented as a function of stand age or volume (Swallow and Wear 1993). An advantage of this formulation is that profit and amenity benefits are directly related.

3.4. Graphical Display of Profit and Amenity Functions

If the functional forms of the profit and amenity functions can be defined using common variables, the functions can be jointly plotted to increase our understanding of their relationships. Figure 3.1 depicts hypothetical, highly stylized profit and amenity functions plotted against value and stand volume. I assumed that the profit (i.e., timber) value begins from zero, after a given volume is reached the value increases for a given period of time, and then, due to stand atrophy, decreases. For the amenity function, I assumed that the bare land (i.e., stand volume = 0) had a positive value and this value increased asymptotically. The shapes of these curves will vary by forest owner and stand.

Figure 3.1. Hypothetical relationship between stand volume and amenity and profit values



The intersection between the functions represent critical points where the amenity and profit values are equal. Between points A and B in this hypothetical example (Figure 3.1), the profit value exceeds the amenity value and the "excess" volume could be harvested to increase the forest owner's net utility. This scenario provides a justification for partial harvesting (i.e., a theoretical reason for not reducing stand volume below a given threshold). Other scenarios may indicate that no trees be harvested (i.e., amenity values > profit values for all values) or that clear-cut harvesting occur when the profit function reaches its maximum value (i.e., amenity values = 0).

3.5. Assumptions

As with all models, there are assumptions that underlie the utility function presented in this chapter. Assumptions are a result of insufficient information, provide simplification to highlight desired attributes, and allow for formulations that are more amenable to analysis. A perfect substitutes form is assumed for the utility function because of its simplicity and its ability to incorporate varying ownership objectives.

The utility function is also assumed to be limited by forest owners' capital availability. The capital available for stand regeneration and other stand improvement projects cannot exceed the difference between forest owners' total capital availability (exogenous and endogenous incomes, savings, and loans) and forest holding costs (e.g., taxes and loan payments). Likewise, if the forest holding costs exceed forest owners' incomes, they are likely to sell the forestland. Of course these are only upper limits. In reality, forest owners will make only a fraction of their total available capital available for forest management activities because of forest owners' investment strategies and the fact that capital is needed for other uses, such as personal expenses.

Forest owners were categorized using a two dimensional array – profit and amenities. Both of the components could be further divided into more refined categories (e.g., profit from timber harvesting and aesthetics, respectively), but the coarse categories were retained because of limited empirical evidence and to simplify discussion. The three owner categories in the model are based on an arbitrary division of the profit-amenity continuum. Although the basic categories are intuitive and supported by previous studies (Chapter 2), the methods for classifying the owners (e.g., the breakpoints in Table 3.1) are debatable.

The profit function presented in this chapter is a reasonable representation of the factors that influence the income generated from timber harvesting and other market-based transactions. Leasing was the only non-timber market value explicitly incorporated. There were obviously other potential revenue sources, such as the sale of pine straw or production of environmental services (e.g., carbon sequestration), but they were ignored. These alternative revenue sources would influence the total profit received and, depending on the product being generated, could influence timber harvesting decisions. The influence on harvesting decisions would have to be made separately for each revenue source. The theoretical and empirical basis for the influences of these alternative management objectives on harvesting behavior have not been extensively researched.

The profit function assumes that forest owners possess perfect knowledge and perfect information regarding prices and technical possibilities. These are common economic assumptions, but the validity of the assumptions is not consistent across forest owners. This assumption is reasonable for some forest owners, particularly those with larger forestland holdings who own principally for profit. This assumption does not hold for countless other forest owners, such as those with smaller landholding with amenity benefits as their primary ownership objective, who may never harvest or harvest only once during their ownership tenure.

The specification of the amenity function was a major assumption. The exact shape of the amenity curve is unknown because of our lack of understanding about the factors influencing this complex concept. Ideally, amenities would be represented by an n-dimensional matrix incorporating many forest and forest owner characteristics, but we lack the empirical data to define and populate this matrix.

The assumptions about the relationships between utility and profit and amenities were derived from the results of previous studies and deductive reasoning. Increases in profits and amenities are assumed to increase utility, $\frac{\partial U}{\partial P} > 0$ and $\frac{\partial U}{\partial A} > 0$, at a decreasing rate, $\frac{\partial^2 U}{\partial P^2} < 0$ and $\frac{\partial^2 U}{\partial A^2} < 0$. In addition, the volume of timber harvested could not exceed the volume available, $0 \le v_h \le v$.

3.6. Maximizing Forest Owner Utility

The utility function can be maximized using a modification of the approach proposed by Hartman (1976). Forest owners receive utility from their forestland over a given period of time, t, that is equal to the summation of the amenity, A, and profit, P, values for the period weighted by the owners' preferences for these benefits, α (Equation 3.3). To account for opportunity costs, the values are adjusted by a discount factor, e^{-rt}. Opportunity costs account for the fact that resources are limited. For example, if financial resources are devoted to forestry activities, they cannot be used for alternative investments. The discount factor, r, should be determined for each forest owner, but prevailing interest rates (e.g., three percent) are commonly used as an approximation.

(Equation 3.3) $$U = \alpha e^{-rt} P(t) + (1-\alpha)\int_0^t e^{-rx} A(x) \partial x$$

Optimal harvesting rotation lengths and harvesting decisions are determined by satisfying first- and second-order maximization conditions are. The first-order maximization condition is:

(Equation 3.4) $$U'(t) = (1-\alpha)e^{-rt} A(t) + \alpha e^{-rt} P'(t) - r\alpha e^{-rt} P(t) = 0$$

where primes (e.g., U') indicate derivates.

Which simplified to:

(Equation 3.5) $$\alpha P'(t) + (1-\alpha)A(t) = r\alpha P(t)$$

This condition implies that the rotation length should be set at the point where the financial opportunity cost, $r\alpha P(t)$, is equal to the change in profit plus the amenity values for the time period. If $\alpha = 1$, the first-order condition for calculating the financially optimal rotation length is derived, $P'(t)/P(t) = r$.

To ensure the solution is a global maximum and not a global minimum, the second-order maximization conditions also must be satisfied. This is achieved by defining the second-order derivative of the utility function as less than zero (Equation 3.6 and 3.6):

(Equation 3.6) $$U''(t) = e^{-rt}\left[\alpha P''(t) - r\alpha P''(t) + (1-\alpha)A'(t)\right] - re^{-rt}\left[\alpha P'(t) - r\alpha P(t) + (1-\alpha)A(t)\right] < 0$$

where double primes (e.g., U'') indicate second derivates.

Which simplified to:

(Equation 3.7) $$\alpha P''(t) + (1-\alpha)A'(t) < r\alpha P'(t)$$

3.7. Summary

The theoretical model developed here provides a means to increase our understanding of the harvesting behavior of family forest owners. Forest owners make harvesting decisions by optimizing the profit and amenity values they derive from their forests. The relative weights that forest owners assign to profit and amenity benefits can be used to segment forest owners into classes. Profit values are a function of volume harvested, stumpage prices, establishment costs, and the cost of holding forestland. Amenity values are less well understood, but I assumed that they are positively related to stand age or volume. The shape of the amenity curve may vary by owner (group) and the specific amenity being examined (e.g., aesthetics).

Based on the theoretical model, empirical models were used to address specific issues of interest. The largest, most general, issue was whether forest owners value both profits and amenities. More specifically, I wanted to empirically identify which variables were the most important for understanding harvesting behavior. For example, what is the relationship between timber harvesting behavior and stumpage values? Another major issue addressed was whether forest owners were separable into profit, multiple-objective, and amenity groups and this division aids in understanding harvesting behaviors. I was also interested in combining these issues and identifying the most powerful predictors of timber harvesting behavior by owner group. The profit group should have the strongest response to market variables (e.g., stumpage value), the amenity group should respond more to forest conditions (e.g., stand age and volume), and the multiple-objective group should respond to a mix of both sets of variables.

4. Empirical Models

Not everything that counts can be counted,

and not everything that can be counted counts.

- Albert Einstein

Empirical data were coalesced and logistic regression models were developed to gain further insights into the timber harvesting behavior of family forest owners in the southeastern United States. Family forest owners included families, individuals, and other groups of individuals who were not legally incorporated and owned at least one acre of forestland.

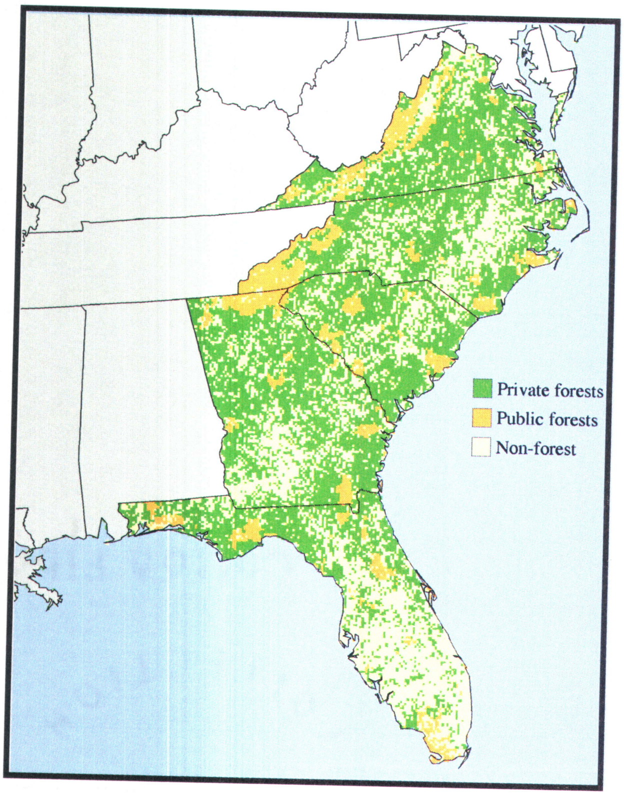
The empirical models were based on the theoretical findings from the previous chapter (Chapter 3). To incorporate profit and amenity values, biophysical and socioeconomic variables were examined. To differentiate among family forest owners, they were segmented into the three groups discussed in Chapter 3 – profit, multiple-objective, and amenity (Table 3.1).

After describing the study area and data sources, I present a model that I used to categorize family forest owners. The timber harvesting (dependent) and independent (predictor) variables are then described and summarized. Bivariate and multivariate logistic regression models are presented that quantify the relationships between timber harvesting and the biophysical and socioeconomic predictor variables.

4.1. Study Area

The southeastern United States (Figure 4.1) – Florida, Georgia, North Carolina, South Carolina, and Virginia – was selected for this study because of its high proportion of privately owned forestland, importance in national timber supply, and availability of appropriate data. There are 88.6 million acres of forestland in the Southeast (Smith et al. 2004); this accounts for 12 percent of the nation's forestland area and contributes 27 percent of the volume of timber that is annually removed. Eighty-six percent of the Southeast's forests are privately owned. The estimated 2.0 million family forest owners represent the dominant ownership type and collectively control 49.3 million acres (USDA Forest Service, National Woodland Owner Survey, unpublished data on file with author).

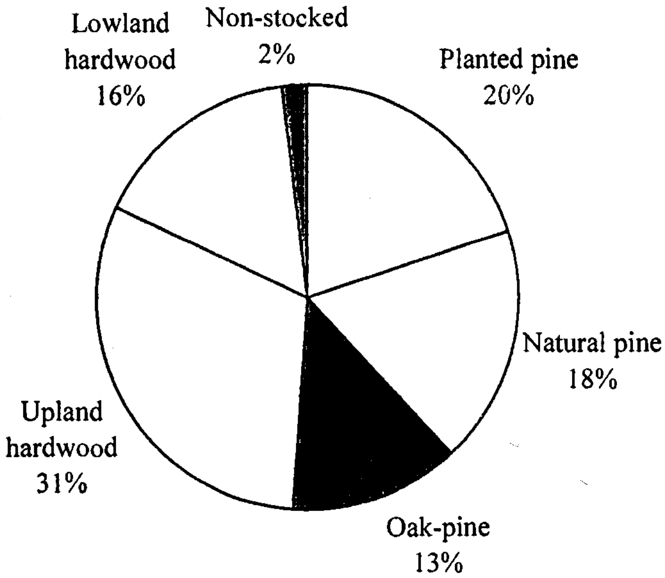
Figure 4.1. Forest and forest ownership distribution in the southeastern United States



Data sources: Forests – University of Maryland, MODIS Vegetation Continuous Fields; Public ownership – University of California Santa Barbara, Managed Area Database; States – ESRI Data and Maps

Upland hardwood is the dominant forest type on private forestland in the Southeast, followed by planted pine, natural pine, lowland hardwood, and oak-pine (Figure 4.2) (Alig and Butler 2004). Loblolly pine (*Pinus taeda* L.) is the dominant species in the region by volume (Smith et al. 2004) and the region's most commercially important species. Other common species include longleaf pine (*Pinus palustris* Mill.) and various oak (*Quercus* spp.) and gum (*Nyssa* spp.) species.

Figure 4.2. Distribution of forest types on private forestland in the southeastern United States



Source: Alig and Butler 2004

4.2. Data Sources

The primary data for the individual-choice, timber harvesting models were derived from forest inventories (Table 4.1) and forest owner surveys (Butler et al. in press) conducted by the USDA Forest Service's Forest Inventory and Analysis (FIA) program. The probability of harvesting (a binary variable calculated for each plot) was modeled using biophysical and socioeconomic variables derived from these and other data sources described below.

Table 4.1. USDA Forest Service, Forest Inventory and Analysis forest inventories used to model family forest owners' timber harvesting behavior in the southeastern United States

State	Dates	References
Florida	1987, 1995	(Brown 1999)
Georgia	1989, 1997	(Thompson 1998)
North Carolina	1984, 1990	(Johnson 1991)
South Carolina	1993, 2001	(Conner et al. 2004)
Virginia	1992, 2001	(Johnson 1992)[a]

[a] As of May 2005, the most recent data for Virginia were still being analyzed and published

FIA established a national grid of sampling points with one point per approximately 6,000 ac (2,428 ha). If the sample point is determined to be forested, an inventory plot is installed. These permanent plots consist of four, fixed-radius subplots with a combined sampling area of 0.2 ac (0.08 ha). For the forested portions of the plots, information on tree species, size, volume, and condition are recorded in addition to information on the disturbance history and general physical attributes (U.S. Forest Service 2003, Alerich et al. 2004).

These permanent inventory plots are remeasured, on average, every 7 years to monitor changes in forest attributes and calculate growth, removal, and mortality statistics. Due to changes in the sampling design, only a subset of the plots and a subset of the trees on these plots were remeasured during successive inventories. Timber removals can only be calculated for remeasured plots, so only remeasured plots were considered in the analyses presented below. To avoid confounding timber harvesting behavior with factors that influence land use changes, only plots with land use classified as forest during both inventories were included in the analyses.

In 2002 and 2003, a random subset of the owners of the forested FIA plots was surveyed as part of FIA's National Woodland Owner Survey (NWOS) (Butler et al. in press). These owners were contacted using mailed questionnaires and telephone interviews to solicit information on 30 questions related to their attitudes, behaviors, and other pertinent characteristics.

Detailed ownership information related to the forest inventory plots was available only through the NWOS, so only plots where ownership survey data were collected were analyzed. The forest inventory and forest owner survey data were from random samples and, consequently, no sampling or coverage biases (Dillman 2001) should have been introduced. Consequently, the results can be extrapolated or aggregated to cover the entire region with a high degree of confidence. Based on comparisons between forest owners who responded via the initial mail surveys and those who responded to more intensive survey methods (i.e., telephone interviews), no significant, non-response biases were detected.

Other data sources included TimberMart-South (TimberMart-South 2000) and the U.S. Census (U.S. Census Bureau 2001). TimberMart-South collects quarterly information on stumpage prices for multiple product types based on transactions within sub-state areas of 12 southern states. The product types consistently reported since the late 1970s include softwood sawtimber, softwood pulpwood, hardwood sawtimber, and hardwood pulpwood. Information on housing densities was taken from the 2000 U.S. Census.

4.3. Family Forest Owner Groups

Based on ownership objectives, family forest owners were assigned to one of three groups – profit, multiple-objective, or amenity. These categories are supported by theoretical justifications (Chapter 3) and previous research (Chapter 2). Forest owners in the profit group own forestland because they are primarily interested in earning money from their land, through the sale of timber or other sources of revenue (e.g., leases or land sales). Amenity forest owners are interested, primarily, in the aesthetics, privacy, recreation, and/or other non-market goods. As the name implies, multiple-objective forest owners value both profits and amenities. This segmentation is based on the arbitrary division of a continuum; few owners have strictly amenity or profit motivations and, consequently, these categories represent the relative importance owners assign to profits and amenities.

A decision model was used to assign forest owners to the ownership groups (Figure 4.3). On the NWOS, the respondents were asked to rate reasons for owning forestland (Table 4.2) on a 7-point Likert scale with one being very important and seven being not important. These ratings were recoded as high (Likert value of 1 or 2), medium (Likert value of 3, 4, or 5), or low (Likert value of 6 or 7). The higher value of the recoded timber production and land investment objectives values was taken to be the relative importance of profit values. The over-all importance of amenities was the highest value of the recoded aesthetics, privacy, nature protection, home/farm, hunting, and recreation objectives. The non-timber forest product (NTFP) and firewood production objectives were not analyzed because relatively few (12 and 8 percent, respectively) of the owners ranked these objectives as high.

Figure 4.3. Decision model used to classify family forest owners

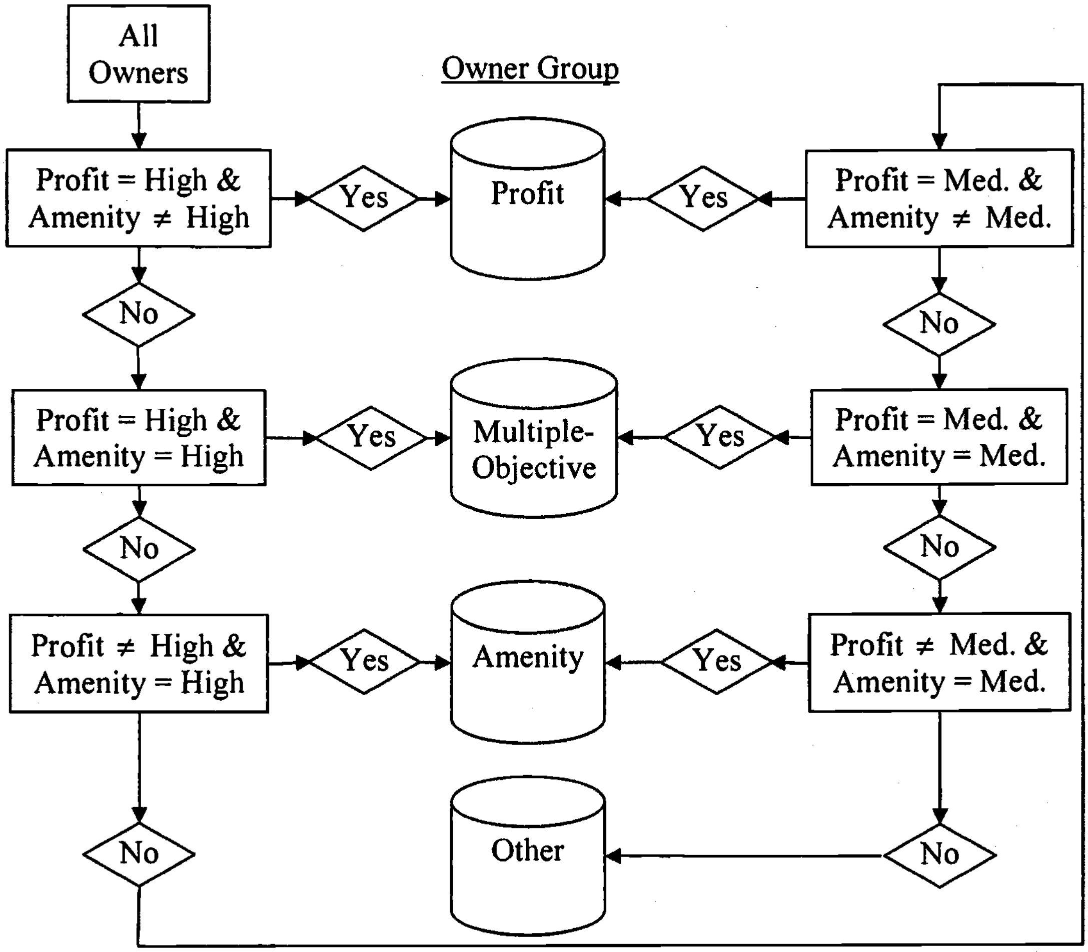


Table 4.2. Importance of ownership objectives for family forest owners in the southeastern United States

Objective	Description (text included in survey)	Importance [a] High	Medium	Low	No answer
		Percentage of family forest owners [b]			
Aesthetics	To enjoy beauty or scenery	60	24	8	8
Nature protection	To protect nature and biological diversity	50	29	11	10
Land investment	For land investment	58	23	10	8
Home/Farm	Part of my farm, home or vacation home	57	16	18	9
Privacy	For privacy	51	20	17	11
Family legacy	To pass land on to my children or other heirs	66	20	8	6
Timber production	For production of sawlogs, pulpwood or other timber products	46	24	22	8
Hunting	For hunting or fishing	42	27	23	8
Recreation	For recreation, other than hunting or fishing	27	30	31	12
Firewood production	For production of firewood or biofuel (energy)	8	22	56	13
NTFPs	For cultivation/collection of non-timber forest products	12	27	49	13

[a] High includes forest owners who rated the objective as 1 or 2 on a 7-point Likert scale (1 = very important and 7 = not important); medium includes forest owners who rated the objective as 3, 4, or 5; and low includes forest owners who rated the objective as 6 or 7.
[b] Due to rounding, percentages may not sum to 100.

The decision model (Figure 4.3) was used as follows. Owners who rated one or more of the profit objectives as high and none of the amenity objectives as high were classified as profit owners. Owners who rated one or more of the amenity objectives as high and none of the profit objectives as high were classified as amenity owners. Owners who rated one or more of the profit objectives *and* one or more of the amenity objectives as high were classified as multiple objective owners. For owners who rated no profit or amenity objectives as high, the same classification scheme was applied to their medium ratings. Owners who failed to rate any of the amenity or profit objectives as high or medium were classified as other.

Using the decision model outlined in Figure 4.3, 9 percent of the family forest owners in the Southeast were assigned to the profit group, 62 percent to the multiple-objective group, and 25 percent to the amenity group. The 4 percent of the family forest owners classified as "other" were dropped from further analyses.

4.4. Timber Harvesting – The Dependent Variable

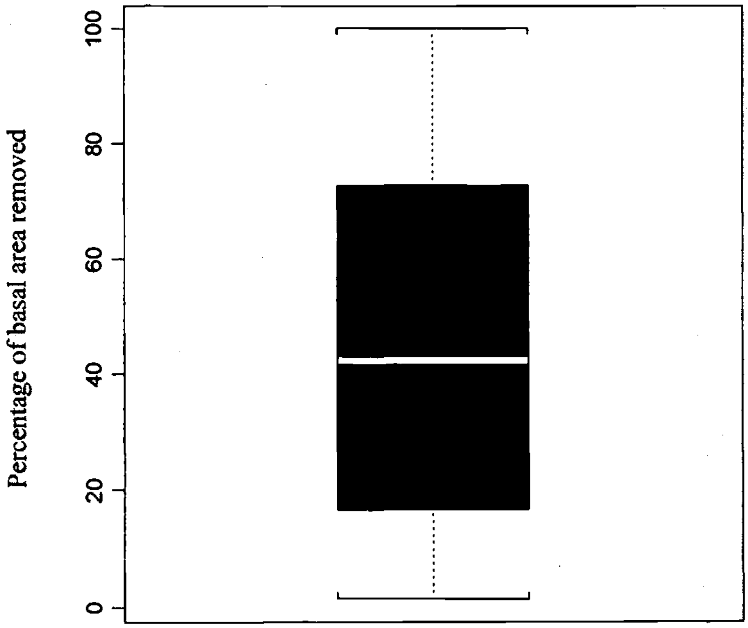
The dependent, timber harvesting variable was calculated using FIA plot-based, field measurements. Trees were measured at two points in time and the fate of each tree (i.e., growth, mortality, or removal) was recorded. Plots where at least 25 percent of the basal area was removed between inventories (Equation 4.1) were categorized as harvested and assigned a harvest value of one. All other plots were assigned a timber harvest value of zero. Twenty-one percent of the family forest plots in the Southeast were classified as harvested.

(Equation 4.1) $$H = 1 \text{ if } \left[\left(\frac{BA_{rem}}{BA_{rem} + BA_{res} + BA_{mort}}\right) \times 100\right] \geq 25$$

where H = harvest, BA_{rem} = basal area removed, BA_{res} = residual basal area, and BA_{mort} = basal area lost to natural mortality.

Specifying a 25 percent threshold for defining harvested plots was arbitrary, but appeared reasonable. For example, using this threshold, 90 percent of the basal area removed from family forestland was from the harvested plots and two-thirds of the plots with one or more trees removed were classified as harvested (Figure 4.4). The box plot in Figure 4.4 depicts the distribution of the harvesting intensities (i.e., percentage of basal area removed) for forested plots with one or more trees removed. Box plots graphically represent the median, interquartile range, outliers, and extreme values of the variable being described (Fisher and van Belle 1993).

Figure 4.4. Distribution (median, interquartile range, outliers, and extreme values) of harvesting intensities for family forests in the southeastern United States*



* Excludes plots with no trees harvested

The likelihood of timber harvesting differed by owner group. The profit group had the highest proportion of plots that were harvested (29 percent), followed by the multiple-objective and amenity groups (20 and 18 percent, respectively).

4.5. Biophysical and Socioeconomic Predictor Variables

Timber harvesting behavior is posited to be a function of biophysical and socioeconomic factors. Descriptions and summary statistics for the predictor variables included in the empirical models are presented for all of family forest owners and by family forest owner group. In general, the attributes of family forest owners classified as multiple-objective owners were intermediate to those of owners in the amenity and profit groups.

Biophysical Predictor Variables

Biological and physical attributes set the basic constraints on what a stand is and what it is capable of becoming. Direct measures or proxies of biological and physical attributes were derived from FIA forest inventory data (Table 4.3). These variables characterize the structure, composition, geo-climatic, and historic attributes of the stands.

Table 4.3. Descriptions and summaries of biophysical variables used in the empirical analysis of timber harvesting behavior of family forest owners in the southeastern United States

Variable	Description	Expected sign*	Units or categories	Owner group: Total	Profit	Multiple-objective	Amenity
Basal area	Basal area of trees	+	ft^2/ac	105 (52) †	103 (51)	104 (54)	108 (48)
Softwoods	$\geq$ 1.0 in. dbh	+	ft^2/ac	46 (46)	52 (48)	46 (46)	42 (45)
Hardwoods		+	ft^2/ac	59 (54)	51 (48) [c]	58 (55)	66 (51) [a]
Volume	Net cubic foot	+	ft^3/ac	1,695 (1,316)	1,764 (1,270)	1,636 (1,338)	1,830 (1,270)
Softwoods	volume of trees	+	ft^3/ac	763 (993)	1,000 (1,198)[bc]	749 (976) [a]	697 (929) [a]
Hardwoods	$\geq$ 5.0 in. dbh	+	ft^3/ac	931 (1,164)	764 (945) [c]	887 (1,183)[c]	1133 (1,176)[ab]
Stocking	Percentage of full stocking	+	percent	41 (20)	40 (21)	40 (20) [c]	44 (20) [b]
Forest type	Species composition based on the plurality of trees and source of regeneration	+	planted pine	14% ‡	17% [c]	15% [c]	8% [ab]
		+	natural pine	35%	44%	35%	32%
		+	oak-pine	11%	12%	10%	13%
		+	upland hardwood	28%	12% [bc]	27% [ac]	38% [ab]
		Ref	lowland hardwood	12%	15%	13%	9%
Species composition	Percentage softwood as a function of basal area	+	percent	47 (37)	51 (38)	48 (37) [c]	42 (37) [b]
Ecological province	Broad regions with similar biogeo-climatic characteristics	+	coastal	48%	52% [c]	52% [c]	37% [ab]
		+	piedmont	42%	37%	42%	45%
		Ref	mountain	10%	11%	7% [c]	19% [b]

Table 4.3. (Continued).

Variable	Description	Expected sign*	Units or categories	Owner group			
				Total	Profit	Multiple-objective	Amenity
Site index	Average height that a dominant or co-dominant will reach in 50 years	+	ft/50 years	71 (12)	71 (12)	71 (12)	72 (12)
Slope	Percent slope as measured on the plot	-	percent	9 (13)	7 (11) [c]	8 (11) [c]	15 (17) [ab]
Stand age	Average age of trees in the dominant stand size class	+	years	37 (25)	38 (21)	35 (24) [c]	43 (26) [b]

* The expected sign is the anticipated relationship between the probability of timber harvesting and the given variable. For polytomous variables (more than two discrete values or levels), the reference level is indicated as "Ref."

† For continuous variables, means and standard deviations (given parenthetically) are listed.

‡ For polytomous variables, percentages are listed.

[a] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the profit group.

[b] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the multiple-objective group.

[c] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the amenity group.

Stand Structure - The quantity and quality of trees are primary constraints on the short-run availability of timber. Basal area, volume, and stocking are common metrics used to quantify these attributes. Due to FIA sampling and estimation protocols, diameters, and hence basal areas, were recorded for trees 1.0 in. dbh or greater and volumes were calculated for trees 5.0 in. dbh or greater. In addition to estimates for all tree species, basal area and volume variables were calculated for softwoods and hardwoods to assess the relationship of these species groups to harvesting behavior. The larger markets and traditionally higher market values for softwoods should make these species more appealing to people with stronger profit motives. Hardwoods may increase amenity values due to aesthetic appeal and increased biodiversity.

Stand basal areas and volumes varied widely across the region, from zero following extreme stand replacement events (e.g., intense fires or clear-cut harvests) to over 200 ft^2/ac of basal area or 2,500 ft^3/ac of volume for older stands on productive sites. The total stand basal areas and timber volumes did not differ substantially among the owner groups, but the softwood and hardwood components did (Table 4.3). The ratio of hardwoods to softwoods (by basal area) was approximately 1.0 for the profit group and 1.2 and 1.6 for the multiple-objective and amenity groups, respectively. This observation is likely related to owners in the multiple-objective and profit groups having greater interest in the more commercially-prized softwood species and being more likely to use intensive management practices to foster them.

To fully capture the growth potential of a stand, the proper number of trees must be maintained commensurate with the stage of stand development (e.g., age), site quality, and forest type. This occupancy level is assessed by comparing the stand characteristics to an appropriate stocking standard and the comparison between the two is the stand stocking (Smith et al. 2004). Thirty-four percent of the stands in this study were classified as well stocked (60-99 percent of full stocking) and five percent were over stocked (≥ 100 percent of full stocking) (Table 4.3). Half of the plots were moderately stocked (35-59 percent of full stocking) and the remainder of the plots were poorly stocked (< 35 percent of full stocking). These stocking level categories were defined by FIA (Alerich et al. 2004).

Species Composition - Species composition was quantified by grouping stands into forest types and calculating the percentage of the stand basal area that was accounted for by softwoods. The planted pine, natural pine, oak-pine, upland hardwood, and lowland hardwood forest types are a simplification and a modification of the FIA forest types and are commonly used in resource assessments (e.g., Wear and Greis 2002). Over half of the plots were classified as upland hardwood or natural pine, but distributions varied among owner groups (Table 4.3). Pine types, and planted pine in particular, were more common on forestland owned by people in the profit and multiple-objective groups than on forestland owned by amenity forest owners.

On average, 47 percent of the basal area of family forests was softwoods (Table 4.3). The percentages were slightly higher for the profit and multiple-objective groups (Table 4.3), likely due to the relative value of this species group from a market perspective and the natural successional patterns of the region. The difference between the species compositions of the profit and amenity groups was marginally significant ($p = 0.06$).

Geoclimatic Attributes

Geologic, pedologic, climatic, and other physical/biophysical attributes control the inherent productivity of a stand, constrain species composition, and influence its suitability for human endeavors, such as timber harvesting. Ecological province, site index, and slope were the geoclimatic variables analyzed.

Ecological provinces are broad areas that are subject to similar biological, geological, and climatic regimes. The Outer Coastal Plain Mixed Forest (Coastal), Southeastern Mixed Forest (Piedmont), and Central Appalachian Mountain Broadleaf Forest (Mountain) ecological provinces were the dominant ecological provinces in the study area. The majority of stands were in the Coastal and Piedmont provinces, 48 and 42 percent, respectively (Table 4.3). The Mountain province occupied a relatively small percentage of the region and had a higher percentage of public ownership.

Stand productivity varied from low (site index less than 40) to high (site index greater than 125) with an average site index of 71 (Table 4.3). Site index represents the height of a dominant or co-dominant tree of the dominant species on the site at 50 years of age. Site index did not vary significantly among the owner groups.

In addition to affecting a stand's biological characteristics, slope affects, among other things, the types of timber harvesting methods that are feasible. Amenity owners' plots had an average slope of 15 percent, significantly higher than the 7 or 8 percent for the forestland owned by people in the other groups. Steeper sites often provide more appealing vistas and owners who are less interested in timber production may be less concerned about harvesting constraints.

Stand History

Stand age was used as a proxy for stand history. Observed stand ages ranged from 0 to 130 years, with an average of 37 years (Table 4.3). Stands on amenity owners' forestland tended to be older than those of the other groups, although stands in excess of 100 years were found among all the owner groups. These patterns are consistent with the aesthetic (and spiritual?) ownership objectives of the amenity group that tend to favor older stands and the timber harvesting objectives of the owners in the other groups that encourage younger stands via shorter rotations.

Examination of average stand ages masks some of the characteristics of the underlying distribution of stand age classes (Figure 4.5). For example, family forest owners in the multiple-objective group had an appreciably greater percentage of their forestland in young (i.e., less than 20 years) age classes. Supporting the observation that the forestland owned by family forest owners in the amenity group was, on average, substantially older than the forestland of owners in the other groups, 27 percent of the amenity owners' forestland was 60 years or older, compared to 17 and 13 percent for the forestland owned by multiple-objective and profit owners, respectively.

Figure 4.5. Distribution of stand age classes for (a) profit, (b) multiple-objective, and (c) amenity family forest owners in the southeastern United States. Error bars are standard deviations.

a.

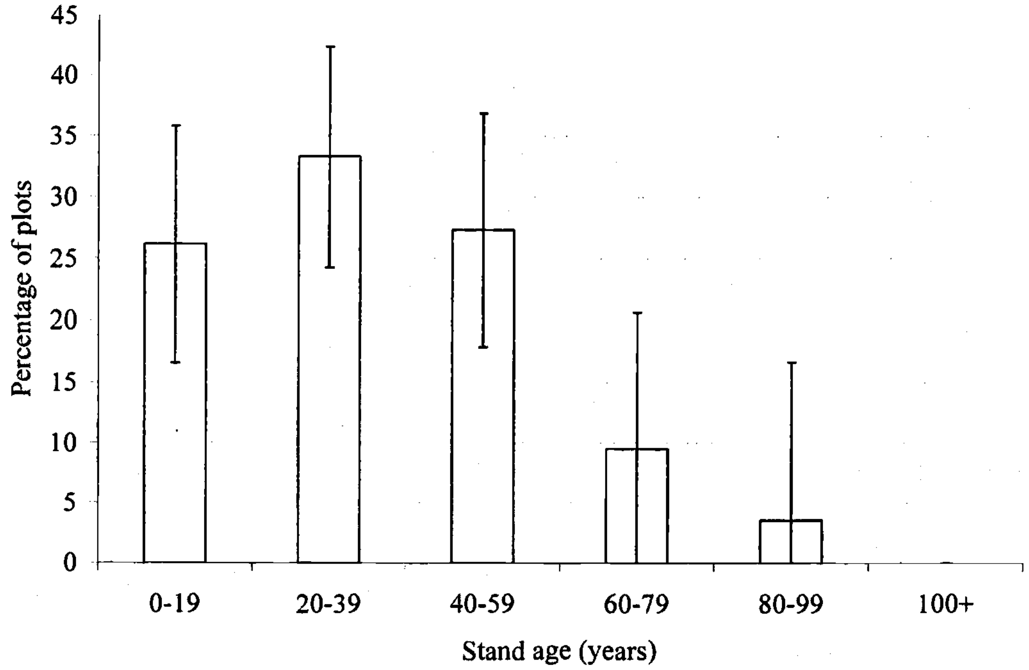
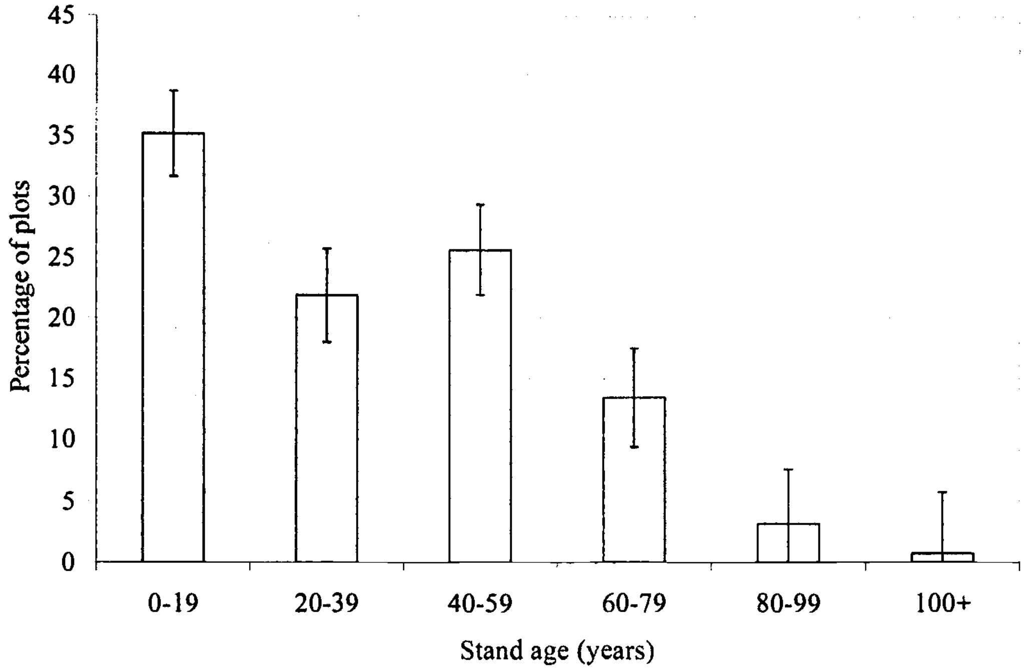
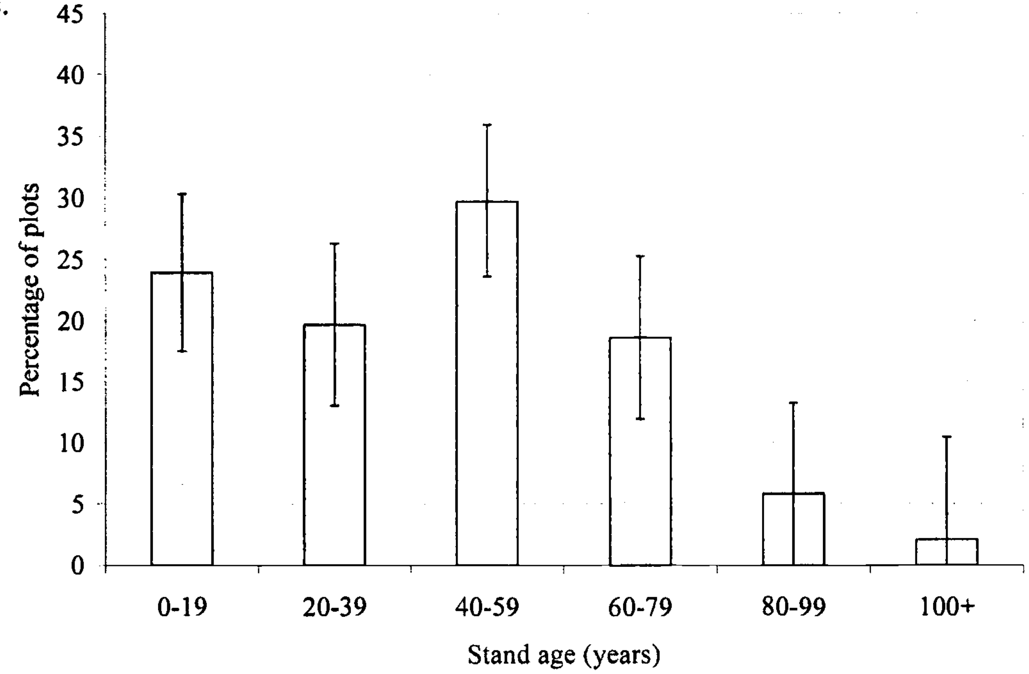


Figure 4.5. (Continued).

b.



c.



Socioeconomic Predictor Variables

In addition to biological and physical factors, social and economic factors have been shown to be important predictors of the behavior of family forest owners (Dennis 1989). Socioeconomic variables related to community and forest owner demographics, market forces, and the characteristics of the forest owners' forest holdings and management practices were examined (Table 4.4).

Table 4.4. Descriptions and summaries of socioeconomic variables used in the empirical analysis of timber harvesting behavior of family forest owners in the southeastern United States

Variable	Description	Expected sign*	Units or categories	All Owners	Owner group		
					Profit	Multiple-objective	Amenity
Stumpage value	Estimated value of standing trees sold for forest products	+	US$/ac	200 (281)†	199 (243)	186 (279)[c]	239 (301)[b]
Softwood sawtimber		+	US$/ac	85 (166)	116 (214)	83 (166)	77 (140)
Softwood pulpwood		+	US$/ac	4 (7)	5 (8)[c]	4 (7)[c]	3 (5)[ab]
Hardwood sawtimber		+	US$/ac	107 (241)	74 (145)[c]	95 (236)[c]	155 (280)[ab]
Hardwood pulpwood		+	US$/ac	4 (5)	4 (4)	4 (6)	4 (4)
Housing density	County-level housing density	-	houses/mi^2	51 (73)	55 (73)	47 (60)	63 (101)
Planted	Stand is artificially regenerated	+	yes	15%‡	18%[c]	16%[c]	9%[ab]
Timber production	Importance of timber production as an ownership objective	+	1=high; 7=low	3 (2)	2 (2)[c]	2 (2)[c]	5 (2)[ab]
Forest holdings	Acres of forestland owned	+	100 ac	13 (114)	8 (13)[c]	18 (139)[c]	3 (7)[ab]
Home	Forestland associated (within 1 mi) with owner's primary residence	-	yes	53%	20%[bc]	56%[a]	58%[a]
Farm	Forestland associated (within 1 mi) with owner's farm	+	yes	38%	24%[b]	43%[ac]	32%[b]

Table 4.4. (Continued).

Variable	Description	Expected sign	Units or categories	All Owners	Owner group: Profit	Owner group: Multiple-objective	Owner group: Amenity
Land tenure	Length of ownership tenure	+	years	29 (21)	34 (31)[c]	30 (19)[c]	24 (17)[ab]
Income	Annual household income	-	US$1,000	69 (57)	79 (59)[c]	72 (59)[c]	58 (49)[ab]
Owner age	Age of the forest owner	-	years	64 (12)	68 (13)[bc]	63 (12)[a]	64 (12)[a]
Management plan	Owner has a written forest management plan	+	yes	21%	27%[c]	24%[c]	12%[ab]
Advice sought	Owner has sought forest management advice within the previous five years	+	yes	53%	59%[c]	59%[c]	31%[ab]
Manager	Professional forester manages the forestland	+	yes	20%	29%[c]	23%[c]	9%[ab]
Green certification	Forest owner participates in a green certification program	+	yes	6%	9%[c]	8%[c]	2%[ab]
Conservation easement	Easement restricts forestland use or management	?	yes	7%	9%	7%	5%
Cost share	Owner has participated in a publicly funded, cost-share program	+	yes	35%	49%[c]	39%[c]	16%[ab]

* The expected sign is the anticipated relationship between the given variable and the probability of timber harvesting.
† For continuous variables, means and standard deviations (listed parenthetically) are listed.
‡ For dichotomous and polytomous (more than two discrete values or levels) variables, percentages are listed.
[a] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the profit group.
[b] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the multiple-objective group.
[c] Mean or proportion is significantly different ($p \leq 0.05$) from the mean or proportion of the amenity group.

Financial Variables – Stumpage values represent the value of standing timber if the trees were to be sold for conversion into sawn, pulped, chipped, or other end-products. As stumpage values and, consequently, financial rewards increase, the probability of harvesting should also increase. Stumpage values are difficult to model because they are dependent upon the species, size, quality, and quantity of trees, timber markets, extraction and transportation costs, transaction costs, and the forest owners' direct or indirect knowledge of these factors. Many of these data are only available from cross-sectional data sources that mask the idiosyncrasies of individual timber sales.

Estimates of stumpage values were generated by combining forest mensuration and market data. Market data were from TimberMart-South's (2000) quarterly, sub-state stumpage reports for softwood sawtimber, softwood pulpwood, hardwood sawtimber, and hardwood pulpwood product groups. Board feet and cubic feet estimates of trees by species group and diameter class were tabulated from the FIA data. The specialization of mills and harvesting equipment for processing specific sizes of trees makes the relationship between stumpage values and tree diameters non-linear. The observed harvesting probabilities by species group – hardwoods and softwoods – and diameter classes were calculated, normalized, and used to adjust stumpage values. Per acre stumpage values were derived by summing the product of the adjusted stumpage values and per acre stand volumes by product group (Equation 4.2).

(Equation 4.2)

$$s_i = \sum_{j}^{z} \sum_{k}^{4} a_j p_k v_{jki}$$

where s_i = per acre stumpage value for plot i, a_j = diameter class adjustment factor, p_k = stumpage price for product group k, and v_{jki} = per acre volume by product group and diameter class for plot i.

Due to data limitations, the stumpage values were, in some cases, significantly lower than the true market values. The cross-sectional stumpage prices were for trees of average quality and average diameter and to adjust for diameter preferences, I discounted these averags. The stumpage values may be better interpreted as relative values rather than absolute values that are obtainable on the open market.

Stumpage values ranged from zero for young and unproductive stands to over $2,000/ac for mature, productive stands with an average of $200/ac (Table 4.4). Softwood sawtimber values tended to be higher for forestland owned by people in the profit group and hardwood sawtimber values tended to be higher for forestland owned primarily for amenity purposes. This pattern is likely related to management practices and the preference of profit-oriented owners for softwoods.

Land Ownership Characteristics – In addition to biological and physical characteristics of the forestland, basic ownership characteristics, including the size of the forestland holdings and length of tenure, should influence the opportunities available to and the constraints encountered by forest owners.

Due to economies of scale (Row 1978, Cubbage 1983) and the restrictions imposed by finite forestland holdings to meet multiple objectives, forestland holding sizes influence the number and types of opportunities available. Family forests in the Southeast ranged in size from one acre to more than 100,000 ac. The mean holding size was 1,332 ac (Table 4.4), but the median value was substantially lower (182 ac). The mean forest holding size was highest for the multiple-objective group, but so too was the variability (i.e., there were a few owners with exceptionally large forest holdings). Examining median values, the profit and multiple-objectives groups had similar sizes of forest holdings (270 and 229 ac respectively) which were substantially higher than that for owners in the amenity group (74 ac). This pattern is likely related to forest owners more interested in privacy and home sites being more likely to own smaller landholdings than forest owners who have stronger financial motivations.

The longer families own forestland, the more likely it is that they will encounter personal, biological, and market conditions that are favorable for harvesting. Their relationship with their land can also change and this too can affect their propensity to harvest trees. Most family forest owners had owned their land for relatively long periods of time (mean = 29 years) (Table 4.4). The average land tenure of owners in the amenity group was significantly lower than the average for owners in the other groups; averages did not significantly differ between the profit and multiple-objective groups.

Demographics – Demographics affect forest owners at multiple scales. At the personal-level, income and age should influence the availability of financial resources, financial needs, and planning horizons. Mean annual family incomes were highest for the profit group, intermediate for the multiple-objective group, and lowest for the amenity group, with an over-all average of $69,000 per year (Table 4.4). Forest owners' ages averaged 64 years, with higher average ages for owners in the profit group than owners in the other groups.

The demographics of local communities can influence forest owners' behaviors by influencing their norms and values. Wear et al. (1999) found that as population densities approached 150 people/mi^2, the expected future timber harvesting levels approached zero. Population and housing density were highly correlated in my study area ($\rho > 0.99$). Housing density had a stronger theoretical relationship to forest management and has been widely used for wildland-urban interface studies (e.g., Macie and Hermansen 2002). Housing densities ranged from less than five to close to 1,000 houses/mi^2. The average housing density was 51 houses/mi^2, with a higher average for the amenity group than for the other groups (Table 4.4). This is probably related to people interested in owning forestland as part of their home (e.g., some amenity owners) wanting to live closer to more residential areas (i.e., higher housing densities) that are closer to job sites, shopping, and other cultural amenities. An obvious over-simplification, the county-level housing density variable implies that housing units are uniformly distributed across counties and ignores variability within a county.

Forest Management Activities – Stand origin, management plans, receipt of forestry advice, green certification, conservation easement, and cost-share variables were examined to measure management intentions and intensities. Due to their relationship with timber production and profit-maximization motives, most of these variables showed higher rates of occurrences for the profit and multiple-objective groups than for the amenity group (Table 4.4). The exception was conservation easements for which amenity owners showed a slightly higher propensity.

Above, I presented univariate summaries of the dependent and independent variables that will be used in the empirical models. In addition to setting the general context for family forests and families forest owners in the Southeast, some intriguing differences among owner groups were highlighted that will be further discussed in Chapter 6. Now the predictor variables will be used in bivariate and multivariate logistic regression models to assess their relationships with timber harvesting.

4.6. Timber Harvesting Models

To examine the effects of the biophysical and socioeconomic predictor variables on timber harvesting behavior, logistic regression models were developed. These models were run with and without the owner groups as a "by" variable ("by" variables define rules for subsetting data) to assess whether relationships varied among groups. The bivariate models allowed pair-wise relationships to be examined and the multivariate models allowed more complex relationships to be assessed. Due to multicollinearity, quasi-complete separation, and other reasons described below, I was able to include only a subset of the predictor variables in the final multivariate models.

The dependent variable, timber harvesting, was constructed as a binary variable and, consequently, was analyzed using logistic regression. This is a common approach for modeling timber harvesting behavior (Jamnick and Beckett 1988, Løyland et al. 1995, Prestemon and Wear 2000).

Logistic regression (Hosmer and Lemeshow 1989, Allison 1999) is a common tool for exploring relationships between a dichotomous dependent variable, such as timber harvesting, and independent predictor variables. To transform the discrete outcomes to a continuous scale and obtain many of the desirable features of ordinary linear regression, the log of the odds is calculated (Equation 4.3). Because individual observations still have discrete values, maximum likelihood techniques are used to solve this equation.

(Equation 4.3)
$$\log\left(\frac{p}{1-p}\right) = \alpha + \beta X$$

where p = probability of the event, $\frac{p}{1-p}$ = odds of the event occurring, α = intercept term, β = vector of coefficients, and X = vector of independent variables.

To facilitate the interpretation of the logistic regression models, the estimated regression coefficients were back-transformed. The e^{β} transformation represents the odds ratio or the percentage change in the odds of the dependent variable occurring given a one-unit increase in the independent variable while controlling for all other variables in the model (Hosmer and Lemeshow 1989).

Variable Transformations

In the implementation of statistical models, it is often advantageous to use variables that have approximately normal distributions. This minimizes the effects of extreme values and can make some non-linear relationships linear. Many of the continuous variables had distributions that were skewed towards smaller values. Depending on the severity of the skewness and examination of diagnostic statistics (e.g., quantile-

quantile plots), a log, square-root, or no transformation was used. For the slope, size of forest holdings, stumpage value, and housing density variables, log transformations were used. Square-root transformations were used for the basal area, volume, stand age, and land tenure variables.

Model Diagnostics

In the development of regression models, attention must be given to the relationships among the predictor variables to avoid quasi-complete separation, multicollinearity, and other features that generate unstable and suboptimal results.

Due to the iterative, maximum likelihood technique used to estimate the parameters of logistic regression models, variables that perfectly or nearly perfectly predict the dependent variable cause complete or quasi-complete separation and generate nonunique solutions (Allison 1999). This most often arises from discrete variables and small sample sizes. Variables that caused complete or quasi-complete separation were reported as such, dropped from the model, and contingency tables between this variable and the dependent variable were subsequently investigated.

Multicollinearity yields unstable results because one or more variables are highly correlated and, consequently, the coefficient estimates are unreliable. Tolerance statistics, Pearson correlation values, contingency tables, and t-tests were used to assess multicollinearity (Allison 1999). Pearson correlation values, contingency tables, and t-tests were examined to assess the general relationships among the predictor variables, but these tested for only a narrow range of relationships (e.g., pair-wise and linear). Tolerance statistics provide a more robust tool for assessing multicollinearity by sequentially regressing each of the independent variables against all of the other independent variables, calculating the coefficient of determination (i.e., R^2 value), and subtracting this value from one (Allison 1999). Variables with low tolerances have high degrees of multicollinearity. Efforts were made to avoid combinations of variables that generated tolerances lower than 0.4.

The goodness-of-fit and predictive power of the models were assessed using log likelihood ratios and adjusted-R^2 statistics (Allison 1999). The log-likelihood ratio quantifies the strength of the model compared to a model with no predictor variables; the associated X^2statistic is used to assess the significance of this statistic. The coefficient of determination or R^2 value quantifies the predictive power of the model. Due to the distribution of the dependent variable of logistic regression models, the standard computations of the coefficient of determination, standard-R^2, will never reach 1.0 (Nagelkerke 1991). By dividing the standard-R^2 value by the maximum obtainable standard-R^2 value, the adjusted-R^2 values range from 0.0 to 1.0.

A single observation or a small group of observations can have a large impact on a regression model if the observations are sufficiently different from the other observations. These outliers may be the result of measurement errors or they may represent real variability within the data. The influence of individual observations was quantified by examining changes in X^2 values, changes in regression coefficients, and the extremeness of the observations (Fisher and van Belle 1993). Although observations with extreme values were present, models generated with and without the outlier variables were not substantially different and all observations were retained.

The multivariate logistic regression model was built using an iterative process to better isolate problematic combinations of variables. The variables were entered into the model by descending order of predictive power. After each variable was added, the model was checked for quasi-complete separation and multicollinearity. If problems were observed, the suite of variables that had the highest predictive power was retained. This model building approach is not synonymous with stepwise regression. The variables included were selected because of theoretical considerations and were only dropped from the model because they caused problems with one or more other variables in the model.

Bivariate Logistic Regression Models

Bivariate logistic regression models were created that paired each predictor variable with the dependent harvesting variable. Separate models were generated by combining and separating the data by owner group. The results from the bivariate models are summarized in Table 4.5.

Table 4.5. Ninety-five percent confidence intervals for odds ratios and predictive powers of bivariate logistic regression models of timber harvesting behavior for family forest owners in the southeastern United States

	All owners		Owner group: Profit		Owner group: Multiple-objective		Owner group: Amenity	
Variable	Odds ratio	R^2 [a]	Odds ratio	R^2 [a]	Odds ratio	R^2 [a]	Odds ratio	R^2 [a]
Basal area [b]	(0.87, 0.90)***	0.36	(0.88, 0.97)***	0.19	(0.87, 0.90)***	0.36	(0.83, 0.90)***	0.46
Softwood [b]	(1.09, 1.20)***	0.06	(1.03, 1.35)**	0.10	(1.08, 1.21)***	0.06	(1.02, 1.24)**	0.05
Hardwood [b]	(0.92, 1.00)*	0.01	(0.81, 1.05)	0.02	(0.92, 1.03)	<0.01	(0.86, 1.05)	0.01
Volume [b]	(0.97, 0.98)***	0.28	(0.97, 1.00)***	0.12	(0.97, 0.98)***	0.27	(0.96, 0.98)***	0.38
Softwood [b]	(1.03, 1.05)***	0.13	(1.02, 1.07)***	0.18	(1.03, 1.05)***	0.11	(1.02, 1.07)***	0.14
Hardwood [b]	(0.98, 1.00)*	0.01	(0.96, 1.01)	0.02	(0.98, 1.01)	<0.01	(0.97, 1.01)	0.01
Stocking	(1.03, 1.60)**	0.01	(0.69, 2.18)	0.01	(0.99, 1.72)*	0.01	(0.70, 1.97)	<0.01
Forest type		0.05		0.13		0.04	Quasi-complete separation	
Planted pine	(0.54, 2.29)		(0.15, 5.58)		(0.45, 2.28)			
Natural pine	(1.29, 3.96)***		(0.60, 10.77)***		(0.79, 3.09)**			
Oak-pine	(0.51, 2.34)		(0.03, 4.23)		(0.47, 2.73)			
Up. hardwood	(0.37, 1.41)**		(0.03, 4.23)		(0.26, 1.23)**			
Low. hardwood	Reference level							
Percent softwood	(1.69, 4.35)***	0.03	(1.09, 16.89)**	0.08	(1.37, 4.41)***	0.03	(0.91, 6.99)*	0.03
Ecoregion		<0.01		<0.01		0.01		<0.01
Coastal	Reference level							
Piedmont	(0.66, 1.35)		(0.36, 2.68)		(0.63, 1.5)		(0.41, 2.22)	
Mountains	(0.34, 1.26)		(0.13, 3.73)		(0.10, 1.17)*		(0.42, 3.35)	
Site index	(1.00, 1.03)	<0.01	(0.99, 1.04)	0.01	(0.99, 1.02)	<0.01	(0.98, 1.02)	<0.01
Slope [c]	(0.96, 0.99)***	0.02	(0.94, 1.03)	0.01	(0.95, 1.00)**	0.02	(0.95, 1.00)*	0.03
Stand age	(1.07, 1.25)***	0.02	(0.92, 1.56)	0.03	(1.05, 1.28)***	0.03	(0.96, 1.37)	0.02

Table 4.5. (Continued).

			Owner group					
	All owners		Profit		Multiple-objective		Amenity	
Variable	Odds ratio	R^2[a]	Odds ratio	R^2[a]	Odds ratio	R^2[a]	Odds ratio	R^2[a]
Stumpage value[c]	(1.12, 1.36)***	0.04	(1.04, 1.89)**	0.10	(1.09, 1.39)***	0.04	(0.94, 1.48)	0.02
Softwood sawtimber[c]	(1.20, 1.40)***	0.09	(1.15, 1.79)***	0.19	(1.13, 1.37)***	0.063	(1.14, 1.63)***	0.11
Softwood pulpwood[c]	(1.35, 1.81)***	0.07	(0.91, 1.89)	0.04	(1.29, 1.85)***	0.066	(1.29, 2.64)***	0.10
Hardwood sawtimber[c]	(0.84, 0.98)***	0.01	(0.74, 1.13)	0.01	(0.84, 1.01)*	0.01	(0.76, 1.04)	0.02
Hardwood pulpwood[c]	(0.80, 1.08)	<0.01	(0.60, 1.32)	0.01	(0.75, 1.08)	<0.01	(0.80, 1.67)	0.01
Housing density[c]	(0.63, 0.97)**	0.01	(0.27, 1.03)*	0.07	(0.60, 1.03)*	0.01	(0.59, 1.39)	<0.01
Stand origin	(0.49, 1.35)	<0.01	(0.15, 2.24)	0.01	(0.53, 1.67)	<0.01	(0.04, 2.29)	0.02
Timber production	(0.85, 1.00)*	0.01	(0.79, 1.30)	<0.01	(0.79, 1.00)*	0.01	(0.77, 1.25)	<0.01
Home	(0.39, 0.77)	0.02	(0.06, 1.27)*	0.06	(0.39, 0.96)**	0.02	(0.30, 1.36)	0.01
Farm	(0.68, 1.39)	<0.01	(0.50, 4.27)	0.01	(0.63, 1.49)	<0.01	(0.41, 2.09)	<0.01
Forest holdings[c]	(0.97, 1.17)	<0.01	(0.57, 1.01)*	0.06	(1.01, 1.27)**	0.01	(0.75, 1.22)	<0.01
Income	(1.00, 1.01)	<0.01	(0.98, 1.00)	0.03	(1.00, 1.01)	0.01	(0.99, 1.01)	<0.01
Management plan	(0.96, 2.13)	0.01	(0.71, 5.47)	0.03	(0.84, 2.17)	<0.01	(0.33, 3.33)	<0.01
Advice sought	(0.76, 1.51)	<0.01	(0.32, 2.27)	<0.01	(0.64, 1.52)	<0.01	(0.60, 2.91)	<0.01
Manager	(0.53, 1.37)	<0.01	(0.08, 1.14)*	0.07	(0.60, 1.80)	<0.01	(0.14, 2.90)	<0.01
Green certification	(0.57, 2.30)	<0.01	(0.20, 6.24)	<0.01	(0.54, 2.56)	<0.01	Quasi-complete separation	
Conservation easements	(0.52, 2.08)	<0.01	(0.44, 10.41)	0.02	(0.31, 1.90)	<0.01	(0.26, 6.74)	<0.01
Cost share	(0.93, 1.92)	0.01	(0.39, 2.77)	<0.01	(0.85, 2.04)	<0.01	(0.47, 3.45)	<0.01

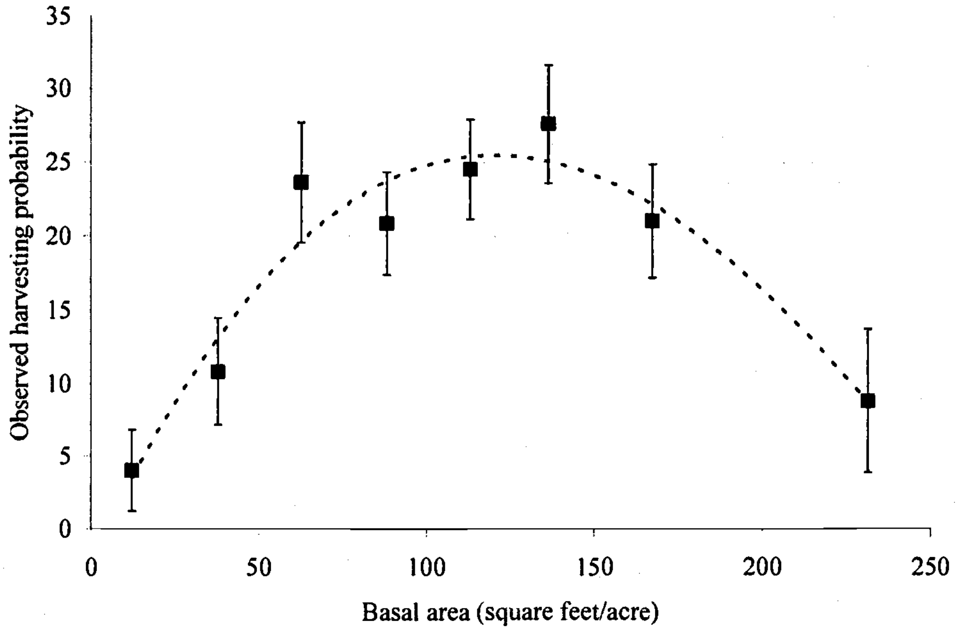
Table 4.5. (Continued).

			Owner group					
	All owners		Profit		Multiple-objective		Amenity	
Variable	Odds ratio	$R^{2\,a}$	Odds ratio	$R^{2\,a}$	Odds ratio	$R^{2\,a}$	Odds ratio	$R^{2\,a}$
Land tenure [b]	(0.84, 1.07)	<0.01	(0.47, 0.97)**	0.12	(0.97, 1.32)	0.01	(0.52, 0.91)***	0.09
Owner age	(0.98, 1.01)	<0.01	(0.93, 1.01)*	0.05	(0.99, 1.03)	<0.01	(0.95, 1.01)	0.02

***p<0.01; ** p <0.05; * p <0.10
[a] Adjusted-R^2
[b] Square-root transformed
[c] Log transformed

With the exception of site index, the biophysical predictor variables produced significant models (i.e., $p < 0.10$) (Table 4.5). The bivariate models with the highest predictive powers and best fits were the stand structure variables (i.e., basal area and volume). The softwood basal area and volume variables had the expected positive relationships to timber harvesting, but the hardwood and combined basal area and volume variables were negatively related. One reason for the this over-all negative relationship is that the relationship is non-linear. For the total basal area, the probability of timber harvesting increases until basal area reaches approximately 125 ft^2/ac and then, the probability of harvesting decreases (Figure 4.6). The hardwood volume and hardwood basal area variables produced negative relationships, indicating an over-all negative relationship between timber harvesting and stands with substantial hardwood components.

Figure 4.6. Observed relationship between probability of timber harvesting and stand basal area for family forest owners in the southeastern United States. Error bars are standard deviations.



The forest type and green certification variables caused quasi-complete separation in the bivariate timber harvesting models for the amenity owners (Table 4.5). For the forest type variable, the problem arose because there were relatively few observations in the planted pine and lowland hardwood forest types (15 and 17 plots, respectively, of the 188 plots owned by amenity owners). Two of these planted pine plots and two of these lowland hardwood plots were harvested. The problem with the green certification variable arose because only 3 of the 188 amenity owners had their forestland green certified. Of the plots on these three owners' forestland, one was harvested.

A lower percentage of the socioeconomic predictor variables produced significant bivariate variable models as compared to the biophysical variables. Of the socioeconomic variables, the stumpage value of softwood sawtimber had the highest predictive power (adjusted-R^2 = 0.09) (Figure 4.7) followed closely by the stumpage value of softwood pulpwood (adjusted-R^2 = 0.07) (Table 4.5). The timber production (Figure 4.8), stumpage value of hardwood sawtimber, housing density, home, management plan, and lease variables produced significant models, but none had a predictive power greater than 0.02. The negative relationship between hardwood sawtimber stumpage values and harvesting was the only unexpected, significant sign associated with the socioeconomic variables.

Figure 4.7. Observed relationship between probability of timber harvesting and relative softwood sawtimber stumpage values for family forest owners in the southeastern United States. Error bars are standard deviations.

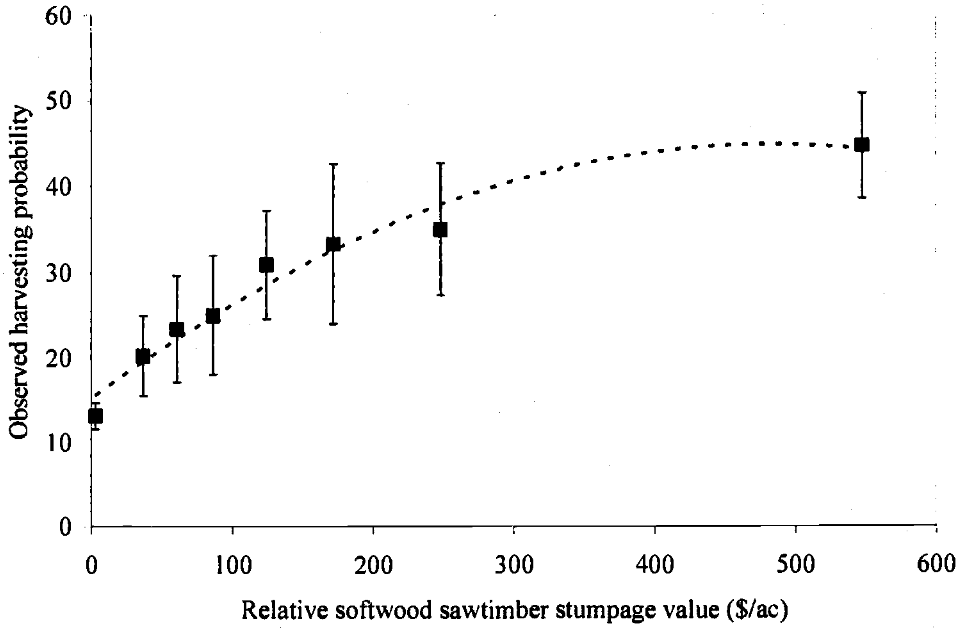
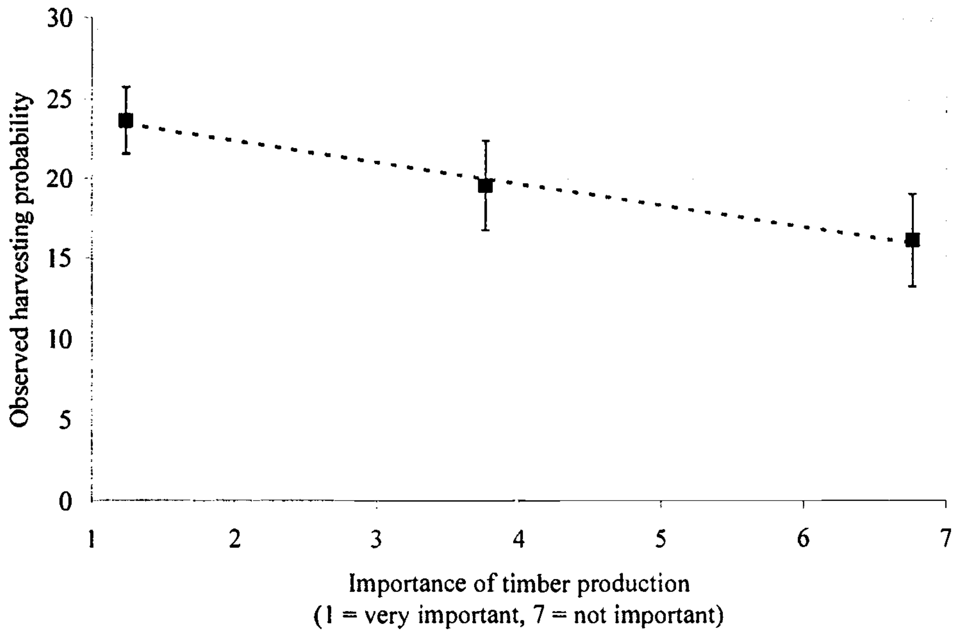


Figure 4.8. Observed relationship between probability of timber harvesting and the importance of timber production for family forest owners in the southeastern United States. Error bars are standard deviations.



Among the owner groups, the directions of the relationships for the significant variables did not differ, but the significance levels did (Table 4.5). For example, the timber production variable was important only in the multiple-objective group model; the home variable was significant in the profit and multiple-objective group models; and land tenure was significant in the profit and amenity group models. The former pattern was, at least partially, a result of how these groups were generated, but the other patterns suggest differences among the owner groups.

Multivariate Logistic Regression Models

Separate multivariate logistic regression models are presented with and without owner groups as "by" variables. The all-owner model was developed first and used as the starting point for the owner group models. The results from the multivariate models are summarized in Table 4.6.

The first variable to enter the all-owner timber harvesting model (i.e., the variable with the highest predictive power) was basal area. Due to multicollinearity, I dropped the other stand structure variables (i.e., volume and stand size). The softwood sawtimber and softwood pulpwood stumpage value variables, and species composition were the other variables retained that incorporated stand structure characteristics without causing multicollinearity. Either forest types or species composition could have been retained, but I retained species composition because it was a continuous variable and, consequently, less likely to cause multicollinearity problems. Table 4.6 lists the variables retained in the final model.

Table 4.6. Ninety-five percent confidence intervals for odds ratios of multivariate logistic regression models of timber harvesting behavior for family forest owners in the southeastern United States

		Owner group		
Variable	All owners	Profit	Multiple-objective	Amenity
Basal area [a]	(0.83, 0.97)**	(0.60, 1.08)	(0.83, 0.99)**	(0.67, 1.07)
Softwood sawtimber stumpage value [b]	(1.11, 1.43)***	(1.08, 2.34)**	(0.99, 1.33)*	(0.93, 1.58)
Softwood pulpwood stumpage value [b]	(1.13, 1.84)**	(0.58, 2.21)	(0.92, 1.58)	(1.21, 3.56)**
Timber production	(0.76, 0.99)**	(0.60, 1.40)	(0.70, 1.03)*	(0.54, 1.11)
Home	(0.27, 0.74)**	(0.01, 1.14)*	(0.25, 0.90)**	(0.15, 1.37)
Slope	(0.96, 1.01)	(0.95, 1.08)	(0.92, 1.00)*	(0.98, 1.04)
Stand origin	(0.36, 1.69)	(0.02, 2.18)	(0.29, 1.52)	(0.02, 10.38)
Farm	(0.79, 2.22)	(0.05, 5.12)	(0.72, 2.60)	(0.66, 6.66)
Income	(0.99, 1.00)	(0.97, 1.00)*	(0.99, 1.00)	(0.97, 1.00)*
Management plan	(0.68, 2.49)	(0.76, 37.75)*	(0.46, 1.93)	(0.10, 4.87)
Green certification	(0.57, 3.11)	(0.27, 56.90)	(0.72, 4.73)	(<0.01, 20.05)
Professional management	(0.36, 1.37)	(0.02, 0.89)**	(0.32, 1.45)	(0.13, 13.81)
Conservation easement	(0.45 2.37)	(0.08, 18.59)	(0.43, 3.26)	(0.31, 22.71)
Species composition	(0.21, 1.07)*			
Advice	(0.31, 1.06)*			
Cost-share	(0.62, 2.05)			
Adjusted - R^2	0.47	0.57	0.46	0.60
Sample size (n)	462	58	295	118

***$p < 0.01$, ** $p < 0.05$, * $p < 0.10$
[a] Square-root transformed
[b] Log transformed

Of the retained variables, basal area, softwood sawtimber stumpage value, softwood pulpwood stumpage value, timber objective, and home accounted for 85 percent of the predictive power of the all-owner model and had the same signs as the bivariate models. The two other significant variables – species composition and advice – had the opposite signs as their respective bivariate models.

The owner group models had the same variables as the all-owners model except that species composition, advice, and cost-share were dropped due to multicollinearity issues, primarily in the profit group model. The amenity group model had the highest predictive power (*adjusted-*R^2 = 0.60) followed by the profit group model (*adjusted-*R^2 = 0.57) (Table 4.6); the multiple-objective group model had a substantially lower predictive power (*adjusted-*R^2 = 0.46). In the amenity group model, only softwood pulpwood stumpage value and income variables were significant (Table 4.6). Softwood sawtimber stumpage value, home, income, management plan, and professional manager were significant variables in the profit group model, but professional manager had an unexpected negative relationship. The multiple-objective group model had timber objective, home, slope, and green certification as significant variables, all with the expected signs.

4.7. Summary

The empirical observations provide support for some aspects of the theoretical model, provide new insights, and reveal new questions. I will mention some of the key findings here, but I withhold discussion for subsequent chapters.

The theoretical model posited that family forest owners could be divided into three groups. I presented an empirical method for accomplishing this task, which supported this supposition and showed some of the advantages of doing so.

The descriptive statistics provided a basic understanding of family forests and family forest owners in the Southeast. Many of these attributes varied substantially among the owner groups. Family forest owners were older than the general population (Butler and Leatherberry 2004) and most had owned their forestland for relatively long periods of time. They were willing to conduct forestry activities, such as harvesting timber, but most of them had not invested in written management plans and only about half had sought forest management advice (Table 4.4).

There is a substantial amount of timber on the forestland owned by family forest owners, but the composition, structure, and history varies appreciably. Upland hardwood forest types and hardwoods in general dominate the landscape (Table 4.3).

As would be expected, the forest owners with the greatest interest in timber production had the greatest concentrations of pine plantations and, more generally, softwoods.

The bivariate and multivariate models supported the findings of previous research and provided additional insights. By combining forest and forest owner survey data, the importance of biophysical and socioeconomic factors could be effectively addressed. Over-all, the biophysical variables had higher predictive powers, but many of the socioeconomic variables were significant, especially in the owner group models (Table 4.5). The stand structure variables (e.g., basal area and volume) had exceptionally high predictive powers. The coefficients for these variables had negative signs for the total and hardwood components, but positive signs for the softwood components.

Many of the predictor variables were correlated with each other and 22 of the original 38 variables had to be dropped because of multicollinearity or other problems. Of the significant variables retained in the final model, two were biophysical variables (basal area and species composition), three were socioeconomic (timber objective, home, and management advice), and two were combinations (softwood sawtimber and softwood pulpwood stumpage values) (Table 4.6). In the final, multivariate model for all family forest owners, the coefficients for 9 of the 16 variables were not significantly different than one. The importance and significance of these variables varied considerably among the forest owner groups.

5. Aggregating the Individual-Choice Model

Using data sources based on random samples allows the results of the models presented in Chapter 4 to be aggregated with a high degree of confidence. I aggregated results of the individual choice model at a level that was previously only feasible for traditional aggregate timber harvesting models (e.g., Adams and Haynes 1996, Abt et al. 2000). Aggregated individual-choice models allow for analysis of an unprecedented level of detail.

5.1. Timberland Availability

One of the 67 indicators of forest sustainability included in the Montreal Process Criteria and Indicators, indicator 2.a, is the availability of forests for the production of timber (U.S. Forest Service 2004). This topic is related to timber supply and a nation's ability to meet its own solid wood and wood fiber consumption demands.

Over a given period of time, only a portion of forestland will be harvested in a country. Traditionally, forest sustainability assessments in the United States [e.g., Renewable Resource Planning Act Assessment (Haynes 2003)] have made unsubstantiated assumptions about the availability of forestland for harvesting. The probability of timber harvesting will vary according to biophysical and socioeconomic factors (Chapters 3 and 4). Traditional timber supply models examine aggregate measures of forest resource conditions, but make little use of social data beyond market values and broad owner classes (e.g., Prestemon and Abt 2002b, Haynes 2003). A more detailed examination of the interactions among biophysical and socioeconomic factors through the study of individuals' choices, such as Chapter 4, will increase our understanding of timber harvesting behavior and allow for more insightful assessments of timber supply and forest sustainability.

Very little family forestland will be permanently removed from the timberland availability pool unless it is converted to another land use, but the harvesting rates and intensities will be altered. The economic threshold for harvesting may be very high, but it is still conceivable that trees will be harvested. For example, the primary reason for having trees in subdivisions is rarely, if ever, to generate income from timber sales, but many of the trees will eventually be removed. If the trees are to generate income for the owners and be transformed into forest products depends, in part, on the quality of the trees (e.g., decay and growth form) and markets. Income received by the forest owners will be further influenced by the extraction costs and their knowledge of fair-market timber values.

5.2. Timber Flow Scenarios

The flow of timber from family forestland is being altered and has a direct impact on timber availability and regional and national timber supplies. Due to the systematic sampling design, the results of the models presented in Chapter 4 can be aggregated to address this issue. The potential impacts of shifts among owner groups, increased numbers of primary residences associated with forestland, and increased stumpage values were examined. Explicit policy tools, such as cost-share, were not examined because they were not found to be significantly related to harvesting.

These analyses can be thought of as sensitivity analyses. In this sense, the sensitivity of the models were tested in relation to key attributes.

Methods

The results from the individual-choice timber harvesting models (Table 4.6) were used to test the influence of three, hypothetical scenarios on the flow of timber from family forests in the southeastern United States. Each owner group was modeled and predicted separately with the 1/5 ac forest inventory plots as the units of analysis. By multiplying the coefficients by the variables, the odds of each plot being harvested were predicted (Equation 5.1). The probability of harvesting was calculated as the odds divided by one plus the odds, $p = \frac{o}{1+o}$.

(Equation 5.1) $$O_g = \beta_g X_g$$

> where O_g = a vector of predicted odds of timber harvesting for owner group g, B_g = a vector coefficients for owner group g, and X_g = a matrix of variables for family forest owners in owner group g.

To transform the predicted probabilities into discrete values, I assumed that plots owned by amenity owners with probabilities of at least 0.2, plots owned by multiple-objective owners with probabilities of at least 0.35, and plots owned by profit owners with probabilities of at least 0.25 were harvested. These thresholds were selected to make the owner group harvesting probabilities for the base case scenario similar to the observed probabilities [i.e., 29 percent for the profit group, 20 percent for the multiple-objective group, and 18 percent for the amenity group (Chapter 4)].

The area-frame sampling design (U.S. Forest Service 2003) allowed the predictions to be extrapolated to the population of interest (i.e., family forests in the southeastern United States). The volume harvested by each owner group was determined by summing the observed volume of timber removed per plot, summing the volumes by owner group, and dividing by the total observed volume harvested on all family forestland. These proportions were then multiplied by the total volume of trees harvested from family forests in the southeastern United States to determine total volumes harvested per owner group. Alternatively, each plot could have been assigned an expansion factor based upon the acres it represented and thus expanded to the region (Alerich et al. 2004).

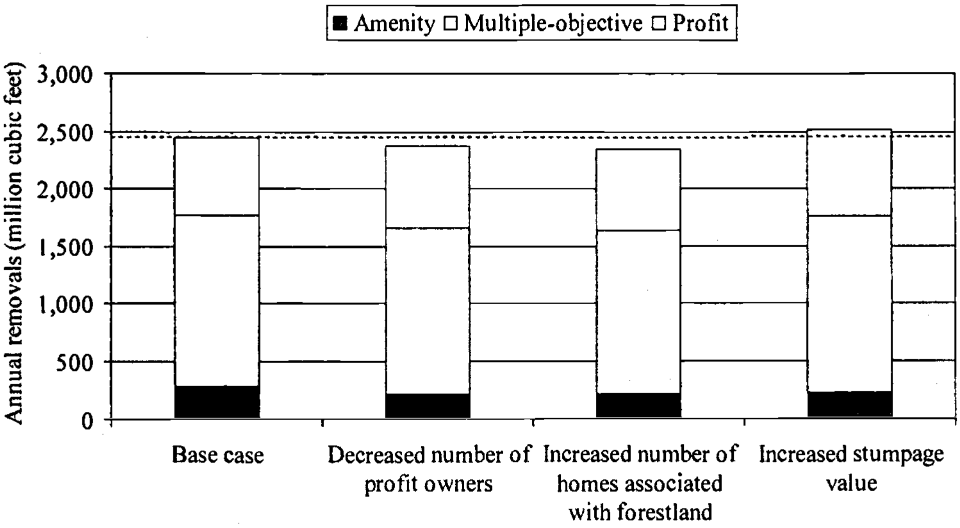
In addition to the base case, three other scenarios were tested: shifts among owner groups, increased association of forests with primary residences, and increased stumpage values. For the base case or unperturbed scenario, the variables were identical to the ones used to estimate the models (Chapter 4). For the owner group shift scenario, 10 percent of the profit owners' plots and an equal number of the multiple-objective owners' plots were randomly selected and were recoded as multiple-objective and amenity owners' plots, respectively. This changed the coefficients associated with the recoded plots. In addition, the social variables for the shifted plots were assigned the mean value of the new group; the biophysical and stumpage price variables were not altered. To mitigate the impact of the random selection process, the analysis was repeated 25 times and means were calculated.

Primary residence and increased stumpage value scenarios were more straight forward than the shifts among the owner groups. For the former, the number of plots owned by people with primary residences within one mile of their forestland (i.e., the home variable) were increased by 5 percent. This was simulated by randomly recoding an appropriate number of plots not associated with primary residences, repeating this process 25 times, and calculating the means. Stumpage values were increased by increasing the softwood sawtimber stumpage variable by \$1.65, $\exp(0.5) = 1.65$, and predicting the harvesting probabilities. Multiple iterations were unnecessary for this last scenario because no random selection processes or other random functions were used.

Results

In 2001, timber removals in the southeastern United States totaled 4,363 million ft^3 (Smith et al. 2004). Family forest owners control 56 percent of the forestland in the Southeast and they contribute an equal amount of the region's timber supply (USDA Forest Service, Forest Inventory and Analysis, unpublished data on file with author); timber removals from family forests in the Southeast totaled an estimated 2,443 million ft^3 in 2001. Contributions to this supply are disproportionate among the family forest owner groups. The owners in the profit group controlled 10 percent of the family forestland and contributed 14 percent of the timber supply. Owners with multiple objectives contributed 64 percent of the timber supply and owned 65 percent of the family forestland. The amenity owners contributed 20 percent of the annual harvest, but controlled 24 percent of the family forestland (Figure 5.1).

Figure 5.1. Summary analyses testing the effect of different scenarios on annual timber removals from family forests in the southeastern United States by scenario and owner group



Based on these analyses, shifts in the amount of forestland controlled by owners in each of these groups will impact the flow of timber. Over the past decade, the relative importance of amenity values has increased, while those associated with timber production have decreased (Butler and Leatherberry 2004). A continued decrease in the number of family forest owners with profit motivations seems likely, as does an increase in the number of owners with purely amenity objectives. A 10 percent decrease in the area of forestland owned by family forest owners with profit owners in the Southeast and an equal increase in the area of forestland owned by family forest owners with primarily amenity motivations, will reduce the timber flow from family forestland by three percent or 72 million ft^3 per year (Figure 5.1).

Similarly, an increase in the number of owners who have their homes associated with their forestland will decrease timber flow. The odds of harvesting trees for people with their homes associated with their forests is, on average, 55 percent lower than for absentee owners (Table 4.6). If the amount of forestland owned by family forest owners in the Southeast with homes associated with their forestland were to increase by five percent, the annual timber harvest would be reduced by an estimated 99 million ft^3 or four percent of the family forest harvest in the Southeast (Figure 5.1).

One factor that would increase the flow of timber is an increase in softwood sawtimber stumpage prices. For a \$1.65 ($e^{0.5} = 1.65$) increase in the average softwood sawtimber stumpage value, the odds of harvesting would increase, on average, by 13 percent. This amount of an increase would cause a three percent increase in the timber flow from family forests in the Southeast (77 million ft^3/year) (Figure 5.1). This substantial increase is likely to be fully realized only if the increase is immediate and temporary (Prestemon and Wear 2000).

These analyses are contingent upon numerous assumptions. Simply stated, the scenarios assume *certis plarabus* or all else remaining constant. This is not a plausible assumption, but it does allow for the implications of the results of the timber harvesting models to be applied to relevant scenarios.

5.3. Other Factors Influencing Timber Supply

Timber harvesting is but one factor that influences timber supply. Land use change and reforestation trends will also impact it. Urbanization is the leading cause of forest loss in the southern United States (Wear and Greis 2002) and large-scale shifts between forest and agricultural land uses, including losses and gains in both directions, are also occurring (Alig et al. 2003). Specific patterns of land use change vary across the region (Prestemon and Abt 2002a). The northern and western portions of the southern United States were projected to gain forestland due to large-scale abandonment of agricultural land and losses of forestland to urbanization were projected to be concentrated in the Piedmont region.

The area of pine plantations, particularly on forest industry lands, is projected to increase for the foreseeable future (Prestemon and Abt 2002b, Alig and Butler 2004). Given the fact that pine plantations provide a disproportionate share of the region's forest growth and timber supply, this is a key assumption in projecting future timber supplies. The published studies that examine reforestation practices (see review in Alig et al. 1990) suggest significant room for increased productivity (Fecso et al.

1987, Alig and Butler 2004). Reforestation has been found to be positively correlated with pulpwood prices, knowledge of cost-share programs, household income, and technical assistance and negatively correlated with reforestation costs and the owner being a farmer. For encouraging reforestation practices, cost-share programs have been found to be effective (Fecso et al. 1987, Royer and Moulton 1987).

6. Discussion

Human nature can be modified to some extent, but human nature cannot be changed.

– Abraham Lincoln

In the previous chapters, I presented theoretical (Chapter 3) and empirical (Chapter 4) timber harvesting models for family forest owners. The results from these models were largely consistent with previous research (Chapter 2), but significant new insights were developed. The major findings include the theoretical and empirical support for the segmentation of family forest owners into amenity, multiple-objective, and profit groups and the identification of biophysical (e.g., basal area) and socioeconomic (e.g., stumpage value and ownership objectives) variables that are significant predictors of timber harvesting behavior. The union of broad-scale forest inventory and forest owner survey data was a strength of the empirical models, but, as discussed below, there are many modifications that can be incorporated in future research to further improve our understanding of the harvesting behavior of family forest owners.

Some other interesting findings were related to land tenure, family legacy, and owners' ages. The average land tenure for family forest owners in the Southeast was 29 years (Table 4.4). The long tenure may be related to the importance of family legacy and the relatively advanced age of many family forest owners (Butler and

Leatherberry 2004). Sixty-nine percent of the family forest owners in the Southeast rated family legacy as important (Likert value of 1 or 2) and 20 percent of the family forestland is owned by people 75 years of age or older (USDA Forest Service, National Woodland Owner Survey, unpublished data on file with author). Although ownership has been relatively stable, the advanced age of many forest owners portends large-scale land transfers in the near future. This observation is supported by the 28 percent of the owners who reported planning to sell or transfer some or all of their forest land in the next five years (USDA Forest Service, National Woodland Owner Survey, unpublished data on file with author). Many forest owners want to preserve their family legacies, but they are worried about their ability to do so; sixty-four percent of the owners rated "keeping land intact for [their] children" as a major concern. These patterns have important implications for harvesting and other forest ownership attributes. Will the next generation of family forest owners behave like the current one?

One thing that is lacking from the empirical models presented in Chapter 4 is validation of the empirical findings. Some sensitivity analyses are presented in the context of the policy analyses in Chapter 5, but more validation is needed to verify the findings. In this context, the results of the empirical models should be treated as preliminary findings. After a larger sample size is coalesced (and the data can be effectively divided into model and validation sets) or models are constructed for multiple regions, validation tests can be conducted.

6.1. Owner Groups

Classifying family forest owners into profit, multiple-objective, and amenity groups based on their ownership objectives is supported by the findings from the theoretical model (Chapter 3), empirical results (Chapter 4), and previous studies (e.g., Kuuluvainen et al. 1996). The theoretical explanation for these groups was derived by using a utility maximization model with a perfect substitutes functional form to model the individual choices of family forest owners. The groups exist along the profit-amenity continuum, so specific breakpoints between the groups are arbitrary. Although previous studies have used similar theoretical models (e.g., Kuuluvainen et al. 1996), my study provides the first explicit, theoretical justification for grouping family forest owners.

The empirical data and models (Chapter 4) support the existence of these three groups of family forest owners. As would be expected, the starkest differences were between the owners in the profit and amenity groups. Twenty-nine percent of the plots owned by people classified as profit owners were harvested versus 18 percent for the amenity group. The forestland owned by people in the profit group was more likely to be planted pine forests and, correlated with this trait, tended to have a higher proportion of softwoods (Table 4.3). The forests of the amenity-oriented owners tended to be older and have larger trees and more hardwoods (Table 4.3). The profit-oriented family forest owners were less likely to have their homes associated with their forestland and more likely to have written management plans and to have sought forest management advice (Table 4.4). In general, the traits of the multiple-objective owners were intermediate to the other two groups.

Differences were also apparent among the owner groups in the logistic regression models (Chapter 4). Softwood sawtimber stumpage value, home, income, management plan, and professional advice were significant variables in the multivariate model for the profit group (Table 4.6). Basal area, softwood sawtimber stumpage value, timber production, home, and slope were significant in the model for the multiple-objective group (Table 4.6). For the amenity owners, softwood-pulpwood stumpage price and income were significant (Table 4.6).

Segmenting family forest owners into profit, multiple-objective, and amenity groups is also supported by previous research. Although the specific names varied, owner groupings similar to those found in the southeastern United States were identified in Missouri (Kurtz and Lewis 1981), Wisconsin (Marty et al. 1988), Arkansas (Walkingstick et al. 2001), western Oregon and western Washington (Kline et al. 2000), and Finland (Kuuluvainen et al. 1996). The proportion of owners in a given group varied appreciably among the study areas.

Segmenting family forest owners into subgroups has important implications for timber harvesting models and many other forestry issues, such as communicating with family forest owners. The objective of timber harvesting models is to increase our understanding of forest owner behavior; by identifying more homogeneous groups, researchers can generate more accurate models. In areas such as forest policy and forestry extension, programs can be targeted to better meet the needs and objectives of a wider range of family forest owners than has been traditionally possible.

6.2. What Controls Timber Harvesting Behavior?

Timber harvesting is the result of interactions among biophysical and socioeconomic processes. Ideally, these interactions would be captured in one or a series of equations and sufficient information could be collected to empirically test them. The complexity of these interactions and our current state of knowledge makes fully obtaining this goal unlikely.

The theoretical model, presented in Chapter 3, posited that the timber harvesting behavior of family forest owners was controlled by the value of the amenities and profits that forests provide. The functional form of the model combined elements of the models proposed by, among others, Hartman (1976) and Kuuluvainen et al. (1996). By extending their models, I was able to theoretically differentiate among groups of family forest owners.

The amenity and profit values were further posited to be influenced by biophysical and socioeconomic factors. Evidence from the empirical models (Chapter 4) supports this assumption and that interactions among these factors vary according to their preferences for profits and amenities (i.e., vary among owner group).

Stand structure variables were the strongest predictors of timber harvesting behavior (Table 4.5). This finding is consistent with previous research (e.g., Løyland et al. 1995, Prestemon and Wear 2000), but it is difficult to fully compare my study with previous research because previous research has not united biophysical and socioeconomic factors as fully. The stand structure attributes (Table 4.3) described broad constraints on what was available for harvesting and, hence, were expected to be significant predictors.

The stand structure metrics indicated divergent patterns depending on the species groups – hardwood, softwood, or all – examined (Table 4.5). The hardwood and combined variables were negatively related to timber harvesting; for example, as (the square root of) the hardwood volume increased, the probability of harvesting decreased. Square-root transformations imply that relationships are more dramatic for smaller values of the predictor variables than for larger values.

The opposite patterns were observed for the softwood-specific versions of these variables. Due to the higher value of softwoods, particularly sawtimber, owners should be more responsive to financial incentives that are associated with softwoods. Hardwoods are less likely to be harvested and more likely to have some aesthetic and wildlife values that are not associated with the softwoods. The hardwood stumpage values were also somewhat misleading because they did not account for the fact that softwoods represent two-thirds of the region's timber harvest (Smith et al. 2004) and softwoods were, thus, easier to market.

As was expected, the higher that forest owners rated timber as an ownership objective, the more likely it was that they had harvested trees during the remeasurement period (previous seven years) (Figure 4.8). These owners also had higher concentrations of softwoods on their forestland. The observations for the softwood variables are more consistent with previous research than the observations for hardwoods. This may be related to the limited scope of previous studies (e.g., Prestemon and Wear 2000) and different regions examined (e.g., Dennis 1989).

Having homes associated with forestland or forestland being located in areas of relatively high housing density were negatively related to harvesting (Table 4.5). The negative relationship with housing densities is consistent with studies that examined the relationships between harvesting and road distance (Løyland et al. 1995) and population densities (Wear et al. 1999). Due to personal, social, and economic factors these forest owners will place increased importance on amenities.

Løyland et al. (1995) and Jamnick and Beckett (1988) found positive relationships between harvesting with homes associated with forestland, but these studies were conducted in Norway and New Brunswick, Canada, respectively, where cabins and vacation homes may be more important than in the southeastern United States. The negative relationship with homes in the Southeast seems reasonable because these forest owners would like be more interested in aesthetics, privacy, and other amenities that are, presumably, negatively related to harvesting.

Underlying Forces

The models presented above (Chapters 3 and 4) and previous research (Chapter 2) provide support for variables that are correlated with timber harvesting behavior, but as with most modeling efforts, the ultimate causal factors are not discernable.

Demographics and other social pressures exert enormous pressures on family forests and family forest owners. The extent and nature of these pressures varies greatly across the nation. Population density has been shown to be negatively related to timber availability (Wear et al. 1999). Near major population centers, urbanization is pushing the influence of urban and suburban populations further into rural landscapes (Egan and Luloff 2000). More homes in the forests are increasing the interface between wildland and developed land uses and complicating forest management practices (Macie and Hermansen 2002).

Environmental paradigms have been shifting in the United States since the environmental movement that began in the 1960s. An increasing percentage of owners are more interested in the "preservation" (i.e., no consumptive use) of the forests rather than the "wise-use" or conservation (i.e., consumptive uses that meet people's needs without harming the long-term health and sustainability of the forests) of these lands. The public's increasing expression of NIMBY (Not in My Backyard) sentiments is one factor leading to a disconnect between wood fiber demand and supply in this county. This paradigm shift also has influenced the shift in forest management from sustained-yield or multiple-use forestry to new forestry or forest ecosystem management (Bengston 1994).

At the micro-scale, many of the causal factors are sociological, psychological, financial, or a combination thereof. Family legacy is an important objective and a primary concern of many family forest owners. Sixty-nine percent of the forest owners rated family legacy as important (Likert value of 1 or 2) and 64 percent of the owners indicated that keeping land intact for their heirs was a great concern (Likert value of 1 or 2) (UDSA Forest Service, National Woodland Owner Survey, unpublished data on file with author). Many harvesting decisions are influenced by the owners' personal financial situations. Using forests as a cash reserve is a common ownership objective (Blatner and Greene 1989) and harvesting is less likely if forest owners do not have a financial need (Løyland et al. 1995). It is assumed that many forest owners commercially harvest trees relatively rarely and hence are unaware of the full value of their forests. These factors combine so that many forest owners apparently "buy high and sell low."

Why are Trees Retained Past Financial Maturity?

The trends for profit-maximizing owners to harvest stands at financial maturity prior to biological maturity (i.e., the culmination of mean annual increment) is well documented (Hartwick and Olewiler 1997), but the factors leading to retention of trees beyond biological maturity have been less rigorously addressed. This is at least partially attributable to the fact that the former trend can be explained using standard and widely accepted economic models, but the latter requires the synthesis of broader concepts (e.g., amenity values) and is less well grounded in economic theories or at least applied economic models.

Along with factoring in amenity values, researchers' abilities to model the financial value of stands are limited. Insufficient information is available to fully account for differences in tree quality and quantity, local markets, extraction costs, transportation costs, transaction costs, tax structures, and forest owners' knowledge, preferences (e.g., willingness to clear cut), and personal experiences.

In addition to having limited knowledge on how to include amenity values, temporal changes in the relative importance of amenity and profit values may need to be examined. Some forest owners may harvest trees due to unforeseen financial needs (e.g., health care costs). Forest owners who do not have explicit financial motivations for owning their forests still appreciate and value the ability of the forestland to act as a capital investment that can be drawn down in times of need (Blatner and Greene 1989). These unplanned needs can be modeled as stochastic events (e.g., Provencher 1995), but this factor needs to be addressed in fuller detail in future research. Unfortunately, many of the approaches for modeling stochastic events require the decision process to be relatively simple and constant across the population of interest in order for the model to be computationally feasible. This is one reason that Provencher (1995) limited his investigation to timber harvesting on slash pine stands with site indices between 60 and 70 owned by the forest industry in southeastern Georgia.

When family forest owners harvest trees, they often report multiple (i.e., concurrent or overlapping) reasons for harvesting. The most common reason cited for why trees were harvested in the Southeast was that "the trees were mature"; fifty-five percent of the family forest owners cited this as a reason for harvesting (UDSA Forest Service, National Woodland Owner Survey, unpublished data on file with author). Other common reasons why trees were harvested ($\geq$ 25 percent of the respondents who had harvested trees) were to improve the quality of the remaining trees, that it was part of their management plan, they needed money, price was right, and to salvage trees that were damaged by natural disturbances. These findings are supported by other studies (e.g., Fecso et al. 1987), but the criteria used to assess what family forest owners mean by mature have not been investigated.

6.3. Improving Timber Harvesting Models

The models and conclusions presented in this dissertation represent an advance in timber harvesting models, but there are numerous innovations that will provide further advancements. The theoretical model (Chapter 3) was a modification of previous models (e.g., Hartman 1976 and Kuuluvainen et al. 1996). I used this model as a basis for segmenting family forest owners into groups, but I was unable to address the persistent question about the shape of the amenity curve.

Ultimately, empirical data are needed to determine the shape of the amenity curves. Direct (e.g., contingent valuation) or indirect (e.g., expenditure function approach) methods could be used to assess the value of these non-market goods (van Kooten 1993). Direct methods involve asking forest owners to place a monetary value on levels of specific amenities. This approach has been used for many non-market goods (Bateman and Willis 1999), but is hampered by it being based on hypothetical scenarios. By measuring the effect of the non-market goods on market goods, indirect assessments can be made.

The strength of my empirical models (Chapter 4) was rooted in the robust sampling frame that allowed me to combine biophysical and socioeconomic variables and to aggregate the results (Chapter 5). I, as many previous researchers, examined harvesting as a binary phenomenon and ignored the issue of harvesting intensity. Treating harvesting as a discrete choice was not a limitation of the individual choice approach, but a limitation of the statistical model I selected. Censored regression (e.g., Dennis 1989, Kuuluvainen et al. 1996) has been used to model harvesting intensity, but the results of logistic regression are simpler to interpret and are satisfactory for many research objectives. Supporting the use of logistic regression, Dennis (1989) found that acres offered for sale was more important to timber supply than harvesting intensity.

Results based on forest and forest owner surveys need a sufficient sample size to be reliable – the power of the resulting statistics and models is a function of sample size, population variability, the magnitude of the pattern being examined, and desired degree of reliability (Fisher and van Belle 1993). For example, it is inappropriate to use FIA data to make inferences for individual counties, let alone individual forest owners, but using FIA data to examine a multi-state region should provide a robust dataset. The FIA inventory plots occupy only a fraction of each forest owner's total forest holdings, but the randomly selected plots are assumed to be an unbiased, although far from inclusive, representation of a forest owner's total forest holdings. This assumption is strengthened as the sample size increases.

Calculation of realistic stumpage values was difficult and the values that I produced more closely represented relative, rather than real, values (Chapter 4). Stumpage prices are generally available from cross-sectional data sources. The idiosyncrasies of species composition, tree quality, volumes harvested, harvesting constraints, local markets, landowners' forestry and marketing knowledge, and their willingness to perform specific silvicultural practices (e.g., clear-cutting) are masked by cross-sectional data. Ideally, stumpage values would be modeled based on individual timber sales and adjusted for the stands of interest. Geographic information systems (GIS) can be used to, at least partially, address some of these deficiencies (e.g., transportation and extraction costs). Accurately modeling the attributes necessary to calculate stumpage values is not a trivial task.

Another use of GIS would be to improve the estimation of housing densities. I used county-level housing density levels, but these data ignored variability within a county. These data could be improved by using more detailed Census subdivisions (e.g., Census blocks) or actual structure counts. A detailed GIS layer depicting locations of houses (or densities) could be used to calculate housing densities around each sample point.

Sampling Units: Forests vs. Forest Owners

A topic that, to my knowledge, has not been discussed in previous timber harvesting studies is the influence of what or who is being sampled and analyzed. Most studies have used data from either area-based forest inventories or forest owner surveys. For models that use the former source, forests are the sampling units; it is forest owners for the latter. Models will differ in the definitions and availability of dependent and independent variables depending on the units of analysis. Traditionally, area-based models captured more of the biophysical variables and owner-based models captured more of the socioeconomic attributes.

The results of the models vary significantly depending on the units of analysis. For example, the harvesting propensities using owner-based data are appreciably higher than those for area-based data (Table 6.1). The area-based harvesting percentages were taken from Chapter 4 and the owner-based harvesting percentages were based on the percentage of family forest owners who reported harvesting sawlogs or pulpwood in the previous 5 years (USDA Forest Service, National Woodland Owner Survey, unpublished data on file with author). The differences are based, in part, on the fact that only a portion of a forest owner's forestland is examined in the area-based models and owner-based surveys cover all of the forestland in an ownership. Although the percentages are higher for the owner-based data, the general patterns are congruous (Table 6.1).

Table 6.1. Percentage of family forests classified as harvested and family forest owners classified as harvesters in the southeastern United States by owner group and data source

	Owner group		
Data source	Profit	Multiple objective	Amenity
Forest inventory	29	20	18
Forest owner survey	42	38	19

The appropriate units of analysis depend on the research objectives and will be constrained by data limitations. Ideally, studies would combine data from both sources. Dennis (1989), Kuuluvainen and Salo (1991), Prestemon and Wear (2000) and the models presented in Chapter 4 included, to varying degrees, biophysical and socioeconomic variables. Volume was the only biophysical predictor variable used by Kuuluvainen and Salo (1991) and road distance was the only socioeconomic predictor variable used by Prestemon and Wear (2000). Prestemon and Wear (2000) limited their study to pine plantations in the Coastal region of North Carolina. Dennis (1989) was the most successful of the previous studies to unite biophysical and socioeconomic variables, but the sample size used in the study was small (n=68), limited in scope (New Hampshire), lacked a strong stumpage value variable, and included only demographic social variables. The study could have been improved had it also included ownership objectives or management practice variables.

7. Conclusions

Private Forests Do the Public Good.

- Anonymous

As a result of lower timber harvests on Federal lands, transfer of millions of acres of forest industry landholdings to other private (including families and individuals) owners, and increasing influences from the wildland-urban interface, the role of family forests in the United States has been evolving. Forests fulfill life support, economic, scientific, recreational, aesthetic, wildlife, biotic diversity, natural history, spiritual, and intrinsic roles (Rolston and Coufal 1991) and the burden for providing these goods and services is being increasingly placed on the 10 million families and individuals who control 42 percent of the nation's forestland (Butler and Leatherberry 2004).

Timber harvesting is the most financially important activity on forestland, but generation of revenue is but one benefit provided by forests. Regardless of the economic (i.e., profit and amenity) value of forests, timber harvesting is the primary means by which working forests are sustained and is the most important disturbance activity occurring on forestland in the United States.

The theoretical and empirical models presented in Chapters 3 and 4 provide new insights into the timber harvesting behavior of family forest owners. Family forest owners are utility maximizers; their harvesting decisions are a result of the current and prospective amenity and financial values they expect to receive and the relative weights they assign to these values. Using a perfect substitutes functional form, forest owners' were shown to fall into amenity, multiple-objective, and profit owner groups (Chapter 3). The concept of separating forest owners according to ownership objectives was reinforced by the empirical findings in Chapter 4.

The timber harvesting behavior of family forest owners is a complex process determined by interactions among biophysical and socioeconomic factors. In the short-run (i.e., a relatively short time period with major inputs, such as land, held constant), forest attributes set the general constraints on what can be harvested. Given the constraints imposed by forest attributes and society (e.g., regulations and social norms), forest owners react to market forces by optimizing the utility or satisfaction they receive from owning forestland. Utility is derived from two broad bundles of goods and services – profits and amenities (Chapter 3). Forest owners manage their forests to balance the production of these bundles.

The models I developed are short-run models describing the harvesting decisions of family forest owners at a given point in time holding inputs constant. A next step could be to transform these models into long-run, dynamic timber supply models that allow land use, forest management practices, forest characteristics, and social factors to vary. Forest characteristics, such as basal area or volume, can be estimated using existing stand growth models. Some social factors, such as housing density, can be projected and other characteristics will have to be dealt with through assumptions and simulation testing. The intensity of forest management (e.g., whether the stand will be artificially or naturally regenerated) will need to be modeled or accounted for using assumptions based on empirical observations. The land use of the given plot is the first variable that needs to be determined and this information can be modeled separately or in tandem. To couple all of this disparate models and assumptions, a series of individual-choice models can be created and then solved through iterative interactions. Individual-choice and aggregate model could also be combined. If it proves more desirable to have one combined model, dynamic programming is an option (e.g., Provencher 1997). Although, in its current state, this dynamic programming can only handle relatively simplistic models and this simplification is very troubling for modeling the behavior of family forest owners.

The amenity and profit bundles are valued differently by each forest owner and based on the relative weightings of these bundles, three broad groups are differentiable – profit, multiple-objective, and amenity oriented owners (Chapter 3). The characteristics of the forest owners, the forestland that they own, and their harvesting behaviors differ substantially among these groups. Shifts among the owner groups and changes within them will affect the flow of timber from the land they own and have important consequences for timber supply (Chapter 5).

Increased information about family forest owners is necessary to make informed decisions about the nation's forest resources and design, implement, and monitor effective programs to help private forest owners meet local and national needs. More studies are needed that integrate socioeconomic and biophysical variables within an individual-choice framework for different regions of the country. And for this information to be most useful, the results need to be able to be aggregated to draw conclusions for broad areas. The pairing of forest inventory and forest owner surveys by the USDA Forest Service provides the necessary platform for this aggregation to be accomplished. Additional research is also needed to further refine the profit, multiple-objective, and amenity groupings, increase our understanding of amenity values, develop more sophisticated methods for estimating stumpage values, incorporation of more spatial and temporal attributes, and the integration of individual-choice harvesting, reforestation, and land use models.

The sustainability of America's forest resources is dependent upon the sustainability of family forests (Butler and Leatherberry 2004). The heterogeneity among family forest owners is a great national asset that helps ensure the production of a wide range of forest goods and services (Larson 2004); this heterogeneity represents an opportunity and a challenge to the forestry community. Family forest owners are facing increasing challenges from population pressures, changing social paradigms, and foreign markets. Forests will remain a dominant feature of the nation's character, but what these forests produce and who receives their bounty is changing. The forestry community and forest policies must also change to meet these new demands and challenges.

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