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HUMAN DIMENSIONS OF PRIVATE FORESTLAND OWNERSHIP:
SAMPLING, ESTIMATION, DECISION MAKING PROCESSES, AND IMPLICATIONS

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ABSTRACT

Private forest landowners (PFLs) own the vast majority of eastern US forests and collectively decide how these forests are managed and, ultimately, whether or not they remain forested. The US has long relied on private forests to provide clean air, protect watersheds and stream banks, the aesthetic backdrops to cities, towns, and communities, countless recreation opportunities, and habitat for myriad species of wildlife, plants, and fungi. Private forests have also provided the majority of US timber supply and economic opportunities for timber production. While research of this important population has been conducted for many years, little has been done to standardize sampling of PFLs and estimation of population parameters thus frustrating comparisons among studies and efforts to track changes over time. This dissertation challenges the presumptions with which PFL research has been previously conducted, lays a foundation for sound, future research, and begins exploring important aspects of private forest landowership. The research presented here focuses primarily on the approaches employed by the United States Department of Agriculture Forest Service to sample PFLs and estimate parameters of the PFL population and of private forestland across the nation. Issues revealed substantively challenge traditional approaches and long-held conclusions about the underpinnings of PFL research as well as how these PFLs have influenced the use and conversion of US forests. With a new foundation, this dissertation also explores decision making processes and the effects of PFL attitudes, values, and beliefs on timber utilization on private lands in the context of an increasingly parcelized forest.

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Chapter 1

Introduction to a Mixed-Methods Investigation of Pennsylvania Private Forest Landowners

The United States is blessed with millions of acres of vast and valuable forestland. From cypress and pine forests of the Southeast to the towering evergreens of the Pacific Northwest to the mixed hardwoods and spruce and fir-covered mountains of the Northeast, forests play a major role in life across the country. Approximately 750 million acres of forestland provide clean air, protect watersheds and stream banks of towns, and are home to myriad species of wildlife, plants, and fungi (Alvarez 2007, Smith et al. 2004). These forests are the backdrop for our communities, the playgrounds for myriad outdoor activities, and a refuge where people can find spiritual refreshment and solitude (Best and Wayburn 2001). Our history as a nation is inextricably linked to the products, lore, and psychology of our forests (Cronan 1983). Our future, too, is tied to the health of our forests and their ability to continue providing traditional amenities while shouldering new demands.

Management of this important resource falls to a variety of owners, both public and private. While all forests provide many public benefits, the majority (56%) of forests in the US are privately owned. (Butler 2008). Collectively, these private forestland owners (PFLs) decide the fate of the nation's forests including limits on public access, production of forest resources, and, perhaps most importantly, whether or not these lands remain forested. In contrast to public land which is usually managed with legislative oversight and scientific and public input, private forests are managed by individual owners to meet their specific goals and according to the resources that may or may not be at their disposal. Understanding these owners' objectives, motivations, behaviors, and intentions for their forestland helps improve stewardship of private forestland, predict how future forests will likely look and function, and improve outreach and assistance to those who decide the fate of the forests we all rely upon.

Regionally, the proportion of forestland privately owned varies substantially and affects efforts to promote sustainable forest management. Whereas western forests are dominated by public ownership the majority of eastern forests are controlled by PFLs. Those concerned with sustainable forest management in the East must carefully consider the influence of management by PFLs on collective forest health and the impact of forest policies on private forestland stewardship. Non-profit organizations, extension programs, private conservation groups, and state agencies must each understand the private ownership context and dynamics that surround forest management to ensure outreach, management, and regulatory policies and programs are successful.

PFL Research

The monitoring of PFL characteristics and ownership trends at the national level is entrusted to the United States Department of Agriculture Forest Service (USFS). In conjunction with the Forest Inventory and Analysis (FIA) program, which monitors forest cover and condition, PFLs are surveyed annually by the National Woodland Owner Survey (NWOS). Responses serve to estimate the population of PFLs, the distribution of forestland by property size, and various other characteristics of forest landownership (Butler et al. 2005).

Butler (2008) estimates there are about 11 million PFLs in the United States who own approximately 423 million acres of forestland. While comparisons among survey reports are cautioned (Ibid), the number of PFLs has increased by about 1.1 million PFLs in the past 12 years (Ibid, Birch 1996). Although most of these owners have forest holdings between one and nine acres, the majority of private forestland is held in larger acreage classes, between 50 and 500 acres. Most PFLs hold forests for non-timber related objectives, do not have management plans, and have not commercially harvested timber from their properties within the last five years (Butler 2008). While national data and analysis are useful for detailing and monitoring national trends among PFLs and general conclusions about their behavior, application at state and local levels often requires more refined information and analysis (DCNR 2005).

In Pennsylvania, most national characteristics hold true. The number of owners has increased from an estimated 492,800 in 1978 to 513,900 in 1994 (Birch 1996) to 533,000 in 2004 (McWilliams et al. 2007). Although most PFLs own forestland in small acreages, the majority of forestland is found on larger tracts and non-timber related interests are found among PFLs, similar to those across the nation. However, the applicability of these results for any sub-state regional or local efforts may be severely limited. Pennsylvania PFLs are a diverse group and issues affecting management decisions differ substantially depending on local economies, development pressures, and other individual and community dynamics.

Further, anecdotal evidence seems to suggest there may be some problems with the PFL population estimates for Pennsylvania. Over the course of 26 years, the population estimate has only increased by 40,200, or just over eight percent. During the same period of this modest growth in PFL population size estimates, the Commonwealth has seen increases in development, sprawl, parcelization and fragmentation of forestland, and liquidation of timber industry lands – the very forces that should be increasing the population of PFLs (Stein et al. 2005). This apparent discrepancy led us to question the methods and results presented by the USFS and hypothesize that PFL populations have been growing at a faster rate and total greater numbers than reported. While most aspects of national and state-wide results are certainly useful for those concerned with private forest stewardship, more and different data are necessary to understand local and regional variation and increase confidence in estimates of PFL population parameters.

Focus on Pennsylvania: Mixed Methods Investigation

In 2005, the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BoF) contracted with The Pennsylvania State University Human Dimensions Unit (HDU) to design and implement a study of Pennsylvania PFLs to complement national data and allow sub-state regional analysis of PFL characteristics and trends. Initial goals of the study were to determine access barriers to private forest resources (e.g., timber, pulpwood), expand service foresters' interaction beyond PFLs typically seeking assistance, and increase confidence in estimates of population numbers and parameters of Pennsylvania PFLs. In addition, we wanted to understand regional variation across the state, determine distinct segments or types of PFLs, and link PFL beliefs, attitudes, and behaviors to measures of forest sustainability.

To meet these goals, the HDU partnered with BoF foresters and administration to design a mixed method, longitudinal study of Pennsylvania PFLs. Mixed method research capitalizes on the strengths of both quantitative and qualitative methods by allowing overlap and feedback among techniques (Tashakkori & Teddlie 1998). Despite much debate in the literature over the benefit of using one method of inquiry over another, pragmatic researchers have embraced the mixing of methods across a wide range of research application (Johnson & Onwuegbuzie 2004). Mixing qualitative and quantitative methods allows researchers to capitalize on the strengths of each and compensate for weaknesses. Mixed methods research contextualizes inquiry based on the intended application of results or the nature of the observed phenomenon. In other words, mixed methods allow researchers to match methods to the question at hand, thus maximizing applicability of results. Additionally, mixed methods allow a "triangulation" of observations and conclusions, adding confidence that results are not merely an artifact of a singular method (Jick 1979, Bouchard 1976, Webb 1966).

Importantly, mixed methods use collaboration among methods to steer inquiry. Using different methods to explore the same phenomena is often called "multi-methods" and is distinct from mixed methods in that methods are used independently of one another rather than in an integrated fashion (Brewer 1989). Although using various methods independently can be useful, truly mixing methods provides feedback on the research design and enhances the accuracy of all observations. In a mixed methods design, qualitative observations are allowed to influence quantitative investigation and vice versa (Tashakkori & Teddlie 1998). Mixing methods allows the strengths of qualitative and quantitative methods to not only inform the research question at hand, but also improve the methodology of research in a dynamic fashion throughout the course of investigation.

While the fundamental question and impetus for this study relates to quantities of timber volumes and access (i.e., if quantities of timber volumes remain steady, or even increase, then why is forest industry struggling to find round wood?), many equally important questions abound concerning the condition and future of private forests. For example, what is the nature and sustainability of current management, development, and harvesting practices? What are the beliefs, values, and attitudes of Pennsylvania PFLs and do they differ from national trends or among regions within the state? How will PFL decisions likely affect future forests and what can be done by BoF and others to encourage sustainable, Pennsylvania forestland? The answers to these questions have very practical implications for forest industry, the BoF, and all stakeholders interested in healthy forests.

As these questions do not lend themselves to any one particular method of investigation, a mixed methods design forms the foundation for this study of Pennsylvania PFLs. Components of this study include a mail survey, semi-structured and structured interviews, cognitive mapping exercises, forest inventories, GIS analysis of parcel and other spatial data, and analysis of secondary data (e.g., US Census). Over the course of the entire study, feedback among methods allowed modification and improvement of each component based on observations, results, and conclusions from others.

To allow such feedback and capture change over time, this study also employs a five-year, three-panel, longitudinal design. Each panel consists of three, nested components: a mail survey to a large number of PFLs across the state, semi-structured and structured interviews with a subset of survey respondents, and assessments of the forestland owned by those same participants. Duplication of survey questions allows triangulation of responses while different methods of inquiry revealed varied aspects of the same research question. For example, respondents were asked questions regarding ownership objectives using three different methods: with a categorical question on the survey, an open-ended question during an interview, and through a cognitive mapping exercise. Results from each method contribute important pieces to our complete understanding of why PFLs own forestland and what is most important to them about their forests.

The investment of DCNR BoF in this study marks an important shift in traditional approaches to forest stewardship by a state agency. The mission of the BoF is to "ensure the long term health, viability and productivity of the Commonwealth's forests and to conserve native plants." It is no small thing that the BoF interpretation of "the Commonwealth's forests" includes not only those forests owned by the state, but extends to all the forests of Pennsylvania regardless of ownership. Private forests provide public benefits and a prosperous future for Pennsylvania will rely heavily on the sustainability and health of all Pennsylvania forests. It is our hope that this study provides an important first step for DCNR and agencies across the country toward recognizing the importance of private forests, an investment in understanding PFLs, and a commitment to designing the most effective outreach and assistance programs possible.

Dissertation Outline

To conduct the best possible study to support DCNR's private forestland stewardship program we first set out to design the best possible sampling protocol. Careful sampling design ensures sample characteristics are representative of population parameters and allows results to be generalized to an entire population of interest (Thomas 2002). Decisions must be made with regard to obtaining a sample, making observations, and estimating characteristics of the whole population (Ibid). While PFL studies have been common over the past 25 years, methods of sampling have varied substantially (Metcalf 2006). Before concerning ourselves with methods of inquiry, observations from respondents, and results and conclusions about Pennsyvania's PFLs, we were forced to carefully assess the sampling methods employed by others and design the most comprehensive, unbiased sampling protocol possible. Unfortunately, this has not been an easy or swift process.

The standard-bearer for studies of PFLs has been the USFS NWOS. The survey has been conducted for decades and results have been published by countless researchers (Butler 2008). No other source has consistently provided data on PFLs across the United States as evidenced by the frequent citations across the PFL literature, including this study. Despite the ubiquitous presence of NWOS influence, the sampling procedures they employ are not vetted in the literature and results from the survey are often published without detailed explanations of the sampling underlying them. As a result, a substantial part of this dissertation is dedicated to assessing the NWOS sampling methodology, recommending modifications to improve sampling for future PFL studies, and proposing methods for analyzing data collected using less than ideal methods.

Specifically, Chapter Two evaluates the USFS methods and equations for estimating PFL population size. Although these methods have been used by the USFS for over 35 years, we present analysis demonstrating errors in methods and interpretation of the estimation equation. The magnitude of impact of these errors on USFS results rests on the frequency of multiple "selections" of PFLs by random points – something unknown without access to USFS data. However, implications for USFS results and other PFL studies wishing to replicate USFS methods are discussed.

Chapter Three assesses the hexagon grid system and plot placement employed under the Enhanced FIA design to locate forest sampling plots and PFLs. We examine the potential for this sampling design to biases sampling plots toward more forested areas characterized by less parcelization and lower PFL populations thus suppressing PFL population estimates. Further, we examine the interactive effect of hexagon and PFL property boundaries on PFL inclusion probabilities. This effect, unaccounted for in current NWOS/FIA methods, may have biased results toward characteristics of PFLs with smaller forestland holdings.

Chapter Four details our sampling design and survey methods, and addresses practical implications of errors in our design. While we have since realized the importance of including PFLs multiple times when they are selected more than once by a random point placement design, we did so only after our sampling and survey implementation was complete. After laying the groundwork for the statistical analysis of our data, Chapter Four continues by reviewing the results of our statewide survey of

Pennsylvania PFLs. Mail surveys were sent to 6,600 PFLs across the Commonwealth exploring many aspects of private forest landownership including acquisition, management by past owners, ownership objectives, absentee ownership, current and future behaviors including posting, timber harvesting, subdivision, management planning, use of assistance from foresters, extension personnel, attitudes and values toward timber harvesting, stewardship, cooperation among neighbors, conservation, recreational access, and sociodemographics. After detailing frequencies and cross tabs of these parameters, we explore differences among PFLs from various geographic regions across the state. Further, PFL attitudes, values, and behavior are explored with regard to commercial harvesting, parcelization, and future plans. A logistic regression is presented showing significant effects of PFL attitudes on commercial harvesting behavior. Implications of these results for outreach and assistance programs are discussed.

Among the initial goals for this study was to answer questions regarding access to forest resources on private land. While USFS volume estimates have shown increasing volumes in high-value species, forest industry has lamented reduced access and decreasing quality of timber resources on private forestland. Chapter Five examines the interactive affect of parcelization patterns and PFL attitudes and behaviors on access across two Pennsylvania counties. We closely explore how forestland is parcelized in Berks and Huntingdon counties using GIS parcel data. Attitudes and behaviors of PFLs are then explored based on property size – how do PFLs with smaller properties differ from those with PFLs with larger properties with regard to harvesting and access decisions? Results detail biophysical and social constraints to timber harvesting, specifically focusing on the interactive effect of parcelization and PFL decisions on access to private forest resources.

Conclusion

Forests are and have always been an integral and important part of life across this country. The impressive investments toward acquisition and careful management of public forests are testament to the integral nature of forests in our national life. We rely on forests to protect wildlife and water and to provide resources, recreational opportunities, and respite. Nevertheless, the future of our nation's forests depends on our investment in private forests as much as the public. The forests surrounding our communities are mostly private, especially in the east. The decisions of these forests' owners will determine whether or not the values and goods supplied by forests will be sustained in the future.

In Pennsylvania, these PFLs face increasingly difficult decisions. Most of Penn's Woods was clearcut and burned 100 to 120 years ago. The even-aged forests that have grown from the "ashes" are being asked to meet traditional demands for resources while new demands increase. Society will likely continue to turn to forests for timber and non-timber resources, recreational opportunities, aesthetic beauty, and solace. And as forests' role in watershed health, energy supply, and biodiversity protection are better understood, the conflicting demands on PFLs will likely grow.

Private forests have always helped meet traditional uses and will play a large roll in meeting future demands. PFLs facing increasing demands are also confronted with challenging financial and social landscapes. Property taxes are rising while timber prices are falling and many PFLs are "land-rich" while being "capital-poor." How will PFLs navigate financial decisions as resources are constrained and demands continue? Complicating PFL decisions are patterns of high-grading harvests which rob forests of their long-term value in favor of short-term profits. Rumors, if true, seem to indicate many PFLs are even robbed of these short-term profits by dishonest "timber beasts" interested only in their bottom line.

Furthermore, the sustainability of private forests is jeopardized by several complicating factors. Forest pests such as the hemlock woolly adelgid, the emerald ash borer, and Asian long-horned beetle threaten to severely damage, if not eliminate, certain tree species from eastern forests. Invasive and interfering vegetation such as Japanese stilt-grass, hay-scented fern, multi-flora rose, barberry, and tree of heaven, among others, are changing the ability of oak-hickory and northern hardwood forests to maintain sustainability. Further, overbrowsing by white-tailed deer has limited the ability of forests to naturally regenerate, a process critical to the sustainability of Pennsylvania forests.

If private forests are to meet these demands despite increasing complexity and challenges, public support will be needed. The first step toward lending a hand is to understand where help is needed and how best to extend support. Assistance from BoF outreach programming, land-grant university extension efforts, non-profit stewardship actions, or independent forest association and group activities will be most productive and most efficient when it is based on a clear understanding of PFLs, private forest management patterns, and the pathways through which PFLs receive, process, and implement new information.

It is our hope that results from this study will help PFLs and interested stakeholders increase the sustainability and health of private forests in Pennsylvania and beyond. We believe our results provide insight toward improving PFL research design, predictions of resource availability, design of outreach and assistance programs for extension and agency programs, effectiveness of non-profit stewardship activities, forest owner associations' and groups' applicability to PFLs, and local and state planning and regulatory efforts. Here we present the first results of this study and the groundwork for future analysis with an eye toward implementation and application and a hope that we all may benefit from a better understanding of PFLs and a renewed commitment to the health of private forests.

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Chapter 2

Evaluation of the United States Forest Service Private Forest Landowner Population Size Estimation Equation

Introduction

Precise and accurate estimates of PFL population size are critical tools for stakeholders concerned about the health and sustainability of private forests. PFL population size estimates inform an understanding of how forestland is parcelized among owners, development of outreach and assistance programming, and policy discussions. Consistency in estimation methods over time allows stakeholders to track ownership trends, shifts in forest landownership patterns, and the expansion of parcelization.

The US Department of Agriculture Forest Service (USFS) has long been the lone source of PFL population size estimates for states, multi-state regions, and the nation. Beginning with Kingsley and Finley (1975), many USFS researchers have provided estimates of PFL population size for various estimation units (e.g., states) over the past 35 years (Kingsley 1975, 1976; Birch and Kingsley 1978; Birch and Dennis 1980; Birch 1982, 1983, 1986, 1996, 1997a, 1997b, 1997c; Birch, Lewis, and Kaiser 1982; Widmann and Birch 1988; Birch, Hodge, and Thompson 1998; Leatherberry, Kingsley, and Birch 1998; Leatherberry 2000, 2001, 2003; Birch and Butler 2001; Leatherberry 2001, 2003; Barnett et al. 2002; Butler and Leatherberry 2004; McWilliams et al. 2005, 2007; Woodall et al. 2005; Widmann et al. 2007; Butler 2008; Meneguzzo et al. 2008; Moser et al. 2008; Perry et al. 2008; Crocker et al. 2009; Haugen et al. 2009; Piva et al. 2009;

Widmann et al. 2010; Butler, O'Conner, and Payton 2010; Butler, Martin, and O'Conner 2010; Butler et al. 2010, and others).

For Pennsylvania, the USFS estimate of PFL population size increased from 492,800 in 1978 (Birch and Dennis 1980), to 513,900 in 1994 (Birch 1996), and to 533,000 in 2004 (McWilliams et al. 2007). While this estimate increased by 40,200 PFLs, anecdotal evidence suggests growth in the PFL population size should have been considerably higher than the modest growth of 3.7 percent over the last decade and only around 8 percent over the entire 26 years. Indeed, this relatively modest increase in the estimated PFL population size occurred simultaneously with a period of enormous development, sprawl, parcelization and fragmentation of forestland, and liquidation of timber industry lands – the very forces that should be increasing the population of PFLs (Dedrick et al. 2000; Sampson and DeCoster 2000; Best and Wayburn 2001; Mehmood and Zhang 2001; Stein et al. 2005; Alig 2006; Butler 2008; D'Amato et al. 2010).

In light of this apparent inconsistency, the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BoF) funded this study, in part, to examine the established methods and estimates of PFL population size. One of the main goals of this study was to evaluate the USFS methods for sampling PFLs and estimating PFL population size. In addition, we wanted to design and implement a sampling scheme and estimation procedure capable of providing a more accurate and precise estimate of the Pennsylvania PFL population size.

Over the course of this study we worked to fully understand the NWOS design and its implications on sampling bias and the interpretation of results. Many of the discoveries detailed in this chapter have come after several years of trial and error and efforts to understand anomalies and behavior associated with the analysis of PFL survey data. Here we reduce these issues to their simplest forms and assess their effects objectively. The conclusions presented allow us to present the results of this study as accurately as possible and, perhaps more importantly, recommend the most efficient and unbiased method for drawing a representative sample for future PFL studies.

This Chapter begins with a review of PFL population size estimates throughout the PFL literature with a focus on the role of USFS estimations. Next, to provide context and allow an evaluation of the USFS estimation techniques, we revisit basic statistical theory regarding sampling and population parameter estimation. Following these reviews, we detail the traditional sampling design used by the USFS to select PFLs for studies prior to the year 2000 when the enhanced Forest Inventory and Analysis (FIA) system was established. Chapter Three provides a review of the enhanced FIA sampling design and resulting implications on PFL study results.

With this historical sampling context established, we present the USFS PFL population size estimation equation, track its evolution through the USFS literature, and present our hypotheses regarding problems with the equation's design and use. We then detail our methods for analyzing spatial parcel and landuse/landcover data to enumerate PFL populations in some Pennsylvania counties as a way to evaluate our hypotheses. Using these spatially explicit PFL data we present an analysis of the performance of the USFS PFL population estimation equation under different sampling designs. Finally, we discuss our findings and recommendations for the USFS and future PFL researchers.

Defining private forest landowners (PFLs)

First, we must clarify the meaning of "private forest landowner" (PFL) and demonstrate its consistency with similar terms employed by the USFS. The USFS defines a non-industrial private forest landowner (NIPF) as an owner who is not industrial and owns one (1) acre of contiguous forestland that is at least 10 percent stocked (Butler 2008). Industrial owners are those who own land for the expressed purpose of wood product production and/or own processing facilities for wood products (e.g., sawmill). We define PFL as synonymous with NIPF. We have chosen to adopt the PFL term because it defines forest landowners in terms of what they are, rather than what they are not, as discussed by Finley et al. (2001). Regardless, as the definition remains identical to the USFS NIPF definition, so to does the population of interest and the sampling frame.

Recently, the NWOS and others have adopted the term "Family Forest Owners" or FFO (e.g., Butler 2008; Kilgore et al. 2008; D'Amato et al. 2010). It is important to recognize that FFOs are a subset of PFLs. PFLs includes all private owners who are not considered forest industry. FFOs are a subset of PFLs that excludes non-forest industry businesses as well as organizations, associations, non-profit groups, and any formally associated or incorporated group. FFOs are "families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land" (Butler 2008, p.3). Throughout this dissertation we use the inclusive and positively defined term PFL.

Review of PFL Population Size Estimates

The USFS has long been the lone source of PFL population size estimates for states, multi-state regions, and the nation. Beginning with Kingsley and Finley (1975), many USFS researchers have provided estimates of PFL population size for various estimation units (e.g., states) over the past 35 years (Kingsley 1975, 1976; Birch and Kingsley 1978; Birch and Dennis 1980; Birch 1982, 1983, 1986, 1996, 1997a, 1997b, 1997c; Birch, Lewis, and Kaiser 1982; Widmann and Birch 1988; Birch, Hodge, and Thompson 1998; Leatherberry, Kingsley, and Birch 1998; Leatherberry 2000, 2001, 2003; Birch and Butler 2001; Leatherberry 2001, 2003; Barnett et al. 2002; Butler and Leatherberry 2004; McWilliams et al. 2005, 2007; Woodall et al. 2005; Widmann et al. 2007; Butler 2008; Meneguzzo et al. 2008; Moser et al. 2008; Perry et al. 2008; Crocker et al. 2009; Haugen et al. 2009; Piva et al. 2009; Widmann et al. 2010; Butler, O'Conner, and Payton 2010; Butler, Martin, and O'Conner 2010; Butler et al. 2010, and others).

Prior to Kingsley and Finley (1975), publications addressing private forest ownership did not report PFL population size (e.g., Mason 1937; Woods 1941; Barraclough and Rettie 1950; Gedney 1956; Mignery 1956; Anderson 1960; Muench 1966; Stone 1970). Since the first published estimate (Kingsley and Finley 1975), the USFS has remained the sole source of PFL population size cited by many authors (e.g., Birch and Pywell 1986; Bourke and Luloff 1994; Egan et al. 1995; Barden, Jones, and Biles 1996; Jacobson 1998; Jenkins 1998; Dedrick et al. 2000; Esseks and Moulton 2000; Best 2002; Edwards and Bliss 2003; Kittredge 2004; Belin et al. 2005; Downing and Finley 2005; Kendra and Hull 2005; Germain, Anderson, and Bevilacqua 2007; D'Amato et al. 2010). While the USFS will likely remain an important source for PFL population size estimates, some recent work suggests enumerations will be possible as digital spatial data of parcel boundaries and landcover/landuse become increasingly available (Metcalf 2006; Kittredge et al. 2008).

Despite the plethora of citations of USFS PFL population size estimates, details of the methodology employed by USFS to sample PFLs and produce population size estimates are less commonly reported and where they have been, most provide only brief details. The methods for PFL population size estimation were initially reported by Kingsley and Finley (1975) along with the first state level estimate. These methods were repeated with no substantive changes by many USFS authors for 35 years (c.f., Kingsley 1975; Kingsley and Birch 1977; Birch and Kingsley 1978; Birch and Dennis 1980; Birch 1982, 1983, 1986, 1996; Widmann and Birch 1988; Leatherberry, Kingsley, and Birch 1998; Birch and Butler 2001; Leatherberry 2001).

The first publication to make significant changes to the description of methods, but not the methods themselves, was Butler, Leatherberry, and Williams (2005). They provided an updated summary of sampling and estimation methods, equations, and examples of various calculations. Other USFS publications citing PFL population size estimates documented methods by referencing the Butler, Leatherberry, and Williams study (c.f., Butler 2008; Moser et al. 2008; Perry et al. 2008; Crocker et al. 2009; Haugen et al. 2009; Piva et al. 2009), referring readers to a USFS website (c.f., Meneguzzo et al. 2008; Widmann et al. 2010), or excluded any mention of methodology (c.f., Birch, Lewis, and Kaiser 1982; Birch, Hodge, and Thompson 1998; Leatherberry 2000; Barnett 2002; Leatherberry 2003; Butler and Leatherberry 2004; McWilliams et al. 2005;

Woodall et al. 2005; McWilliams et al. 2007; Widmann et al. 2007; Butler O'Conner, and Payton 2010; Butler, Martin, and O'Conner 2010; Butler et al. 2010).

A review of these methods is presented in this Chapter and provides details of the estimation equations used by Butler et al. (2005). As well, it reviews the estimation equation evolution through previous USFS publications (Kingsley and Finley 1975; Birch and Dennis 1980; Birch 1996).

Review of Sampling Literature

In any survey design, estimation of population parameters relies on the correct pairing of sampling design with appropriate estimation equations (Cochran 1963; Kish 1965; Thompson 2002; Lohr 2009). For instance, basic estimation equations should only be paired with simple random sampling (SRS) data while stratified sampling equations should only be used with data collected using stratified sampling techniques. Although a seemingly obvious observation, we believe this is an important starting point for assessing the USFS methods for estimating private forestland and PFL population parameters. Incorrect pairing of sampling designs with estimation equations results in, at best, increased variance estimates and, at worst, biased results.

This section reviews statistical literature on the appropriate equations for population estimation given specific sampling designs. Following this review we detail the USFS sampling design prior to 2000 when the enhanced FIA system was implemented. This basic statistical review provides an important background of established sampling principals for evaluating the USFS estimation equations given their sampling methods. To begin this sampling review, we revisit the definitions of selection and inclusion probabilities.

Selection and inclusion probabilities

Under certain sampling designs, different individuals in the population can "...have different probabilities of being included in the sample" (Thompson 2002, p.51). To describe these probabilities, statisticians use two similar, but importantly different concepts: selection and inclusion probabilities (Thompson 2001; Khawaja 2005; Lohr 2009). Selection probability (p_i) is the probability that the i^{th} unit will be selected on any given draw of a sampling procedure (Khawaja 2005). Inclusion probability (π_i) is the total probability that the i^{th} unit will be selected over the course of all draws (Khawaja 2005). For instance, envision a raffle where individuals are allowed to purchase only one ticket, three winners will be drawn, and tickets holders can win multiple times (i.e., their ticket will be replaced after they win). If 50 raffle tickets are sold, each person's probability of selection (p_i) *for each prize* is 1/50 or 0.02.

The inclusion probability is a bit more complicated. First, recall that the probability any two events both occur is the product of their two independent probabilities. For example, the probability of rolling two, six-sided die, getting a five on the first die and a six on the second die (or any other specific pair) is [(1/6)*(1/6)]. The easiest way to calculate whether one event *or* the other occurs is to calculate the probability that both events do not occur and subtract that from certainty, 1.00. This is often written as:

$\pi_i = 1 - (1 - p_i)^n$ (Thompson 2002)

In our ticket example, the probability that each ticket holder does *not* win over three draws is $(1 - 0.02)^3$. Thus the inclusion probability (π_i) for each ticket holder is:

$\pi_i = 1 - (1 - 0.02)^3 = 0.058808$

Under traditional "without replacement" designs, selection probabilities vary during sampling. Inclusion probabilities are always constant throughout sampling, yet differ depending on the replacement design. For example, consider if the rules of our raffle are changed so that people can only win once (i.e., their ticket will be removed permanently if they win). On the first draw, each ticket holder has a selection probability of 1/50 or 0.02. On the second draw, the remaining ticket holders' selection probabilities change to 1/49 or 0.020408, and so forth. However, ticket holders' inclusion probabilities remain unchanged for the entire raffle and equal:

$\pi_i = 1 - [(1 - 0.02) * (1 - 0.020408) * (1 - 0.020833)] = 0.06$

The distinction between inclusion probabilities and selection probabilities becomes important as we review estimation equations. Under different sampling designs, estimation equations require use of one of these two probabilities, which are not interchangeable.

Estimation equations for two sampling designs

Sampling textbooks provide equations for unbiased estimates of population parameters and variances with samples drawn under different sampling design (e.g., Cochran 1963; Kish 1965; Thompson 2002; Lohr 2009). The following general equations are typically provided for use with samples drawn using SRS with replacement:

$$\bar{y}_n = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad \text{and} \qquad \hat{\text{var}}(\bar{y}_n) = \frac{s^2}{n}$$

where $\bar{y}_n$ is the sample mean and y_i is the value of variable y for the i[th] member of the sample, n is the sample size, and s^2 is the variance of variable y in the sample. The following equations are provided for use with samples drawn using probability proportional to size (PPS) with replacement:

$$\tau_p = \sum_{i=1}^{n} \frac{y_i}{p_i} \qquad \text{and} \qquad \hat{\text{var}}(\tau_p) = \frac{1}{n(n-1)}\left(\sum^{n} \frac{y_i}{p_i} - \tau_p\right)^2$$

where τ_p is the population total, and p_i is the probability of selecting the i[th] unit of the population on each draw. These equations were originally introduced by Hansen and Hurwitz (1943) for use with samples drawn PPS with replacement. They have subsequently been referred to as the Hansen-Hurwitz estimator (HHE).

In 1952, Horvitz and Thompson provided the following equations for use with samples drawn using PPS with or without replacement (i.e., any design):

$$\hat{\tau}_\pi = \sum_{i=1}^{v} \frac{y_i}{\pi_i} \qquad \text{and} \qquad \hat{\text{var}}(\tau_\pi) = \sum_{i=1}^{v}\left(\frac{1}{\pi_i} - \frac{1}{\pi_j}\right)y_i^2 + 2\sum_{i=1}^{v}\sum_{j>i}\left(\frac{1}{\pi_i\,\pi_j} - \frac{1}{\pi_{ij}}\right)y_i y_j$$

where π_{ij} is the probability that both the i[th] and j[th] units are included in the sample and v is the effective sample size. Note that while n is the sample size, v is the effective sample size given the details of any particular sampling design. These equations are usually referred to as the Horvitz-Thompson estimator (HTE). While unbiased, the variance estimation is cumbersome and difficult to compute for sample sizes greater than two or three, thus biased measures of variance are often provided as substitutes (Thompson 2002).

It is important to note SRS equations are designed to estimate population *means* and PPS equations (both HHE and HTE) are designed to estimate population *totals*. Population total (τ) is not necessarily equivalent to population size (N). For example, if we are studying income among firefighters in town Y, "τ" would be the total income of all firefighters (i.e., the sum of all their salaries), not the number of firefighters (N).

The HHE and HTE can be used to estimate population size only when the variable of interest (y_i) is a "count" variable. For example, if we are attempting to estimate the number of cows in a town, sampling units could be farms. Inclusion probabilities may differ by farm, yet once a farm is chosen, all cows on the farm are counted and this number constitutes the value of our variable of interest. After selecting n farms and tallying the number of cows (y_i) at each farm, the HHE or HTE can be used to obtain unbiased population size estimates. We revisit this concept later as these equations are applied to PFL samples and used to estimate PFL population size.

Each of these three sets of equations is applicable only to data collected under a specific sampling design; the first for SRS samples, the HHE for PPS samples with replacement, and the HTE for PPS samples under any design (Thompson 2002, Lohr 2009). To understand which equations should be employed for estimating private forestland and PFL parameters, we must first understand how samples of each are drawn.

Evaluation of USFS Sampling and Estimation Methods

USFS sampling design prior to the enhanced FIA sampling system

For the purposes of this Chapter, we revisit the original sampling approach employed by the USFS prior to the introduction of the enhanced FIA sampling design in 2000. As discussed in Chapter Three, this enhanced FIA sampling design introduces certain biases into the PFL sampling design and imposes a layer of complexity better left aside momentarily for the purposes of assessing private forest and PFL population parameter estimation equations. Further, the PFL population estimation equation was initially developed for use under this original sampling design. Evaluation of this equation first requires an understanding of the sampling design for which it was developed.

Prior to the implementation of the enhanced FIA system in 2000, FIA/NWOS plots were placed across each estimation unit, usually a state or multi-state region[1] (Bechtold and Patterson 2005; Frayer and Furnival 1999). The points that fell on private forestland were used to draw two simultaneous samples, each under a distinctly different sampling design. The first sample was of private forestland, drawn using SRS and "with replacement" techniques; each acre of forestland has an equal probability of being selected on any given draw. The second sample was of PFLs, drawn using probability proportional to size (PPS) and "modified" without replacement techniques; each PFL has

[1] Prior to 2000, each USFS region implemented a unique sampling design although plots were commonly placed using some type of systematic grid over aerial photos taken at various scales (Frayer and Furnival 1999).

an equal probability of being selected on any given draw, despite being included only once in the sample.

These two samples are used to estimate parameters of two separate although related populations: private forestland and PFLs. Throughout this chapter we will refer to *parameters of private forestland* and *parameters of PFLs*. The difference between these two populations and the methods for estimating their parameters is central to our discussion.

Parameters of private forestland measure how much forestland is affected by PFL characteristics while parameters of PFLs measure owner characteristics. For example, for the latter, consider the *PFL parameter* "posting of forestland." This measure would reflect the *percentage of PFLs who post their forestland*. The related, but importantly different parameter of *private forestland* would be the *percentage of private forestland posted*. As certain behaviors, such as posting, are related to the amount of forestland owned, frequency of behavior among PFLs often does not equate to the amount of forestland affected by that behavior. To continue the example, suppose we find that 40 percent of PFLs post their forestland. Consider, however, that PFLs with larger properties are more likely to post. As a result, the 40 percent of PFLs who post might control 65 percent of private forestland. Parameters of PFLs and parameters of private forestland are related but distinctly separate concepts.

In studies of PFLs, random point placement over a geographic area draws two samples: one of PFLs and another of private forestland. Selection probabilities for PFLs are PPS, related to the acres of private forestland owned, while selection probabilities for private forestland are equal (i.e., each acre of forestland has the same probability of inclusion). As the sample of private forestland is drawn with equal inclusion probabilities, SRS equations can be used to estimate private forestland parameters. However, estimation of PFL parameters must account for the PPS nature of the PFL sample and employ HHE or HTE equations.

“Modified” without replacement design

The NWOS seems to employ a “modified” without replacement sampling design. Let us clarify what we mean by “modified” without replacement design. Under such a design, the probabilities of selection remain constant even though PFLs cannot be selected more than once. In a true, without replacement sampling design, individuals selected for the sample are removed from the sampling pool before another individual is drawn (Thompson 2002). As we have seen (see the raffle example), this removal affects the selection probabilities of the remaining individuals in the sampling pool for subsequent draws.

However, NWOS does not employ this method. PFLs and their forestland are not removed from the sampling pool when they are selected. Multiple points may fall on the same PFL property, thus the probabilities of selection and inclusion do not vary or differ from what their values would be under a with replacement design. Despite remaining in the sample pool, PFLs are only included in the sample once regardless of how many points fall on their property (i.e., the number of times they are selected) (Kingsley and Finley 1975; Butler et al. 2005). This makes intuitive sense as sending multiple surveys to the same PFL seems illogical. The maintenance of constant selection probabilities despite including PFLs only once in the sample constitutes what we are calling a modified without replacement sampling design.

Butler et al. (2005) provide an example of statistical estimation procedures in their Appendix III. This Appendix clearly shows their use of a modified without replacement treatment of data (pp.34-36). While explaining the process for estimating the population of landowners in a specific area (i.e., a state), the authors use only the unique values provided by survey respondents, despite multiple selections of some owners. For example, while landowner "108" (found in Butler et al. 2005 Appendix III) was selected three times, landowner 108's responses were used only once when estimating population parameters (see step 2, p.35). When using a true *with* replacement design, landowner 108's responses would be used three times in all calculations. If using a true *without* replacement design, landowner 108 would not have been selected more than once.

This description from Butler et al. (2005) indicates a modified without replacement approach. Similarly, throughout the USFS literature, authors have included only unique respondents despite the distinct possibility that multiple FIA plots fell on a respondent's property (e.g., Kingsley and Finley 1975; Birch and Dennis 1980; Birch 1996). The details of this design will prove important as we explore the use of estimation equations on forestland and PFL data collected in this fashion.

Application of estimation equations to USFS samples

The USFS samples of private forestland and PFLs, drawn by random points, are used by the NWOS to estimate population parameters of private forestland and PFLs. As the sample of private forestland was drawn using SRS and with replacement techniques, certain equations are appropriate for estimating population parameters of private forestland (e.g., how much forestland is posted). As the sample of PFLs was drawn using PPS and modified without replacement techniques, different equations are appropriate for estimating population parameters of PFLs (e.g., how many PFLs post their forestland).

Given the sampling design described by the USFS (Bechtold and Patterson 2005; Butler et al. 2005) and established sampling theory (Cochran 1963; Kish 1965; Thompson 2002; Lohr 2009), accurate and unbiased estimates of *private forestland parameters* must be made using SRS equations where values are included for each and every random point dropped, one through "n." When variables are measured at each point, the premise of equal inclusion/selection probabilities is maintained. If any points are excluded (e.g., a second point owned by the same PFL), this premise is violated and estimates are no longer unbiased.

Due to the modified replacement design employed by the USFS, HTE equations must be used to obtain unbiased estimates of *PFL population parameters*. Even though PFLs are selected by multiple points, they are only included once in the sample. This is a classic application of HTE equations to a with replacement sampling design where only unique members of the population are included in the sample, despite multiple selections (e.g., Thompson 2002, p.55). Under such a design, the effective sample size of PFLs (ν) can be something less than the sample size (n) of random points dropped. Importantly, however, probabilities of inclusion are a function of the sample size (n), not effective sample size (ν), and are not equal to probabilities of selection.

Probabilities of selection for PFLs, on any given draw, are proportional to the size of their forest holdings. Selection probabilities are calculated:

$p_i = a_i/A_f$

where a_i is the acres of private forestland owned by the i^{th} PFL and A_f is the total acres of private forestland acres in an estimation unit. Inclusion probabilities are a function of this selection probability and the number of points dropped (n) in the estimation unit. Inclusion probabilities are calculated:

$\pi_i = 1 - (1 - p_i)^n$

If HTE equations are to be employed, this calculation of inclusion probabilities must be used.

It is possible, with a slight modification to the USFS design, to estimate PFL population parameters using the HHE equations. For example, if PFLs are sampled with replacement (i.e., their survey responses are included each and every time a random point falls on their property), HHE equations are appropriate. In fact, using HHE equations may be more desirable than using HTE equations as unbiased estimates of variance are not substituted (Thompson 2002).

While it is relatively clear which equations should be paired with each sampling design, some parameters of private forestland ownership can cause confusion. Specifically, the number of PFLs in an estimation unit (i.e., PFL population size) can be both a parameter of private forestland and of PFLs. In other words, each sampling point *and* each unique PFL sampled can provide an estimate of the PFL population size in an estimation unit. The samples (private forestland or PFLs) and estimation equations (SRS, HHE, or HTE) necessary for an unbiased estimate differ depending on the “perspective” from which the question is approached.

We conclude the USFS has fundamentally confused the samples and estimation equations appropriate for obtaining unbiased estimates of PFL population size for 35 years. Despite this confusion, we believe results may not have been dramatically affected. However, researchers wishing to employ the USFS sampling and estimation methods at smaller geographic scales or with larger sample sizes may not be as fortunate. The following section details the evolution of USFS estimation equations, techniques, their associated errors, and the process by which this may not have caused serious discrepancies.

Evolution and assessment of USFS equation for estimating PFL population size

The first USFS publication containing an equation for estimating PFL population size was *The forest-land owners of Delaware* (Kingsley and Finley 1975, p.9). Their formula read (with n_r and a_i substituted for N_r and A_i, respectively):

$$w_x = \frac{CFL_p/n_r}{a_i}$$

where, w_x is the weighted number of PFLs represented by the respondent, CFL_p is the area of privately owned forestland in the state, n_r is the number of respondents in the survey, a_i is the forested acres owned by the respondent, and Σw_x is the estimated number of PFLs in the state.

Kingsley and Finley assert:

> "(b)ecause the sample [of PFLs] developed is proportional to forest area rather than to the number of owners, it introduces a bias in estimating number of owners. To overcome this bias it was necessary to weight the numbers of owners obtained in the sample" (p. 9).

However, it appears this equation does not include weights and is instead an algebraic equivalent to the SRS population estimation equations found in most sampling textbooks. Consider the following manipulation of the equation:

$$N_{PFL} = \Sigma w_x$$

$$= \Sigma \left(\frac{CFL_p/n_r}{a_i} \right)$$

$$= \Sigma \left(\frac{1}{a_i} \cdot \frac{CFL_p}{n_r} \right)$$

$$= \Sigma \left(\frac{CFLp}{a_i} \cdot \frac{1}{n_r} \right)$$

$$= \frac{1}{n_r} \quad \Sigma \left(\frac{CFL_p}{a_i} \right)$$

where, N_{PFL} is the estimated population size of PFLs. Essentially, each observation (PFL) is providing an estimate of the number of owners (CFL_p/a_i). The averaging of these estimates, obtained by dividing the sum of these estimates [$\Sigma(CFL_p/a_i)$] by the number of observations (n_r), provides a mean estimate of the PFL population size. This is simply an averaging of the estimates of PFL population size provided by each observation; no weights are included.

For example, consider a sample of four PFLs owning 10, 50, 100, and 200 acres, respectively in a state with 1,000 acres of private forest. Using the Kingsley and Finley formula, the estimate of owners would be:

$$N_{PFL} = \frac{1{,}000/4}{10} + \frac{1{,}000/4}{50} + \frac{1{,}000/4}{100} + \frac{1{,}000/4}{500}$$

$$= 25 + 5 + 2.5 + 0.5$$

$$= 33.$$

From a different perspective, each member of our sample provides an estimate of the PFL population size. Averaging these estimates provides the mean estimate of PFL population size. The calculation would proceed:

$$N_{PFL} = [1{,}000/10 + 1{,}000/50 + 1{,}000/100 + 1{,}000/500] / 4$$

$$= [100 + 20 + 10 + 2] / 4$$

$$= 132 / 4$$

$$= 33.$$

Each observation provides an equal, unweighted contribution toward the final estimate. As this simple exercise demonstrates, these two equations yield identical estimates of PFL population size. As such, the Kingsley/Finley equation is no more than an algebraic equivalent to a mean estimate equation used with SRS data:

$$N_{PFL} = \Sigma \frac{CFL_p/n_r}{a_i} = \bar{y}_n = \frac{1}{n} \sum_{i=1}^{n} y_i$$

where y_i is an estimate of the number of owners (CFL_p/a_i) provided by the ith respondent for i=1 to n.

While this equation has never been published in peer-reviewed literature, results from its use have (e.g., Bourke and Luloff 1994; Egan et al. 1995; Barden, Jones, and Biles 1996; Dedrick et al. 2000; Best 2002; Bliss 2003; Kittredge 2004; Butler and Leatherberry 2004; Belin et al. 2005; Kendra and Hull 2005; Germain, Anderson, and Bevilacqua 2007, D'Amato et al. 2010); moreover, it has persisted in the USFS literature (see earlier review). After introduction by Kingsley and Finley (1975), two authors made non-substantive algebraic changes in their presentation of this equation. Birch and Dennis (1980) republished the same equation with a slight algebraic modification:

$$N_{PFL} = \Sigma w_x$$

$$= \Sigma \left(\frac{CFL_p/n_r}{a_i} \right) \qquad \text{(Kingsley \& Finley 1975)}$$

$$= \Sigma \left(\frac{CFLp}{n_r} \cdot \frac{1}{a_i} \right)$$

$$= \frac{CFL_p}{n_r} \; \Sigma \; \frac{1}{a_i} \qquad \text{(Birch \& Dennis 1980)}$$

Birch again published a modified version of the equation after changing the term "CFL_p" to "T_p":

$$N = \frac{T_p}{n_r} \; \Sigma \; \frac{1}{a_i} \qquad \text{(Birch 1996)}$$

Most recently, Butler et al. (2005) republished the Kingsley and Finley (1975) equation with some additional particularly problematic modifications[2]. Specifically, Butler et al. (2005) provide an equation "adapting the HTE" for estimating the number of PFLs (N):

$$\hat{N}_d = \frac{1}{n_o} \sum_{i=1}^{v} \frac{y_i}{\pi_i} \qquad \text{(Butler et al. 2005, p.15)}$$

The authors treat y_i as "...a binary variable with a value of one indicating inclusion of observation *i* in domain d" (p. 15). For estimating the total PFL population size within an estimation unit, the domain is "PFL," and y_i equals one (1) for all respondents. Thus, y_i is a "count" variable measuring the population within each sampling unit (recall the cows/farm example).

To review, when the variable of interest is *not* a count variable, say "income of town Y's firefighters," population total would be the total income of all firefighters in town Y, not the number of firefighters. When the variable of interest *is* a count variable,

[2]In addition to the issues addressed in the chapter text, we are also troubled by inconsistencies in the citations provided by Butler et al. (2005). Specifically, the authors provided the following formula they purport to use in estimating variances associated with estimates derived from Birch's equation, which they equate with the Horvitz-Thompson estimator (HTE): Var $(N_d) = A_f^2\ 1/(n_o(n_o\text{-}1)\ \Sigma\ \{(y_i/a_i) - [\Sigma\ (y_i/n_o a_i)]\}^2 + \mathrm{var}(A_f)[\Sigma(y_i/n_o a_i)]^2$ where N_d is the number of private forest landowners within an estimation unit, A_f is the total amount of private forestland within an estimation unit, n_o is the number of private forest landowners in the sample, and y_i is a binary variable with a value of one indicating inclusion of observation i in domain d. The citations provided for this equation include Grosenbaugh (1958) and Erikson (1995). In the latter of these two publications, we find a similar equation, save for the exclusion of the A_f term and its associated variance: $V(T(s)) = 1/n(n\text{-}1)\ \Sigma\ (y_i/q_i - T_{hh(s)})^2$ where $T_{hh(s)} = 1/n\ \Sigma\ (y_i/q_i)$. This equation, however, is the variance estimator for the Hansen-Hurwitz estimator (HHE) not the HTE, as suggested by Butler et al. The variance estimator for the HTE is also provided by Erikson (1995): $V(T_{ht(s)}) = \Sigma\ y_i^2/\pi_i\ (1/\ \pi_i\ \text{-}1) + \Sigma\ y_i y_j/\pi_{ij}\ (\pi_{ij}/\pi_i\pi_j\ \text{-}1)$.Whether or not the authors have substituted this equation for the cumbersome HTE variance estimation equation is not explicitly addressed. Neither Erickson (1995) nor Grosenbaugh (1958) suggest such a substitution.

for example "number of cows at a farm," population total equals the population size in the estimation unit. Thus, by treating y_i as a count variable, the authors purport to estimate the PFL population size. Thompson (2002, p.56-57) provides support for this approach citing an HTE for estimating population size:

$N = 1/\pi_i$

However, there are other serious problems with the equation presented by Butler et al. (2005). The HTE was designed to estimate population total (τ). This equation is, again:

$$\hat{\tau}_\pi = \sum^{v} \frac{y_i}{\pi_i} \qquad \text{(Thompson 2002, p.53)}$$

Notice, however, this equation does not include the left most term on the right side of the equation provided by Butler et al. (2005) (i.e., "$1/n_o$"). This, we assume, is the "adaptation" alluded to by the authors. *Without* this term, and when y_i is a count variable, the HTE does in fact provide an estimate of population size. However, we were unable to find this term anywhere in the sampling literature and there is no discussion of, or justification for, its inclusion provided by Butler et al.

A structurally similar term is found in the sampling literature, but functions entirely differently. Thompson (2002) describes how the HTE can be used to estimate a population mean by dividing the population total (τ) by population size (N), or an unbiased estimate thereof. Dividing by sample size (n or "n_o") is entirely different and not theoretically defined.

Additionally, the authors suggest inclusion probability is identical to selection probability. Specifically, they state, "π_i = the inclusion probability or a_i/A_f," where A_f is the "estimated area of private forest land [sic] in the estimation unit" (Butler et al. 2005, pg.15). This is simply inaccurate if any more than one (1) sampling point is used. Consider a PFL owning 1,000 acres in a state with 150,000 acres of private forestland where 250 sample points were dropped. Their selection probability would be:

$$
\begin{aligned}
p_i &= a_i / A_f \\
&= 1{,}000 / 150{,}000 \\
&= 0.0066667
\end{aligned}
$$

while their inclusion probability would be:

$$
\begin{aligned}
\pi_i &= 1 - (1 - p_i)^n \\
&= 1 - (1 - 0.0066667)^{250} \\
&= 0.8121754.
\end{aligned}
$$

If, however, only one sampling point is used, the inclusion probability is the same as the selection probability. In other words, their selection probability would be:

$$
\begin{aligned}
p_i &= a_i / A_f \\
&= 1{,}000 / 150{,}000 \\
&= 0.00666667 \\
&= \pi_i \\
&= 1 - (1 - p_i)^n \\
&= 1 - (1 - 0.00666667)^1 \\
&= 0.00666667
\end{aligned}
$$

Accordingly, where $n > 1$, equating selection probabilities with inclusion probabilities is problematic.

The equation presented by Bulter et al. (2005) appears to be an attempt at reconciling the Kingsley and Finley (1975) equation with the HTE. With the inclusion of the term ($1/n_o$), the treatment of y_i as a constant (1) across all PFLs, and the miscalculation of inclusion probabilities, the equation provided by Butler et al. (2005) reduces to the same SRS equation provided by Kingsley and Finley (1975), Birch and Dennis (1980), and Birch (1996). With the inclusion probability for the ith PFL miscalculated by dividing the acres of forestland owned by the ith PFL (a_i) by the total acres of private forestland in the estimation unit (A_f), the Butler et al. (2005) equation reduces:

$$\hat{N}_d = \frac{1}{n_o} \sum_{i=1}^{v} \frac{y_i}{(a_i / A_f)}$$

$$\hat{N}_d = \frac{1}{n_o} \sum_{i=1}^{v} \frac{y_i * A_f}{a_i}$$

As the term "A_f" is a constant, it can be moved outside the summation:

$$\hat{N}_d = \frac{A_f}{n_o} \sum_{i=1}^{v} \frac{y_i}{a_i}$$

If y_i always equals one (1), as purported by Butler et al. (2005), this equation simplifies:

$$\hat{N}_d = \frac{A_f}{n_o} \sum_{i=1}^{v} \frac{1}{a_i}$$

This reduced equation is identical to that presented by previous USFS authors (e.g., Kingsley and Finley 1975, Birch and Dennis 1980, Birch 1996).

However, as our review has demonstrated, the Kingsley and Finley equation (1975) is simply a SRS mean operator *not* an HTE incorporating weights as suggested by the authors (p.9):

> "Because the sample developed is proportional to forest area rather than to the number of owners, it introduces a bias in estimating number of owners. To overcome this bias it was necessary to weight the numbers of owners obtained in the sample."

We suspect the erroneous modifications presented by Butler et al. (2005) were an attempt to reconcile the text presented by Kingsley and Finley (1975) suggesting an HTE approach with the decidedly non-HTE equation.

Implications of USFS equations

Despite the errors found in the USFS equations, it is possible PFL population size estimates were relatively unaffected. As shown, the Kingsley and Finley equation (1975) simply provides an averaging of estimates. However, with a slight change of perspective, this equation can in fact provide an unbiased estimate of the PFL population size if certain prerequisites are met. Recall that *parameters of private forestland* can be estimated using SRS equations. As each acre of forestland has the same probability of selection, simple mean estimates of forestland parameters are unbiased. If we consider that each sample point of forestland can provide an estimate of PFL population size, we can use this equation to provide an unbiased estimate.

Using Birch's (1996) version of the equation (and symbols), we can obtain PFL population size estimates by ascertaining the private forest holding size (a_i) of the property on which each and every random sample point falls (not simply each unique PFL respondent). By dividing the total acres (T_p) of private forestland in an estimation unit by this private forest holding size (a_i), each random sample point provides an estimate of the PFL population size (N_{PFL}). Importantly, sample size (n) should be the number of *sampling points*, not the number of respondents. The number of respondents, for other equations, is the *effective* sample size (ν). As long as these estimates are averaged across all sample points (n), not respondents (ν), the estimate of the PFL population size is unbiased. In this manner, this equation may very well have provided unbiased estimates of PFL population size in past USFS studies.

Nonetheless, two potential sources of bias may have been introduced in USFS studies. First, if the number of respondents (ν, or n_r) is used in lieu of the number of sample points (n), estimates may be biased. We say "may be biased" because in certain instances these two values (n, ν) may not differ. For example, if there are no instances where multiple random sampling points fall on the same property, sample size will equal effective sample size (i.e., $n = \nu$) and the mean estimate of PFL population size from "respondents" will not differ from the mean estimate provided by "sample points." However, NWOS studies have always used respondents, not each sample point, to estimate PFL population size.

A different source of bias could be introduced from an uneven distribution of non-responses. For example, if non-response is related to the acres of forestland owned by PFLs (a_i), results will be biased regardless of whether "respondents" or "sample points" are used to estimate PFL population size. In most studies, including the NWOS, values for forest holding size (a_i) are only available when PFLs respond to a survey making testing of this bias impossible. Future studies with access to this information should explore potential non-response bias by acreage. The ability to do this may become available as more units of government create GIS landownership databases.

Provided that response among survey recipients is unrelated to forest acreage and responses are applied to all sample points falling on each respondent's property, PFL population size estimates can be unbiased. Therefore, it is possible NWOS results have not been biased by the misinterpretation of estimation equations. Results for the NWOS are usually based on approximately 250 respondents per state or estimation unit (Butler et al. 2005). At this low sampling intensity, it is possible very few multiple sample points fell on properties owned by the same PFL. Comparisons between FIA sample plots and respondents should allow an examination of the frequency of this phenomenon.

On the other hand, for researchers wishing to apply these equations in studies with larger sample sizes or smaller geographic areas of interest, multiple property selections are increasingly likely. As the number of sample points (n) diverges from the number of respondents (v), we hypothesize estimates will become increasingly biased. Specifically, PFL population estimates will be too high and other variables will be biased toward those characteristics of PFLs with smaller forest holdings.

Evaluating the USFS PFL Population Estimation Equation

Based on our review of USFS methods and statistical sampling literature, we hypothesized the existence of errors in the USFS approach to estimating PFL population size. Specifically, we believed the USFS estimation equation, as presented by Kingsley and Finley (1975) and repeated by others (e.g., Birch and Dennis 1980; Birch 1996; Butler et al. 2005), has been misapplied to PFL samples. Further, we believe this mistake may not have resulted in substantial errors to USFS estimates of PFL population size as long as sampling intensities remained low (i.e., few instances of multiple FIA plots falling on a given PFL property or properties).

To examine these hypotheses, we explored digital spatial data of parcel boundaries in certain Pennsylvania counties. Combining these parcel data with landuse/landcover data allowed an enumeration of PFL populations in these Pennsylvania counties. Such spatially explicit PFL databases were used throughout our study for a variety of tasks including drawing the sample and enumerating PFL populations. In the following section we provide our methods for combining digital spatial parcel data with landuse/landcover data to create spatially explicit PFL databases and using these data to examine the effectiveness of the USFS sampling design and estimation equation.

Spatial analysis of parcel databases and landuse/landcover data

Many counties in Pennsylvania have digital, spatially explicit databases of property boundaries and property owner information (Metcalf 2006). These spatial databases are essentially digital maps of all property boundaries within a county and contain associated tables with ownership information for each parcel. Using these databases in conjunction with spatial landuse/landcover data allowed us to build spatially explicit PFL databases and enumerate PFL populations. Before using these data to explore our hypotheses, we describe our process for combining GIS parcel databases with spatial landuse/landcover data to develop spatially explicit PFL population databases.

Each county in Pennsylvania keeps parcel boundary records for property tax purposes. While approximately half of Pennsylvania counties have GIS parcel databases, two issues must be addressed to convert parcel databases into PFL databases. First, few counties keep records of how much forestland is held by each owner, even those with GIS parcel data. In addition, multiple "parcels" are frequently owned by the same owner (Kittredge et al. 2008).

Our analysis methods address these two issues to enumerate PFL populations in each county and build spatially explicit databases of individual properties and forestland locations. Landuse/landcover data were joined to GIS parcel databases specifying forestland information for each parcel. Then, multiple parcels belonging to a unique owner were combined using tabular and spatial analysis techniques. These techniques are described here in detail.

GIS parcel databases were acquired from county tax assessment, GIS, or planning offices. These databases record the spatial location of all parcel boundaries and associated attributes (e.g., owner name, mailing address). Landuse/landcover data were obtained from the Pennsylvania Spatial Data Access (PASDA) website (http://www.pasda.psu.edu). This dataset ("PALULC2000") was developed from the Landsat enhanced thematic mapping program which classified landuse/landcover into 15 categories (Warner 2000). These data were in grid format with grid cells of size 30 meters square.

To begin the analysis, we extracted the "forest" categories from the landuse/landcover data. Four categories in the PALULC2000 dataset were considered forested: coniferous forest, mixed forest, deciduous forest, and woody wetlands (value codes 7, 8, 9, and 10 respectively). We assumed grid cells categorized as forested met the 10 percent stocking requirement for PFLs as at least 50 percent of the grid cell must exhibit forested spectral qualities to be categorized as forest. Grid cells with these values were isolated and converted to two shapefiles: points (for_pts_county) and polygons (for_poly_county). File names are included parenthetically; in the actual analysis, "county," in the file name, was replaced with the actual county name or an abbreviation thereof.

Because we were interested in forest acreages as they are determined by parcel boundaries (i.e., how much forestland is on each parcel/owned by each owner), we clipped the GIS parcels with the forest polygons (for_poly_county). This process imposes the parcel boundaries onto the forest polygons (for_clip_county). Where separate fragments of forestland fell on the same parcel, the clip process made these polygons multi-part polygons, meaning they were essentially a single polygon with separate pieces. To obtain accurate acreage calculations, noncontiguous acres of forestland must be treated separately (see "Defining Private Forest Landowners"). To ensure this, the clipped forestland (for_clip_county) was exploded (for_explode_county). Exploding is a process that separates multi-part polygons into individual, single part features.

After exploding, we calculated the acreage of each forest fragment, now delineated by natural breaks in forest cover and parcel boundaries. All fragments less than one acre in size were deleted as PFLs were defined as owning at least one acre of contiguous forestland. After deleting, we selected the forest points (for_pts_county) intersecting the remaining forestland (for_explode_county). These points were then exported as their own shapefile (for_pts_1ac+_cnty) and converted to a raster dataset (for1a_cnty). This resulting raster showed the location and shape of each piece of contiguous forestland one acre in size or larger.

As described previously, multiple parcels are often owned by one landowner. To ensure an accurate estimate of the PFL population, we needed to identify unique owners in the parcel database. To do this, each county parcel dataset was dissolved by the owner name attribute (parcels_dissolve_county). The dissolve process merged parcels owned by the same owner into multipart polygons, thus treating them as one property. As a result, each record in this dataset represented a forest landowner.

The dissolve process only combines polygons with identical attributes. In other words, records are only combined if the spelling of the owner name is exactly the same. Efforts were made to combine parcels obviously owned by the same person/entity despite minor differences in spelling (i.e., “John E. Doe” and “Jonathon E. Doe”), but in many cases it was not possible to determine separate owners (i.e., “John Doe” vs “John E. Doe”) unless mailing addresses were available and identical.

To determine the acres of forestland on each owner’s property, we ran a zonal statistic on the “parcels_dissolve_county” and “for1a_cnty” datasets. This process adds a count attribute field to the “parcels_dissolve_county” dataset and populates it with the number of grid cells from “for1a_cnty” that intersect each polygon (i.e., property). As grid cells are 30 meters square, five grid cells were needed to equal one acre (i.e., 5 * $900m^2$ = 1.11 acres). All records intersecting five or more grid cells were then exported as “forested_parcels_county” and the grid cell count was converted to acreage (i.e., # of grid cells * 900 m^2/grid cell * 0.0002471 acres/m^2).

The resulting dataset now included all forest landowners (i.e., private, public, and industrial) who owned one or more contiguous acres of forestland. To classify these owners by ownership class, names were examined and assigned to an appropriate ownership category (i.e., public, industrial, or private). This process was sometimes aided by other attributes in the dataset or auxiliary data (i.e., GIS data of public ownerships). For example, some counties have a taxable status attribute where public entities have unique attributes denoting tax-exempt status.

Records in the “forested_parcels_county” dataset determined to be privately owned (i.e., not public, not owned by forest industry) were then selected and exported as the final private forest landowner dataset (PFLs_county). This final dataset was used to detail PFL ownership populations, develop forestland and PFL distributions, and assess sampling procedures as discussed below.

Examining performance of USFS estimation equation

Based on our review of sampling literature and assessment of the USFS methods, we hypothesized the USFS equation would fail as the effective sample size of PFLs (ν) deviated from the number of random sampling points (n). In other words, the USFS equation is effectively equivalent to SRS equations. Thus, estimates of PFL population size should be accurate at any sample size when samples are drawn with replacement (i.e., where $n = \nu$). Conversely, estimates of PFL population size should progressively deteriorate (by increasing) as sample size increases under without replacement sampling designs (i.e., where n does not equal ν).

To test the performance of the USFS equation for estimating PFL population size, we turned to the database of PFLs generated from GIS parcel and landuse/landcover data in Huntingdon County (see process described earlier). This database contained one record for each PFL and a field, “private forest acres owned,” with a value for each PFL. From this database we drew multiple samples at increasing sample sizes from 10 to 400, in intervals of 10. Samples were drawn directly from the database of PFLs according to a PPS sampling design using the “R” statistical analysis software. This process was iterated 1,000 times at each sample size.

The first set of samples was drawn “with replacement” to simulate collecting information at each and every random sampling point. The second set of samples was drawn “without replacement” to simulate only collecting information about unique PFLs selected by random sampling points. Samples were used to estimate the PFL population using the USFS equation at increasing sample sizes (Figure 2-1).

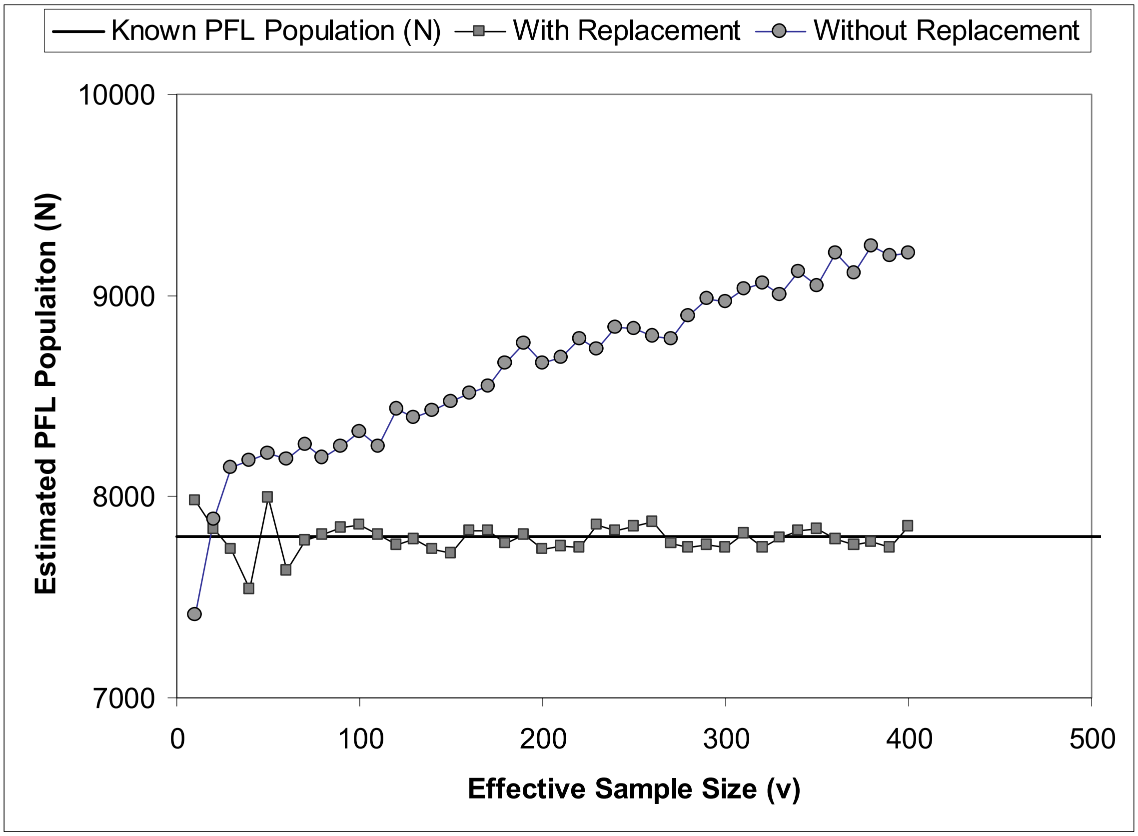

Figure 2-1: Estimates of PFL population size for with and without replacement designs over increasing effective sample sizes in Huntingdon County, PA.

As Figure 2-1 shows, samples drawn with replacement improve as effective sample size increases whereas samples drawn without replacement deteriorate as effective sample size increases. It is important to note the difference between effective sample size (ν) and sample size (n). Sample size is the number of random points dropped over an estimation unit. Effective sample size is the number of PFL selected by those random points. If we allow each point to select a PFL, perhaps even the same PFL multiple times, sample size is equal to effective sample size. If we limit our sample to including each unique PFL only once, no matter how many random points fall on their property, effective sample size may be lower than sample size.

In Figure 2-1 the x-axis is effective sample size. For samples drawn with replacement, sample size is equivalent to effective sample size. For the samples drawn without replacement, sample size is usually larger than effective sample size. When samples size remains low, multiple selections of PFLs remain uncommon and effective sample size approximates sample size. However, as sample size increases, multiple selections increase and effective sample size decreases in relative size. For example, when effective sample size is 10, sample size is likely very close to 10. When effective sample size is 300, sample size is likely substantially higher than 300.

It is important to note that while with and without replacement estimates diverge at relatively low effective sample size, this is a function of scale. For larger geographic areas, sample size and effective sample size will diverge at larger sample sizes than those used in the Huntingdon County example. Without spatially explicit PFL data for the entire state, it is impossible to know at what sample size this divergence becomes common. Regardless, these results demonstrate that when sample sizes are large enough, given the geographic extent and pattern of land ownership, sample size will deviate from effective sample size and PFL population size estimates will suffer under the NWOS approach.

These results also reveal the functionality of the estimation equation originally presented by Kingsley and Finley (1975) and reprinted by Birch (1996) and Butler et al. (2005). When the equation is applied to respondents, as described by these authors, PFL samples are essentially drawn without replacement and estimates will deteriorate as effective sample size deviates from sample size. When the equation is applied to sampling points, as we are suggesting, PFL samples are essentially drawn with replacement and estimates will improve as sample size and effective size increase together. These results show the Kingsley and Finley equation (1975) is in fact an SRS equation and must be used to estimate parameters of *private forestland* not PFLs. Fortunately, PFL population size can be estimated as a parameter of private forestland allowing use of this equation if certain prerequisites are met (i.e., all sample points are used, not simply each unique PFL selected by sample points).

Recommendations for Future PFL Studies

Based on this review of sampling literature and the USFS sampling design, we believe the following methods are ideal for estimating private forestland and PFL population parameters: Private forestland population parameters and associated variance should be estimated using SRS equations, as each acre of forestland has an equal probability of inclusion. As long as the variable of interest is measured on all sampling points (n), or a random selection thereof (i.e., not a biased sample due to uneven non-response), estimates of private forestland population parameters are unbiased.

PFL population size is simply one private forestland population parameter. The variable "population size" is measured at each sampling point (n) by dividing the total private forestland in the estimation unit (A_f) by the acres of the private forest holding on which the sampling point fell (a_i). USFS equations have effectively treated data in this manner despite misinterpretation of estimation equations. Further, resulting estimates may not have been biased because the number of random sampling points (n) may not have substantially differed from effective sample sizes of PFLs (ν).

PFL population parameters can be estimated using either HHE or HTE equations, although the HHE is preferred. If PFL variables are measured at each and every sample point, or a random selection thereof (i.e., not a biased sample due to uneven non-response) the number of sample points (n) equals the number of PFLs in the sample data (ν). In other words, PFLs are included in the sample data however many times a random sampling point fell on their property. When employing "with replacement" sampling of PFLs, HHE equations can be used to estimate population parameters and associated variance. These equations account for uneven selection probabilities (i.e., PPS) among PFLs and the "with replacement" nature of the sample data.

However, if PFL variables are measured only once per PFL, regardless of how many points fell on the PFL property, HTE equations must be used. With this treatment of sample data, the number of sample points (n) may not equal the number of PFLs in the sample (ν). In other words, PFLs are included only once regardless of how many random sampling points may have fallen on their property. As a result, PFLs are drawn in a "modified" *without* replacement manner. Importantly, since the effective sample size of PFLs is variable (i.e., not fixed to equal n), selection probabilities are constant for each PFL. Inclusion probabilities are a function of these selection probabilities and the sample size (n), not the effective sample size. The HTE equations account for uneven inclusion probabilities (i.e., PPS) among PFLs while also addressing the without replacement nature of this sample data.

HTE variance equations are cumbersome and biased substitutes are commonly employed (Thompson 2002, Lohr 2009). As such, the HHE equations are preferred and sample data should be collected in a complementary manner when possible. When data are collected with replacement, PFL data is collected for each and every sampling point and both private forestland and PFL population parameter estimates are easily made from the same dataset: SRS equations can be used to estimate private forestland parameters and HHE equations can be used to estimate PFL parameters.

Conclusion

Estimates of PFL population size were first provided in 1975 by the USFS. Methods and the equation for obtaining these estimates were briefly explained by the first authors (Kingsley and Finley 1975) and repeated, unchanged for many years (e.g., Kingsley 1975; Kingsley and Birch 1977; Birch and Kingsley 1978; Birch and Dennis 1980; Birch 1982, 1983, 1986, 1996; Widmann and Birch 1988; Leatherberry, Kingsley and Birch 1998; Birch and Butler 2001; Leatherberry 2001). Butler et al. (2005) provided a revised and more detailed presentation of these methods; however, no substantive changes were made.

Through this 35-year history, we could find no instance where USFS methods were presented in non-USFS publications (e.g., peer-reviewed journals). Regardless, the USFS PFL population size estimates have been cited in countless articles by USFS and non-USFS researchers alike (e.g., Birch and Pywell 1986; Bourke and Luloff 1994; Egan et al. 1995; Barden, Jones, and Biles 1996; Jacobson 1998; Jenkins 1998; Dedrick et al. 2000, Esseks and Moulton 2000; Best 2002; Bliss 2003; Kittredge 2004; Belin et al. 2005; Downing and Finley 2005; Kendra and Hull 2005; Germain, Anderson, and Bevilacqua 2007; D'Amato et al. 2010).

Despite these many citations, we hypothesized the USFS has long confused the nature and application of the PFL population size estimation equation. First presented by Kingsley and Finley (1975) and republished by others (e.g., Birch and Dennis 1980; Birch 1996; Butler et al. 2005), this equation has been applied to respondents in PFL studies to estimate PFL population size. Results show this approach fails as the occurrence of multiple FIA plots on individual PFL properties increases.

The review presented here has shown the USFS estimation equation is essentially an SRS equation, appropriate for estimating parameters of forestland where inclusion probabilities are equal. PFL population size can be seen as a parameter of forestland. This equation provides an unbiased estimate of PFL population size as long as effective sample size equals actual sample size (i.e., number of sample points on respondent properties equals number of respondents). As this equation is essentially a SRS equation, attempts to represent it as an adaptation of the HTE falter. For example, Butler et al. (2005) add an undefined term and a misinterpretation of inclusion probabilities to the Kingsley and Finley (1975) equation to reconcile differences with the HTE.

Despite the USFS misinterpretation of this equation, their estimates were likely unaffected as this premise was most likely not violated often or to a substantive degree. It is possible, however, that multiple sampling points did fall on individual PFL properties. In estimation units with increased sampling intensity (i.e., number of sampling points/acre) or an abundance of PFLs with large properties, the probability of multiple points falling on the same property would increase. Other studies wishing to employ these sampling and estimation techniques may experience this phenomenon more frequently. For example, if sampling intensity is increased (i.e., relationship between sample size and geographic area of interest) or if the area of interest is characterized by PFLs with larger properties, estimates of PFL population size would be artificially inflated.

USFS estimates of PFL population size in Pennsylvania have increased from 492,800 in 1978 (Birch and Dennis 1980), to 513,900 in 1994 (Birch 1996), and to 533,000 in 2004 (McWilliams et al. 2007). This relatively modest increase in the estimated PFL population size took place over a period of enormous development, sprawl, parcelization and fragmentation of forestland, and liquidation of timber industry lands – the very forces that should be increasing the population of PFLs (Dedrick et al. 2000; Sampson and DeCoster 2000; Best and Wayburn 2001; Mehmood and Zhang 2001; Stein et al. 2005; Alig 2006; Butler 2008; D'Amato et al. 2010). Although our investigation of the USFS estimation methods intended to explore this seeming contradiction, results show estimates of PFL population size prior to 2000 (i.e., the implementation of the enhanced FIA sampling design) were likely unaffected by the errors presented here.

However, significant concerns remain that estimates made after the implementation of the enhanced FIA sampling system may significantly underestimate actual PFL population sizes. Fundamentally, as sampling strategies change, population parameter estimation techniques must change as well to remain unbiased. While the sampling design underwent a substantial overhaul in 2000, techniques for estimating PFL and private forestland parameters (including PFL population size) remain unchanged. Chapter Three will describe the changes in sampling imposed by the enhanced FIA system and assess potential impacts on PFL and private forestland parameter estimation, including PFL population size.

Future studies employing sampling methods similar to USFS prior to 2000 should be sure to collect PFL information at each and every sampling point. If done correctly and in the absence of non-response bias, SRS equations can be used to provide unbiased estimates of private forestland parameters and HHE equations can be used to provide unbiased estimates of PFL parameters. The USFS equation provides researchers with an SRS equation to estimate PFL population size, a parameter of private forestland.

Precise and accurate estimates of PFL population size are an important tool for all stakeholders concerned about the health and sustainability of private forests. PFL population size estimates inform an understanding of how forestland is parcelized among owners, development of outreach and assistance programming, and policy discussions. We believe these results provide clarity to the methods employed by the USFS in estimating PFL population size over the past 35 years. As well, this review provides a grounded and consistent foundation for future research on PFL population size estimates.

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Chapter 3

Evaluating the Influence of the Enhance Forest Inventory and Analysis Sampling Design on Forestland and PFL Parameter Estimation

Introduction

In 2000, the US Department of Agriculture Forest Service (USFS) made significant nationwide modifications to the sampling design used in the Forest Inventory and Analysis (FIA) program. Because of these changes, much work has been done to re-align estimation techniques for environmental variables (e.g., forest area, volume) within this new sampling frame (e.g., Bechtold and Patterson 2005; Bechtold and Scott 2005; McRoberts 2005; Patterson and Reams 2005; Reams et al. 2005; Scott et al. 2005). As sampling of private forest landowners (PFLs[1]) for the National Woodland Owner Survey (NWOS) and previous USFS studies of PFLs ties directly to that of FIA (Kingsley and Finley 1975; Kingsley 1975; Kingsley 1976; Birch and Dennis 1980; Birch 1982, 1983, 1986, 1989; 1996; Widmann and Birch 1988; Leatherberry, Kingsley, and Birch 1998; Leatherberry 2001; Birch and Butler 2001; Butler 2008), these changes directly affect the statistical techniques used for estimating private forestland and PFL parameters, including the size of the PFL population.

Precise and accurate estimates of PFL population size are an important tool for all stakeholders concerned about the health and sustainability of private forests. PFL

[1] The term "private forest landowner" (PFL) is synonymous with "non-industrial private forest landowner" (NIPF) used throughout USFS and other literature. See Chapter Two for a complete definition.

population size estimates inform an understanding of how forestland is parcelized among owners, development and implementation of outreach and assistance programs, and policy discussions. Consistency in estimation methods over time allows stakeholders to track among many things, ownership trends, shifts in forest landownership patterns, access to resources, and the expansion of parcelization.

In Pennsylvania, the USFS estimate of PFL population size has increased from 492,800 in 1978 (Birch and Dennis 1980), to 513,900 in 1994 (Birch 1996), and to 533,000 in 2004 (McWilliams et al. 2007). While the aggregate estimate has increased by 40,200 PFLs, anecdotal evidence suggests growth in the PFL population size should have been somewhat higher than this modest growth of around eight percent over 26 years. The relatively small increase in the estimated PFL population size took place over a period of enormous development, marked by urban sprawl, parcelization and fragmentation of forestland, and liquidation of timber industry lands – the very forces that should be increasing the population of PFLs (Dedrick et al. 2000; Sampson and DeCoster 2000; Best and Wayburn 2001; Mehmood and Zhang 2001; Stein et al. 2005; Alig 2006; Butler 2008; D'Amato et al. 2010).

In light of this apparent inconsistency, the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BoF) funded this study, in part, to examine the established methods and estimates of PFL population size. Accordingly, among the main goals of this study was to evaluate USFS methods for sampling PFLs and estimating PFL population size. Further, we set out to design and implement a sampling scheme and estimation procedure to provide a more accurate and precise estimate of the Pennsylvania PFL population size.

Over the course of this study, we worked to fully understand the NWOS design and its implications on sampling bias and the interpretation of results. Many of the discoveries detailed in this chapter have come after several years of trial and error and efforts to understand anomalies and behavior associated with the analysis of PFL survey data. Here we reduce these issues to their simplest forms and objectively assess their effects. Findings presented in this paper are fundamental to allowing us to complete the objectives set out by the BoF and, perhaps more importantly, recommend the most efficient and unbiased method for drawing a representative sample for future PFL studies and estimating PFL and private forest parameters.

In Chapter Two we examined the USFS PFL population size estimation equation and found significant errors in its interpretation and implementation across many USFS studies. While we concluded these errors may have inflated pre-2000 estimates; however, we believe the low sampling intensity within states likely nullified significant impact. As such, the equation errors alone can not explain what seem to be only modest increases in PFL population size estimates over a period of high development and parcelization. In this chapter we evaluate the influence of the enhanced FIA sampling design on PFL and private forestland parameter estimation. Specifically, we address the effect of the FIA sampling design on PFL inclusion probabilities and the failure of parameter estimation equations to account for the two-stage, FIA sampling design.

This Chapter begins with a review of the enhanced FIA sampling design, including the introduction of a hexagonal sampling grid, and the associated sampling of PFLs for the NWOS. Next we detail two base problems relating to the failure of USFS parameter estimation techniques to 1) properly calculate PFL selection probabilities; and

2) account for the two-stage sampling design of the Enhanced FIA. To address the former, we present a brief review of statistical literature and discussion of selection and inclusion probability calculation within the enhanced FIA sampling design. To address the latter, we present an analysis of spatially explicit PFL databases in conjunction with a simulated hexagonal sampling grid in certain Pennsylvania counties. To conclude we discuss the individual and combined effects of these results on PFL and private forestland parameter estimation, including PFL population size estimates. Finally, we suggest future research to quantify the effects of these results.

Review of Enhanced FIA Sampling Design

The USFS has long conducted surveys of forest cover, composition, and volume (Frayer and Furnival 1999; Gillespie 1999). Historically, these surveys were conducted in a semi-independent fashion by USFS regional offices (Frayer and Furnival 1999; Gillespie 1999; Bechtold and Patterson 2005; McRoberts 2005). This approach allowed each region to determine the frequency, intensity, and design of their inventory program (Frayer and Furnival 1999; McRoberts 2005). While this system of forest inventory was adequate for many years (Frayer and Furnival 1999), the 1980s and 1990s brought increased discussion of national consistency and regularity in inventory methods and schedules (American Forest Council 1992; American Forest and Paper Association 1998; Gillespie 1999; Schreuder, Hansen, Kohl 1999; McRoberts 2005).

The Agricultural Research, Extension, and Education Reform Act of 1998 (P.L. 105-185), commonly referred to as the 1998 Farm Bill, made significant changes to the

USFS inventory design (McRoberts 2005; Reams et al. 2005). Among the goals of that legislation were efforts to create consistency across regions, establish annual inventories, and coordinate program efforts of FIA and Forest Health Monitoring (FHM) (Bechtold and Patterson 2005; McRoberts 2005; Reams et al. 2005). For reference, the FHM program began in 1990 as

> "…an independent, cooperative effort among multiple State and Federal Agencies focused on assessing and monitoring the health and sustainability of the Nation's forest using nationally standardized inventory procedures" (McRoberts 2005, p3).

In 1995, transition began from regional FIA efforts and sampling designs to a national system based on the FHM sampling grid (Sesco 1995; McRoberts 2005). The 1998 Farm Bill codified the integration of the FIA and FHM programs, specifically the plot placement and ground sampling components (McRoberts 2005; Reams et al. 2005). The FHM sampling frame was initially developed by the US Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (Overton, White, and Stevens 1990; White, Kimerling, and Overton 1992; Brand et al. 2000; Reams et al. 2005). In 2000, the "enhanced" FIA sampling design and estimation procedures were adopted and fully implemented (Bechtold and Patterson 2005; McWilliams et al. 2007). As FIA and NWOS are closely linked (Butler, Leatherberry, and Williams 2005), the modifications to the FIA design simultaneously changed the PFL sampling methods employed by the NWOS. To better understand the NWOS sampling design, we first review key aspects of the FIA sampling design.

The enhanced FIA program has three distinct sampling phases: stratification of land areas; measuring traditional variables; and, measuring additional ecosystem health variables (Bechtold and Patterson 2005; McRoberts 2005; Reams et al. 2005; Bechtold and Scott 2005; Scott et al. 2005). Phase One, stratification of forestland, is completed by FIA regions using remotely sensed data, aerial photography, or a combination thereof. This stratification is done to reduce variance of future estimates of forest cover and volume. Stratification can be as simple as classifying land as forest and non-forest or can also incorporate variables such as ownership, land class, and forest type. Each region determines the level of stratification appropriate given local forest conditions, available data, and office resources (Reams et al. 2005).

The latter two phases focus on direct measurement of forest conditions and directly influence how PFLs are sampled for NWOS. To locate plots for inventory, FIA partitions the landscape using hexagons covering approximately 6,000 acres, a strategy modified from the FHM program (Reams et al. 2005). Sampling points (i.e., plots) are placed at a random location within each hexagon (i.e., random azimuth and distance from hexagon centroid) unless existing FHM or FIA sampling plots could be used[2] (Reams et al. 2005). In hexagons where FHM plots did not exist, plots were established using a variety of methods: if present, previously established FIA plots were used (to enable comparisons with historical FIA data); if there were multiple FIA plots within the hexagon, the FIA plot closest to the hexagon center was used; random plots were located within each hexagon containing no existing FHM or FIA plots. At a course scale, this placement strategy produces what resembles a systematic grid of plots while maintaining

[2] Although not addressed here, the adoption of existing FHM and FIA sampling plots into the Enhanced FIA violates rules of random sampling and may bias both FIA and NWOS results. While this is likely a valuable “trade-off” to allow longitudinal analysis of these plots, the affect of this violation should be assessed transparently in USFS literature.

some level of randomness at a finer scale to protect the exact plot location as required by law (Reams et al. 2005).

The technique of random sampling within spatially defined strata is often used to achieve uniform coverage of a population or area (Thompson 2002; Lohr 2009). In other words, the hexagonal sampling grid prevents FIA sampling points from randomly clustering in one area more than another ensuring even distribution across the landscape. Reams et al. (2005, p.25) also suggest the hexagon grid "increases the chances of sampling infrequent forest types" and the random placement of plots within the hexagonal grid cells reduces the likelihood that plot placement coincides "with a systematic lands feature or spatially periodic phenomenon."

Plots within hexagons fall on all types of land use (e.g., row crops, mines, residential), forest and non-forest alike. However, only forested plots are inventoried by FIA. Plots are continuously inventoried (on a 5-year to 7-year cycle) unless they become non-forest or inaccessible (e.g., loss of landowner permission, hazardous conditions). Non-forest plots are re-visited each cycle to determine if non-forest conditions remain. If non-forest plots revert to forest, they are again included in the inventory.

This exclusion of non-forest points creates issues with both PFL and private forestland parameter estimation. After much review, we believe the selection of forested plots from among all FIA plots constitutes a second stage of sampling. We revisit this later in our discussion; however, for now it is sufficient to understand the four steps in the sampling process:

1) partitioning the landscape into grid cells (hexagons),

2) placing a random plot within each hexagon,

3) classifying plots as forest and non-forest, and

4) inventorying only forested plots.

Non-forest points provide information about the distribution and extent of forest cover in an estimation unit, but do not contribute to measures of forest characteristics; nor are they used to select PFLs for inclusion in the NWOS.

Sampling for and the implementation of the NWOS are tied directly to the sampling for FIA (Butler et al. 2005). After FIA plots are located and determined to be forested (and private), owners of properties where these plots fall are identified and contacted by the NWOS. Mail surveys are administered and responses are used to calculate population parameters across a wide range of variables and applied at different levels of geographical interest, usually states or multi-state regions. NWOS implements cycles to correspond with FIA inventory rotations.

This method of sampling PFLs is known as “probability proportional to size” or “PPS” (Thompson 2002; Butler et al. 2005). In a simple random sample (SRS), selection probabilities are equal. However, when dropping random points over an area to select individual PFLs, the probability of selection for each PFL is proportional to the amount of forestland owned. In other words, PFLs with more acres of forestland are more likely to be included in the sample than PFLs with fewer acres of forestland.

When using a PPS sampling design, population parameter estimations must account for these unequal selection probabilities (Thompson 2002; Lohr 2009). If done correctly, population parameter estimates can be unbiased (Hansen and Hurwitz 1943; Horvitz and Thompson 1952; Thompson 2002; Lohr 2009). While we consider the FIA/NWOS sampling design one of the most random methods employed by a range of

PFL studies (Metcalf 2006), we hypothesize its design and implementation introduces certain errors into, at least, NWOS results, if not FIA results as well. The following sections detail our hypotheses, describe our methods to test and evaluate them, and discuss the implications of our results on the NWOS and for others interested in conducting, or using data from similar studies of forestland landowners.

Hypotheses Regarding the Influence of the Enhanced FIA/NWOS Sampling and Estimation Techniques on PFL and Private Forestland Parameter Estimation

Our first hypothesis considers the influence of the FIA/NWOS hexagonal grid system on selection probabilities for PFLs. Accurate estimates of population parameters require accurate calculation of selection probabilities (Thompson 2002, Lohr 2009). We hypothesize the hexagon sampling grid interacts with property boundaries to influence selection probabilities. Specifically, we hypothesize this interaction results in variable selection probabilities for PFLs depending on how their forestland is divided by the hexagon grid system. Thus, PFLs owning the same amount of forestland in an estimation unit (i.e., state) may have different selection probabilities depending on the spatial relationship of their forestland to hexagon boundaries.

If this hypothesis is correct, selection probabilities are not simply a function of the amount of forestland owned in an estimation unit (i.e., state, state sub-region, or multi-state unit), but rather a function of the amount of forestland owned in each hexagonal grid cell. Further, and more problematic, accurate calculations of selection probabilities would require knowledge of the exact location of all property and forest boundaries and their relationships to hexagon boundaries. In the absence of this information, PFL selection probabilities cannot be accurately calculated.

Our second hypothesis considers the enhanced FIA/NWOS sampling design and assertions that forested plots can be treated as a simple random sample. Estimation equations for forestland parameters were developed on the presumption that forested plots are sampled under a SRS design (Reams et al. 2005; Butler et al. 2005). Concomitantly, estimation equations for PFL parameters are predicated on a sample of PFLs drawn under a PPS design (Butler et al. 2005).

However, we submit that the placement of FIA plots on all land-uses (i.e., forest and non-forest) and the subsequent exclusion of non-forest plots constitutes a two-stage sampling design. Consider that while the initial placement of FIA plots (forest and non-forest) approximates a systematic sample and thus can be treated as a simple random sample (Cochran 1977; Thompson 2002; Reams et al. 2005; Lohr 2009), the subsequent exclusion of non-forest points is not a random action, thus constituting a second stage of sampling. For instance, the probability that a plot placed within a hexagon is forested is directly related to the size of the hexagon and the amount of forestland within that hexagon. In other words, hexagons with less forestland are less likely to contain forested plots. Thus, forested plots are located in areas with greater forest cover and less so in areas with less forest cover. Without correcting for a two-stage sampling design, population parameter estimates (e.g., forestland and PFL parameters) are biased (Cochran 1977; Thompson 2002; Lohr 2009).

We hypothesize that average forestland holding among PFLs (i.e., acres of forest owned) relates positively to percent forest cover within hexagonal grid cells. If this relationship exists then the absence of estimation equations accounting for the two-stage sampling design means estimates of PFL parameters are biased toward characteristics of PFLs with larger forestland holdings. As forest holding (i.e., number of acres of forestland owned) is correlated with many other PFL parameters (e.g., ownership objectives, harvesting behavior), this may affect many aspects of NWOS results, including estimates of the acres of forestland owned by PFLs with certain characteristics (e.g., acres of private forestland owned by PFLs over the age of 65, or by PFLs who post their forestland). While forestland parameters (e.g., volume) may relate to percent forest cover within hexagons, we leave this hypothesis for future research.

Hexagon Sampling Grid Affect on Selection Probabilities for PFLs

Accurate calculation of inclusion probabilities depends on accurate calculations of selection probabilities as the former is a function of the latter (see Chapter Two for a discussion of selection and inclusion probabilities). We hypothesize the hexagon sampling grid changes selection probabilities for PFLs whose property/forest boundaries are intersected by hexagon grid boundaries. As inclusion probabilities are a function of selection probabilities, we hypothesize they too are affected by the interaction of hexagon and property/forest boundaries. Specifically, we hypothesize that selection probabilities for PFLs are a function of how much forestland they own in each hexagonal grid cell within an estimation unit. This differs from current methods suggested by the NWOS, as discussed below.

Current methods for calculating selection probabilities

Butler et al. (2005) suggest selection probabilities are calculated by dividing the acres of forestland owned by the i^{th} PFL by the total private forest acres in the *estimation unit* (i.e., state, or multi-state region). We suggest selection probabilities are calculated by dividing the acres of forestland owned by the i^{th} PFL by the total private forest acres in the *hexagons where their land falls*. In simple examples, where PFLs own land in only one hexagon, we agree that although these two approaches yield different weighting values, estimates of population parameters are not adversely influenced. However, in more complex situations, where PFLs own land in multiple hexagons, these two approaches differ substantively.

Consider first a simple example: a single 6,000 acre hexagon where four landowners own 1, 10, 100, and 1,000 forested acres, respectively. Their probabilities of selection are determined by two factors: whether or not the random point is forested and the percentage of the forestland they own. If this particular hexagon has 3,000 acres of forestland, the selection probability calculation would be:

$p_i = 3000/6000 * a_i/3000$

where a_i is the acres of forestland owned by the i^{th} PFL. However, the term "forested acres in the hexagon" (i.e., 3000) cancels with itself and the equation simplifies:

$p_i = a_i/6{,}000$

The NWOS, instead, uses the following formula for calculating selection probabilities:

$p_i = a_i/A_f$

where A_f is the total acres of forestland in the estimation unit (i.e., the state or multi-state region, not a hexagon). While these two equations yield different probabilities and therefore different weighting factors for each individual PFL, it does not influence estimates of population parameters *in this simple example*, as we will show. Essentially, the differences between these equations can be looked at as a simple transformation: multiplying weighting factors by a constant, thus leaving population parameter estimates unaffected. The following comparison demonstrates this consistency.

Consider again the simple example of four PFLs owning forestland within a 6,000 acre hexagon (each owning 1, 10, 100, and 1,000 acres, respectively); let us estimate a population parameter mean and variance. First, we use the total acres in the hexagon to calculate probabilities (a_i/6,000)), then we use total acres of forestland in a unit of analysis (a_i/A_f). Mean and variance estimates will not differ using these two different approaches. Table 3-1 shows the four example landowners, their respective acreages, weighting factors, and values for a variable of interest (x). Weighting factors in Table 3-1 (w) are the inverse of the probability of selection (i.e., p_i^{-1}), calculated: (a_i/6,000).

Table 3 - 1: Four example PFLs with respective variables, probabilities, and weighting factors of interest based on selection probabilities of a_i/6,000 where a_i=acres of forestland owned by the i^{th} PFL within a USFS sampling hexagon

PFL (i)	Forested Acres (a_i)	Variable of Interest (x)	Probability of selection = a_i/6,000	Weighting factor (w)	w*x	w*x^2
1	1	20	0.000166667	6,000	120,000	2,400,000
2	10	35	0.001666667	600	21,000	735,000
3	100	50	0.016666667	60	3,000	150,000
4	1,000	65	0.166666667	6	390	25,350
				Σ = 6,666	Σ = 144,390	Σ = 3,310,350

Using these numbers, we estimate the mean of the variable of interest by multiplying the values by corresponding weights and dividing by the sum of the weights:

$$\mu_{hex} = \Sigma\, [x_i * w_i] / \Sigma\, w$$

$$= 144390 / 6666$$

$$= 21.66$$

To get the weighted variance, we first subtract the correction term ($n * \mu_{hex}^2$) from the weighted sum of squares [$\Sigma(w * x^2) / ((\Sigma w)/n)$], then divide by the degrees of freedom ($n – 1$):

$$Var(\mu_{hex}) = \{[\Sigma(w * x^2) / ((\Sigma w)/n)] - (n * \mu^2)\} / (n -1)$$

$$= \{[3,310,350 / (6,666/4)] – (4 * 21.66^2)\} / 3$$

$$= (1986.41 – 1876.62) / 3$$

$$= 109.79 / 3$$

$$= 36.6$$

Repeating this analysis where selection probabilities are calculated (a_i/A_f) instead of ($a_i/6000$) leaves the mean and variance estimates unchanged. Table 3-2 shows the four example landowners again, their respective acreages, weighting factors, and values for the variable of interest. Weighting factors (w) are, again, the inverse of the probability of selection (i.e., p_i^{-1}). However, in this Table 3-2, p_i is calculated: $a_i/150,000$ (where 150,000 is the total acres of private forestland in the estimation unit).

Table 3 - 2: Four example PFLs with respective variables, probabilities, and weighting factors of interest based on selection probabilities of a_i/150,000 where a_i=the acres of forestland owned by the i^{th} PFL in the estimation unit

PFL (i)	Forested Acres (a_i)	Variable of Interest (x)	Probability of Selection = a_i/150,000	Weighting factor (w)	w*x	w*x^2
1	1	20	0.0000067	150,000	3,000,000	60,000,000
2	10	35	0.0000667	15,000	525,000	18,375,000
3	100	50	0.0006667	1,500	75,000	3,750,000
4	1,000	65	0.0066667	150	9,750	633,750
				Σ = 166,65	Σ = 3,609,750	Σ = 82,758,750

Using these modified numbers, we estimate the mean of the variable of interest by multiplying the values by corresponding weights and divide by the sum of the weights:

$$\mu_{Af} = \Sigma\ [x_i * w_i] / \Sigma\ w$$

$$= 3{,}609{,}750 / 166{,}650$$

$$= 21.66$$

To get the weighted variance we, again, subtract the correction term ($n * \mu_{Af}^2$) from the weighted sum of squares [$\Sigma(w * x^2) / ((\Sigma w)/n)$], then divide by the degrees of freedom ($n - 1$):

$$Var(\mu_{Af}) = \{[\Sigma(w * x^2) / ((\Sigma w)/n)] - (n * \mu^2)\} / (n - 1)$$

$$= \{[82{,}758{,}750 / (166650/4)] - (4 * 21.66^2)\} / 3$$

$$= (1986.41 - 1876.62) / 3$$

$$= 109.79 / 3$$

$$= 36.6$$

It is clear from this simple example that weighting based on area in each hexagon (6,000 acres) or the total private forestland in a unit of analysis (A_f) does not affect the estimate of population parameters or their variance. This consistency results from the equal treatment of all members of the sample – all weights are adjusted equally by a common factor. As we will show, however, selection probabilities *may* differ among PFLs owning the same amount of forestland in the estimation unit (e.g., state) depending on how their property boundaries interact with hexagon boundaries. In other words, the probability of selection of a PFL in Pennsylvania who owns 100 acres of forestland located in only one hexagon differs from the probability of a Pennsylvania PFL who owns 100 acres of forestland divided among multiple hexagons.

Before addressing our hypothesis further, it is important to review the sampling design in more detail, specifically at a smaller scale. When the hexagon grid (with grid cells 6,000 acres in size) is laid out across the landscape it can interact with each property one of two ways: either intersect properties (i.e., a property can fall within two or more hexagon grid cells) or not (i.e., an individual property falls inside only one grid cell). In other words, each property may fall inside one grid cell or two or more grid cells.

The method suggested by Butler et al. (2005) for calculating selection probabilities is based on total forestland in the estimation unit (e.g., state). This method assumes that selection probabilities are equal for PFLs owning the same amount of forestland in the estimation unit, regardless of how their properties are divided among hexagons. For example, if a 1,000 acre property (where all 1,000 acres are forested) falls completely within one hexagon, the selection probability would be calculated:

(1,000/6,000)

or

16.67 percent.

While this calculation is correct, the error is found in the calculation of the selection probability of an identical property bisected by a hexagon boundary. The traditional approach assumes selection probabilities remain unchanged for PFLs whether or not their forestland is divided by hexagon boundaries. For example, if the property is divided in such a way that 300 acres fall in one grid cell and 700 acres fall in a second grid cell, the *incorrect* calculation would be:

[(300/6,000) + (700/6,000)]

or

(0.05 + 0.116667)

or

16.67 percent.

We are suggesting selection probabilities differ among PFLs who own the same amount of forestland in the estimation unit but whose forestland is divided differently among hexagons. To evaluate this assertion we provide the following review of basic statistical literature and examples.

Review of probability calculations for independent and mutually exclusive events

At the root of this issue are the concepts of mutual exclusivity and independence. Two events (e.g., X and Y) are said to be mutually exclusive if they cannot occur at the same time; they are said to be independent if the occurrence of X does not influence the occurrence of Y (Hinkle, Wiersma, and Jurs 2003). Stated another way, if mutually exclusive, the probability of X *and* Y occurring is zero (0) and, if independent, the probability of X *and* Y occurring is P(X)*P(Y).

Applied to this discussion of selection probabilities for properties under the hexagon grid sampling, it is clear we are dealing with independent events. For example, if our property of 1,000 acres is divided between two hexagonal grid cells, there is a probability the property is selected zero times, once, or twice (or however many times equal to the number of grid cells the property falls within). As it is possible for our property to be selected more than once, the selection "events" in each grid cell are not mutually exclusive. Further, the selection of a property in one grid cell does not influence the selection of the same property in a second (or third or fourth, etc.), thus making the events independent, not conditional (Hinkle et al. 2003).

Central to our hypothesis is the calculation of selection probabilities. According to the addition rule (Hinkle et al. 2003), the probability that events X *or* Y occur [i.e., $P(X \cup Y)$], that is to say either X, *or* Y, *or* X and Y occurs, is as follows:

$P(X \cup Y) = P(X) + P(Y) – P(X \text{ and } Y)$,

where P(X) is the probability that event X occurs, P(Y) is the probability that event Y occurs, and P(X and Y) is the probability that both X and Y occur. The probability that both X and Y occur (P(X and Y)) is simply the product of P(X) and P(Y). Therefore the probability of X or Y occurring is:

$P(X \cup Y) = \{P(X) + P(Y) – [P(X)*P(Y)]\}$.

Thus, in our previous example, the selection probability for a 1,000 acre property divided between two 6,000 acre hexagonal grid cells such that 300 acres falls in one cell and 700 acres falls in another cell should be:

$\{(300/6000) + (700/6000) – [(300/6000)*(700/6000)]\}$

or

(0.05 + 0.11667 – 0.00583335)

or

16.08 percent.

As 16.08 percent does not equal 16.67 percent, it is clear the interaction between hexagon boundaries and property boundaries influences inclusion probabilities.

Applying formulas for multiple independent events we find the equation for the selection probability of a property intersected by three hexagons is:

$$P(X \cup Y \cup Z) = \{P(X) + P(Y) + P(Z) \ldots$$
$$\ldots - [P(X)*P(Y)] - [P(X)*P(Z)] - [P(Y)*P(Z)] \ldots$$
$$\ldots + [P(X)*P(Y)*P(Z)]\}$$

and as the number of hexagons intersecting a property increases, the selection probability equation increases in complexity. This equation can also be written:

$$P(X \cup Y \cup Z) = 1 - [1 - P(X)] * [1 - P(Y)] * [1 - P(Z)]$$

Regardless, the probability decreases as a property is increasingly divided among any number of hexagons.

An example at a larger scale can demonstrate the concept more clearly. If a property is 6,000 acres in size, the same size as the hexagons, and the property happens to fall exactly and completely within one hexagon, the probability of selection would equal:

(6,000/6,000)

or

100.00 percent.

If, however, the property is intersected by the hexagonal grid system, parts of the property would fall in two or more hexagons. Let us examine the example where 4,000 acres falls in one hexagon and 2,000 acres falls in a second. Under traditional assumptions, the probability of selection would be:

[(4,000/6,000) + (2,000/6,000)]

or

100.00 percent.

Problematically, this calculation shows a certainty of selection despite the fact there are areas within the two hexagons not part of the property. According to the treatment we are suggesting, the accurate calculation would be:

{(4,000/6,000) + (2,000/6,000) – [(4,000/6,000)*(2,000/6,000)]}

or

(0.6667 + 0.3333 – 0.2222)

or

77.77 percent.

At a still larger scale, the traditional approach clearly defies logic. For example, take a 10,000 acre parcel divided among three hexagons into 2,000, 3,000, and 5,000 acre pieces. Traditional calculations for the selection probability would be:

[(2,000/6,000) + (3,000/6,000) + (5,000/6,000)]

or

(0.3333 + 0.5 + 0.8333)

or

166.67 percent.

Probabilities of selection cannot exceed 100 percent or “certainty.” Instead, the probability for this property should be calculated:

{(2,000/6,000 + 3,000/6,000 + 5,000/6,000) – [(2,000/6,000)*(3,000/6,000)] …

…– [(2,000/6,000)*(5,000/6,000)] – [(3,000/6,000)*(5,000/6,000)]…

…+ [(2,000/6,000)*(3,000/6,000)*(5,000/6000)]}

or

(1.667 – 0.166 – 0.277 – 0.416 + 0.138)

or

94.77 percent.

Whether applied to large properties, which make intuitive sense, or small properties, which may not, it is clear the interaction between hexagon boundaries and property boundaries does influence selection probabilities.

As the probabilities for PFLs owning the same amount of forestland differs based on an interaction with hexagon boundaries, the method of calculating probabilities of selection reported by Butler et al. (2005) biases population parameter estimates. As shown earlier, population parameter estimates remain consistent whether probabilities of selection are calculated based on total private forestland in an area (A_f) or on the amount of land in each hexagon (6,000 acres) *only for properties not intersected by hexagonal boundaries*. However, for properties intersected by hexagon boundaries, probabilities of selection are affected by the interaction among boundaries and not simply calculated by $a_i/6000$ or a_i/A_f. Thus, using the total private forestland in a unit of analysis to calculate selection probabilities (i.e., a_i/A_f) ignores the interactive effect of hexagon boundaries and parcel boundaries on selection probabilities and therefore biases population parameter estimates. This issue compounds itself when probabilities of selection are used to calculate inclusion probabilities. As a result, estimates provided by HHE equations [using selection probabilities (p_i)] and HTE equations [using inclusion probabilities (π_i)] are both biased by ignoring the interaction between hexagon and PFL forestland boundaries.

Extent and influence of hexagon and parcel boundary interaction

As the above discussion demonstrates, selection probabilities differ among PFLs owning the same amount of forestland in the estimation unit but whose properties are divided differently among hexagons. This influence on selection probabilities is expressed unevenly across properties depending on how evenly properties are divided. For example, the selection probability for a 1,000 acre property will differ depending on how that property is divided by the hexagonal boundaries. In the most simple example, a 1,000 acre property could fall entirely within one grid cell or be divided between two. Figure 3-2 depicts the selection probability for a 1,000 acre property when it falls entirely within one grid cell and how this probability changes as an increasing percentage of that property is located in a second grid cell until the property is evenly divided between the two.

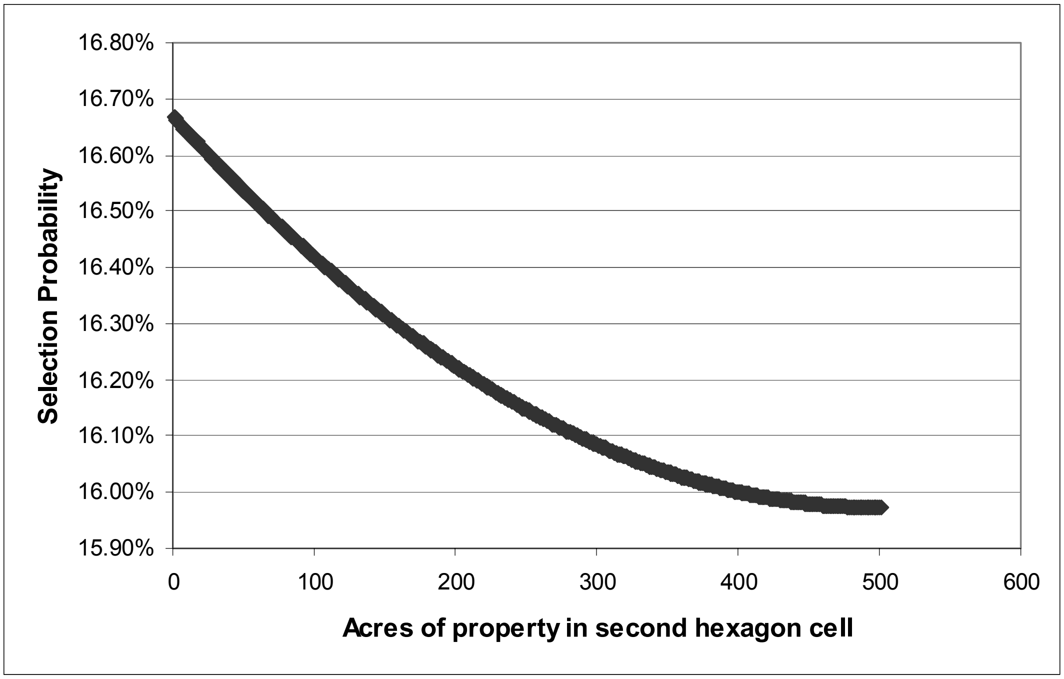

Figure 3 - 1: Selection probability for a 1,000 acre, completely forested property as an increasing percentage of that property is located in a second sampling hexagon

This interaction and subsequent lowering of selection probabilities affects larger properties more substantially. For example, a 1,000 acre property divided in half by a hexagon boundary will have its selection probability affected to a greater degree than a 100 acre property divided in half by a hexagon boundary. Figure 3-3 shows the percent probability change for 1,000 acre, 500 acre, and 100 acre properties as they are increasingly divided by hexagon boundaries.

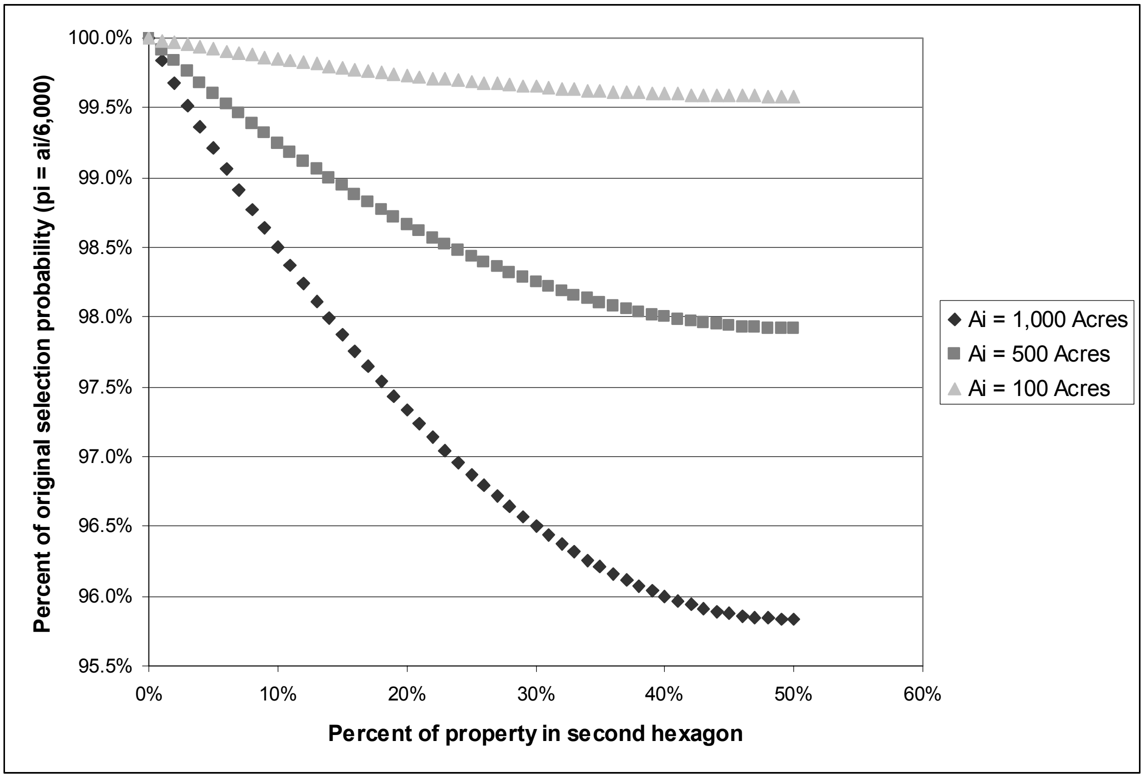

Figure 3 - 2: Percent reduction in selection probabilities for three completely forested properties as increasing percentages of those properties are located in a second sampling hexagon

We were curious to understand the frequency of this phenomenon, its potential for impacting selection probabilities, and its impact on survey results. Although this interaction affects calculations of selection probabilities for those properties where hexagon boundaries cross property boundaries, it was not clear to what extent this interaction influenced PFL properties. To explore this interaction and characterize its influence, we examined digital parcel data in conjunction with a hexagon grid system comprised of 6,000 acre grid cells.

In about half of Pennsylvania's counties, digital parcel maps were available (Metcalf 2006). We chose to use some of these data to assess the extent of interaction between hexagon and property boundaries. After acquiring and preparing digital parcel data from county offices (see Chapter Two), we generated a simulation of the USFS 6,000 acre, hexagonal grid across each county[3]. A spatial join allowed us to count how many hexagons intersected the properties of each PFL. Intersections of more than one hexagon per property indicated instances where selection probabilities would be incorrectly calculated based on traditional assumptions and approaches. If these instances were uncommon, the issue, while correct on a theoretical and mathematical level, would have little "real world" implication. Results proved otherwise.

Initially, we examined three Pennsylvania counties for instances of intersection of multiple hexagons with PFL properties: Berks, Huntingdon, and Indiana Counties. Multiple intersections were common in all three counties. In Berks County, 14 percent of PFL properties intersected two or more hexagons. Multiple hexagon interactions occurred on 21 percent of PFL properties in Huntingdon County and 25 percent of PFL properties in Indiana County.

Properties intersected multiple times were significantly larger than properties fully contained within one hexagonal grid cell. Properties intersected multiple times had an average parcel size of 48.9 acres (SE=2.08) whereas properties intersected only once had an average parcel size of 12.5 acres (SE=0.17). These results demonstrate larger properties are significantly more likely to be intersected by multiple hexagons and thus have incorrectly calculated selection probabilities ($F=1634.399$, $p<0.001$).

[3] Access to the actual USFS Enhanced FIA grid is restricted to protect the location and integrity of FIA plot locations.

This evidence suggests the interaction between hexagon boundaries and property boundaries may have a significant influence on overall selection probabilities. To test for this influence, we analyzed spatially explicit PFL databases in 10 counties (Berks, Centre, Chester, Erie, Huntingdon, Indiana, Juniata, Lehigh, Lycoming, and Perry) in conjunction with a simulated USFS 6,000 acre, hexagonal grid system. Spatially random points were placed in each hexagonal grid cell and determined to be forested or non-forested using Landsat landuse/landcover data (Warner 2000). Forested points were used to select PFL properties.

Across these 10 counties, 823 6,000 acre hexagons were generated (totaling 4,938,000 acres) and spatially random points were placed in each hexagon. Those points deemed forested totaled 465 or 56.5 percent. Of these forested points, 298 (64.1%) fell on private property and were used to select PFLs for this analysis. Acres of private forestland owned by PFLs in this sample ranged from 1.24 acres to 7,773 acres with a mean of 322.4, consistent with a sample drawn PPS with regard to acreage. PFL properties intersected anywhere from 1 to 31 hexagons[4], with a mean intersection of 1.89 hexagons/PFL property.

For each PFL in this sample, selection probabilities within each hexagon were calculated:

$P_{i\ HEX\ n} = a_{i\ HEX\ n} / A_{HEX\ n}$

where $P_{i\ HEX\ n}$ was the probability the i^{th} PFL was selected in the n^{th} hexagon,

[4] Intersection with 31 hexagons is possible as some PFLs own large acreages across many multiple parcels (e.g., railroad companies).

$a_{i\ HEX\ n}$ was the acres of private forestland in the n^{th} hexagon owned by the i^{th} PFL, and $A_{HEX\ n}$ was the total acres of private forestland in the n^{th} hexagon.

Overall selection probabilities for each PFL in this sample were calculated using two methods, the first accounted for the hexagon interaction with property boundaries and the second ignored this interaction. For the first method, which accounted for the hexagon interaction with property boundaries, selection probabilities were calculated:

$$P_i = 1 - (1 - P_{i\ HEX\ 1}) * (1 - P_{i\ HEX\ 2}) * \ldots * (1 - P_{i\ HEX\ n})$$

where P_i was the selection probability for the i^{th} PFL and $P_{i\ HEX\ n}$ was the selection probability for the i^{th} PFL in the n^{th} hexagon. For those hexagons where the i^{th} PFL did not own land, the term $(1 - P_{HEX\ n})$ equaled 1, thus leaving the equation unaltered. For those hexagons where the i^{th} PFL did own land, this equation accurately calculated selection probabilities by accounting for the independent selection probabilities in instances where the i^{th} PFL owned land in multiple hexagons, as discussed above.

For the second method of calculating selection probabilities which did not account for hexagon interactions with property boundaries, selection probabilities were calculated:

$$P_i = P_{i\ HEX\ 1} + P_{i\ HEX\ 2} + \ldots + P_{i\ HEX\ n}$$

Similarly, for those hexagons where the i^{th} PFL did not own land, $P_{i\ HEX\ n}$ equaled zero, thus leaving the equation unaltered. For those hexagons where the i^{th} PFL did own land, this second equation calculated selection probabilities on per hexagon basis; however, it did not account for the independent selection probabilities where the i^{th} PFL owned land in multiple hexagons. Selection probabilities calculated under these two methods were compared for differences using a paired t-test in SPSS v18.0.

Mean selection probabilities for sampled PFLs when not accounting for hexagon interactions with PFL property boundaries equaled 0.0537 with standard error of 0.0085. When the hexagon interaction with PFL property boundaries was accounted for, mean selection probabilities for sampled PFLs equaled 0.04710 with a standard error of 0.0065. The mean difference between the two calculated selection probabilities was 0.0066 with a standard error of 0.0024 and was significant at $p = 0.007$.

These results demonstrate hexagon interaction with property boundaries significantly influences selection probabilities for samples of PFLs. Accounting for this interaction significantly lowers selection probabilities across PFL samples. Because this lowering of selection probabilities is greater for larger parcels (see discussion above), the effect on parameter estimation will vary depending on how variables correlate with acreage. Recall that the hexagon interaction with PFL property boundaries reduces selection probabilities, thereby increasing weights. If unaccounted for, weights for affected PFLs will be artificially low and thus bias results toward characteristics of PFLs owning fewer forest acres.

For variables positively correlated with acreage, failing to account for this interaction will result in an underestimation of PFL population parameters. Inversely, for variables negatively correlated with acreage, failing to account for this interaction will result in an overestimation of PFL population parameters. For those variable unrelated to acreage, little effect is expected. While the magnitude of incorrect estimations will ultimately depend on the range and variance of the target variable, significant differences in selection probabilities suggests the distinct possibility for substantial influence on population parameter estimation and warrants correction.

Perhaps most problematic is that while these selection probabilities are known in our example, they remain unknown for actual PFLs included in the NWOS analysis across the country. Although correct calculations of selection probabilities are relatively simple, they require knowing whether or not a property is intersected by the hexagonal grid system, how many grid cells the property intersects, and exactly how many acres of forestland fall in each grid cell. Without explicit spatial information on property, forest, and hexagon boundaries, these numbers cannot be accurately calculated.

This review and analysis shows the probability of a forest landowner being included in the sample is not a function of the amount of forestland owned in the estimation unit (i.e., state or multi-state region), but rather a function of the amount of forestland owned by each PFL *in each hexagon* in the estimation unit. It matters little how much land is owned in the larger estimation unit if the sample is drawn based on hexagonal grid cells. Instead, accurate calculation of selection and inclusion probabilities should be based on the amount of forestland owned in each cell of the hexagonal grid system that covers the larger unit of interest (e.g., county, state, or country).

As the boundaries of all forest landowners' properties remain unknown, due to a lack of spatially explicit property details (Metcalf 2006; Kittredge et al. 2008), it is impossible to calculate accurate selection probabilities for each PFL under the enhanced FIA/NWOS design except in specific geographic areas. Additionally, the intersection of multiple hexagons with PFL properties is common and more frequently occurs on larger properties. By ignoring this phenomenon, NWOS analysis inflates selection probabilities for large properties. For example, for a 1,000 acre forested property divided evenly between two hexagons, NWOS assumes the selection probability is 1,000/6000 or 16.67 percent when in reality it should be 15.97 percent.

With regard to population size estimation, however, this error has not affected NWOS estimates. The NWOS estimation equation estimates PFL population size as a parameter of private forestland, not as a parameter of PFLs (see Chapter Two). As such, each estimate provided by members of an SRS forestland sample counts equally (i.e., weights are not used) negating any impact of incorrect selection probability calculations.

Importantly though, this systematic error throughout NWOS samples biases estimates of private forestland parameters toward characteristics of PFLs with smaller properties. When selection probabilities are calculated as incorrectly high, weights are artificially reduced. Thus, characteristics of PFLs with larger properties should be weighted more heavily than they currently are by the NWOS. As they are not, NWOS results are skewed, to some degree, toward characteristics of PFLs with smaller properties. A discussion of the impacts of this phenomenon follows a review of our second hypothesis.

Hexagon Plot Placement and Sampling Bias

Our second hypothesis considers a bias imposed by the FIA/NWOS sampling design and the equations used to estimate forestland and PFL parameters. As discussed earlier, we hypothesize a relationship between average forest holding among PFLs (i.e., acres of forestland owned) and percent forest cover within sampling hexagons. If such a relationship exists, the placement of FIA/NWOS plots within hexagons and subsequent exclusion of non-forested plots constitutes a second stage of sampling. Corrections for two-stage sampling must be employed if population parameter estimates are to be unbiased.

Let us provide an analogy to help demonstrate our theory. Take, for example, a researcher curious about the average age of an audience in a theater. Most of the seats are filled, but some remain empty. To sample this audience the researcher chooses one seat at random from each row. If someone is sitting in the selected seat they are asked their age; if no one is sitting in the selected seat the researcher moves on to the next row without collecting age data.

At issue here is the incongruity between the primary and secondary sampling units. In our example, the primary sampling unit (PSU) is "rows" while the secondary sampling unit is "audience members." Somewhat counter-intuitively, "seats" are not a sampling unit. Rather, they provide the mechanism by which primary and secondary sampling units are selected. The selection of seats implements the first stage of sampling, where rows are chosen (based on whether or not the seat chosen is occupied) with probability proportional to how occupied the row is. In other words, rows are selected PPS with probabilities of selection calculated by dividing the number of occupied seats by the number of empty seats.

The selection of seats also implements the second stage of sampling, where audience members are chosen to provide their age. In this example, audience members are selected under an SRS design; each audience member in a selected row has an equal chance of being selected. These two stages of sampling are difficult to tell apart because they happen concurrently; selection of seats implements both stages of sampling simultaneously.

If we reconsider the FIA/NWOS sampling design with this new perspective, we see that locating plots within each sampling hexagon implements both stages in a two-stage sampling design. Plots are first used to select hexagons as primary sampling units; hexagons with forested plots are selected while hexagons with non-forested plots are not. This first stage of sampling is conducted PPS, with probabilities of selection calculated by dividing the amount of forestland in the hexagon by the total hexagon area.

Simultaneously, plots select two secondary samples, one of forestland and one of PFLs. Each plot selects an acre of forestland (as a secondary sampling unit) within each selected hexagon (primary sampling unit). This secondary sample of forestland is selected SRS as each acre of forestland within selected hexagons has an equal probability of selection. Additionally, plots (on private forestland) select a PFL (as a different secondary sampling unit) within each selected hexagon. This secondary sample of PFLs is selected PPS as probabilities of selection for PFLs are calculated by dividing the acres of forestland within the hexagon owned by each PFL by the total acres of private forestland within the hexagon. Table 3-3 delineates the primary and secondary sampling units and designs for the theater example and the USFS samples of forestland and PFLs.

Table 3 - 3: Primary and secondary sampling units and designs for the theater example and the USFS samples of forestland and PFLs

Target Sample	Primary Sampling Unit	Primary Sampling Design	Secondary Sampling Unit	Secondary Sampling Design
Audience	Rows	PPS	Audience	SRS
Forestland	Hexagons	PPS	Forestland	SRS
PFLs	Hexagons	PPS	PFLs	PPS

Again, hexagons are selected as primary sampling units proportionally to the percent forest cover within each hexagon; those hexagons with higher percent forest cover are more likely to be selected and contribute a forested plot to the FIA sample. This PPS design is not accounted for in USFS estimation equations (Bechtold and Patterson 2005; Butler et al. 2005). Further, we hypothesize that percent forest cover also relates to PFL characteristics within each hexagon. Specifically, we hypothesize that average forest holding among PFLs (i.e., acres of forestland owned) relates positively to the percent forest cover within each hexagon. If this hypothesis is correct it will show that forested plots are not selected at random from the entire population of FIA sampling plots (i.e., forest and non-forested plots).

To draw a comparison in our theater example, picture the case where younger people had a tendency to sit in rows with more empty seats. While each audience members' selection probability remains the same (i.e., 1/# seats in a row), the potential for our sample of rows to provide an unbiased sample of audience members is compromised. In other words, rows with younger people are less likely to be selected as primary sampling units than rows with older people. If corrections are not employed for the PPS design of the primary sampling stage, estimates of population parameters will be biased. Specifically, age estimates will be artificially high.

With regard to the FIA/NWOS sampling, we hypothesize that the average size of PFL forest holdings within hexagons are related to the percent private forest cover within the same hexagons. Again, percent private forest cover in each sampling hexagon is a proxy for the probability that a random point within that hexagon is forested and private and therefore contributes to the sample. As a result, if our hypothesis is correct, hexagons less likely to contribute to the sample are home to PFLs with small forest holdings, thus the FIA/NWOS sample is biased toward larger PFLs.

To assess the potential relationship between private forest cover and average forest holding of PFLs in sampling hexagons, we turned again to GIS data of parcel boundaries and forest cover. Digital parcel boundary data were analyzed in ten counties to identify PFLs and the amount of forestland each owned (see Chapter Two). To simulate the FIA/NWOS sampling hexagons, we generated a grid of 6,000 acre hexagons across each of these 10 counties. Private forest cover was derived from spatial landuse/landcover data in conjunction with spatial parcel ownership data (see Chapter Two).

A zonal statistic was calculated for each hexagon to tally the number of acres of private forestland in each hexagon. A zonal statistic essentially counts intersections between vector and raster spatial data; in this case, the number of private forest pixels from 5-pixel blocks intersecting each hexagon. A spatial join was then performed between the hexagons and the PFL spatial database (see Chapter Two for the methods used to generate the PFL database). A spatial join allows attributes of two vector datasets to be combined based on a spatial relationship; in this case, to calculate the average forest holding among PFLs whose properties intersected each hexagon.

Some hexagons were removed from the final analysis because too much of their area fell outside the county of interest or was largely or wholly publicly owned. In these areas, the percent private forest cover was misleading as areas outside the county were considered non-forested due to lack of data (i.e., no data = non-forest). Similarly, hexagons dominated by public ownership showed misleading values for percent private forest cover. Hexagons were included if they were at least 50 percent private and 50 percent within the county of interest.

Figure 3-3 shows the relationship between percent private forest cover and the average PFL forest holding in each sampling hexagon across 10 Pennsylvania Counties. Percent private forest cover, again, is a proxy for the probability that the sampling point within a hexagon is forested and selects a PFL for the sample.

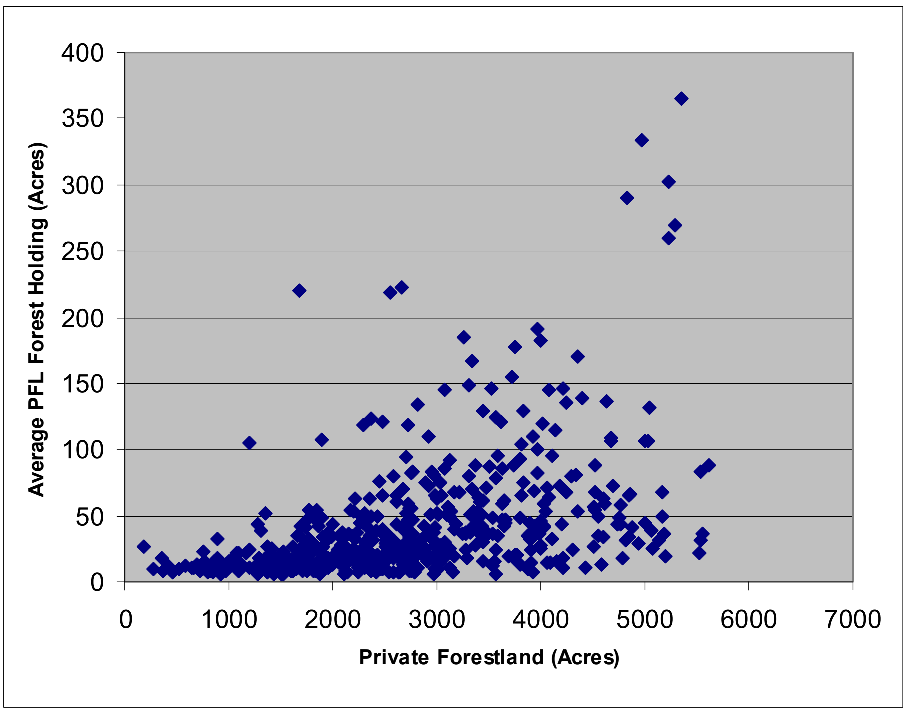

Figure 3 - 3: Relationship between average PFL forest holdings (acres) and acres of private forestland in each sampling hexagon across 10 counties

Figure 3-4 shows the relationship between private forestland acres and a log transform of the average PFL holding in each hexagon. A linear regression analysis shows a significant, positive relationship between percent private forest cover and the log of average PFL forest holding across all sampling hexagons with an adjusted R^2 of 0.355 ($b=0.0002$, constant=0.92, $F=297.57$, $p<0.000$).

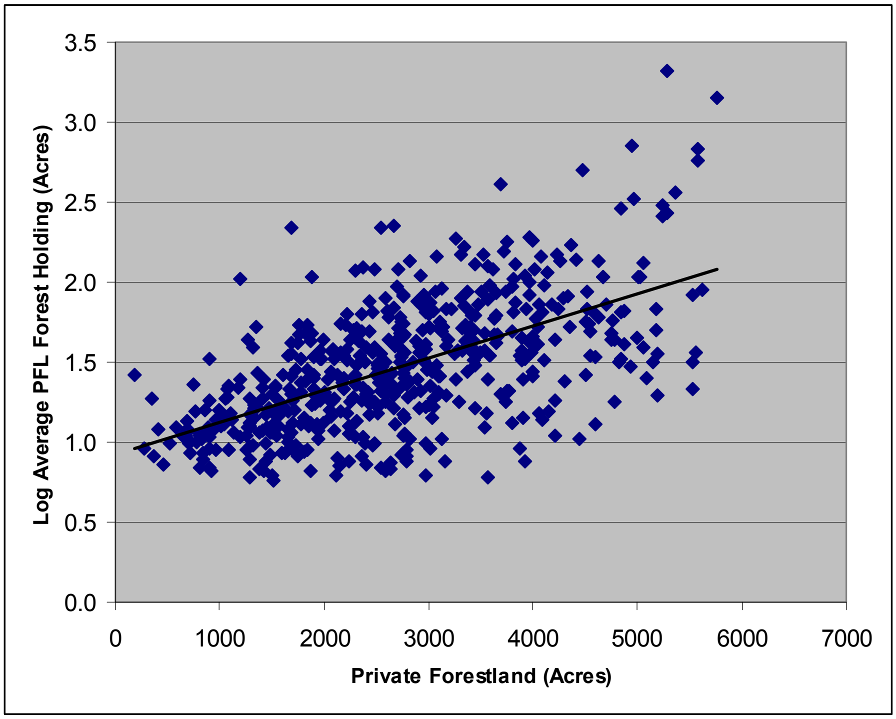

Figure 3 -4: Relationship between Log10(average PFL forest holdings (acres)) and acres of private forestland in each sampling hexagon across 10 counties

Alternatively, consider that given any random set of sample points within hexagons, some less-forested areas of the state do not contribute PFLs to the sample. In other words, under any given random sample of points, certain areas of the state are excluded from analysis. Because of relationship between percent forest cover and average PFL forest holding, we see that excluded areas of the state are also typically characterized by PFLs with smaller forest properties. At the heart of this issue is the two-stage sampling design which is apparently ignored during analysis stages for NWOS at least, and perhaps FIA as well. As described, we interpret the FIA/NWOS sampling design as a two-stage design, sometimes called a “multistage” design (Cochran 1963; Thompson 2002; Lohr 2009). In a two-stage design, a sample of secondary units is selected from a selected sample of primary sampling units (Cochran 1963; Thompson 2002; Lohr 2009). For example, a researcher interested in national school performance may select a sample of states (i.e., primary sampling units) and then assess performance at a sample of schools (i.e., secondary sampling units) within only those states selected. Selection of both primary sampling units and secondary sampling units can be done using a SRS approach, one based on unequal probabilities of inclusion or a combination of multiple approaches (Cochran 1962; Thompson 2002, Lohr 2009). Sampling designs employed during each stage of sampling must be accounted for to avoid unbiased estimates of population parameters (Cochran 1962; Thompson 2002, Lohr 2009).

Discussion and Conclusion

Results show two significant issues with the FIA/NWOS sampling scheme: 1) inclusion probabilities for PFLs are affected by the relationship between their forestland boundaries and the sampling hexagon boundaries; and 2) sampling hexagons with less forestland are characterized by smaller forestland holdings and less likely to contribute PFLs to the NWOS sample. Inversely, more heavily forested hexagons are more likely to contribute to both a FIA and NWOS sample and these hexagons, on average, have PFLs with larger acreage properties. While the first issue has likely not affected PFL population size estimates, the disproportionate inclusion of PFLs with larger properties has likely resulted in a substantial lowering of the PFL population estimate. These results have the potential to impact NWOS estimates of both PFL population and private forestland parameters.

The interaction of hexagon boundaries with PFL properties affected a large number of PFLs in the three counties assessed (between 14 and 25%). For these PFLs, selection probabilities were incorrectly calculated. As demonstrated, this interaction occurred more frequently on larger properties than smaller properties and affected larger properties to a greater degree than smaller properties. While the influence of ownerships being split by hexagon boundaries predominately and most strongly affects the probability of selection of PFLs with large ownerships, the relative difference is actually small (e.g., ≤ 4.2% for a 1,000 acre property, less for smaller properties). Unknown, however, is the cumulative affect of this pattern of influence and more research is needed to explore this is greater detail.

Probabilities of inclusion for PFLs in a PPS sample are related to the acres of forestland owned; PFLs with larger forest holdings generally have higher probabilities of selection than PFLs with smaller forest holdings. Correcting for a PPS sample involves incorporating a weighting factor equal to the inverse of selection probabilities (Cochran 1963; Thompson 2002; Lohr 2009). As a result, PFLs with large properties and corresponding large probabilities of selection will have small weights. Conversely, PFLs with small properties and corresponding probabilities of selection will have large weights.

As the interaction between hexagon boundaries and PFL properties is more common on large properties, it affects members of the sample with the smallest weights. In other words, PFLs who don’t “count” as much in our PFL population parameter estimates are the folks whose weights are adjusted most frequently. While it is unclear how much the error of probability calculation may or may not matter, we believe its impact is muted by the fact it influences most frequently those PFLs who are weighted least when estimating PFL population parameters. Additionally, probabilities of selection for the largest PFL properties are affected to the greatest degree. Thus, the properties with the smallest weights are affected to the greatest degree while those with the largest weights are affected least.

Further, even among the largest properties, the change in selection probabilities may not be very large. For example, a PFL owning 1,000 acres of forestland, whose property is evenly divided between two hexagons, would have their selection probability reduced by less than five percent. Admittedly, properties may be intersected by many hexagons as PFLs may own non-adjacent parcels; as a result, selection probabilities may be reduced to a greater degree. However, selection probabilities are affected most when properties are divided evenly, a phenomenon not likely to occur often. While this effect is real and should be taken into account by researchers interested in PFL populations, we do not believe its impacts greatly alter estimates of PFL population parameters.

However, assessing and correcting for the interaction of hexagon and PFL forestland boundaries in NWOS data will not be achieved easily. As previously discussed, spatial data for all PFL and forestland boundaries are not available. Thus, accurate selection probabilities for PFLs cannot be calculated. The absence of these selection probabilities will frustrate attempts by the USFS to make unbiased estimates of PFL population parameters.

Future research should assess the actual impact of incorrect selection probabilities on parameter estimation in NWOS data. For example, using spatial data of hexagon and PFL forest boundaries, correct selection probabilities could be calculated for specific samples of PFLs (i.e., those falling in areas where spatially explicit parcel data is available). Similar to the analysis presented above of the impact of hexagon interactions with PFL property boundaries on selection probabilities in 10 counties, a subset of PFLs from the NWOS sample could be selected and parameter estimates made using incorrect selection probabilities and compared to those estimates using correct selection probabilities.

Although this type of analysis would allow researchers to describe the effect of incorrect selection probabilities on parameter estimation, solutions would be limited by a lack of spatial data on a wide scale. If the USFS is to fully address this issue, researchers will have to use other methods to determine how private forestland for each respondent is divided among hexagons (e.g., spatial parcel data where available) or may need to abandon the hexagon grid system if impacts are too substantial. An assessment of the frequency and magnitude of this phenomenon will inform this decision.

With regard to the second “hexagon effect,” we believe the failure of the estimation equations used by the USFS to adequately account for the FIA/NWOS sampling design has greatly impacted results. Our interpretation of sampling protocol descriptions, leads us to believe FIA/NWOS employs a two-stage sampling design. Hexagons are treated as primary sampling units and secondary sampling units are forestland (for FIA, private forestland for NWOS) and PFLs (for the NWOS). The same set of FIA plots is used to select both primary and secondary sampling units. Plots are attributed as forest or non-forest, thus selecting which hexagons will contribute forestland and PFLs to the FIA/NWOS samples.

Contrary to the relatively simple PPS estimation equations, two-stage sampling requires more complex mathematics to account for the sampling designs employed at both stages of sampling (Cochran 1963; Thompson 2002; Lohr 2009). Specifically, accurate estimates of population parameters must account for the PPS without replacement method with which hexagons are selected and either the SRS without replacement method with which forestland is selected or the PPS "modified" without replacement method with which PFLs are selected (see Chapter Two for a description of "modified" without replacement).

Additionally, we believe selection of only one secondary sampling unit per primary sampling unit may cause serious problems when using two-stage sampling equations to estimate population parameters. Consider that degrees of freedom are calculated as (n – 1). When a sample of one (1) is drawn within a primary sampling unit, degrees of freedom equal zero thereby frustrating estimation techniques.

We believe these results show the exclusion of adequate correction factors has significantly biased NWOS results toward characteristics of larger PFLs and likely have suppressed PFL population size estimates since 2000. Here and in Chapter Two, we have detailed three errors with the USFS approach to estimating PFL and private forestland parameters. While we believe the misinterpretation of the estimation equation (see Chapter Two) and miscalculation of selection probabilities have not affected results significantly, more research is needed. However, failure to account for the two-stage sampling design has likely dramatically affected results.

Employing population estimation equations that complement the sampling design would account for the relationship between private forest cover and average PFL forest holding we found across hexagon grid cells. Our results indicate that without proper equations, estimates of both forestland and PFL parameters are biased under the current USFS design. We believe the failure of USFS to apply multi-stage sampling equations to their sample data has a large affect on NWOS results, at least, and perhaps FIA results. The results of both FIA assessment of forestland and the NWOS assessment of PFLs are based only on forested plots. Thus, for hexagons with fewer acres of forestland, there is a greater chance of not contributing a forest plot to the FIA or a PFL to the NWOS. Unfortunately, this means the characteristics of all the forestland and forestland owners in this hexagon are excluded from the FIA and NWOS samples. Since plots are permanent, this exclusion is also permanent unless non-forest plots become forested again in the future.

As our analysis has shown, hexagons with fewer acres of forestland are also home to PFLs with smaller forest holdings. These results show that areas with PFLs who have smaller forest holdings are disproportionately excluded from the sample. PFL population size estimates using a sample biased in such a manner will underestimate the actual PFL population and survey results will be biased toward the characteristics of PFLs with larger properties.

While we believe our results regarding PFL population estimation (see Chapter Two) and hexagon/forestland boundary interaction have not impacted the FIA forestland sample, we believe the proportional exclusion of less forested hexagons may have a direct impact on FIA results (i.e., volume estimation and forest characterization).

Hexagons with a smaller proportion of forest are less likely to contribute a forested point to the sample and the forests in these hexagons are likely more parcelized, fragmented, and less managed than forests in hexagons more likely to contribute a forested point to the sample. Excluding these areas limits the ability of FIA samples to accurately estimate forestland parameters.

This sampling issue may also explain the only modest increase in PFL population size estimates seen over the past 26 years. Our evaluation of the USFS PFL population size estimate equation showed pre-2000 could have been slightly inflated. This over-estimation would have been caused by the inclusion of only unique PFLs in the estimation procedures. In other words, if multiple FIA plots happened to fall on unique PFL properties, traditional estimation methods would have included their information only once. As discussed in Chapter Two, this error likely resulted in a slight inflation of historical estimates.

With the introduction of the hexagonal grid system in 2000, two factors were introduced that likely suppressed PFL population estimates. First, as FIA plots were now spread evenly across the landscape, instances of multiple FIA plots falling on unique PFL properties was reduced. If the number of multiple PFL selections decreased in 2000, PFL population size estimates also decreased. Admittedly, this was likely a small factor before 2000 and is likely smaller still today. However, the failure of PFL population estimation equations to account for the two-stage design of the enhanced FIA/NWOS sampling of PFLs has likely suppressed estimates substantially.

Results show areas of Pennsylvania characterized by low percent private forest cover are also home to PFLs with smaller average forest holdings. By not correcting for the two-stage sampling design, these areas are essentially underrepresented in NWOS estimation procedures. When estimating PFL population size, PFLs with small forest holdings increase estimates (see Chapter Two). Recall that estimates are made by dividing the total forestland in an estimation unit by the forestland owned by the i^{th} PFL (i.e., A_f/a_i). The disproportionate exclusion of PFLs with small forest holdings from the NWOS sample is likely to have suppressed PFL population size estimates substantially.

The exclusion of these areas may also limit the ability of FIA and NWOS to capture change over time. Areas less likely to contribute to the FIA or NWOS sample are characterized by less forest cover and occur in more developed or fragmented landscapes. These are precisely the areas where forestland is being lost, where development is expanding, and fragmentation and parcelization are having the greatest effect (Dedrick et al. 2000; Sampson and DeCoster 2000; Best and Wayburn 2001; Mehmood and Zhang 2001; Stein et al. 2005; Alig 2006; Butler 2008; D'Amato et al. 2010). In other words, areas less likely to contribute to the FIA and NWOS samples are areas of the greatest change in the landscape.

Further, FIA/NWOS sampling plots are fixed, re-surveyed year after year on a five or seven-year cycle. Thus, whatever change occurs on forestland in a hexagon with a non-forested point will never be captured by FIA or NWOS results. Additionally, when an FIA/NWOS plot becomes non-forested (a sign of change in that hexagon), it is not replaced, therefore excluding that area from contributing to future FIA and NWOS results. While FIA and NWOS samples will show a loss of forestland, the changes in forest conditions and ownership patters in these areas will be unmeasured. Further, these areas, characterized by high populations of PFLs with small forest holdings are excluded from PFL population size estimates.

While mathematical tools exist to address the two-stage sampling design, there should be some concern that increased weighting of variables will increase variance and provide inaccurate, despite being un-biased, estimates of population parameters. Although it would require major changes to FIA/NWOS procedures and additional changes to estimation equations, sampling the forestland within each sampling hexagon would ensure accurate representation of forestland and remove the two-stage nature of current sampling design. Regardless of their form, changes must take place so future estimates are unbiased.

For future studies, two considerations need to be addressed to ensure sampling designs complement estimation equations. First, however samples are drawn, calculation of selection probabilities should account for all sampling stages. Further, data required for their calculation should be available (e.g., hexagon, property, and forestland boundaries). Second, as discussed in Chapter Two, if random points are used to select samples, estimates of forestland and PFL population parameters should be made across all points (n), not simply the effective sample size of unique PFLs (ν). This will ensure estimates of forestland parameters are unbiased and estimates of PFL parameters will not require biased estimates of variance (i.e., allow the use of HHE equations instead of HTE).

For example, future studies drawing samples from random points would be best served by placing points only on forestland, collecting data on every point, using SRS equations for estimating forestland parameters, and using HHE equations for estimating

PFL parameters. Although this would disallow estimates of percent forest cover/forestland area, other methods exist to replace this functionality (e.g., remote sensing techniques). Further, current misinterpretations persistent in the USFS literature need to be amended and/or corrected. Researchers should approach estimates of PFL population size as a parameter of forestland, not of PFLs. As demonstrated, this perspective and the approaches it affords allows simple and unbiased estimates of PFL population size.

Most of the analysis and conclusions presented in this chapter have been reached after several years of trial and error and efforts to understand anomalies and behavior of survey data. We have attempted to simplify these issues and present them so we may fully understand our data, present the most unbiased results possible, and recommend the most efficient and unbiased methods for future PFL studies.

However, the majority of our study was designed before most of the analysis in this chapter was completed and the relationships between survey data and estimation equations were fully understood. Some of the parameters necessary for conducting a completely unbiased study of private forestland and PFLs were met by our study design; some were not. Specifically, though we placed random points on private forestland, we only collected data on one point per PFL. This small, yet important, detail has broad implications for how (and how well) our data can be used. Chapter Four reviews the sampling design and survey methods employed and assesses their impacts on our ability to estimate private forestland and PFL population parameters.

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Chapter 4

Pennsylvania's Private Forest Landowners and Commercial Harvesting Decisions

Introduction

Pennsylvania's landscape is dominated by 16.6 million acres of forestland (McWilliams et al. 2007), providing ample opportunities for, among other things, recreation, wildlife and plant habitat, and protection of clean air and water (Figure 4-1). Pennsylvania forests are among the most valuable sources of wood products in the world and are an important part of the history, culture, and economies of communities across the Commonwealth.

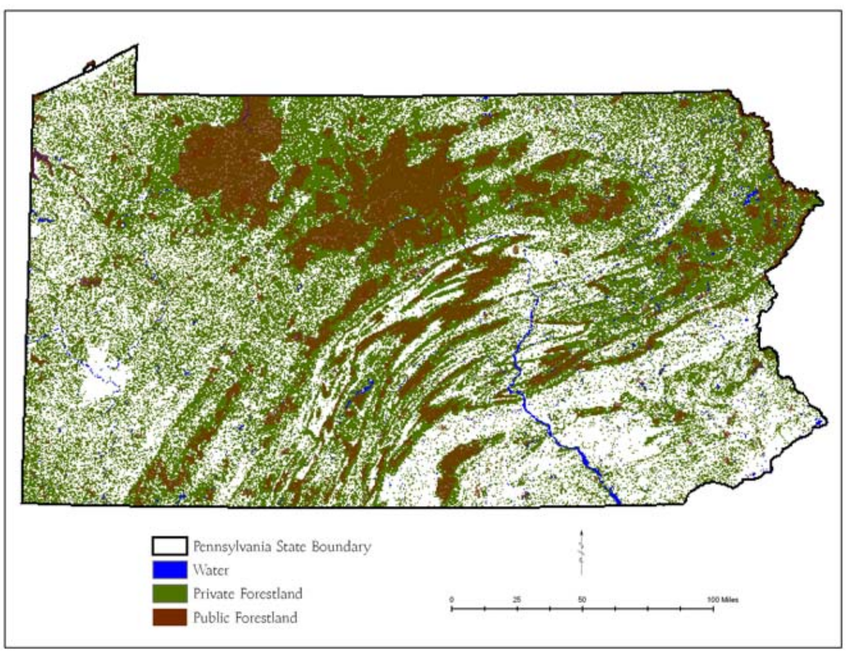

Figure 4 - 1: Public and private forestland in Pennsylvania

The majority of Pennsylvania's forests, approximately 70 percent, are privately owned (McWilliams et al. 2007). Collectively, these private forest landowners (PFLs) determine how 12 million acres of forestland are managed, enjoyed, and ultimately whether they remain forests. Understanding PFLs, their decision making processes, and their various management approaches provides invaluable insights into the future of Penn's Woods. Most importantly, such information is essential for building informed, deliberate outreach programs to partner with PFLs and promote healthy, sustainable forests.

One of the main driving questions behind this study centered on the supply of forest resources from private forestlands. Anecdotal evidence suggested that while timber volumes were increasing on private forestlands, access to these forest resources was becoming increasingly difficult. This Chapter begins an important investigation into characteristics of Pennsylvania PFL and their decision making processes regarding commercial harvesting. Private forests are an important source of forest resources, both traditional and emerging, and understanding characteristics of PFLs and their decision making processes is critical for understanding current limits on supply and predicting future availability. Traditional efforts to predict commercial harvesting among PFLs have focused mostly on sociodemographic variables, tract size, and, in some geographic areas, timber prices, despite speculation that PFL attitudes and values are likely strong predictors of PFL decision making processes. This Chapter presents characteristics of PFLs that relate to harvesting and other management decisions and carefully explores specific aspects of PFL attitudes and values and their capacity for predicting commercial harvesting behavior.

Following a review of past exploration of commercial harvesting decision models, this Chapter will detail the survey methods employed in our statewide investigation of PFLs and the analysis implications of these methods. Relevant results from the first of three mail survey panels are then presented for the state as a whole, for the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BoF) stewardship regions, and for PFLs who have commercially harvested and those who have not. Finally, we detail a logistic regression model assessing the significant factors in PFL harvesting choices, specifically including measures of PFL attitudes and values, before discussing implications of these results.

Results presented here will help managers, outreach coordinators, and extension personnel better define the PFL audience, target messaging, and improve stewardship of private forests in Pennsylvania, specifically with regard to commercial harvesting. Descriptive data regarding PFLs statewide has only previously been provided by the NWOS. Results presented in this Chapter paint a slightly different picture of PFLs, mostly reflecting this study's shift in sampling approach which captures all PFLs evenly, regardless of their proximity to large, forested areas (See Chapters Two and Three). This unbiased[1] sampling and large sample size allows, for the first time, reliable, quantitative data for sub-state regions, specifically the BoF private forest stewardship regions. Initial differences among these regions are presented, laying the ground work for future, more in-depth analysis of geographical variation in PFL population, private forestland issues, and commercial harvesting behavior.

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[1] Sampling schemes, when paired with appropriate estimation techniques, produce unbiased estimates.

These results provide an important baseline measure of PFL population characteristics and decision making processes. The representative nature of this study's sample, large sample size, and unbiased estimation procedures will allow future studies, including the following two panels of mail surveys in this study, to more accurately compare results, track changes over time, and assess the affects of regional influences on private forestland issues (e.g., Marcellus Shale development, changes in economic growth). This initial snapshot of Pennsylvania PFLs lays the groundwork for many future questions and studies of PFLs, private forestland issues, and commercial harvesting decisions among these landowners.

Literature Review: Predicting Commercial Harvesting Among PFLs

Private forests have long been recognized as a major source of timber and wood products for US markets (Young and Richenbach 1987; Rosen, Kaiser, and Baldeck 1989; Dennis 1990; Best and Wayburn 2001; Smith et al. 2001; Beach et al. 2005; Germain, Anderson, and Bevilacqua 2007; Favada et al. 2009). For many years, researchers have been trying to predict harvesting decisions based on several PFL, timber quality, and market variables. Young and Richenbach (1987) found that while most PFLs in Illinois did not intend to harvest timber in the near-term, those who viewed harvesting as compatible with other important uses of their forestland were significantly more likely to do so.

The majority of studies, however, have focused less on PFL beliefs, values, and attitudes in favor of sociodemographic variables and price indexes. A USFS study of

Northeastern[2] PFLs found harvesters held higher proportions of high-value species and white pine (*P.strobus*) and were less educated and less affluent than their non-harvesting counterparts (Dennis 1990). Interestingly, while Dennis (1990) examined many aspects of timber price, none were statistically relevant to Northeastern PFL harvesting decisions. Similarly, Rosen et al. (1989) showed financial considerations do not top PFL priorities and as such, their marketing and search for best possible price suffers.

Those who found price a significant predictor of harvesting choice conducted their studies only in the southern US or abroad. For example, Adams and Haynes (1980) examined softwood timber dynamics, Boyd (1984) researched southern PFLs, Prestemon and Wear (2000) detailed harvesting decisions among PFLs in the coastal plain southern pine stands of North Carolina, and Favada et al. (2009) built models around Finnish forest owner decisions, among others (Kuuluvainen and Salo 1991; Newman and Wear 1993; Kuuluvainen and Tahvonen 1999; Pattanayak and Holmes 2003). There is some evidence that price affects lumber production in Pennsylvania (Luppold and Bumgardner 2006); however, this evidence was aggregated for sub-state regions and not directly linked to individual PFL decisions.

Many studies have found PFL harvesting decisions were significantly influenced by several sociodemographic variables. Boyd (1984) found income negatively related to harvesting decisions while education related positively. Others' findings support these conclusions (Holmes 1986; Hyberg and Holthausen 1989; Kuuluvainen and Salo 1991; Löyland, Kringstad, and Ōy 1995; Kuuluvainen and Tahvonen 1999) while some

[2] The Northeast includes CT, ME, MA, NH, RI, and VT (Dennis 1990, p.176)

contradict. For example, Dennis (1989; 1990) found harvesting suppressed among more educated PFLs.

Several studies found age to be an important predictor of harvesting. Kuuluvainen and Salo (1991), Löyland, Kringstad, and Ōy (1995), Kuuluvainen, Karppinen, and Ovaskainen (1996), and Conway et al. (2000) all found older PFLs less likely to harvest. Most studies, however, found tract size (i.e., amount of forestland owned) to be significant and positively related to harvesting decisions (Binkley 1981; Boyd 1984; Holmes 1986; Hyberg and Holthausen 1989; Lee and Murray 1990; Kuuluvainen and Salo 1991; Löyland, Kringstad, and Ōy 1995; Conway et al. 2000).

Despite the plethora of studies attempting to predict PFL harvesting decisions, few examined the details of PFL attitudes, values, and beliefs but instead focused on externalities such as price. As mentioned, early work by Young and Richenbach (1987) found PFL views of harvesting as compatible (or not) with other uses of forestland was a significant predictor of harvesting behavior. However, this variable and others like it were conspicuously absent from other studies attempting to predict PFL harvesting decisions. In addition, other concepts potentially helpful in predicting the nature of harvesting decisions have not been explored. For example, while traditional forest management has been based on anthropocentric views of forest values (Pinchot 1910), little has been done to characterize PFL views on an anthropocentric/biocentric scale, as others have done for forest and wildlife values (e.g., Manning, Valliere, and Minteer 1999; Vaske and Donnelly 1999; Vaske et al. 2001; Hunter and Rinner 2004; Finley and Kittredge 2006). The analysis presented here measures PFL attitudes toward harvesting, their beliefs about the compatibility of harvesting with healthy forests, and their values of forests on an anthropocentric/biocentric scale in an effort to better predict harvesting decisions.

Methods

Sampling methodology

A review of sampling designs used in other studies found the most widely applicable aspects for sampling PFLs was the National Woodland Owner Survey (NWOS) design (Metcalf 2006). Although lists of PFLs are available for some areas, they are usually limited to only a few towns or counties in any state (Metcalf 2006). Using PFL participants from workshops or conferences severely limits the sampling frame and does not allow inferences about the entire PFL population (Metcalf 2006). Although the current NWOS design has some serious limitations, as discussed in Chapters Two and Three, particular aspects can allow unbiased sampling of PFLs across wide geographic areas (i.e., entire states or multi-state regions) if employed properly.

Identifying PFLs by placing random points on forestland is one unbiased sampling technique which is appropriate for use at most geographic scales. However, for this approach to remain unbiased and allow accurate estimates of population parameters, certain sampling constraints must be met. For example, researchers must be able to accurately calculate selection probabilities for each selected PFL. Additionally, PFL data must be collected at each and every random point so that unbiased estimates can be made of PFL population parameters and the private forestland parameters within the study area.

As detailed in Chapters Two and Three, if PFL samples are drawn in such a manner, SRS equations can estimate forestland parameters and HHE equations can estimate PFL population parameters.

Although placing random points over forestland is a relatively easy spatial analysis technique, identifying PFLs "under" each point is complicated by data availability and time constraints. In the absence of digital or recently updated portable maps (e.g., plat books), ownership data are generally accessible at local or county administrative offices, but can only be gathered by visiting these offices. In Pennsylvania, ownership data in 2005 were only available in spatial formats for approximately half the State's counties (Metcalf 2006). For these counties, identifying PFLs was relatively simple. However, in counties without spatial ownership data, identifying PFLs was more complicated and time consuming, involving trips to local or county offices and using hardcopy or "by hand" mapping techniques. The following section details our methods for placing random points across private forestland in Pennsylvania and using those points to identify PFLs in counties with and without spatial ownership data.

To begin our sampling of PFLs, digital maps of forestland (post-processed Landsat images) were obtained for 66 of Pennsylvania's counties[3] (Warner 2000). Additionally, GIS layers of all public lands were compiled from all available sources (e.g., US Forest Service, PA Game Commission, PA DCNR, PennDOT, county and local offices, etc.) to delineate private forestland within each county. To select PFLs for our sample, 400 points were randomly placed on the private forestland in each county. Parcel

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[3] Philadelphia County was excluded because it contains less than one tenth of one percent of the state's private forestland.

owners were identified by intersecting these random points with GIS parcel data obtained from county GIS, planning, or tax assessment offices. At the time sampling was conducted (2005/06), these GIS parcel data were available for 36 of the 66 counties studied[4] (Metcalf 2006).

In the remaining counties, the location of each random point was triangulated by hand onto plat books or maps and PFLs identified by referencing tax assessment information in county courthouses. Graduate students and volunteers were sent to county offices with laptops, GIS software, and spatial data including the random points, county and township boundaries, state and local roads, streams, water bodies, and public lands. Each random point was transcribed onto county maps by triangulating point location as related to features or the other spatial data. For example, point "x" is directly north of this specific road feature and directly west of this specific township boundary feature. A total of 400 random points were triangulated in each county, yielding a sample of approximately 200-300 PFLs per county (Metcalf 2006).

Analysis implications of sampling methodology

Unfortunately, our design was based on NWOS procedures and implemented prior to our full understanding of its consequences. As a result, there are two aspects of this sampling design which limit analysis. First, PFL information was only collected once per owner, not at every random point. Second, in some cases, more than 400 points were placed in a county to identify 200 individual PFLs. Records of multiple points on PFL

[4] A 2010 census of county offices has shown these data are now available for 49 Pennsylvania counties.

properties and additional point placement were not maintained. These two oversights in sampling negate our ability to accurately estimate PFL and private forestland population parameters.

Without PFL information at each random point, unbiased estimates for private forestland parameters are impossible. For instance, while we can estimate the proportion of PFLs who engage in a behavior (e.g., number of PFLs who post their forestland), we cannot estimate how much private forestland is affected by this behavior (e.g., acres of private forestland posted). As PFL population size is a parameter of private forestland, as discussed in Chapter Two, our sample does not allow an unbiased estimate of the total number of PFLs in Pennsylvania. Due to this oversight, only parameters of the PFL population will be presented in our results. The third panel of this study's mail surveys slated for 2010 corrects this oversight.

Further, without accurate records of how many random points were ultimately placed in each county, inclusion probabilities cannot be accurately calculated. Inclusion probabilities are a function of selection probabilities (p_i) and the number of selections (n): $\pi_i = [1 - (1 - p_i)^n]$ (Thompson 2002). If the number of selections is unknown, this equation cannot be used. Only a few counties had more than 400 points so ignoring this may not be a significant omission; however, it is critical to identify this potential limitation. Again, the third and final panel of this study's mail surveys corrects this oversight.

While there is no impunity in admitting these limitations, it is important to note they are a result of errors published by the NWOS. Our design relied on NWOS publications for guidance; oversights in their design naturally carried through into ours.

Both the inclusion of PFLs only one time (instead of once per intersecting random point) and the miscalculation of inclusion probabilities are suggested by Butler, Leatherberry, and Williams (2005). Specifically, step 2 of Appendix III in this publication (Butler, Leatherberry, and Williams 2005) demonstrates the removal of duplicate PFLs from the sample before estimating PFL population parameters, including population size (p.35). In addition, those authors report an incorrect equation for calculating inclusion probabilities which excludes the number of points dropped as a necessary variable (p.15).

Results presented here were analyzed using SPSS 18.0 and the Complex Samples module. This software allowed an accounting of the county stratification, PPS nature of PFL sampling, and the without replacement approach of our sampling design. County stratification weights were based on the amount of private forestland owned in each county, as a factor of the total private forestland in Pennsylvania. PPS inclusion probabilities were calculated for each PFL using their forestland ownership, the total private forestland in their county, and the number of random points placed in their county, which understandably might have some errors due to our failure to retain data related to sample sizes.

Mail survey methodology

The goals of this study were to identify PFLs across the Commonwealth, determine their ownership objectives, inventory the composition and condition of these private forests, and to assess current management and decision making processes around management and timber supply in a changing landscape. To do this, we combined quantitative and qualitative social research methods with forest measurement techniques and secondary data in a multiple panel (longitudinal) design, as outlined in Chapter One. This Chapter focuses on the quantitative methods used and corresponding results. Future work will detail the qualitative and forest inventory methods used and lessons learned from triangulating across these methods. Despite the separation in reporting, results from all methods have been used to inform and evolve our inquiry over the course of this entire five-year, multi-panel study.

Each of the PFLs drawn for our sample was asked to complete a mail survey exploring many different aspects of forestland ownership. The mail survey was conducted using standard survey techniques (tailored design methodology) with multiple mailings, personalization, and reminders (Dillman 2007). Major themes explored with the survey included harvesting issues and concerns, impacts of development and regulation, attitudes and perceptions about management and harvesting, availability and use of technical assistance, ownership objectives, future plans, and marketing.

The mail survey questionnaire was developed using existing survey instruments, input from Penn State University faculty and graduate students, and BoF personnel. A full copy of the questionnaire is included in Appendix. The first panel of the mail survey was conducted during the spring of 2006. A twenty-page questionnaire was sent to approximately 100 PFLs per county or about 6,600 PFLs statewide. These 100 PFLs were selected using a SRS protocol from the approximately 200-300 PFLs identified in each county using the random point procedure detailed earlier. Following four waves of contact (initial survey, a reminder postcard, and a second and third follow-up survey) and adjusting for undeliverable, deceased, and non-forestland owners, the survey achieved a response rate of 54 percent (N=3,174).

Many results presented here show averages or estimates of the “nominal” landowner. Although this analysis is useful, readers should be aware the “average PFL” likely does not exist. Rather, these results are intended to give a broad overview of forestland ownership in Pennsylvania and the impacts of PFL decisions on a variety of forestland issues, including commercial harvesting. As discussed in Chapter Two, the sampling design of the NWOS has biased past results toward more rural and forested areas of the state dominated by PFLs with larger properties. Results presented here paint a previously unavailable, unbiased picture of PFL characteristics, patterns, and decision making processes in Pennsylvania.

In addition to statewide analysis, we also present a more detailed analysis of PFL characteristics and decision making process. For the first time, these data allow sub-state regional analysis of private forest landownership. We begin this more detailed analysis by presenting characteristics of PFLs that differ among PA BoF regions and help inform questions regarding access to private forest resources. Following this regional analysis, we detail PFL decision making with regard to harvesting through a logistic regression model. While the focus of this Chapter ends here, data from this first panel survey (and future panels) will enable much additional and detailed inquiry. For example, future analysis will explore aspects of ownership such as independent segments of the PFL population, issues affecting access to private timber resources, PFL views of their forestland compared to the view of foresters, the utility of management plans, and willingness to cooperate among PFLs, among many others.

Logistic regression methodology

In the statewide survey of PFLs, we asked many questions measuring attitudes, beliefs, and values regarding several aspects of forest management, including harvesting trees. Specifically relevant to harvesting decisions, we were curious whether PFL values regarding the biocentric/anthropocentric value of forests and the compatibility of harvesting with healthy forests influenced decisions in addition to attitudes toward cutting, tract size and several socio-demographic variables. We hypothesized that PFLs who saw high intrinsic value in forests favoring biocentric over anthropocentric values would be less likely to harvest. Additionally, we hypothesized PFLs who viewed harvesting as compatible with healthy forests would be more likely to conduct harvests.

Survey questions were asked about these concepts, attitudes toward harvesting in general, tract size, and sociodemographic variables. Concepts were measured across nine variables: 1) cutting trees permanently harms the forest, 2) harvesting trees can improve the health of the forest, 3) cutting trees can improve the forest, 4) any cutting of trees harms the water quality of nearby streams, 5) humans shouldn't interfere with nature, 6) healthy forest are important to me, 7) forests have a right to exist for their own sake regardless of human concerns or use, 8) humans should have more love, respect, and admiration for forests, and 9) are you opposed to cutting trees on your forestland. Each of these items were measured using a five-point Likert scale that for eight items ranged from strongly disagree (1) to strongly agree (5); the scale for opposition to cutting trees ranged from very opposed (1) to very willing (5). In addition, several sociodemographic variables were measured including age, income, and education level.

To determine the underlying dimensions of the value-oriented statements, an exploratory factor analysis with varimax rotation was used. The internal consistencies of these factors were tested using Cronbach's alpha reliability coefficients using 0.60 as a threshold (Cortina 1993; Vaske 2008). All analysis was conducted in SPSS version 18.0 with the complex samples module to correct for the stratified, PPS nature of the sample (see earlier discussion).

Tract size was measured by asking respondents how many forested acres they owned across all properties. Opposition to harvesting was included as an independent variable, measuring attitude (as described above). Sociodemographic variables included age, income, and education. Income was recoded from a categorical variable as measured in the mail questionnaire using the mean of each category as the lower or upper limit provided by terminal categories.[5] Education was recoded from a categorical variable to estimated years of higher education.[6]

Commercial harvesting behavior was measured by first asking respondents if they had cut trees from their property in the past 10 years. Those responding positively were then asked what type of wood had been cut. If harvests were described as only "sawlogs for personal use" or "firewood for personal use," respondents were considered to not have conducted a commercial harvest. If harvests were described as "sawlogs for sale," "veneer logs for sale," "pulpwood," or "firewood for sale," respondents were considered to have conducted a commercial harvest. Those responding "Yes" to having cut trees yet

[5] "Less than $15,000" = 15,000; "$15,000 to $24,999" = 20,000; "25,000 to $34,999" = 30,000; "$35,000 to $49,999" = 42,500; "$50,000 to $74,999" = 62,500; "$75,000 to $99,999" = 87,500; "$100,000 to $149,999" = 125,000; and "$150,000 or more" = 150,000.

[6] "None," "Grade School," "Some high school," and "Completed high school or GED" = 0; "Some college/technical school beyond high school" = 2; "Completed college" = 4; and "Graduate/professional school" = 6

described their harvests as non-commercial were added to those responding “No” to having cut trees. In this sample, 45.8 percent of PFLs had cut trees in the past 10 years; however, the majority of these (56.1%) did so for personal use only.

Results

Statewide results

Distribution of PFLs by amount of forestland owned

The majority of Pennsylvania PFLs (63%) own between one and ten acres of forestland (Figure 4-2[7,8] and Table 4-1). The vast majority of PFLs (92%) own 50 acres of forestland or less. A small percentage of owners (8%) own more than 50 acres of forestland.

[7] Acreage categories are from Birch (1996).
[8] All error bars in figures represent standard error calculations

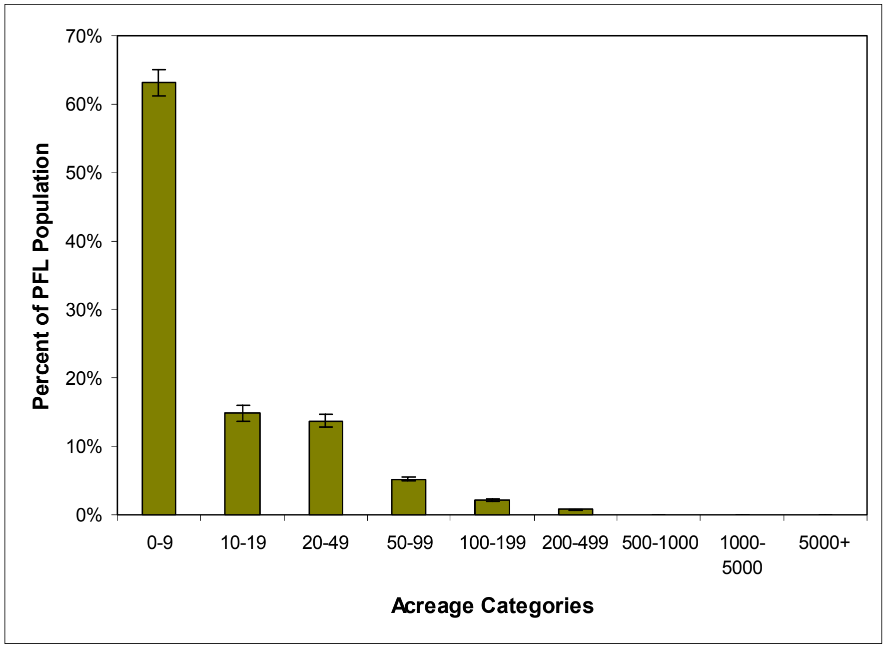

Figure 4 - 2: Distribution of Pennsylvania PFLs by acreage categories

Table 4 - 1: Distribution of Pennsylvania PFLs by acreage categories

		% PFLs	% Std. Err.
Acres Owned	0-9	63.2%	1.9%
	10-19	14.8%	1.1%
	20-49	13.7%	0.9%
	50-99	5.2%	0.4%
	100-199	2.1%	0.2%
	200-499	0.8%	0.1%
	500-1000	0.1%	0.0%
	1000-5000	0.04%	0.01%
	5000+	< 0.001%	< 0.001%

Sociodemographics

Over 80 percent of Pennsylvania PFLs are male. This statistic may be biased as owners' names were collected from tax parcel databases which tend to list male names first. In addition, forestland decisions may be made by married couples, joint owners, groups or associations. Regardless, forestland ownership in Pennsylvania is clearly skewed in favor of males.

The mean age of Pennsylvania PFLs is 57 years and most PFLs, nearly 81 percent, are at least 45 years old (Figure 4-3). Few young adults own forestland with less than one percent of Pennsylvania PFLs between the ages of 18 and 24 and only 2.5 percent between the ages of 25 and 34. Just fewer than 17 percent are between the ages of 35 and 44 while the plurality of PFLs, 29 percent, is between the ages of 45 and 54. The mean age category, 55 to 64, contains 23 percent of PFLs and those over the age of 65 amount to 28 percent of the PFL population. Age is slightly but significantly related to acreage of forestland owned ($p<0.001$), meaning the majority of Pennsylvania forestland is owned by PFLs of or close to retirement age.

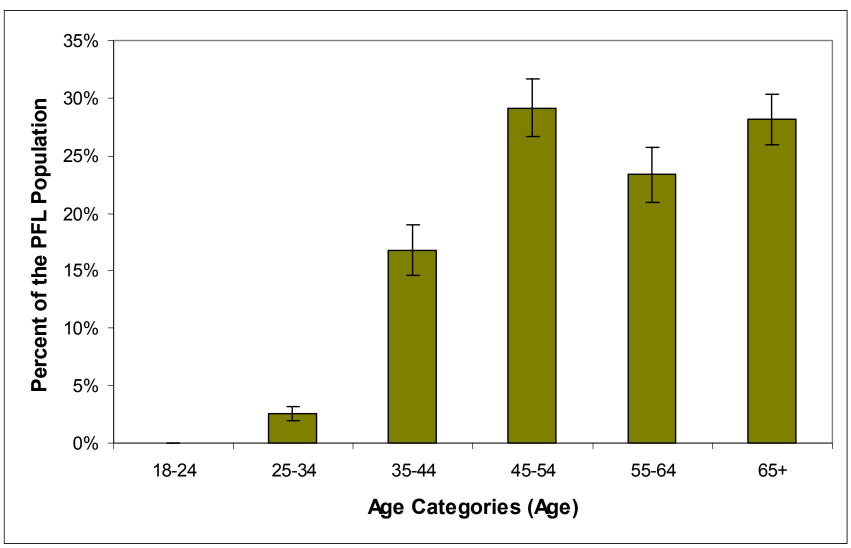

Figure 4 - 3: Distribution of Pennsylvania PFLs by age categories

Most PFLs are either employed full-time (55%) or retired (35%). Only six percent are employed part-time and three percent unemployed. Very few are homemakers (2%)

or students (<1%). PFLs are generally well educated with 65 percent having at least some college. A full 18 percent having an advanced degree, 20 percent are college graduates, 27 percent have some college education or a technical degree, and 31 percent have a high school diploma or GED (Figure 4-4). Three percent attended only grade school and two percent started, but did not finish, high school.

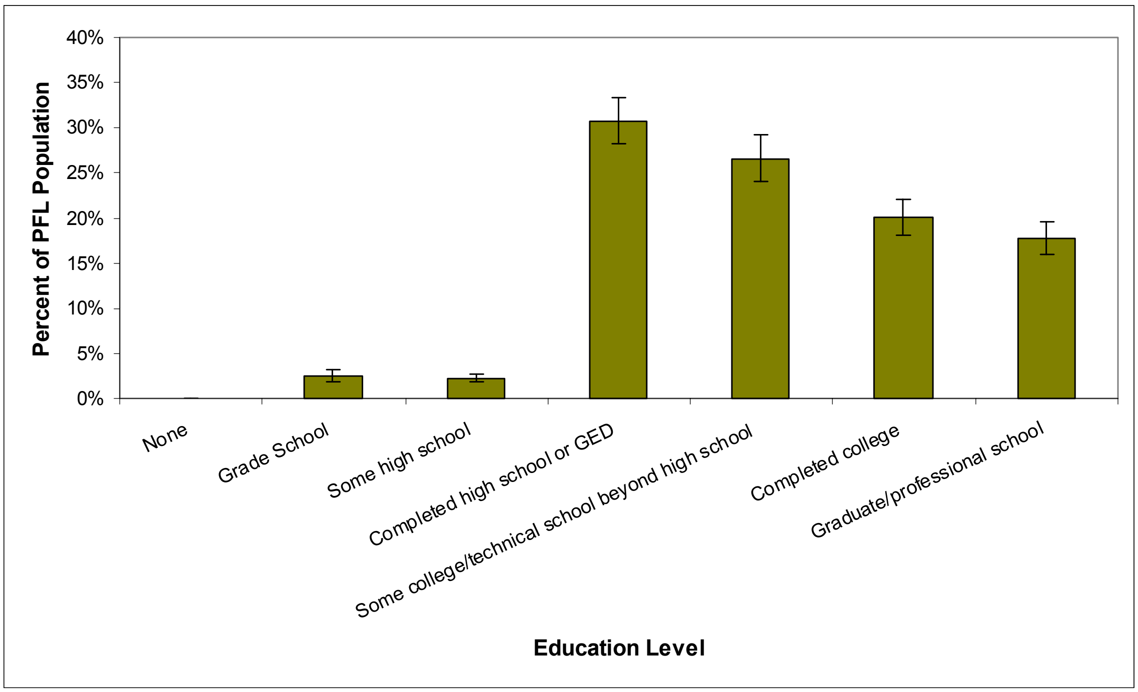

Figure 4 - 40: Distribution of Pennsylvania PFLs by education level

Income was also very high among PFLs (Figure 4-5). Only four percent had a household income less than $15,000 per year and 15 percent had an income between $15,000 and $35,000. Over 40 percent earned between $35,000 and $75,000 per year, 28 percent earned between $75,000 and $150,000, and 12 percent earned over $150,000 per year. The median household income in Pennsylvania for 2004 was just under $44,000 annually according to the US Census.

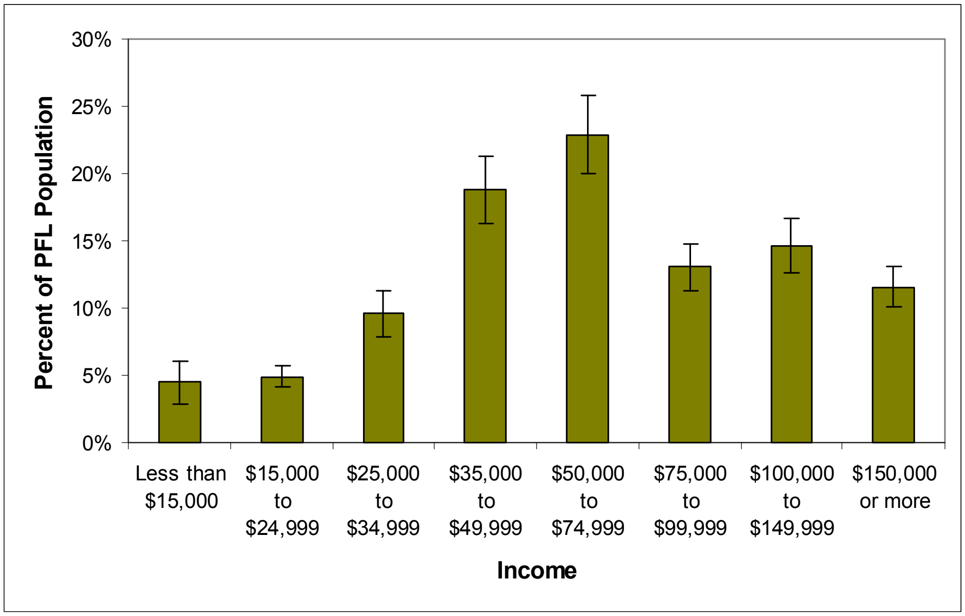

Figure 4 - 5: Distribution of Pennsylvania PFLs by income categories

PFLs lean significantly conservative in their political views (Figure 4-6). While three percent self identified as liberal and nine percent as moderately liberal, 32 percent identified as moderately conservative and 22 percent as conservative. The plurality of Pennsylvania PFLs, 34 percent, described their political views as moderate.

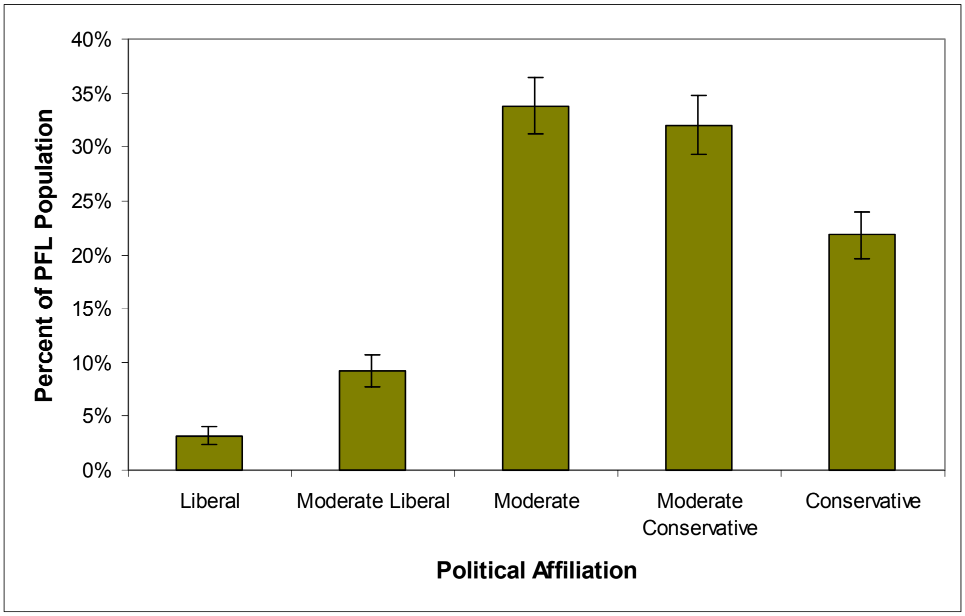

Figure 4 - 6: Distribution of Pennsylvania PFLs by political affiliation

Absentee ownership

Absentee ownership can be defined many ways and helps show how involved owners are in their forestland and the community where their forestland is located. Approximately 73 percent lived within one mile (Figures 4-7) of their forestland. Around 12 percent lived within 30 miles and 5 percent lived between 30 and 100 miles away from their forestland. Eight percent lived between 100 and 250 miles away and 3 percent lived over 250 miles away. Acres of forestland owned was significantly ($p<0.001$) and positively related to distance from forestland (Figure 4-8); absentee owners typically owned larger properties than resident owners.

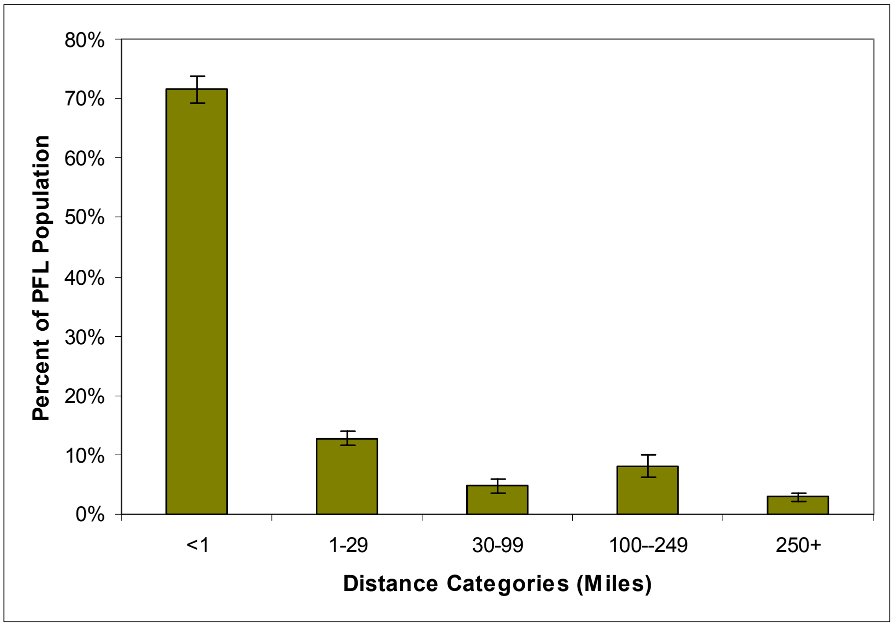

Figure 4 - 7: Distribution of PFLs by proximity to forestland

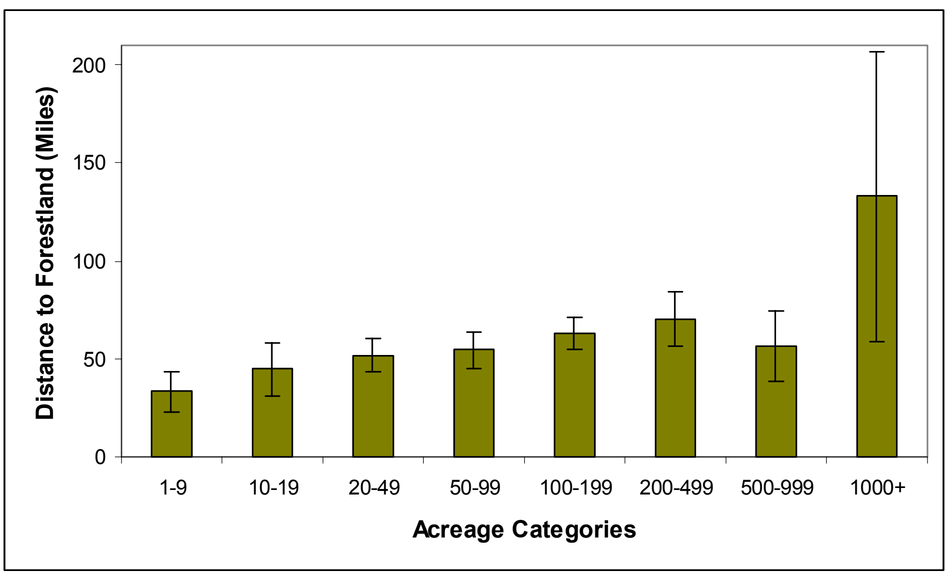

Figure 4 - 8: Distance to forestland (miles) by acreage categories

Distance from forestland, however, does not necessarily reflect a PFL's investment or level of engagement with their forestland. In addition to distance, we asked PFLs how often they visited their forestland (Figure 4-9). Over half, 55 percent, reported living on the property while 12 percent visited at least once per week and 15 percent at least once per month. Another 12 percent visited several times per year and the remaining 7 percent visited once per year or less.

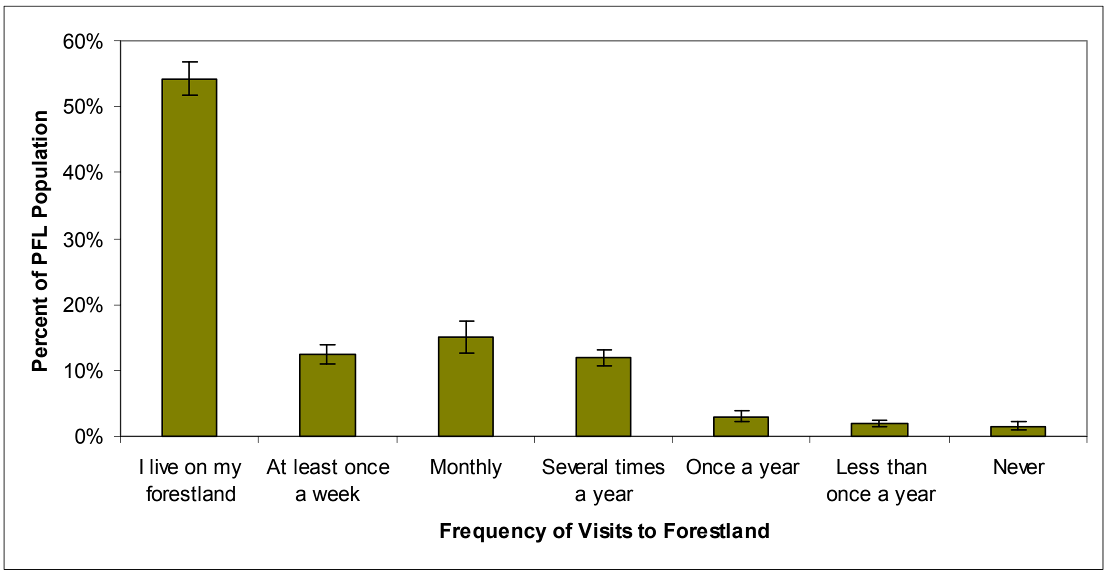

Figure 4 - 9: Distribution of Pennsylvania PFLs by frequency of visits to forestland

Ownership objectives

PFLs own their forestland for a variety of reasons and balance these multiple goals as they decide the future of their forestland. To explore these ownership objectives, we asked PFLs to identify all the reasons they owned their land and then to select the most important reason. Their responses provided insight into the complexity of private forest landownership objectives.

When asked to identify all the reasons important to ownership, wildlife was most often cited by PFLs (62%) followed closely by solitude (59%) and enjoyment of owning (58%) (Figure 4-10). Incidental ownership (i.e., it came with the property) was cited by 49 percent of PFLs. Thirty-four percent of PFLs identified general recreation among their ownership objectives and another 40 percent chose hunting. Personal uses of wood ranked high, 38 percent, while growing timber for sale and land investment ranked low, 13 and 14 percent, respectively.

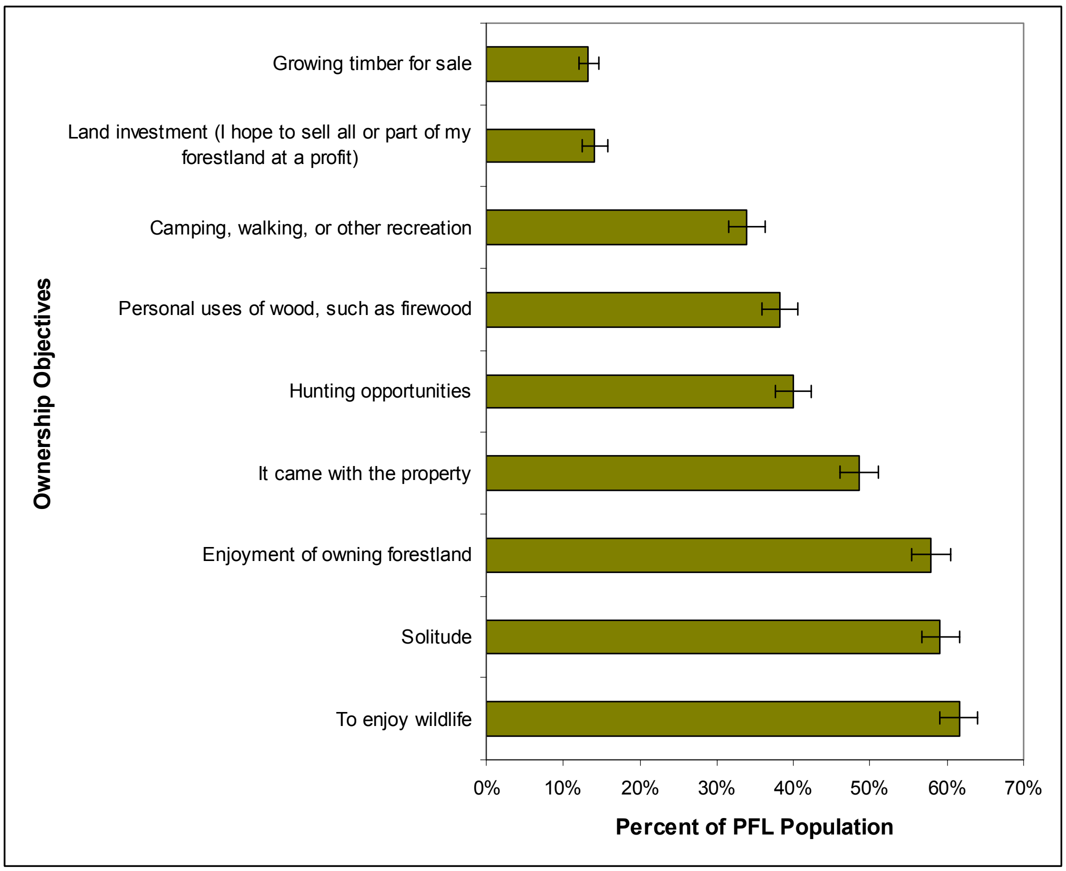

Figure 4 - 10: Distribution of Pennsylvania PFLs by ownership objectives (note: percentages do not sum to 100 as respondents could choose more than one option)

Ownership objectives varied among PFLs depending on the acres of forestland owned. Table 4-2 shows the four top-ranked ownership objectives for each acreage category. Wildlife was important to PFLs regardless of the acres owned. Privacy (solitude), enjoyment of owning, and incidental ownership were dominant reasons among PFLs with smaller properties (i.e., less than 20 acres). Privacy and enjoyment of owning remained important for PFLs with "medium-sized" properties (i.e., up to 200 acres) and hunting increased in importance. For those PFLs with large properties (i.e., more than 200 acres), hunting, timber, and recreation were the most often cited ownership objectives in addition to wildlife.

Table 3 - 2: Ranked ownership objectives of PFLs by acreage categories

		Ranked Ownership Objectives			
		1st	*2nd*	*3rd*	*4th*
Acres Owned	*1-10*	Solitude (61%)	Wildlife (60%)	Enjoyment (56%)	Came with the property (55%)
	10-20	Wildlife (60%)	Solitude (57%)	Enjoyment (55%)	Came with the property (46%)
	20-50	Wildlife (67%)	Enjoyment (63%)	Hunting (60%)	Solitude (57%)
	50-100	Wildlife (70%)	Enjoyment (67%)	Hunting (65%)	Solitude (58%)
	100-200	Hunting (68%)	Wildlife (67%)	Enjoyment (63%)	Solitude (56%)
	200-500	Hunting (72%)	Wildlife (67%)	Recreate (58%)	Estate (57%)
	500-1000	Timber (71%)	Hunting (70%)	Wildlife (69%)	Recreation (58%)
	1000+	Hunting (62%)	Timber (53%)	Wildlife (48%)	Recreate (47%)

When asked to identify the single most important reason for owning, PFL responses changed slightly (Figure 4-11). The most common reason for owning forestland in Pennsylvania was solitude, cited by 22 percent of PFLs. Incidental ownership was the second most common reason among PFLs (16%). Enjoyment of owning was reported by 14 percent of the owners and wildlife by only 10 percent. Seven percent of PFLs owned their forestland specifically as an estate to pass on to heirs. A few PFLs owned specifically for recreation reasons: seven percent for hunting and three percent for other recreation (i.e., camping, walking, or other recreation). Financial objectives ranked low with only four percent of PFLs owning for a land investment and two percent for timber production.

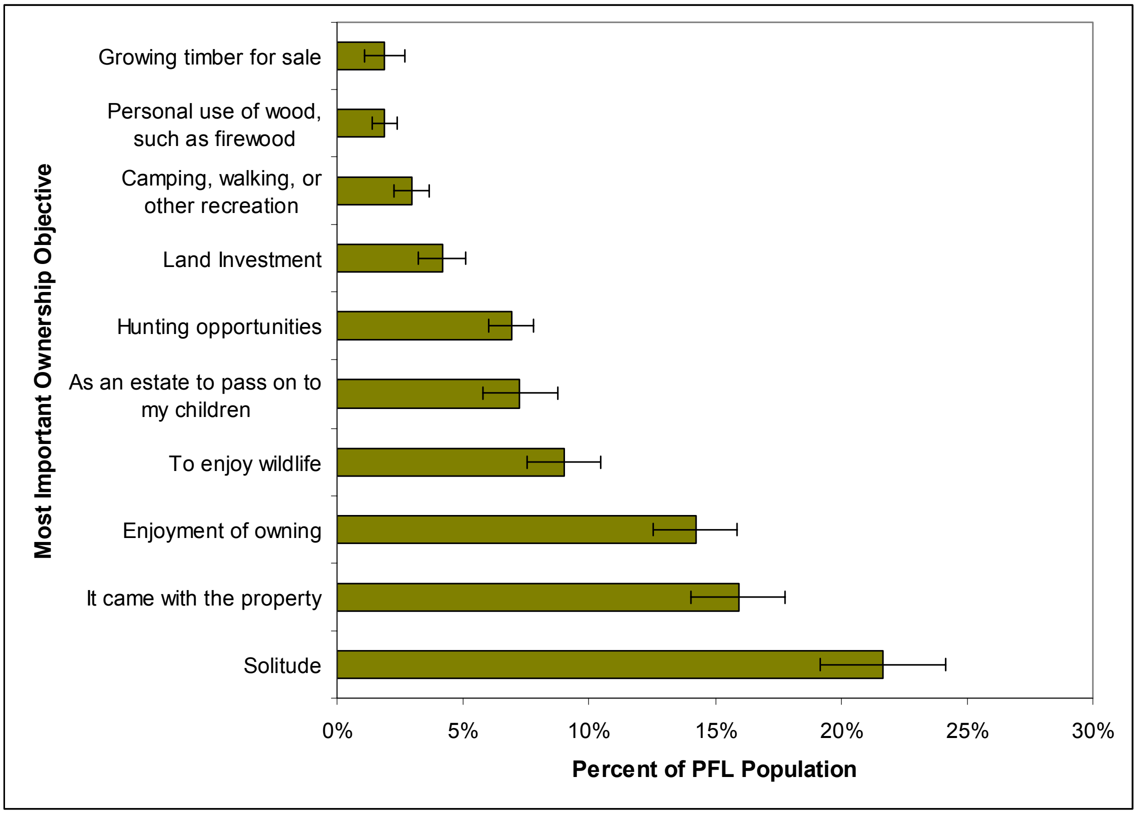

Figure 4 - 11: Distribution of PFL population by most important ownership objective

As the most important ownership objective to PFLs varies with the amount of forestland owned, these results reflect ownership objectives most important to PFLs with smaller properties as there are many more of these "small" owners. Table 4-3 shows the top four most important ownership objectives among PFLs by acreage categories. Solitude and enjoyment of owning were most important for PFLs with 50 acres of forestland or less. Hunting was the number one reason among owners with 50 to 500 acres. Timber was the most important reason for landowners with 500 to 1000 acres and hunting was again most important for PFLs with 1,000 acres of forestland or more. Although wildlife is very frequently cited by PFLs when asked to choose multiple ownership objectives, it was not among the most important reasons for owning, regardless of acres of forestland owned.

Table 4 - 3: Ranked most important ownership objective among PFLs by acreage categories

		Ranked Most Important Ownership Objectives			
		1st	*2nd*	*3rd*	*4th*
Acres Owned	*1-10*	Solitude (31%)	Came with (23%)	Enjoyment (14%)	Wildlife (12%)
	10-20	Enjoyment (21%)	Solitude (18%)	Came with (16%)	Estate (10%)
	20-50	Enjoyment (21%)	Hunting (18%)	Solitude (13%)	Came with (11%)
	50-100	Hunting (19%)	Estate (14%)	Enjoyment (13%)	Solitude (13%)
	100-200	Hunting (25%)	Enjoyment (16%)	Estate (12%)	Solitude (11%)
	200-500	Hunting (22%)	Enjoyment (19%)	Estate (14%)	Land Investment (10%)
	500-1000	Timber (25%)	Hunting (20%)	Land Investment (14%)	Enjoy (12%)
	1000+	Hunting (24%)	Timber (16%)	Enjoyment (15%)	Estate (10%)

These results indicate ownership objectives differed for PFLs owning different amounts of forestland. As the majority of PFLs own relatively few acres of forestland (Figure 4-2), ownership objectives among these owners do not likely "apply" to much forestland across the state. However, ownership objectives that were less common among all PFLs may be important among those PFLs controlling large amounts of forestland (i.e., those PFLs in the larger acreage categories).

Tenure

PFLs have owned their forestland for an average of 18 years. A simple linear regression showed acreage of forestland owned was positively and significantly related to tenure (R^2=0.14, p<0.001); PFLs owning more forestland tended to have owned longer than PFLs with fewer acres of forestland (Figure 4-12). However, as average tenure was

18 years, the average PFL was likely to sell at least part of their forestland sometime over the next two decades. Major management activities may take place most frequently during ownership exchanges. This “turnover” in ownership presents challenges and opportunities with regard to timber extraction, parcelization, and general engagement with existing and future PFLs.

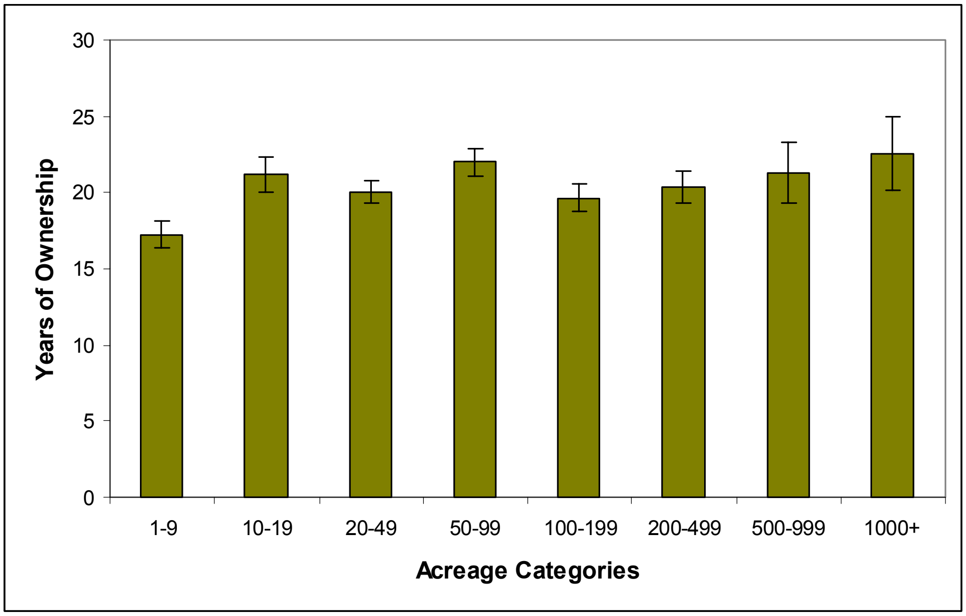

Figure 4 - 12: Mean years of forestland ownership by acreage categories

Activities

Many PFLs used their forestland for a variety of activities or engaged in forest or other types of management (Figure 4-13). Most PFLs have recreated or hunted on their properties (50% and 56%, respectively) and slightly fewer than half have improved wildlife habitat (48%). Interestingly, many PFLs (29%) indicated they had reduced fire hazards, an activity usually associated with more fire-prone areas of the country. Non-timber forest products (NTFP) have been harvested by 30 percent of PFLs for personal use, but by only 5 percent for commercial purposes. Fish habitat and streamside buffers have been improved by 12 and 7 percent of PFLs, respectively. Only one percent of PFLs leased their forestland to a club or organization. Larger landowners are slightly more involved across all these activities, except reducing fire hazards. Future intentions to participate in these activities closely mirrored past behaviors (Figure 4-14).

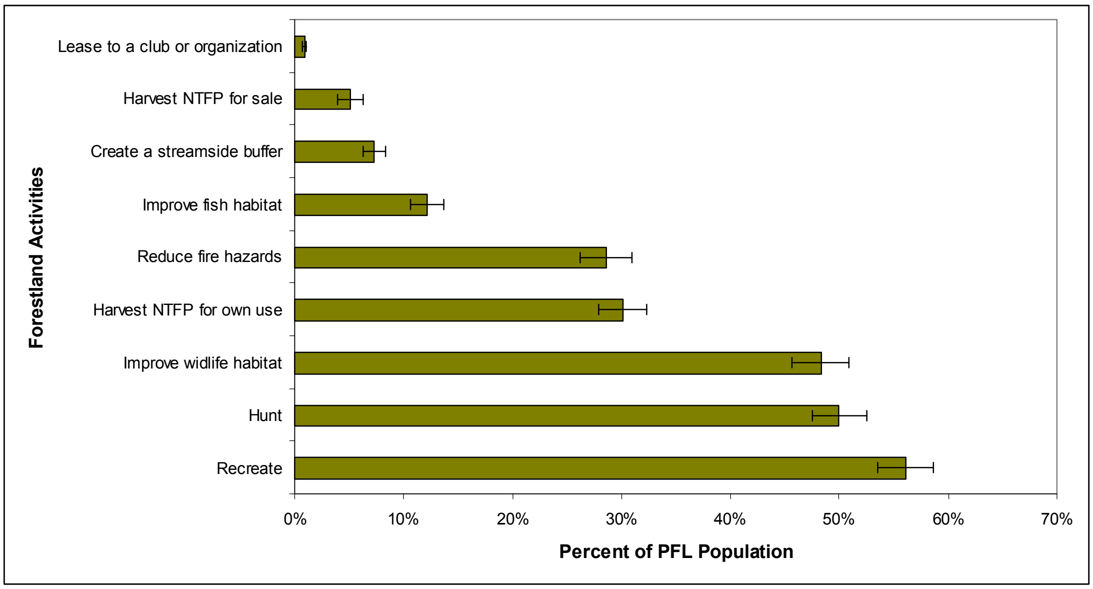

Figure 4 - 13: Percent of PFL population participating in forestland activities

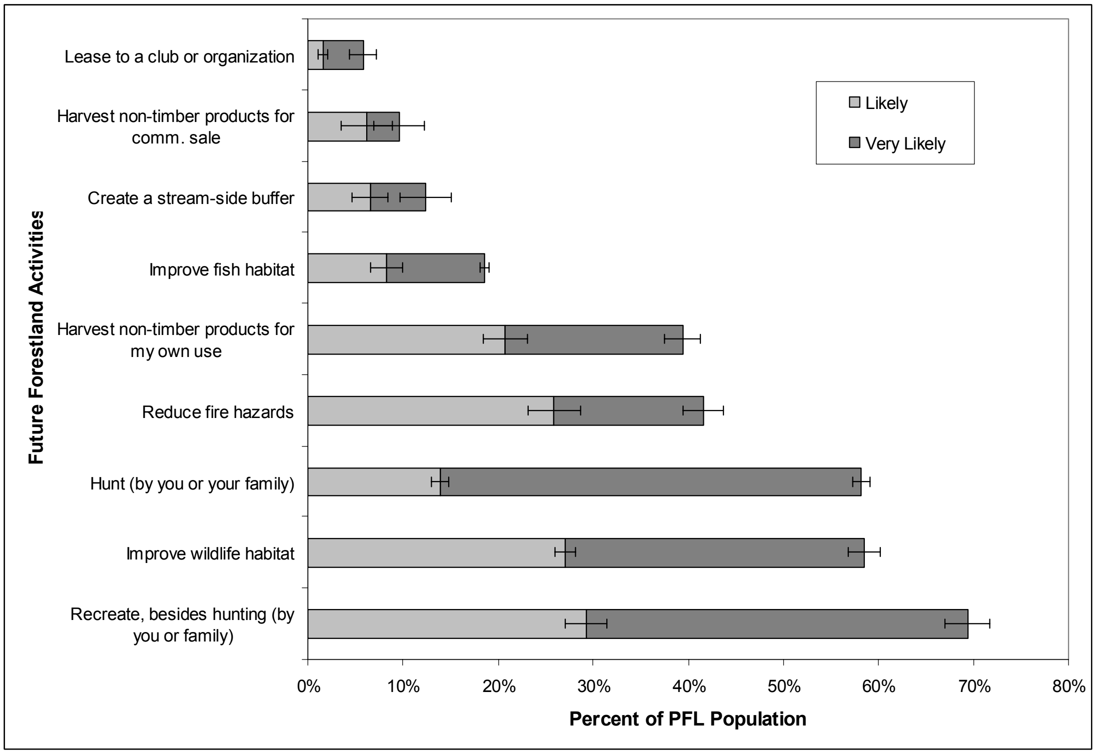

Figure 4 - 14: Percent of PFLs "Likely" and "Very Likely" to participate in forestland activities in the future

Harvesting

Nearly half of PFLs, 46 percent, harvested trees from their property over the last 10 years (1996 to 2006). However, the majority of these owners harvested trees for personal use such as firewood (Figure 4-15). Only 20 percent of all PFLs harvested trees commercially (i.e., sawlogs, veneer, pulpwood, or firewood for sale). Harvesting and commercial harvesting were both significantly related to acres of forestland owned (Figure 4-16).

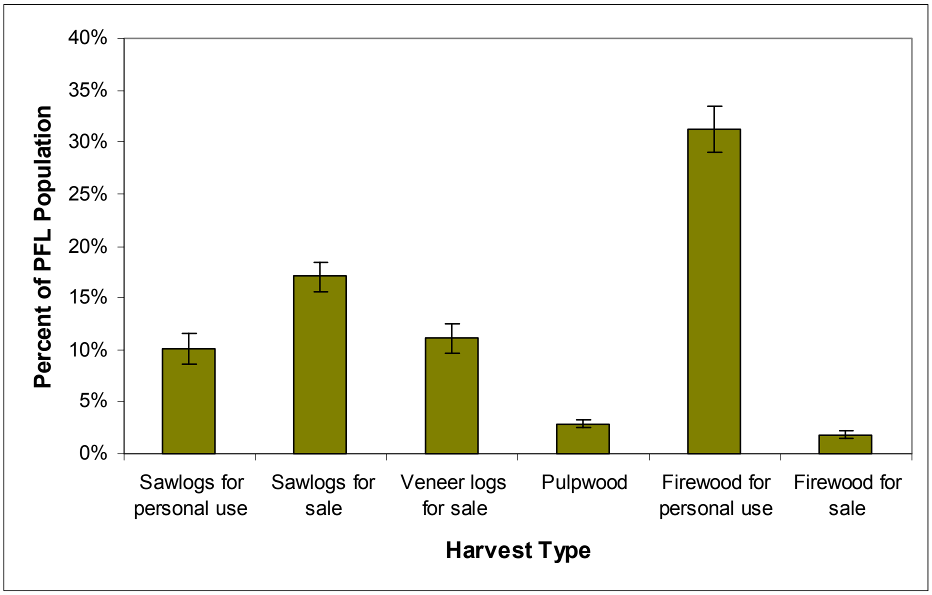

Figure 4 - 15: Distribution of harvesting PFLs by harvest type

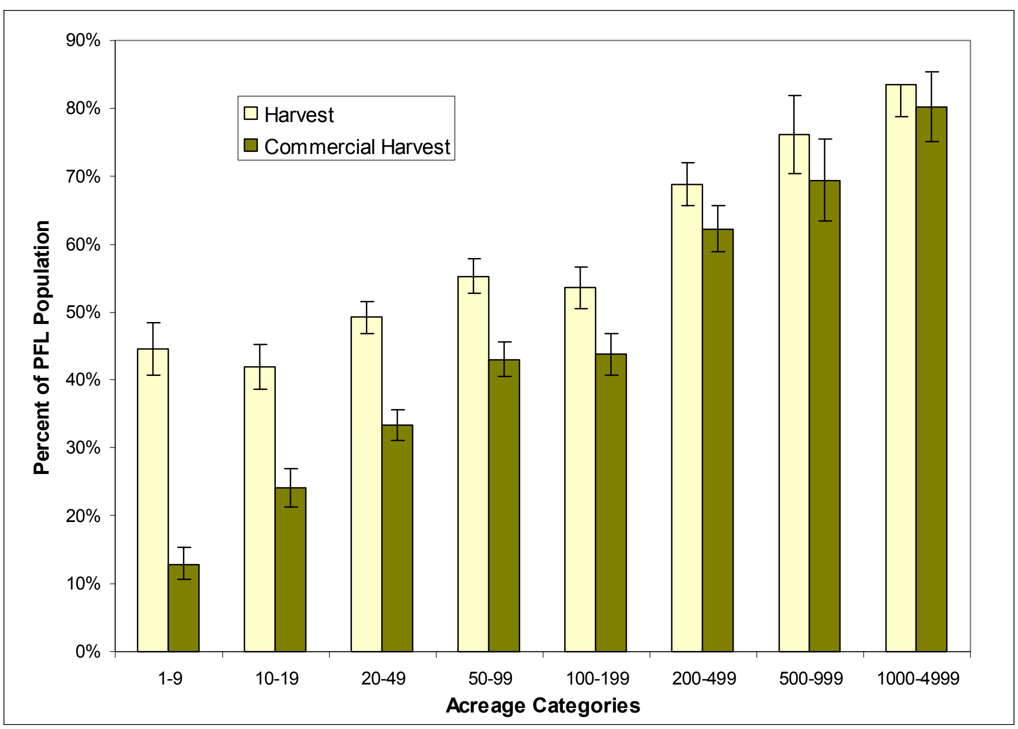

Figure 4 - 16: Distribution of Pennsylvania PFLs who have harvested trees and harvested trees commercially by acreage categories.

Commercial harvests were managed in a variety of ways on private forestland. Respondents were asked how the harvests were managed on their property. Their responses were grouped into five categories: self (i.e., managed the harvest themselves), direct sale to logger or timber company, advice (i.e., from Penn State Extension, consulting forester, industry forester, BoF forester), hired forester (i.e., a consulting forester), or other. Responses sum to over 100 percent as respondents could choose multiple items.

Although many PFLs (36%) managed commercial harvests themselves, the largest percentage of commercial harvests on Pennsylvania's private forests were direct sales to loggers or timber companies, 32 and 44 percent, respectively (Figure 4-17). Relatively few PFLs who had commercially harvested (12%) hired consulting foresters to manage the harvests. Consulting, state, and extension foresters provided advice to 30 percent of commercially harvesting PFLs, while 7 percent of PFLs received advice from an industry forester.

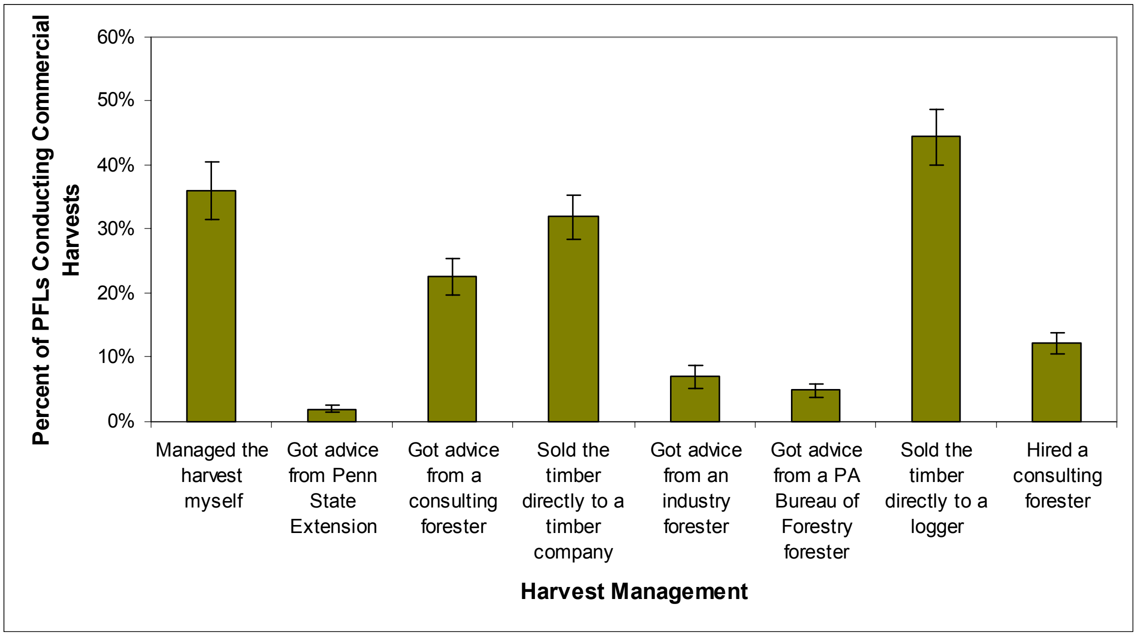

Figure 4 - 17: Distribution of commercially harvesting PFLs by management type

We asked PFLs to describe the types of harvests that occurred on their forestland. As traditional forestry terms are not familiar to many PFLs (e.g., shelterwood, high-grade, salvage), owners were asked to describe harvests in layman's terms. Most PFLs described harvests as having "only cut a few select, large trees" (Figure 4-18). Other common descriptions were "cut most of the large trees" and "cut trees of all sizes but left a lot of trees." Although these terms are vague and can be silviculturally interpreted in many ways, these responses may raise questions about the sustainability of the harvests on private forestland.

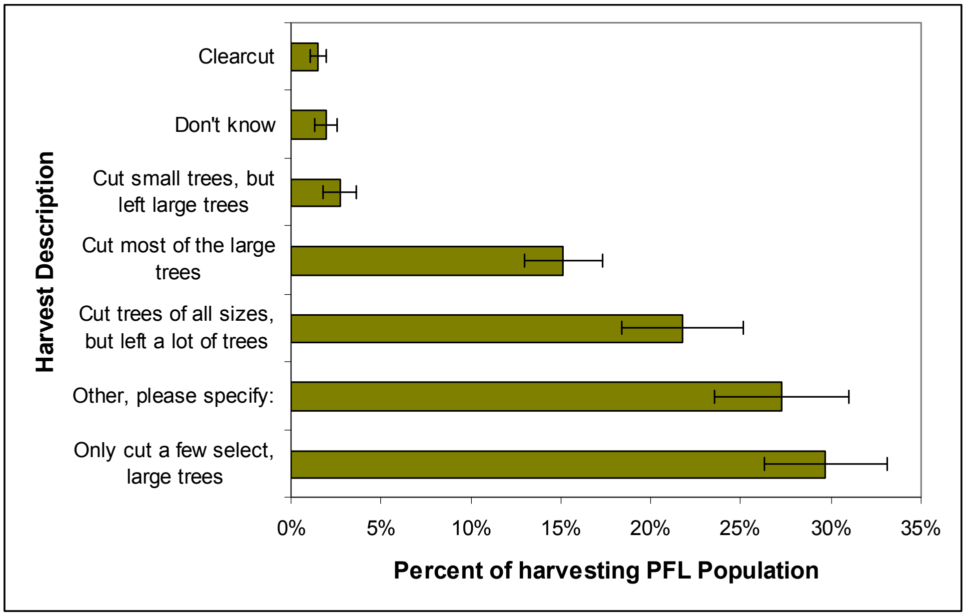

Figure 4 - 18: Percent of harvesting PFLs by harvest description

Attitudes toward harvesting

Opposition to harvesting was relatively common among Pennsylvania PFLs (Figure 4-19). Although most PFLs were either receptive to harvesting (34% willing or very willing) or unopposed (35% neither willing nor opposed), nearly one third (31%) were opposed or very opposed to harvesting. Opposition to harvesting was strongly related to the acres of forestland owned; opposition was more common among PFLs with fewer acres of forestland (Figure 4-20).

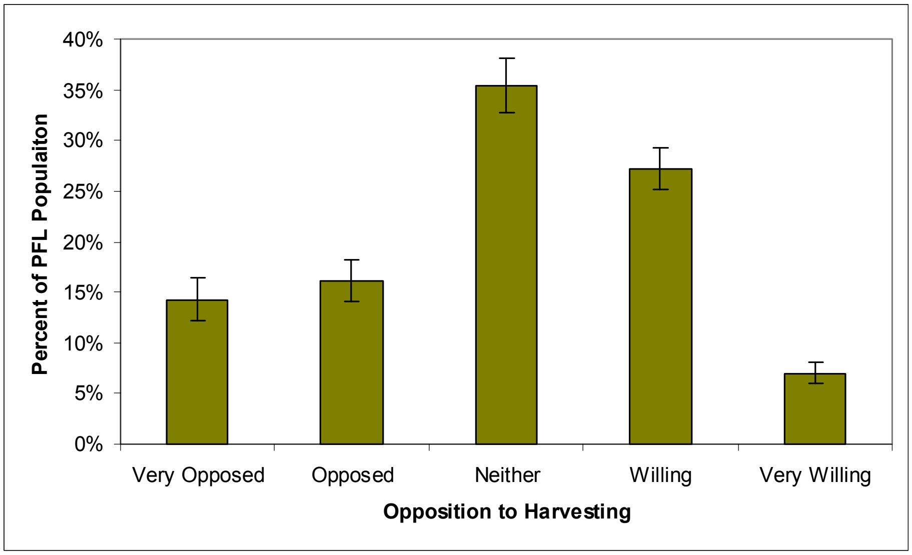

Figure 4 - 19: Distribution of Pennsylvania PFLs by opposition to harvesting

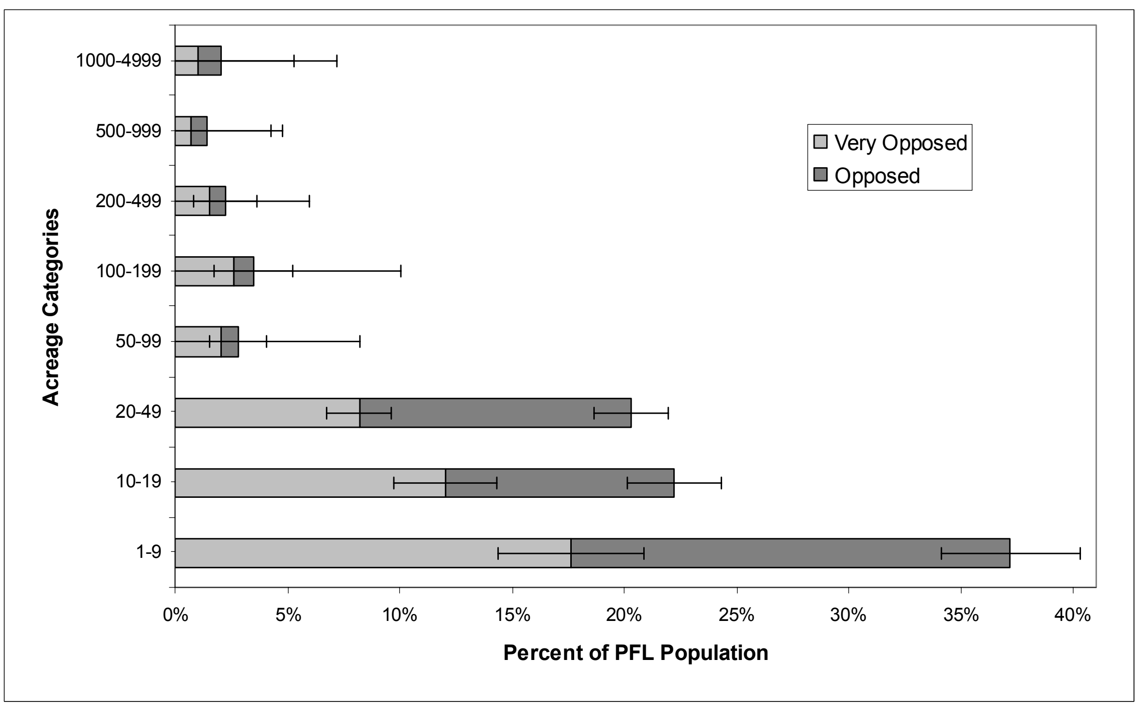

Figure 4 - 20: Percent of PFL population "Opposed" or "Very Opposed" to harvesting by acreage categories

Regardless of opposition to harvesting, PFLs were asked what, if anything, was preventing them from cutting trees. Reasons included general disinterest in harvesting (34%), too small of a property (32%), and concerns about damage to scenic value (26%), wildlife (23%), or the property in general (22%). Some PFLs have not cut trees due to concerns about general impacts of harvests (17%), and specific impacts to hunting (15%) and recreation opportunities (12%). Distrust of loggers (12%) and foresters (10%) rounded out the major concerns PFLs identified with regard to harvesting.

Management plans

Written management plans are often considered an important tool for proper forest planning and management. Plans were not common among PFLs nationally as only two percent of "family" forest owners reported having written one (McWilliams et al., 2007). In Pennsylvania, a slightly higher percentage of all PFLs (not just family forest owners) had written management plans (3.6%). Commercial harvesting may be one impetus for writing a management plan as 51 percent of those with management plans had harvested commercially. Of all owners who had harvested commercially, slightly over 9 percent had written management plans.

PFLs with more acres of forestland were increasingly likely to have written a management plan (Figure 4-21). While only two percent of PFLs with less than ten acres of forestland had management plans, over one-third of owners with 200 acres of forestland or more had written a plan. Regardless of their popularity among large owners, management plans remained uncommon among the PFL population and accounted for relatively few acres statewide. Thus, while written plans are perceived by some foresters as an important tool for promoting sustainable management of private forests, these results indicated serious limits exist to their widespread adoption.

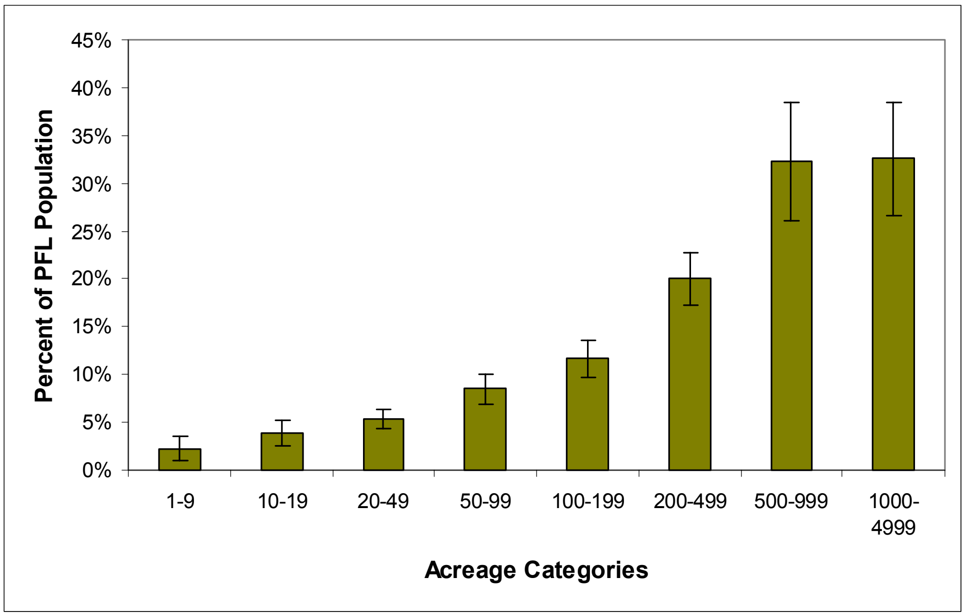

Figure 4 - 21: Percent of PFL population with written management or stewardship plan by acreage categories

Posting

Many PFLs elected to restrict access to their forestland for recreational and/or other uses. Statewide, 38 percent of PFLs posted their forestland. Number of forested acres owned was strongly related to posting (Figure 4-21). Although not specifically addressed in the questionnaire, PFLs who posted may only restrict access to a portion of their property. Thus, it is likely (although not definitive) that not all the forestland owned by posting PFLs is subject to restricted access. Importantly, most PFLs (83%), regardless of whether or not they posted their forestland, do not think forestland is open to recreational use if it is not posted.

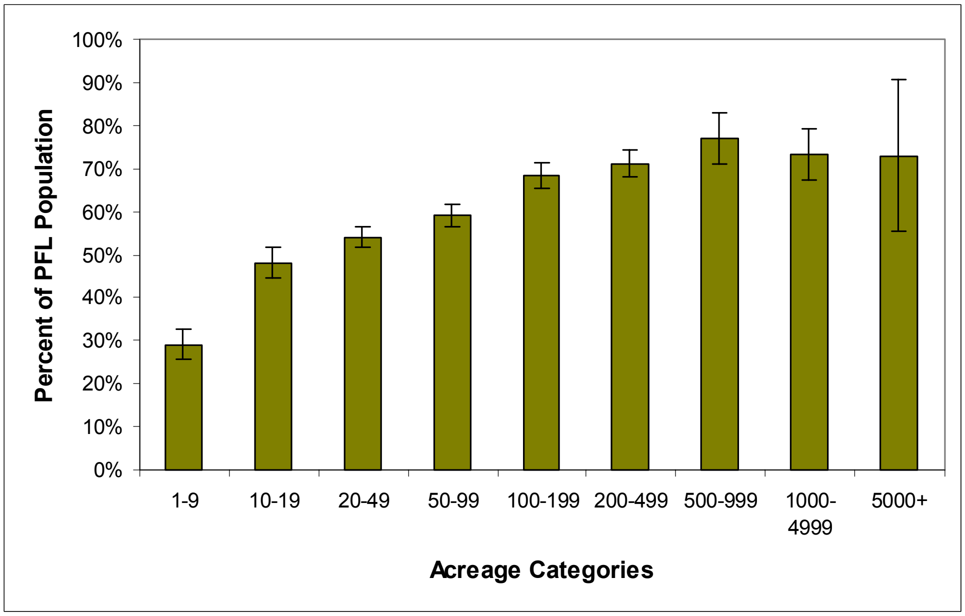

Figure 4 - 22: Percent of PFLs who post all or part of their forestland by acreage categories

PFLs who posted their forestland were often willing to allow recreational access if asked (Figure 4-23). Family and friends were most likely to be allowed access, but around 50 percent of PFLs were willing to allow access for many types of hunting, other recreation, public walking/hiking, or horseback riding. One in four PFLs was willing to provide access for all terrain vehicles (ATVs), if asked. Across each activity, PFLs with larger properties were more likely to provide access, meaning the percent of private forestland available for each activity was higher than the percent of willing PFLs.

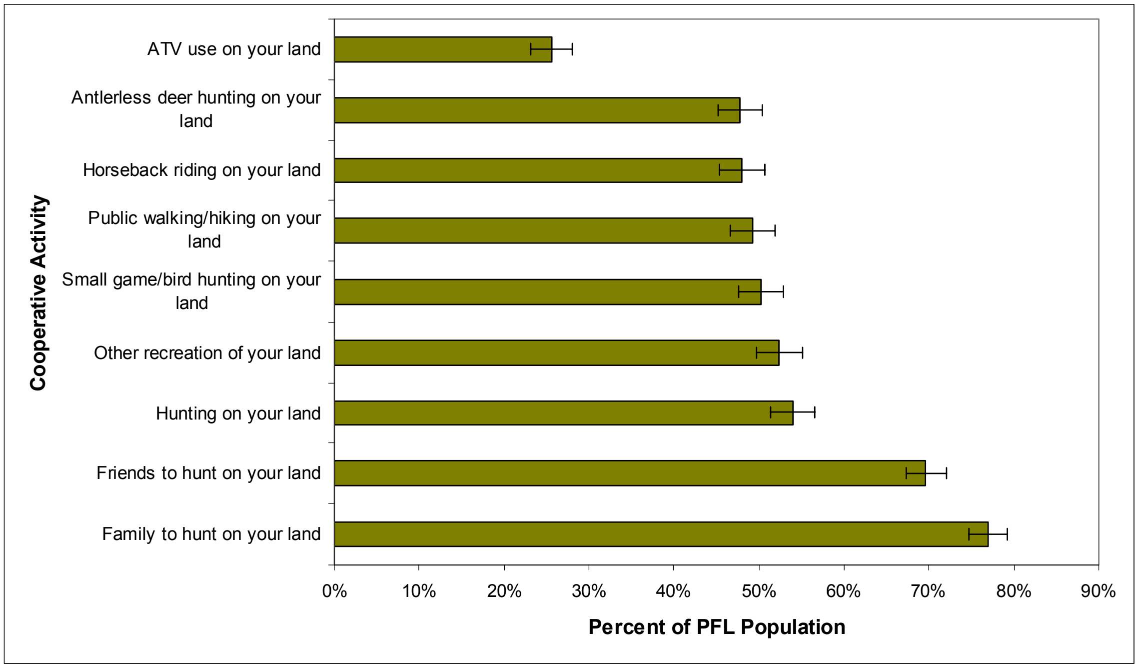

Figure 4 - 23: Percent of PFLs willing to allow access to posted property for certain activities, if permission is requested

Cooperation with neighbors

Nearly 60 percent of PFLs believed neighboring landowners should work together to manage their forests. Reported behavior, however, indicated that many did not currently interact with neighbors and reported a general reluctance to cooperate in the future across a variety of activities. When asked how often they interacted with neighbors, most PFLs reported "sometimes," with more leaning toward "never" than "very often" (Figure 4-24). This was not due to unfamiliarity with neighbors, as PFLs knew an average of two-thirds of their neighbors on a first-name basis. Acreage did not significantly relate to past cooperation or willingness to cooperate in the future.

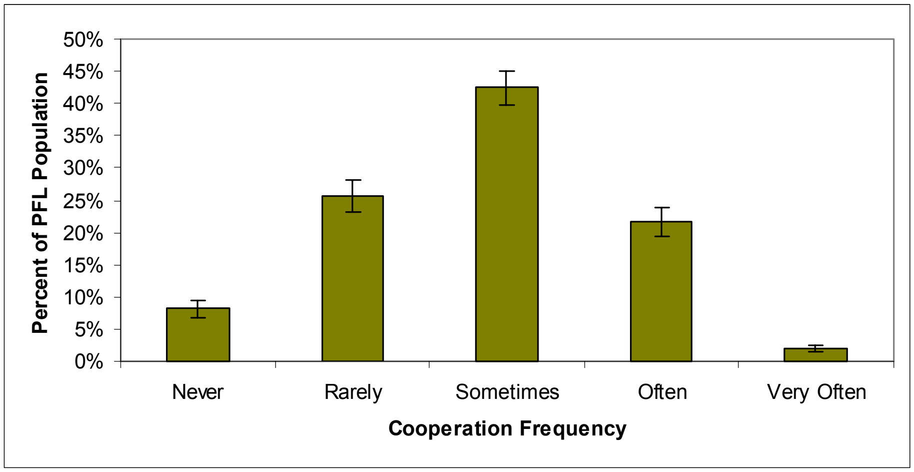

Figure 4 - 24: Interaction rates of PFLs with adjoining neighbors

PFL willingness to cooperate in the future varied significantly by activity type (Figure 4-25). Activities PFLs were relatively willing to cooperate on allowing neighbors to hunt (54%), improving wildlife habitat (42%), and general recreation (40%). Willingness to cooperate was lower for activities such as sharing tools (29%) or large equipment (26%). Most PFLs were unlikely to cooperate on major activities such as building access roads (8%) or trails (18%) and activities concerning finances such as hiring a forester (9%), selling timber (10%), or hiring labor (13%). Willingness among PFLs to cooperate on recreation-based activities may provide a starting point or catalyst for building relationships, rapport, and common ground among neighbors for future collaboration on forestry-related activities. Unwillingness to cooperate on spraying herbicides may reflect opposition to herbicides more than attitudes toward neighbors as only 6 percent of PFLs report past application on their own properties.

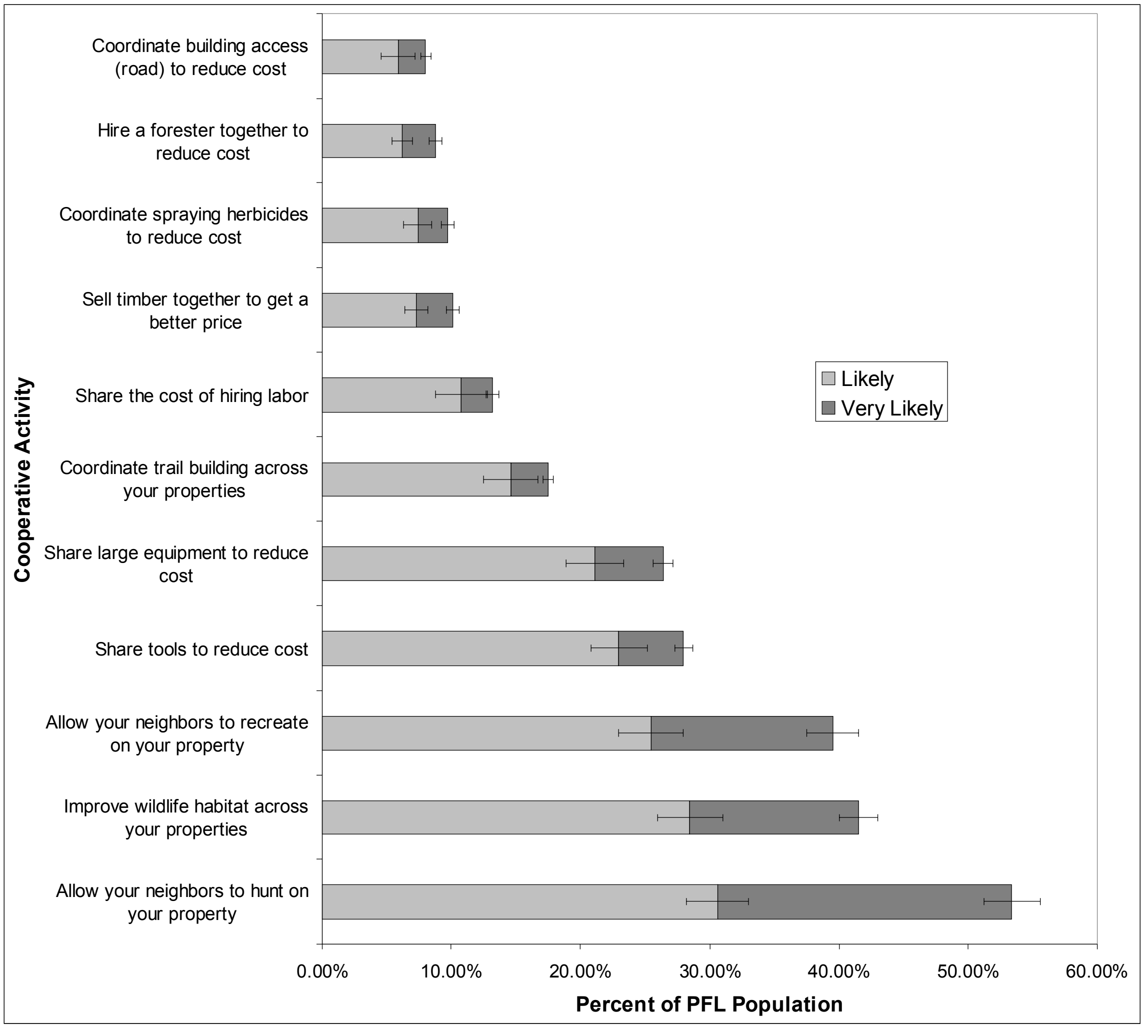

Figure 4 - 25: Percent of PFLs "Likely" and "Very Likely" to cooperate with neighbors by cooperative activity

Future plans

PFLs have a variety of future plans for their forestland. We asked respondents how likely they were to engage in a few, specific activities (Figure 4-26). Approximately 9 percent of PFLs planned to subdivide or subdivide and sell their forestland while 27 percent planned to sell their forestland as is. There was some interest in conservation easements (11%) and establishing family corporations (8%) or trusts (17%). A relatively small percentage of PFLs intended to clear forestland for a road (8%) or building (11%).

Leaving forestland to children was the most common future plan among PFLs. Although 30 percent of PFLs planned to leave their forestland to only one child, the majority (52%) planned to will their forestland to multiple children. These results speak to the importance of estate planning and providing assistance to children who will soon find themselves owners or co-owners of private forestland.

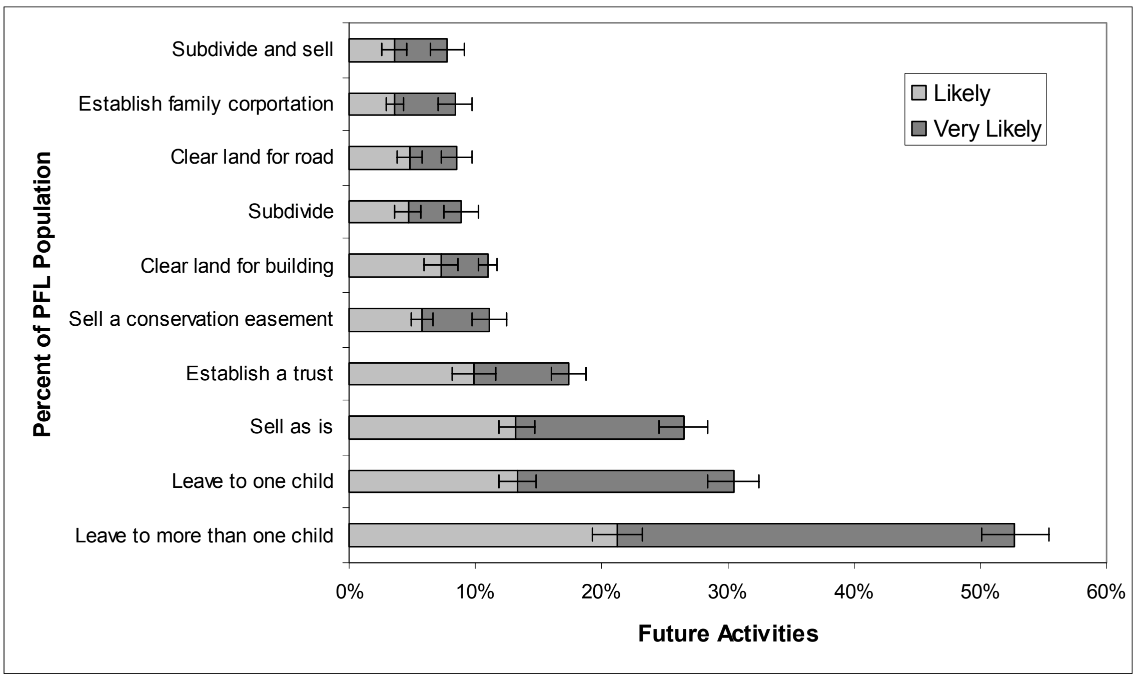

Figure 4 - 26: Percent of PFLs "Likely" and "Very Likely" to conduct future activities

Regional results

Results were analyzed in each of the six, recently adopted BoF private forest stewardship regions (Figure 4-27). The findings indicated significant variation across these regions with respect to the distribution of forestland and owners, ownership objectives, posting rates, commercial harvesting, tenure, and absentee ownership. Across these variables, variation seemed to reflect urban influences in the southwest, southeast, and northeast regions. Although sub-state regions, they still incorporated large areas and encompassed widely diverse landscapes (i.e., parcelization patterns, population density). As such, variation was high both among and within regions[9] suggesting the need for even more localized analysis of PFLs and private forestland issues.

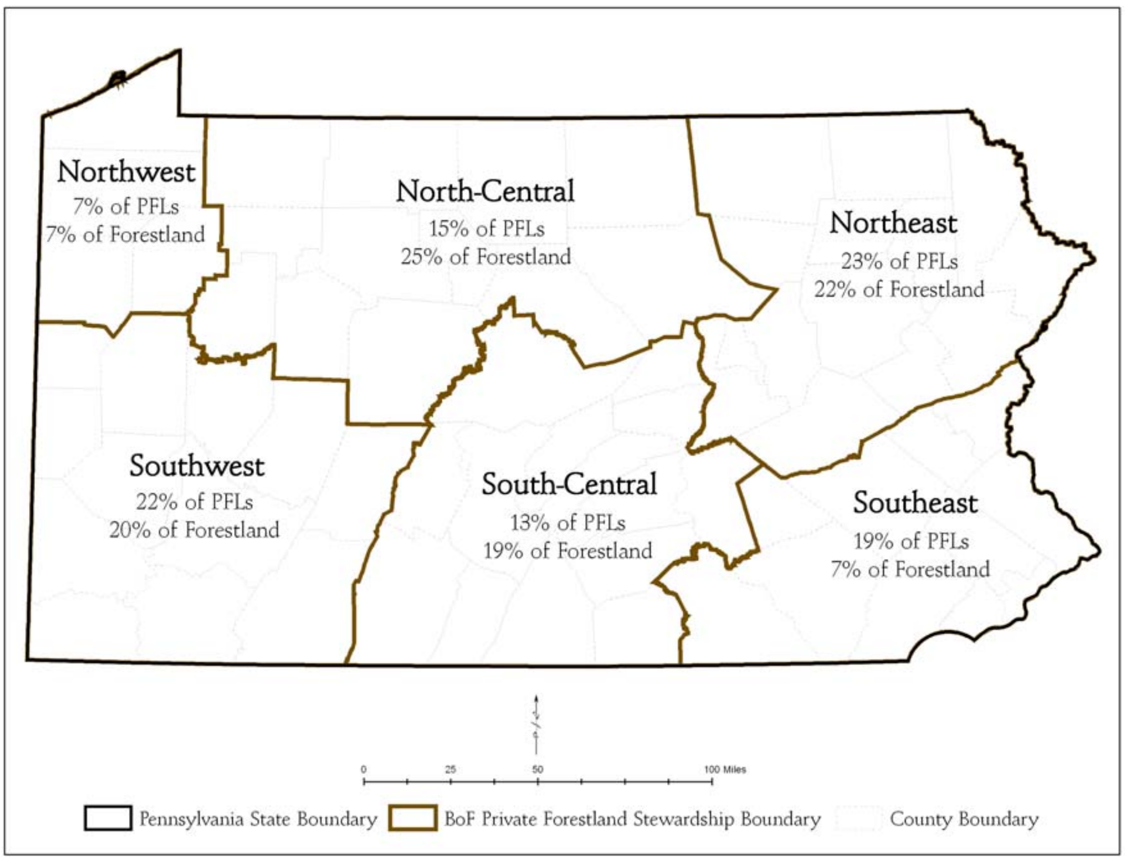

Figure 4 - 27: BoF private forest stewardship regions[10]

[9] Variation within the northwest region is highest because this region contains the fewest counties and results are therefore calculated from a smaller sample size.
[10] Distribution of forestland was calculated from post-processed Landsat Imagery, not survey responses.

The distribution of owners differed significantly among regions (Figures 3-28). A significantly higher percentage of PFLs owned small properties (i.e., 1 to 9 acres) in the southeast, southwest, and northeast than other regions. This was especially the case for the southeast region where 83 percent of PFLs owned small amounts of forestland. Although these survey data do not allow us to calculate how much forestland was owned by these "small" owners, it is likely a significant proportion of the private forestland in these regions was owned by these PFLs. As we have seen throughout previous results, acreage owned related significantly to many variables. Targeting outreach to these small owners is important and presents significant challenges because the population is so high. Regions with higher proportions of small owners must recognize the importance of this audience and the amount of forestland these PFLs control.

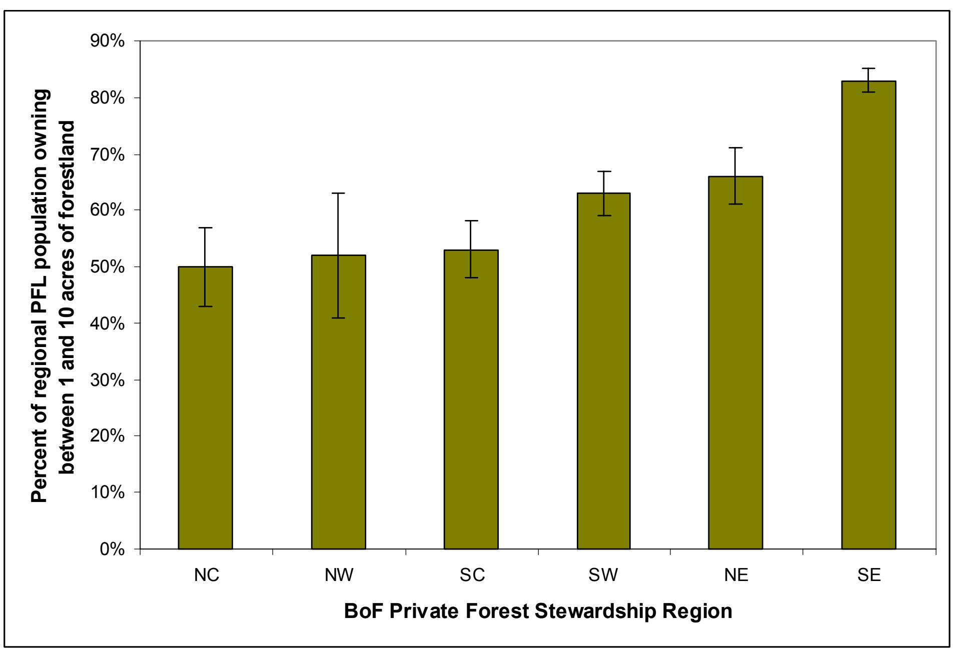

Figure 4 - 28: Percent of regional PFL populations that own between one and ten acres of forestland

Ownership objectives differed significantly among regions. Table 4-4 shows primary ownership objectives cited by PFLs in descending order of frequency for each region. Although solitude, enjoyment of owning, and incidental ownership were common among all regions, the importance of these and other objectives in each region was revealing. For example, hunting was the second most common primary ownership objective in the north-central region and fourth most common in the south-central region. Incidental ownership was by far the most common reason for owning in the southeast, whereas land investment was more important in the northeast than any other region. Timber production remained a low priority for PFLs, although more PFLs in the western regions of the state cited this reason than the central and eastern regions.

Table 4 - 4: Percent of PFLs citing specific ownership objectives by BoF private forest stewardship regions

Ownership Objective	Northwest	% PFLs	% Forest	Northcentral	% PFLs	% Forest
	Estate	25.3	12.5	Solitude	29.4	10.1
	Enjoyment	21.3	20.2	Hunting	15.0	23.0
	Solitude	18.9	15.9	Home/Came with	10.5	7.6
	Home/Came with	12.6	10.7	Estate	9.8	13.7
	Wildlife	4.7	6.0	Wildlife	8.9	6.0
	Hunting	4.5	9.6	Recreation	8.5	4.5
	Land Investment	4.0	5.1	Enjoyment	6.8	12.4
	Timber	3.1	8.9	Personal use of wood	3.0	2.0
	Personal use of wood	2.2	2.3	Land Investment	2.7	6.6
	Recreation	1.7	2.9	Timber	2.0	8.4
	Non-timber income	0.8	1.5	Non-timber income	0.9	2.9

Ownership Objective	Northeast	% PFLs	% Forest	Southwest	% PFLs	% Forest
	Solitude	21.6	11.7	Solitude	31.1	17.4
	Enjoyment	20.3	17.3	Home/Came with	18.1	11.8
	Wildlife	14.9	10.1	Enjoyment	14.7	16.9
	Home/Came with	13.2	10.7	Estate	12.5	10.6
	Land Investment	10.5	6.4	Wildlife	6.8	5.9
	Hunting	8.5	20.4	Timber	5.2	4.7
	Estate	4.9	9.5	Hunting	4.6	12.5
	Personal use of wood	2.2	2.6	Land Investment	3.7	12.5
	Recreation	1.1	4.2	Recreation	1.1	1.7
	Timber	0.2	2.4	Personal use of wood	0.9	0.8
	Non-timber income	0.1	0.6	Non-timber income	0.9	3.6

Ownership Objective	Southcentral	% PFLs	% Forest	Southeast	% PFLs	% Forest
	Enjoyment	22.1	21.1	Home/Came with	39.5	24.2
	Solitude	20.7	10.5	Solitude	23.9	16.1
	Home/Came with	15.2	9.3	Wildlife	13.0	8.0
	Hunting	13.8	23.9	Enjoyment	12.9	22.2
	Wildlife	7.1	5.5	Personal use of wood	2.8	2.5
	Recreation	6.8	3.5	Hunting	2.5	6.6
	Estate	5.7	10.1	Land Investment	2.0	8.6
	Land Investment	3.1	6.9	Estate	1.1	2.7
	Timber	1.7	4.4	Recreation	1.0	3.0
	Personal use of wood	1.6	1.6	Non-timber income	0.3	0.8
	Non-timber income	1.4	1.5	Timber	0.1	0.7

Posting rates differed significantly among regions (Figure 4-29). Posting was least common among PFLs in the southwest and north-central regions and most common in the south-central and northeast regions.

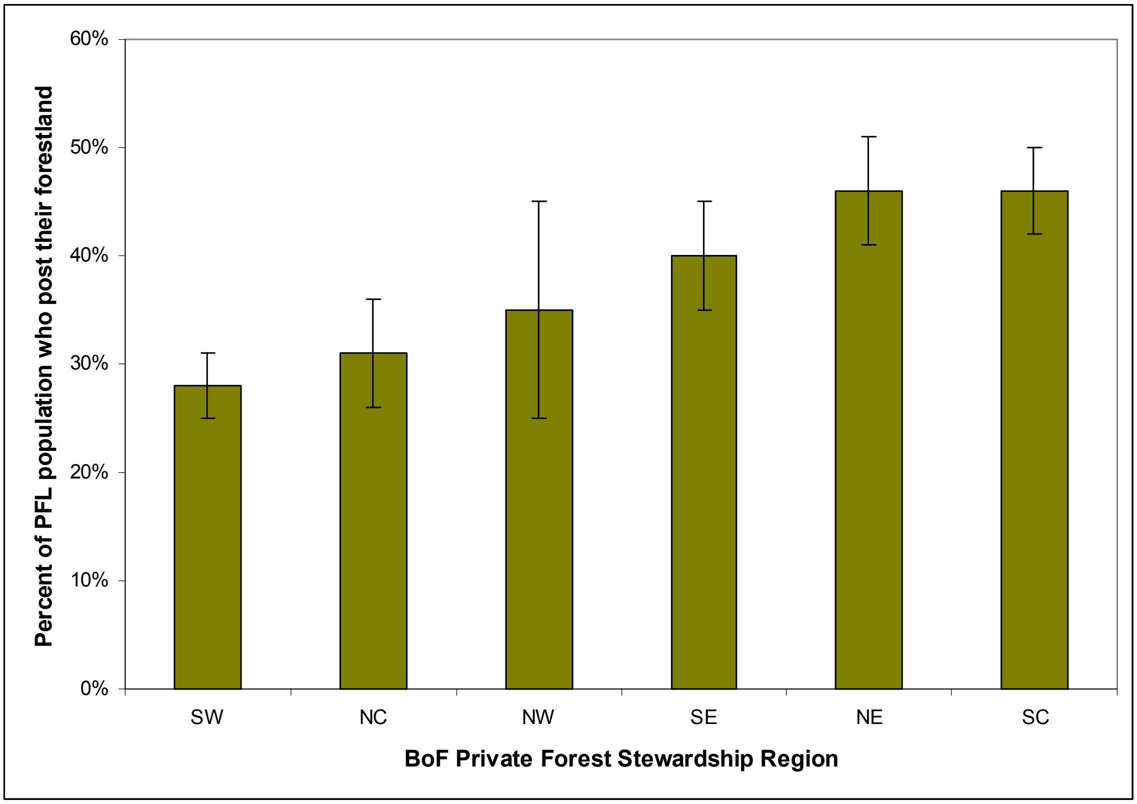

Figure 4 - 29: Percent of regional PFL populations who post their forestland

Commercial harvesting rates also differed significantly by region (Figure 4-30). Harvesting was least common among PFLs in the southeast region (6%) and the northeast (16%) and most common among PFLs in the northwest (43%) and the north-central (28%). These results suggested a negative correlation with commercial harvesting behavior and variables such as overall population size and density, housing density, and other indicators of more urban, populated areas. Again, significant variation existed within regions and may be clouding this relationship. For example, areas closer to Pittsburgh, PA may show lower harvesting rates than other areas within the southwest region. These results suggest more analyses are needed to determine the effects of development and population growth on commercial harvesting rates.

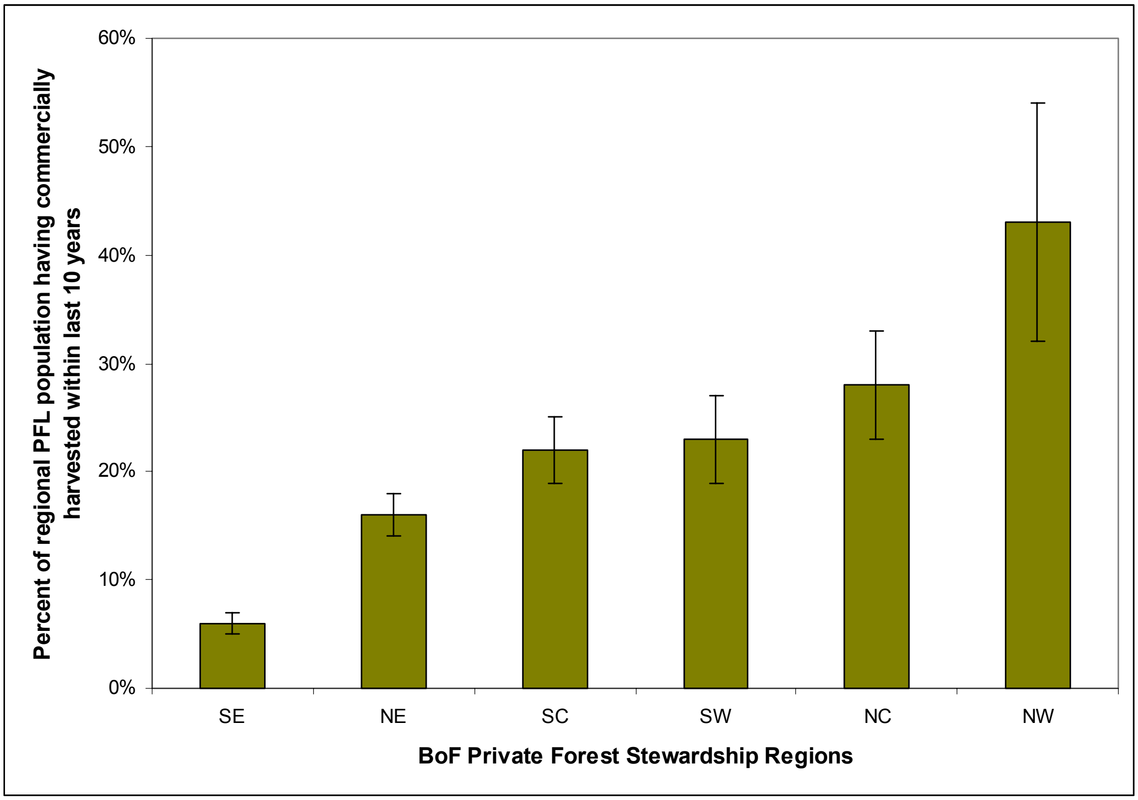

Figure 4 - 30: Percent of regional PFL population having conducted a commercial harvest in the past 10 years

Opposition to harvesting also varied among regions (Figure 4-31). Since opposition was strongly associated with acres of forestland owned, variation in opposition was high within regions. Despite this variation, the southeast region stood out as having significantly more PFLs "opposed" or "very opposed" to harvesting. Similarly, the northeast region stood out as having many PFLs "very opposed" to harvesting. As with commercial harvesting rates, these results suggested a pattern of increased opposition to harvesting among PFLs in more urban regions dominated by PFLs with small forest properties.

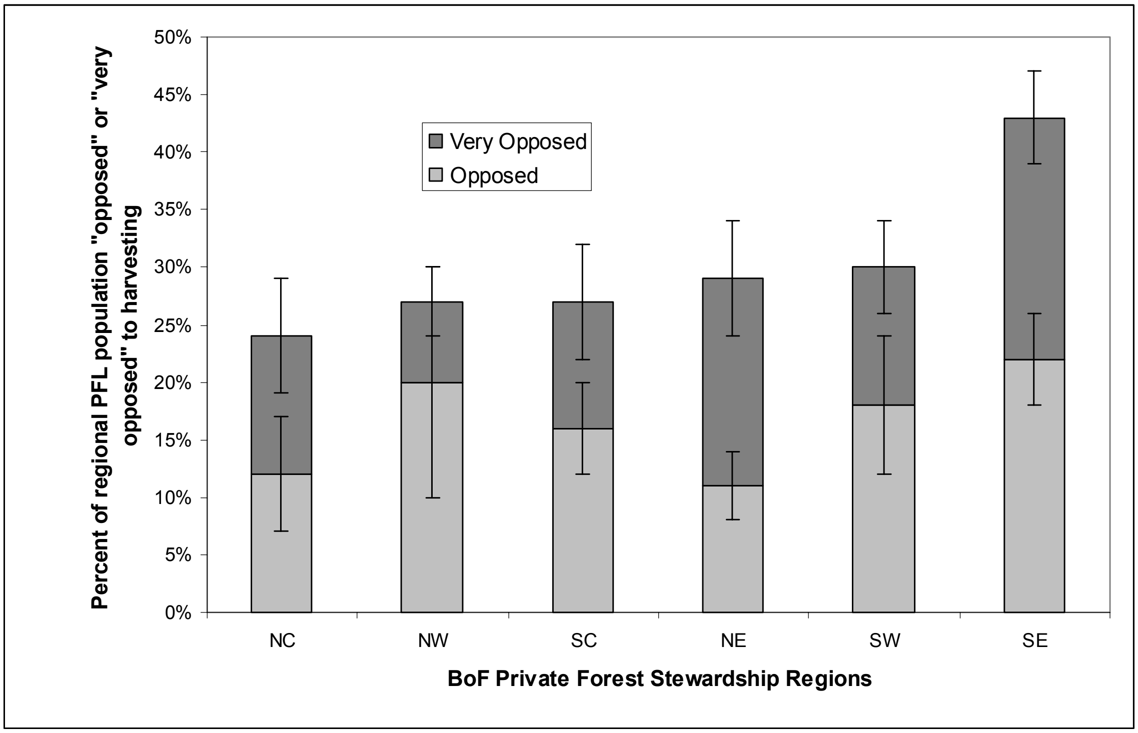

Figure 4 - 31: Percent of regional PFL populations "opposed" or "very opposed" to harvesting

Tenure differed significantly among regions although these differences were not very large. Tenure was longest in the northwest region at 23 years. In the majority of the state, tenure among PFLs was between 19 and 20 years; however, it was much shorter in the southeast at 16 years. This suggested the PFL population in the more developed southeastern region was “turning over” more quickly than other regions. This, compounded with other factors (e.g., increased PFL population, increased “small owner” population, increased incidental ownership, decreased harvesting rates and increased opposition to harvesting), challenge the wisdom of using traditional forestry-related outreach efforts in this region. Further, there may be similar relationships in other developed areas of the state (e.g., Pittsburgh and extreme northeastern PA) not revealed by this regional analysis.

Distance to forestland was significantly different among regions (Figure 4-32). Average distance to forestland was highest in the north-central region at 98 miles. The northwest, northeast, southwest, and south-central regions had an average distance between 20 and 40 miles. Average distance to forestland among PFLs in the southeast region was less than three miles. These results were, again, suggestive of a substantially different PFL population within the southeast region and perhaps other more developed pockets across Pennsylvania.

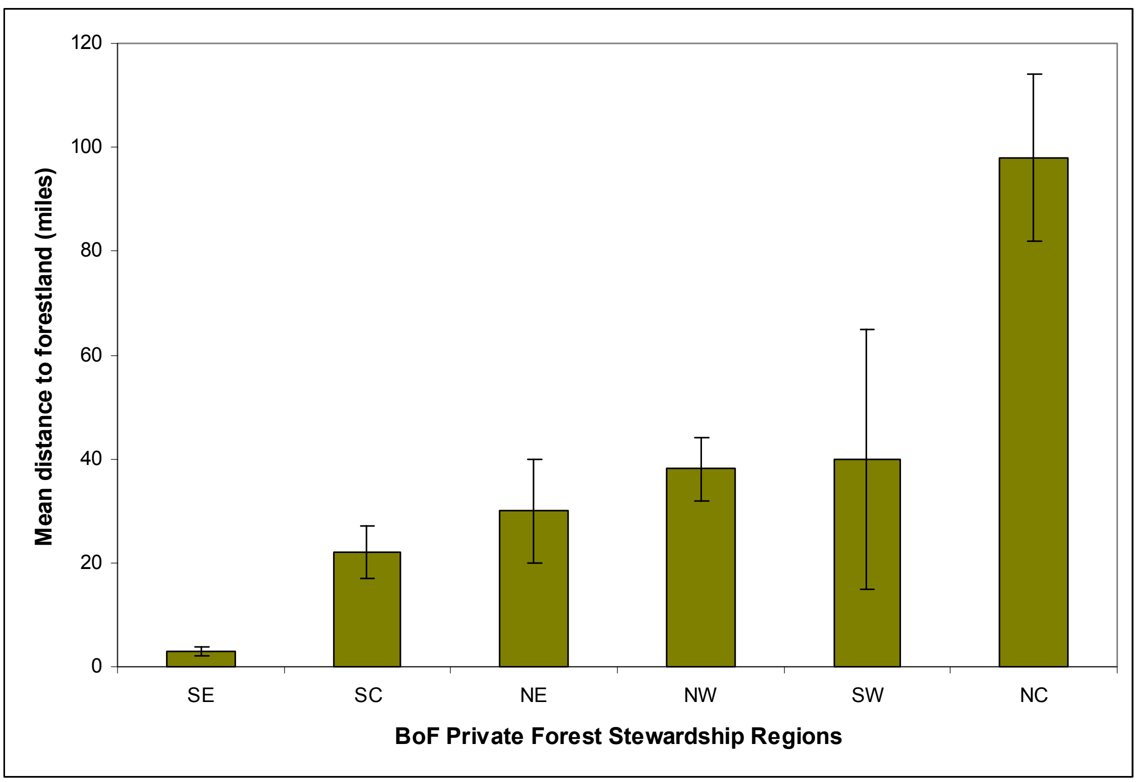

Figure 4 - 32: Mean distance to forestland by BoF private forest stewardship region

Results by commercial harvesting behavior

One of the driving questions of this study concerned the availability of forest resources on private forestland. While timber volumes have been steadily increasing (McWilliams et al. 2007), anecdotal evidence suggested access to this resource was becoming increasingly difficult. Here we present characteristics of PFLs with regard to commercial harvesting. These results help us understand the variables of interest surrounding commercial harvesting behavior among PFLs, current interaction between PFLs and forestry professionals, as well as identify areas of need and opportunity for increased outreach.

Primarily, it was important to understand general characteristics of those PFLs who had commercially harvested as compared to those who had not. Although harvesting PFLs do not differ from non-harvesting PFLs across most variables, results indicated significant differences across a few key variables. These results help us understand the values, attitudes, and motivations of PFLs most willing to allow access to their private forest resources.

Harvesting PFLs were more likely than non-harvesting PFLs to own their forestland for more utilitarian or financial reasons, although they enjoyed equally the solitude and pure enjoyment of owning forestland (Figure 4-33). Harvesting PFLs were significantly more likely than non-harvesting PFLs to own their forestland as a land investment, for growing timber for sale, for non-timber income, and as an estate to pass along to their children. Additionally, they were more likely to own for the hunting opportunities their forestland afforded than their non-harvesting counterparts.

Conversely, they were less likely than non-harvesters to own for general recreational or to enjoy wildlife. Incidental ownership (i.e., the forestland came with the property) was also less common among harvesting PFLs than among non-harvesting PFLs.

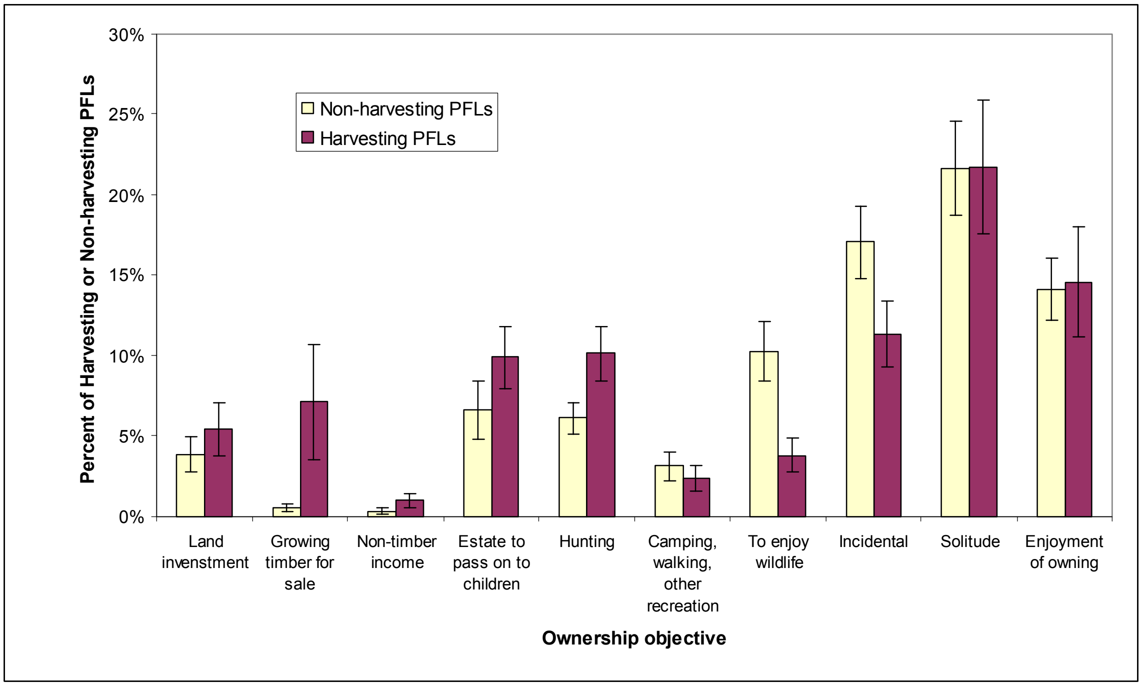

Figure 4 - 33: Ownership objectives for harvesting and non-harvesting PFLs

Across the many activities explored, harvesting PFLs differed from non-harvesting PFLs on only four (Figure 4-34). Harvesting PFLs were significantly more likely to have management plans for their properties. The overall percentage of PFLs with management plans was low, but harvesters were nearly three times more likely to have them than non-harvesters. Harvesting PFLs were more likely to harvest non-timber forest products than non-harvesting PFLs. Hunting and property rights were also more important to harvesting PFLs than their non-harvesting counterparts. Nearly half (48%) of harvesting PFLs posted their forestland and 60 percent hunted. On the other hand, while posting and hunting were common everywhere, non-harvesting PFLs were less likely to do either.

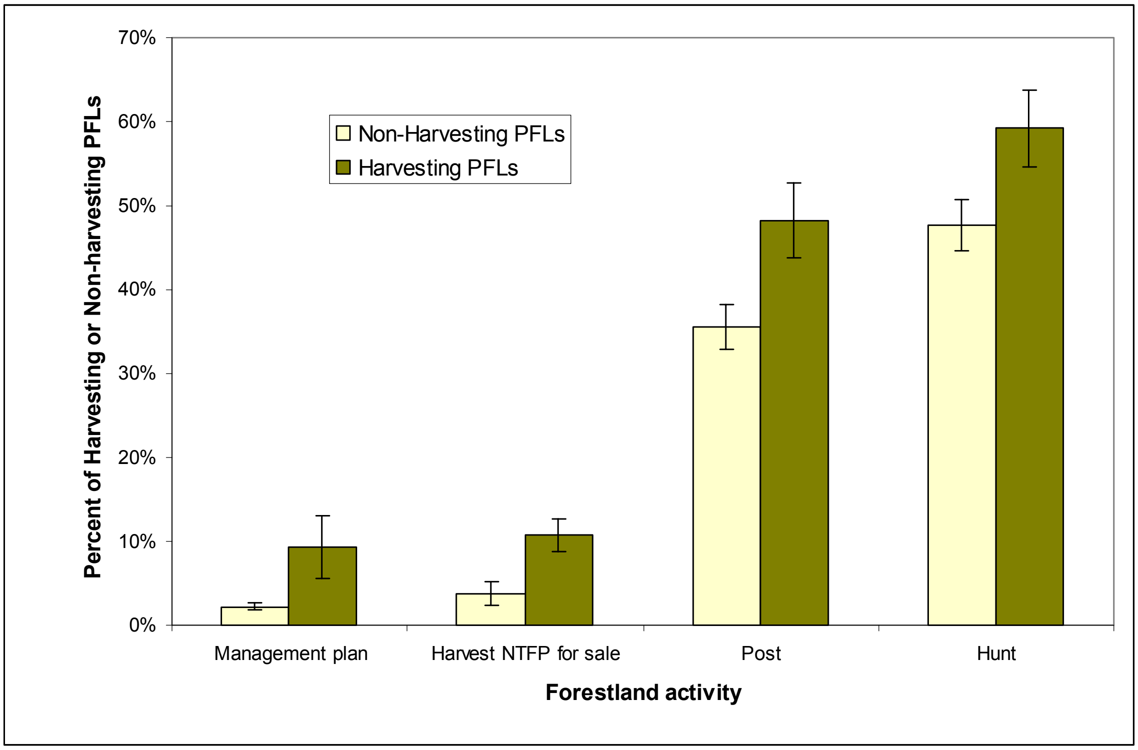

Figure 4 - 34: Forestland activates of harvesting and non-harvesting PFLs

Not surprisingly, harvesting PFLs tended to hold more favorable views of harvesting than non-harvesting PFLs (Figure 4-35)[11]. Harvesting PFLs were less likely than non-harvesting PFLs to agree that cutting trees permanently harmed the forest, any cutting of trees harmed the water quality of nearby streams, forests rarely recovered from clearcutting, and cutting trees usually resulted in soil erosion and destroyed wildlife habitat. Similarly, harvesters were more likely than non-harvesters to agree that harvesting trees could improve the forest and specifically forest health (Figure 4-36).

[11] Agreement scores are measured on a five-point Likert scale where 1 is strongly disagree, 2 is disagree, 3 is neither agree nor disagree, 4 is agree, 5 is strongly agree. This is true for figures 4-34 through 4-37.

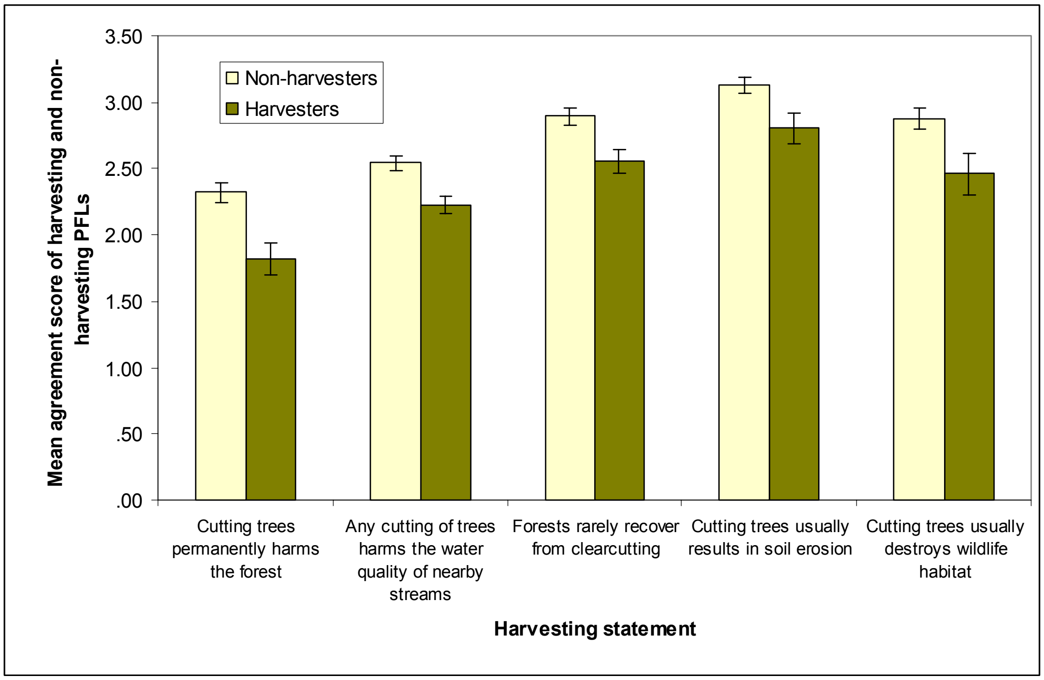

Figure 4 - 35: Mean agreement scores for harvesters and non-harvesters across harvesting statements

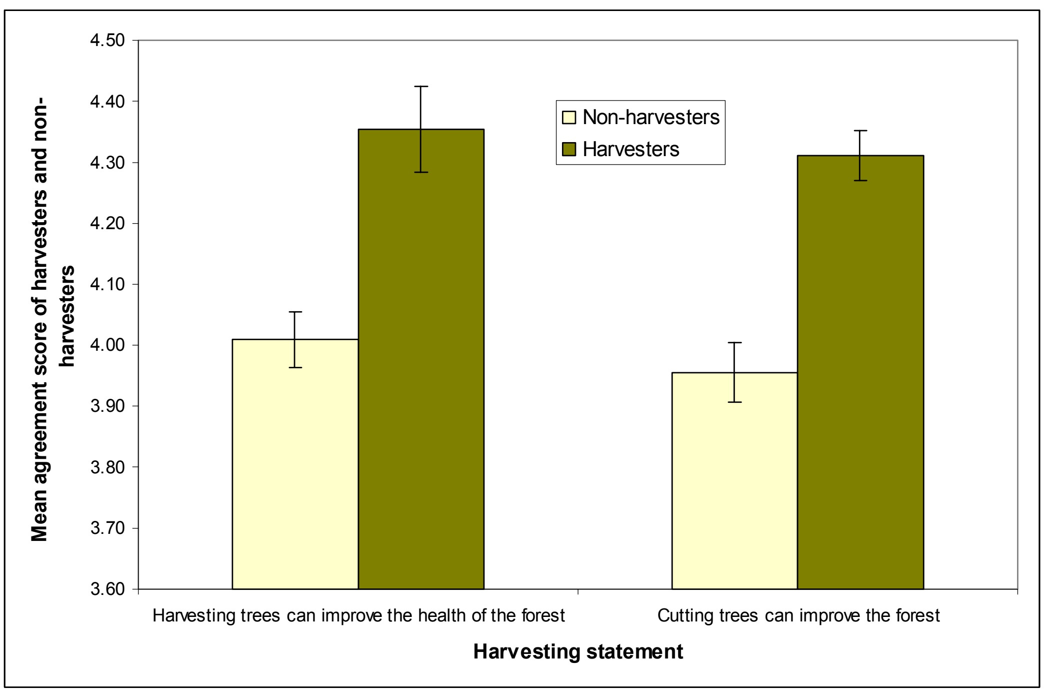

Figure 4 - 36: Mean agreement scores for harvesters and non-harvesters across harvesting statements

As well, harvesters have a more utilitarian view of their forests than non-harvesters (Figure 4-37). Harvesters were less likely than non-harvesters to agree that humans shouldn't interfere with nature and forests had a right to exist for their own sake, regardless of human concerns or use. Harvesters were more likely than non-harvesters to agree that people who own forestland had the right to use that forestland as they see fit and that healthy forests were important.

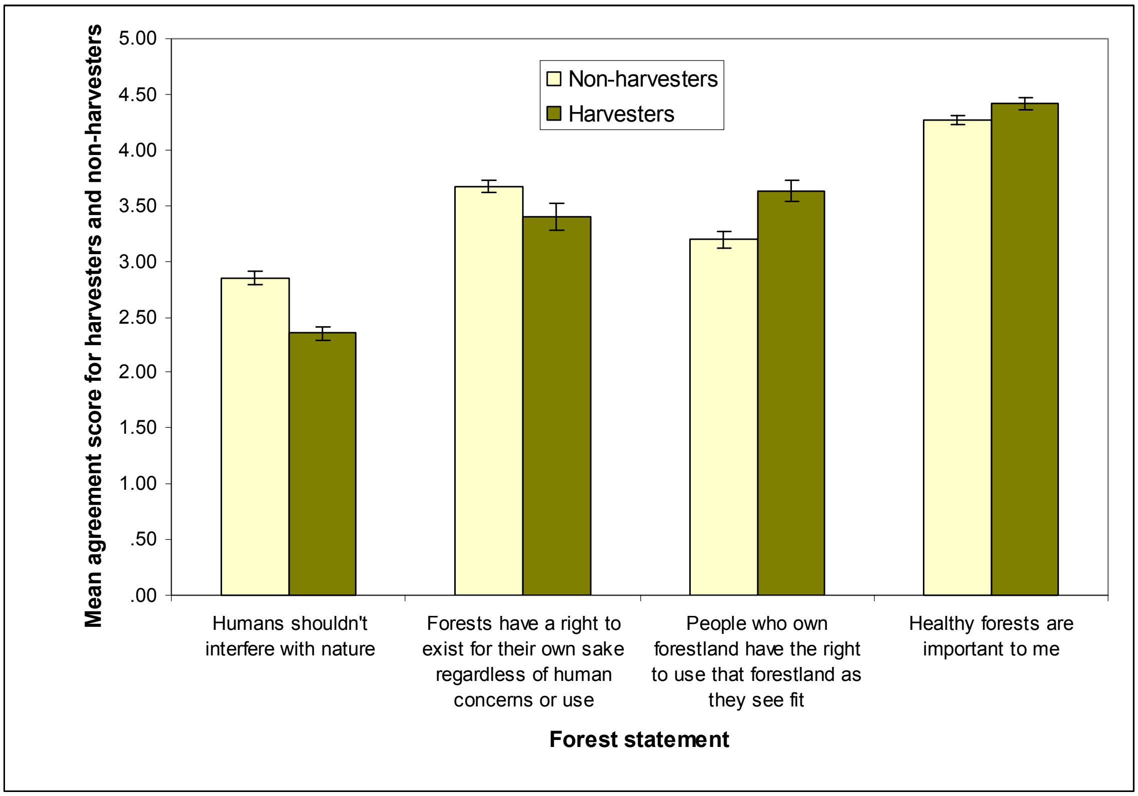

Figure 4 - 37: Mean agreement score for harvesters and non-harvesters across forest statements

Harvesting PFLs tended to differ from non-harvesting PFLs across a few sociodemographic variables. Harvesting PFLs were slightly less educated than non-harvesting PFLs (Figure 4-38), with more having only high school diplomas or GEDs and fewer having earned a graduate or professional degree. Politically, harvesters were also more likely to describe themselves as conservative, and less likely to describe themselves as liberal or moderate liberal than their non-harvesting counterparts (Figure 4-39). Harvesters also had more children than non-harvesters, with the latter having a mean of 2.27 (±0.104) children and the former having a mean of 2.81 (±0.251) children. Other sociodemographic variables (e.g., income, age) did not differ between harvesters and non-harvesters.

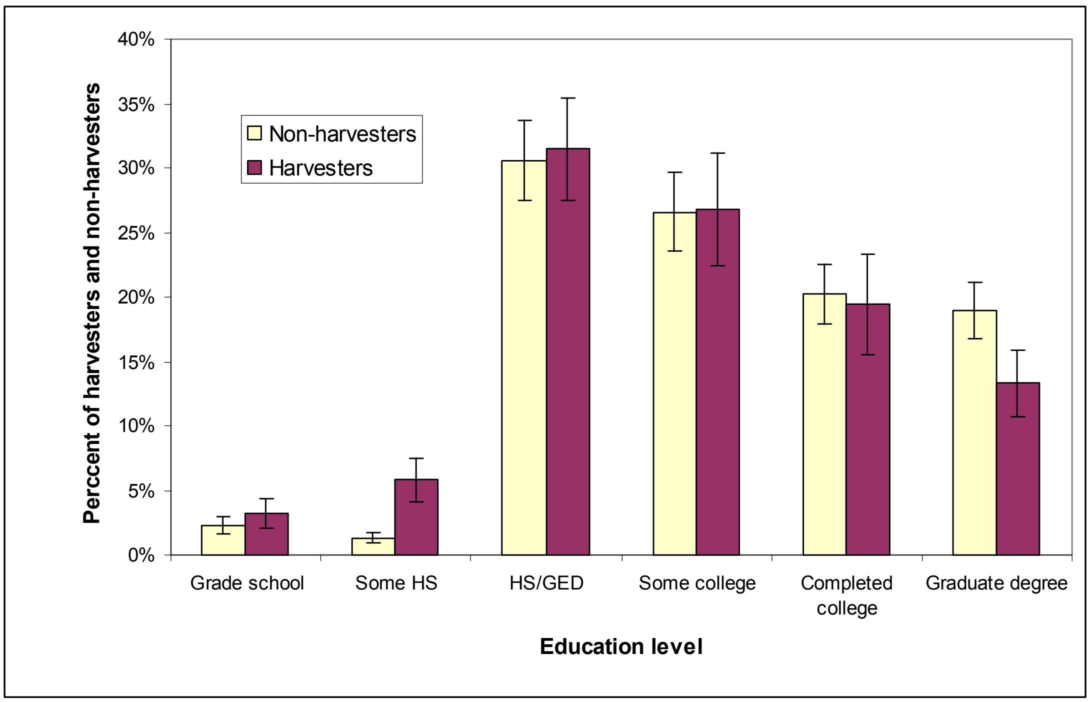

Figure 4 - 38: Education of harvesting and non-harvesting PFLs

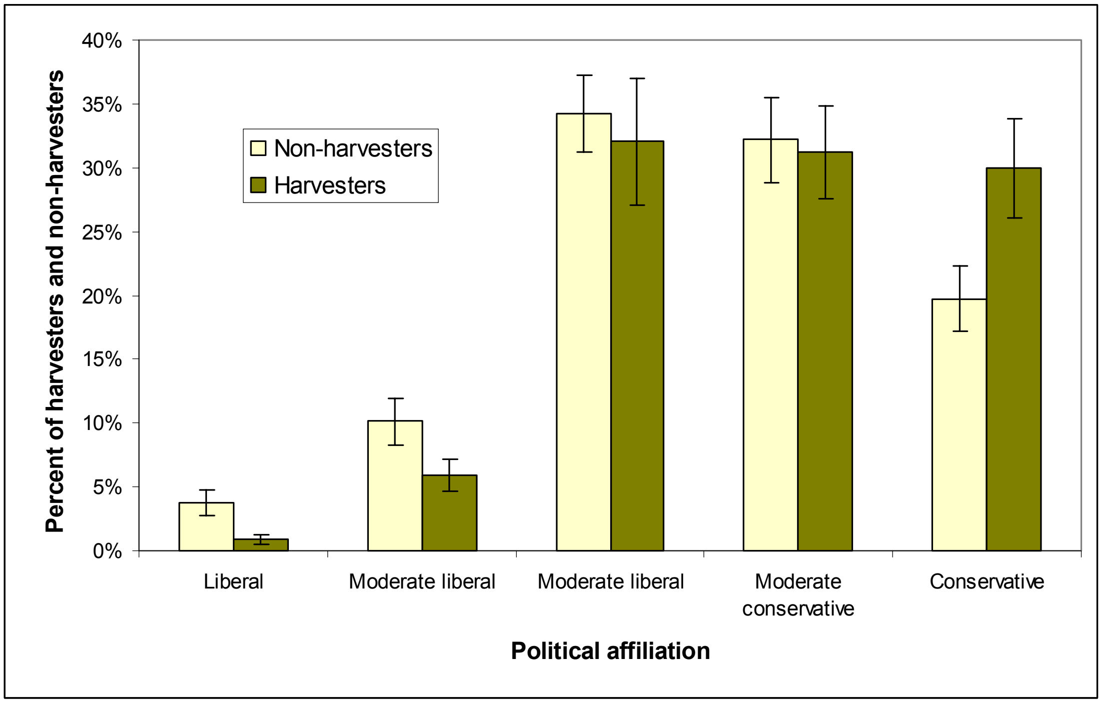

Figure 4 - 39: Political affiliation of harvesting and non-harvesting PFLs

While 20 percent of PFLs had commercially harvested, far fewer interacted with forestry professionals during those harvests. One half of one percent of PFLs had received advice from Penn State extension, 1.3 percent had received advice from PA Bureau of Forestry foresters, and 1.4 percent had received advice from industry foresters. Consulting foresters had reached slightly more PFLs with 4.5 percent of PFLs reporting having received advice and 2.5 percent reporting having hired a consulting forester. All told, 12.4 percent of commercial harvests were managed by consulting foresters and 22.4 percent were managed by PFLs who received advice from consulting foresters. In contrast, only 5 percent of commercial harvests were managed by PFLs who have received advice from BoF foresters, 7 percent with advice from industry foresters, and 2 percent with advice from Penn State extension.

Although some differences existed between harvesters and non-harvesters, for the majority of variables, no differences were detected. Where differences existed, they suggested subtle changes in PFL views of harvesting: harvesters were more likely to view harvesting activities as compatible with other values and uses of their forestland. Whether these views are a prerequisite for harvesting or are a result of witnessing a harvest and resulting changes in forest conditions remains unclear. Regardless, the attitudes, values, behaviors, and sociodemographics of harvesters were only slightly different than those of non-harvesters.

Logistic regression: results and discussion

The exploratory factor analysis extracted two components from the series of value-oriented statements, explaining 54 percent of the variance. Table 4-5 shows the factor loadings, eigenvalues, and explanatory contribution of each factor. The variables associated with the first component (loadings ranged from .588 to .781) included statements evaluating the compatibility of harvesting with healthy forests. The variables associated with the second component (loadings ranged from .702 to .785) included statements evaluating the intrinsic value of forests. The reliability coefficients for the component items were .726 (compatibility of harvesting with healthy forests) and statements measuring compatibility of harvests with healthy forests was .602 (intrinsic value of forests).

Table 4 - 5: Factor analysis of variables

Variable	Factor Loading: Factor 1: Compatability of Harvesting with Healthy Forests[b]	Factor Loading: Factor 2: Biocentric/ Anthropocentric Values of Forests[c]
Cutting trees permanently harms the forest	.700[a]	-.014
Harvesting trees can improve the health of the forest	.776[a]	.168
Cutting trees can improve the forest	.786[a]	.129
Any cutting of trees harms the water quality of nearby streams	.585[a]	-.088
Humans shouldn't interfere with nature	.593[a]	-.283
Healthy forests are important to me	.265	.693[a]
Forests have a right to exist for their own sake regardless of human concerns or use	-.280	.735[a]
Humans should have more love, respoect, and admiration for forests	-.012	.786[a]
Eigenvalues	2.554	1.770
Variation explained	32%	22%

a= factor assignment
b=Chronbach's alpha = .726
c=Chronbach's alpha=.602

Table 4-6 shows the mean and standard errors for all variables included in the logit model. Values are provided for the full sample, those respondents reporting commercial harvests in the past 10 years, and those respondents reporting no commercial harvests in the past 10 years.

Table 4 - 6: Variable means and standard errors for full sample, harvesters, and non-harvesters

Variable	Full Sample	Harvesters	Non-harvesters
Tract size (acres)	17.62 (.801)	36.49 (2.87)	12.87 (.682)
Age	57.5 (.668)	57.25 (1.40)	58.22 (.761)
Income	79,481 (2,810)	67,390 (3,899)	82,584 (3,388)
Educattion (years of higher-ed)	2.58 (.125)	2.24 (.185)	2.67 (.151)
Opposition	2.96 (.059)	3.61 (.141)	2.80 (.063)
Harvest Views	3.79 (.031)	4.08 (.049)	3.72 (.036)
Bio/Anthropocentric Values	2.25 (.036)	2.28 (.075	2.24 (.185)
Commercial Harvest (%)	0.201 (.017)	1	0

Of the seven independent variables included in the logit model, only four were found to significantly impact a PFL's decision to commercially harvest: tract size, income, opposition to harvesting, and PFLs views regarding the compatibility of harvests with healthy forests (Table 4-7). As tract size, income, and positive views of the compatibility of harvesting with healthy forests increased, so did the likelihood that a PFL had conducted a commercial harvest. As expected, opposition to harvesting decreased the likelihood that a PFL had conducted a commercial harvest. Education, age, and our measures of anthropocentric/biocentric forest values did not significantly impact PFL decisions to harvest. The Nagelkerke pseudo r-square for this regression was 0.235.

Table 4 - 7: Beta coefficients, standard errors, and Wald F statistics for variables used in the logit model

Variable	Coefficient	Std. Error	Wald F
Tract Size**	.008	.002	23.790
Education	.059	.054	1.228
Income*	-.000	.000	4.537
Age	-.010	.013	.547
Opposition*	-.546	.215	6.447
Harvest Views**	.915	.211	18.887
Bio/Anthropocentric Values	-.173	.220	.618

* - significance at p <0.05
** - significantst at p<0.001

While biocentric/anthropocentric values were not significantly related to harvesting decisions, PFL views of harvesting were highly significant. There was little variation in responses to the biocentric/anthropocentric questions suggesting our measures need to be adjusted to better reflect this concept. Further, regardless of PFL forest value orientation, PFLs may view harvesting as compatible with healthy forests. Consistent with this theory, results showed that PFLs who believed harvesting was incompatible with healthy forests, regardless of their value orientation, were much less likely to harvest than those PFLs who saw harvesting as an appropriate activity within healthy forests.

These results suggest that while harvesting decisions among PFLs were influenced by some factors, the frequency of harvests may rely on circumstances rather than active PFL decision-making. In other words, harvesting may be limited by certain PFL characteristics or views, but the decision to harvest may arise from sources outside the PFL decision making processes. For instance, tract size was significantly related to commercial harvesting behavior. As tract size increases, so to does the likelihood that a PFL had commercially harvested. This makes intuitive sense as smaller properties are logistically harder to harvest, do not capitalize on economies of scale, and are often located in more developed areas less amenable to traditional timber harvesting operations. This is, in part, simply a reflection of logistical constraints imposed by the parcelization of forestland, just as lack of quality or volume of timber is likely to constrain harvests.

While PFLs are less likely to harvest if they are opposed to harvesting or see it as incompatible with healthy forests, all of these variables only explain approximately 25 percent of the variation in PFL commercial harvesting decisions. Although price may play a role in predicting harvesting behavior, no studies in the Northeast US have found this connection. This lack in explanatory power suggests PFLs may not be actively deciding to harvest, but instead reacting to circumstantial situations such as ownership transfers, unexpected expenses, or offers from interested timber purchasers. Others have suggested a similar impetus behind timber harvesting decisions (e.g., Germain, Anderson, and Bevilacqua 2007).

Further, these results suggest parcelization of forestland may reduce access and availability of private forest resources. Commercial harvesting rates are related to the acres of forestland owned; PFLs with larger properties are more likely to harvest. Similarly, although the majority of PFLs do not oppose harvesting, those with smaller properties are more likely to be opposed. Moreover, as forestland is parcelized, owners of smaller properties are less likely to harvest commercially. Timber production from private lands will be reduced whether the decreased frequency of harvesting among smaller owners is due to personal attitudes, values, and beliefs or outside constraints such as feasibility, market demands, or logistical constraints resulting from tract size.

Conclusion

The future of Pennsylvania's forests and the supply of forest resources lie in the hands of PFLs. Although most of these owners hold relatively small pieces of forestland, all PFLs are integral to sustaining forests across the state. PFLs with small properties collectively control significant portions of Pennsylvania's private forests, especially in more developed areas of the state. Developing methods for engaging this large audience is important and will become increasingly necessary as forestland is further parcelized. On the other end of the spectrum, clear, effective communication and partnership with the few owners who control large amounts of forestland has the potential to impact many acres across Pennsylvania. Outreach and assistance to all PFLs is necessary to encourage stewardship and ensure the sustainability of the private forests that provide so many economic, social and ecological benefits.

As parcelization and transfer of ownership (through sale or inheritance) continue, more acres of Pennsylvania's private forestlands will be controlled by owners holding increasingly smaller tracts of forestland. The objectives and behaviors of such "small" owners have little to do with forestry and/or traditional forest uses (e.g., timber production); in fact, they provide a significant challenge for extension and outreach efforts designed by forestry professionals. Engaging this growing audience will be increasingly important if Pennsylvania's private forests are to continue providing public benefits such as wood production and extending to recreational access, water protection, and habitat, among others.

The majority of owners who have engaged in traditional forestry activities, such as harvesting, have done so with little input from foresters or guidance from a management or stewardship plan. With PFLs describing the majority of harvests as "select cuts" or "removal of most large trees," there should be concerns about the sustainability of future harvests on private forestland. Further, many PFLs have direct plans to subdivide their forestland or intend to leave their forestland to more than one child, which may increase parcelization and contribute to fragmentation of and reduced access to Pennsylvania's private forest resources.

Outreach efforts may be most successful if they are targeted to specific types of owners. Ownership objectives, past behavior, and future plans differ significantly among PFLs based on the acres and region of the state where they own forestland. Results from this study should help to build deliberate outreach strategies for specific segments of the PFL population and regions of the state.

Pennsylvania is a large state, with varying levels of economic development, diverse cultural histories and identities, and localized issues and influences. One-size fits-all approaches do not exist. Rather, outreach and assistance programs must consider and capitalize on the opportunity presented by the diversity of objectives, interests, and contexts of PFLs around the state. Specifically with regard to commercial harvesting, strategies to engage PFLs in rural areas may benefit from traditional approaches. However, in more suburban and urban areas and as development continues to expand, traditional approaches must be questioned and new methods for engaging PFLs in discussions of harvesting. Ensuring a continued supply of forest resources from private forestlands helps to ensure a healthy forest product industry, but also provides PFLs with financial resources to keep private forests forested and continue providing public benefits.

It is clear from this analysis that many PFLs want to engage in activities that maintain the health and sustainability of their forests. Unfortunately, perceptions among PFLs may not accurately reflect reality. For example, while clear-cutting is considered a sound silvicultural treatment and a sound tool in sustainable forest management, it is widely viewed among PFLs as detrimental to forests. As forests are further parcelized, accurate perceptions of commerical harvesting among PFLs are likely to deteriorate. Extension efforts must evolve to engage PFLs with smaller properties if timber supply is to be maintained while parcelization and development continue.

The baseline analyses of Pennsylvania PFLs presented here, their distribution across the state, and pertinent aspects of their management approaches are important for tracking changes over time. These results will help future analysis and studies identify important trends in private forestland use such as recreation, management, harvesting, and parcelization, characterize specific segments of the PFL population, and develop outreach strategies for those segments. These analyses and studies will help natural resource professionals better understand PFLs, the use of private forestlands, and their interactions with PFLs. Encouraging the sustainability of Pennsylvania's private forests will rely on our detailed understanding of those who own those forests and ultimately decide their fate.

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Chapter 5

Biophysical and Social Constraints to Private Forestland Access

Introduction

Private forests have long been an important source for meeting timber demand in the United States (Best & Wayburn 2001; Smith et al. 2001). Moreover, given recent attention to existing energy situations, interest in private forests as a source for biomass and renewable energy stock (Perlack et al. 2005; Benjamin et al. 2009; Galik et al. 2009) when coupled with demand for traditional forest resources (e.g., sawtimber, veneer, pulpwood) is likely to increase pressures on private forestlands (Smith et al. 2001; Alig et al. 2002; Munsell et al. 2008). However, while it is clear private forests will play a dominant role in both traditional and emerging forest resource markets, it remains to be seen how landowner values, attitudes, and behaviors will affect access to these resources.

The majority of forests in the United States are held in private ownership. These owners, often referred to as non-industrial private forestland owners (NIPFs) or private forestland landowners (PFLs), control 56 percent of the nation's forestland (Butler 2008). The dominance of private forestland is especially apparent in the eastern United States, where 75 percent of forests are owned by PFLs (Butler 2008).

As PFLs come from a variety of backgrounds and hold diverse attitudes and values, harvesting activities are not always compatible with PFL ownership objectives or management approaches (Butler & Leatherberry 2004; Eckley & Egan 2005). For this reason, Smith et al. (2001) suggest some portion of the private forestland base is and will remain unavailable for timber production. Similarly, Alig et al. (2002) predict a significant amount of private forestland will be unavailable for timber production over the next decades as timber harvesting decreases in popularity among PFLs. Parcelization of forestland may further reduce the availability of private forestland for timber production as smaller parcel sizes logistically and socially confound harvesting (Dedrick et al. 2000; Edwards & Bliss 2003; Knoot et al. 2009). Despite these conditions, relatively little has been done to quantify the amount of forestland that may be constrained due to biophysical or social factors.

National and regional trends of forestland ownership are well reflected by trends in Pennsylvania, (McWilliams et al. 2007). Even with its large and certified-sustainable public forest system, approximately 70 percent of the forests in the Commonwealth are privately owned (McWilliams et al. 2007). McWilliams et al. (2007) estimate that 12.5 million acres of Pennsylvania private forestland are owned by at least 533,000 PFLs, if not more (see Chapters Two and Three). Within this complex matrix of ownership, forestry operations, long a part of Pennsylvania history and culture, remain important to communities and economies across the state. For example, Strauss, Lord, and Powell (2007) estimate timber harvesting and related industry contribute around 15 billion dollars to the state's economy and employ nearly 100,000 people.

According to the USDA Forest Service (USFS), forestland area in Pennsylvania is remaining steady (McWilliams et al. 2007). Although some forestland is lost each year to development or agriculture, reversion of agricultural lands, especially in the northern counties, has kept pace with these declines (McWilliams et al. 2007). In general, the state's forests are gaining volume in valuable species as trees are maturing. Estimated current standing volume is 88 billion board feet, the highest it has been in the last 100 years (McWilliams et al. 2007).

Ironically, however, timber volume may not be the crucial driver of timber availability. Timber supply has long been equated with physical inventories, ideally somewhat of a constant value, rather than a variable fluctuating with changes in and interactions among parcelization patterns, PFL attitudes and behaviors, and market price. While recent volume estimates show an increasing supply, representatives from the timber industry have lamented reduced access to private forestlands and difficulties locating high volume timber stands (K.Craig, Executive Director, PA Hardwood Development Council, personal communication, July 10, 2006). Access may be reduced where forest stands are located in areas logistically difficult to conduct logging operations or on properties whose owners choose not to allow timber harvests. To date, the degree to which biophysical and social constraints, and the combination of both, reduce access on private forestlands has remained unclear.

Despite the seemingly obvious observation that not all PFLs are willing to harvest trees, recent reports assessing the available supply of forest resources fail to consider the constraints on access imposed by PFLs. For example, the *Report of the Blue Ribbon Task Force on the Low-Use Wood Resource* (Ray et al. 2008, p.iv) suggests "six-million dry tons of 'low use wood' could be harvested annually" from Pennsylvania forests. Despite alluding to the fact that a large percent of these forests are privately owned, the report neglects to adjust estimates of available wood by the constraints imposed by these owners. Similarly, an assessment of biomass availability in south-central Pennsylvania reports available biomass resources based on inventories conducted by the US Department of Agriculture Forest Service (USFS) Forest Inventory and Analysis (FIA) program (High, Altschuh, and Kingsley 2007). Again, although the authors mention that 70 percent of these resources are privately owned, no efforts are made to quantify the constraints those owners' attitudes, objectives, or behaviors may have on actual availability. Nor are biophysical constraints and limits addressed.

To further explore both biophysical and social constraints, the Pennsylvania Hardwood Development Council (HDC) joined with the PA Department of Natural Resources and Conservation (DCNR) Bureau of Forestry (BoF) to fund a pilot study of access constraints. This research explored the effects of biophysical factors imposed by the landscape, social factors imposed by PFLs, and the overlap of these factors on timber availability in two Pennsylvania counties.

Spatial data of parcel boundaries were analyzed to determine forestland parcelization patterns; spatial data of forestland and landscape characteristics were examined to determine biophysical constraints on harvesting; and PFL attitudes and behaviors with regard to timber harvesting was assessed to determine potential social constraints on forestland access. We were curious whether and how forestland parcelization differed between rural and more developed areas of the state, PFL opposition to harvesting differed between these areas, and how access to forestland was limited by biophysical and social factors.

Contextually, it is important to note Pennsylvania has no state timber harvesting regulation – at least for private forestlands – and limits to timber extraction are found only where biophysical factors impede the logistics of timber harvesting operations or local timber ordinances prohibit harvesting. While best management practices (BMPs) do exist in Pennsylvania, they are not enforced, except as they apply to water quality. Thus, biophysical limits are not hard and fast, but flexible as conditions vary among harvesting location and the ability and/or willingness of harvesters and PFLs to address or overcome them. Local timber ordinances are somewhat rare (an estimated 130 out of 1,500 townships) and were therefore excluded from this analysis.

Conceptual Framework

Timber harvests can be limited by constraints of the biological or physical landscape. For example, forestland on extreme slopes, within wetlands, or in stream buffers is logistically difficult to access given increased erosion potential and harvesting equipment limitations (VA Dept. of Forestry 2002; PA DEP 2005). Beyond these logistical constraints, however, PFLs' decision making, based on their attitudes and values toward harvesting, affect access to forest resources on private forestlands (Young & Richenbach 1987; Prestemon & Wear 2000; Butler & Leatherberry 2004; Favada et al. 2009).

Additionally, constraints beyond PFL control may limit harvesting potential. For example, the availabilities of harvesting professionals (i.e., foresters, loggers, etc.), mills to process raw forest materials, or markets for pulpwood and/or biomass stock also constrain harvesting (Rosen et al. 1989). Further, the condition of the forest resource (e.g., immature and/or low quality trees) and fluctuations in demand for wood products all influence whether or not harvesting is economical or even a viable option for PFLs (Rosen & Kaiser 2003; Luppold & Bumgardner 2006; Munsell & Germain 2007).

According to the literature and our own observations (see Chapter Four), PFL attitudes toward harvesting and their willingness and/or ability to overcome obstacles to harvesting are strongly related to the number of forested acres owned (Best & Wayburn 2001; Butler & Leatherberry 2004). Therefore, to understand how these attitudes and other factors affect access to private forestland, we must first understand how forestland is divided (parcelized) among owners. For example, if little forestland is owned by PFLs with small properties, access could be limited only slightly, despite strong opposition toward harvesting among them.

Theoretically, these factors combine in the following manner: biophysical constraints and the pattern of private forestland parcelization are contextual factors within which other factors operate to affect access (see Figure 5-1). Biophysical constraints also work independently to directly affect access to private forestland. In other words, forestland in biophysically inaccessible areas is simply inaccessible, regardless of other factors, including PFL attitudes and behavior.

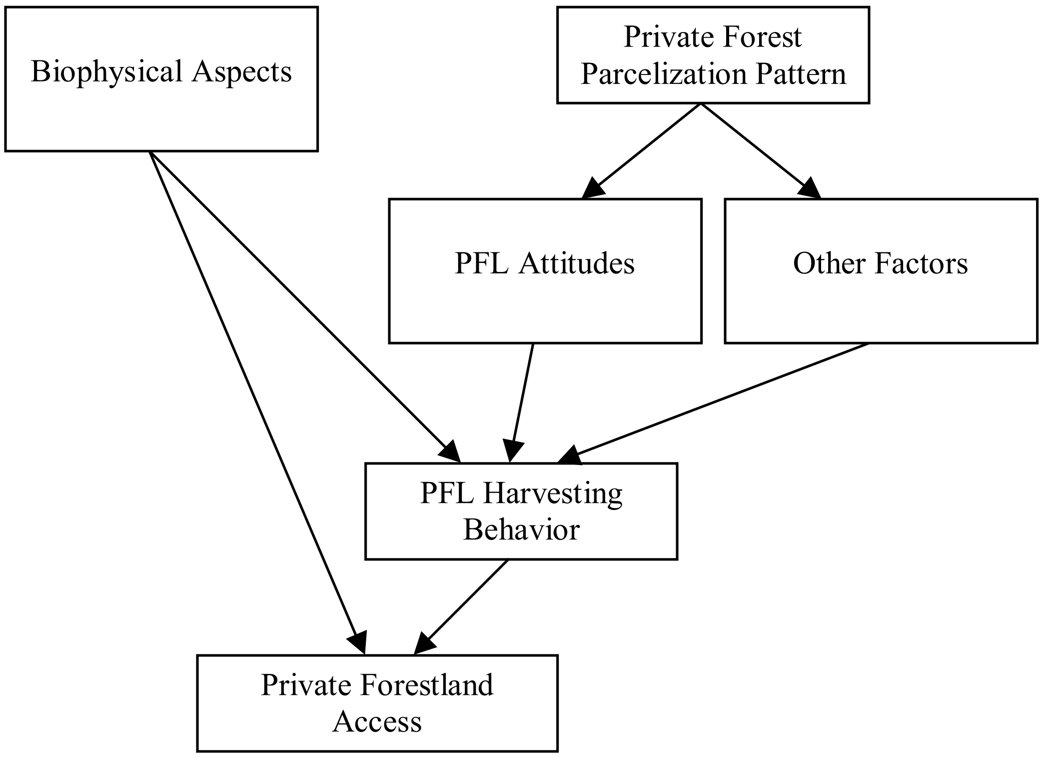

Figure 5 - 1: Conceptual framework of biophysical and social constraints on private forest access

Outside of biophysical constraints, PFL attitudes (i.e., opposition to harvesting) and other factors (i.e., availability of harvesting professionals, market forces, regulation, economy of scale etc.) are influenced by how forestland is parcelized in an area. For example, as many have suggested, harvesting opportunities can be restricted on smaller parcels due to management objectives of owners or logistics and economics of harvesting small properties (Young & Richenbach 1987; DeCoster 1998; Birch and Butler 2001; Butler & Leatherberry 2004). To determine how PFL attitudes and other factors influence access, we must first understand how forestland ownership is distributed among PFLs with various property sizes.

Ultimately, harvesting behavior among PFLs, and thus access to private forest resources, is affected by a combination of PFL attitudes toward harvesting, other factors (e.g., market demands, economy of scale), and biophysical constraints. Understanding these variables and the extent of their overlap will help explain how, and to what degree, access to private forestland may be constrained.

Study Areas

To explore hypothesized differences in timber availability among rural and urban areas of Pennsylvania, we chose to conduct our analysis in Huntingdon and Berks counties (see Figure 5-2). Huntingdon County, located in the south-central part of the state, is 875 square miles and 69 percent forested. Berks County, located in the southeastern part of the state, is 859 square miles and is 41 percent forested. For comparison, statewide forest cover amounts to 58 percent of Pennsylvania's landscape. Private ownership dominates both counties, accounting for 79 percent of Huntingdon County and 89 percent of Berks County (see Figures 5-3 and Table 5-1).

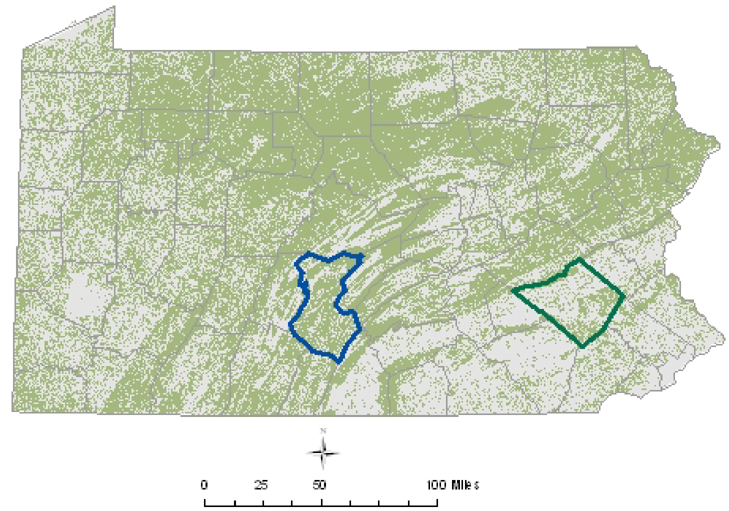

Figure 5 - 2: Forestland in Pennsylvania with study counties highlighted (Huntingdon in blue, Berks in green)

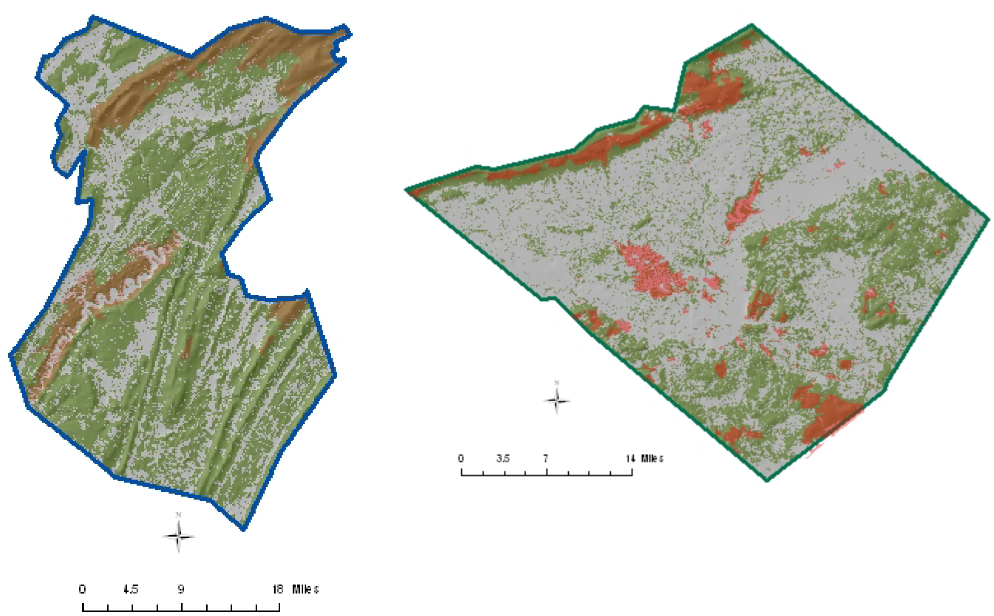

Figure 5 - 3: Private (green) and public (red) forestland in Huntingdon and Berks Counties

Table 5 - 1: Distribution of public and private forests in Huntingdon and Berks Counties

	Public Forest	Private Forest	Total Forest	Total Area
	Acres			
Berks	23,681	201,471	225,152	555,437
Huntingdon	79,509	304,569	384,078	569,520
	Percent			
Berks	11%	89%	100%	-
Huntingdon	21%	79%	100%	-

Population size and growth differ substantially between Huntingdon and Berks County. According to the 2000 US Census, Huntingdon County had a population of 45,771 while Berks County had a population of 401,149. The population in Huntingdon County has remained relatively steady over the past 18 years (3.64% increase) while Berks County has experienced significant growth (19.20% increase) (see Table 5-2).

Table 5 - 2: Population trends in Huntingdon and Berks counties (Source: US Census 2005)

	Population			
County	1990	2000	2006	Percent Change 1990-2006
Berks	336,523	373,638	401,149	19.20%
Huntingdon	44,164	45,586	45,771	3.64%

Timber volume in Pennsylvania has been steadily rising since early in the twentieth century. The most recent estimates put statewide timber volume at 88,522 billion board feet. Although estimated volume has been increasing since 1955, the year the USFS Forest Inventory and Analysis (FIA) program began, the rate of increase has slowed over time (Figure 5-4). According to the recent USFS report on Pennsylvania's forests (McWilliams et al 2007) volume is increasing; however, it is concentrated in larger trees as stand size classes increase, a trend "characteristic of a maturing forest" (pg. 2).

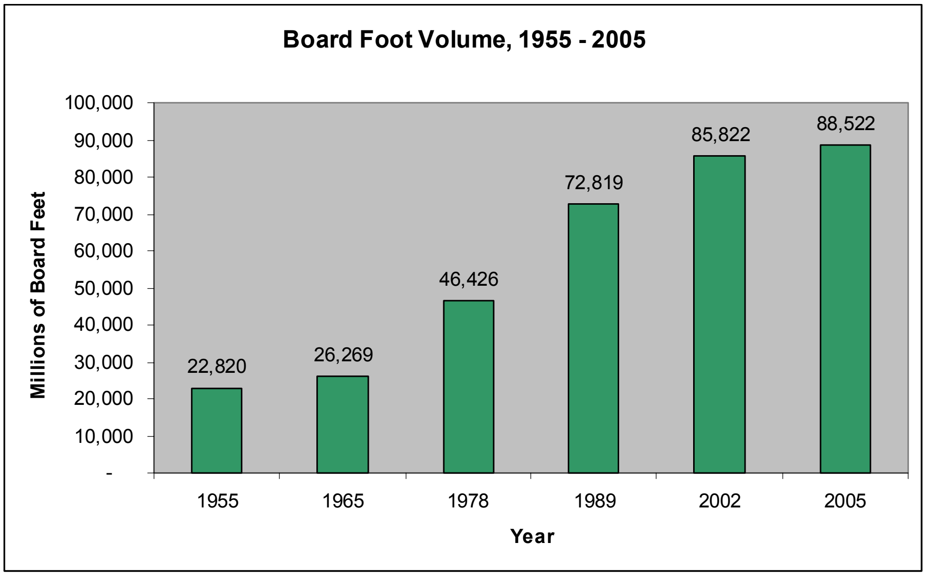

Figure 5 - 4: Pennsylvania total board foot timber volume from 1955 to 2005

These patterns are similar in Berks and Huntingdon Counties: timber volumes have been increasing in these counties albeit at a slower rate in recent years (Figure 5-5). Although patterns of timber volumes are similar in these two counties, development pressure and resulting effects on forestland differ substantially. Since 1989, Berks County has experienced a slight loss of forestland while Huntingdon County has experienced a slight gain (McWilliams et al. 2007). Similarly, Berks County has experienced increased population and housing development while Huntingdon County has experienced little change (US Census 2000). Differences in population and development pressure between these counties have created different forest fragmentation patterns: Berks County has smaller forest patch sizes, less forest considered “core,” and less forestland distant from roads (McWilliams et al. 2007).

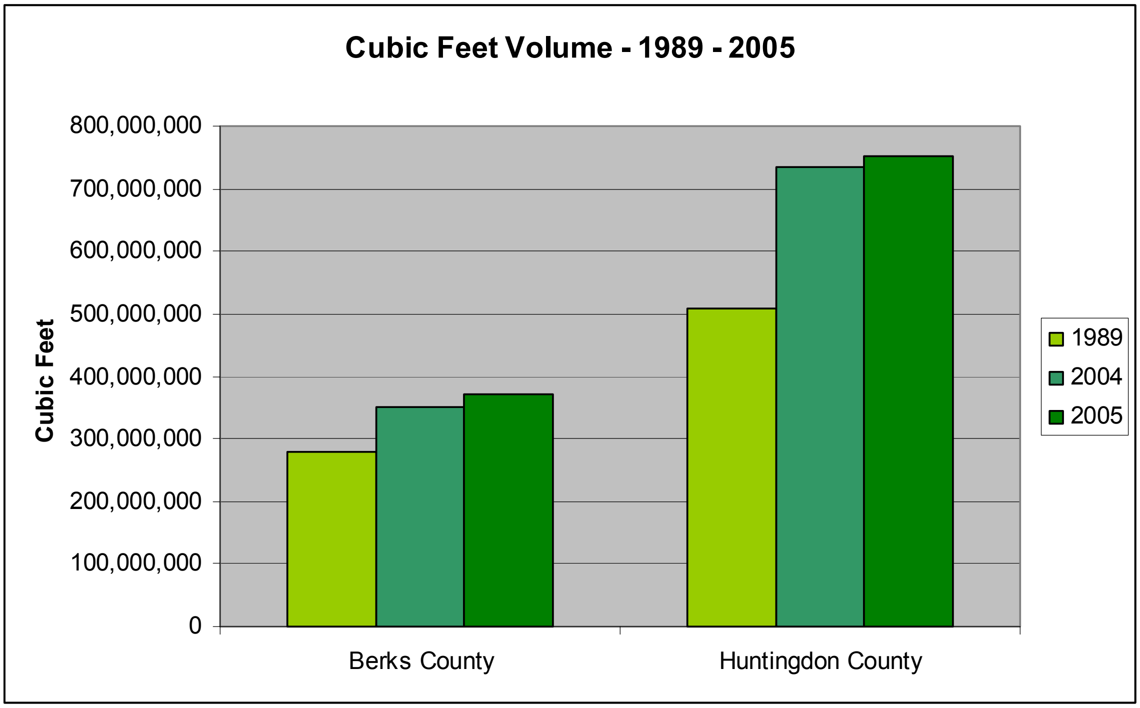

Figure 5 - 5: Cubic feet of timber volume in Huntingdon and Berks counties from 1989 to 2005

Methods

Biophysical constraints

We chose to assess biophysical constraints to timber harvesting using four criteria: slope and proximity to streams, wetlands, and roads. Thresholds for these biophysical constraints, with the exception of water quality issues, are inherently subjective due to the lax regulatory framework in Pennsylvania. To establish reasonable benchmarks for these biophysical factors we turned to the *Timber Harvest Operations Field Guide for Waterways, Wetlands and Erosion Control* published by The Pennsylvania Department of Environmental Protection Bureau of Watershed Management (2005).

In terms of water features, this field guide states "earth disturbances within 50 feet from a stream require a Water Obstruction and Encroachment Permit from DEP Regional Office" (DEP 2005, pg.19). Thus, we chose this buffer distance to determine the area of forestland constrained by proximity to streams. While the field guide also suggests using buffers around wetlands and seeps, it does not specify a minimum buffer. We chose to use 25 feet as a reasonable buffer distance to determine the area of forestland potentially constrained by proximity to wetlands.

There are no legal restrictions to timber harvesting based on slope in Pennsylvania; however, increasing slopes make timber harvesting more difficult, expensive, and dangerous thus limiting harvesting regardless of regulation (VA Dept. of Forestry 2002; PA DEP 2005). While determining a percent slope at which forestland is constrained is subjective, we chose 50 percent to show forestland that is potentially limited by steep slopes. Results are interpreted with the understanding that forestland on 50 percent slopes and higher is not necessarily "off limits" – just that it is limited to some degree.

Similarly, harvesting near roads may be logistically challenging although not legally restricted. Again, we employed a 25 foot buffer to determine the area of forestland constrained by proximity to all state and local roads. The results are interpreted with the understanding that forestland within this buffer is not unavailable – instead, access may be limited.

The area of forestland constrained by these four biophysical factors was measured using spatial data and analysis techniques. Data was obtained from the Pennsylvania Spatial Data Access (PASDA) website and manipulated using ESRI's ArcGIS software. Forested areas were identified using post-processed, remotely sensed data from the Landsat imagery program. These remotely sensed data were created using "imagery from the Enhanced Thematic Mapper (ETM) instrument carried on the Landsat 7 platform" and other ancillary sources by the Penn State Office for Remote Sensing of Earth Resources (Warner 2000, pg.2). From these remotely sensed data, a final landuse/landcover map was created in raster format with 30-meter grid cells, each attributed with one of fourteen landuse/landcover designations: water, low density-urban, high-density urban, hay pasture, row crops, coniferous forest, mixed forest, deciduous forest, woody wetland, emergent wetland, quarry, coal mine, beach, or transitional. These data are available under the title "PALULC2000" on the PASDA website (http://www.pasda.psu.edu). For our purposes we combined coniferous, mixed, and deciduous forests and woody wetlands into a generic "forestland" category. The resulting data are shown in Figure 5-2 as forestland.

Streams were identified using the networked streams of Pennsylvania data produced by PA DEP in 1998 (available under the title "netstreams1998"). Wetlands were identified using the National Wetland Inventory data produced by the US Fish and Wildlife Service in 2005 (available under the title "nwi_poly_statewide2005"). Roads were identified using the local and state road network data produced by PA Department of Transportation (PennDOT) in 2009 (available under the titles “PaLocalRds2009” and “PaStateRds2009”).

Slope was determined by first identifying elevation using digital elevation models (DEMs) produced by the US Geological Society (USGS) (available for each PA county under the title “nedc-countyname”). DEMs were converted to raster datasets and slopes were calculated (in percent) using the ESRI ArcGIS Spatial Analyst software.

Buffers were built around the features of the stream, wetland, and road data to determine areas of influence. Streams were buffered by 50 feet and wetlands and roads were buffered by 25 feet. The slope data were reclassified into two categories: below 50 percent slope and above.

To determine the area of forestland constrained by these factors, each pixel of forestland was attributed with a unique code if it intersected any buffer or areas of 50 percent slope or above. Attribute codes allowed us to determine whether or not each individual forested pixel was constrained and identify the constraining factor or factors.

Social constraints

While many social constraints to timber harvesting exist, we focused on the influence of PFL attitudes and behaviors. Past PFL harvesting behaviors give us the best indication of how PFL attitudes combined and interacted with other factors (e.g., market availability, economies of scale) to influence access to private forest resources. Without dissecting these many variables and their interactions, PFL harvesting behavior shows how access is affected by the full combination of factors. PFL attitudes toward harvesting are among these myriad variables.

Using a statewide survey (see Chapter Four), we asked PFLs to express their attitude toward timber harvesting and report any harvesting they had conducted on their forestland in the past 10 years. Opposition was measured on a five-point Likert scale. Respondents were asked “Are you opposed to cutting trees on your forestland?” and instructed to choose one of the following options: very opposed, opposed, neither opposed nor willing, willing, or very willing.

Harvesting behavior in the last 10 years was measured using a yes/no, dichotomous variable. PFLs reporting harvesting in the last ten years were then asked to characterize the type of harvest. PFLs having conducted only firewood or personal use harvests were excluded leaving only those who conducted “commercial harvests” (e.g., sawlogs, veneer, pulpwood, and/or firewood for sale).

While we directly measured opposition to harvesting among PFLs, all other factors were assumed to have influenced harvesting behavior and were not measured directly. By assessing harvesting behavior among PFLs, we measured how often the combined effects of PFL attitudes, values, and other factors (e.g., availability of harvesting professionals, market forces, regulation, and economy of scale) did not constrain harvests. Conversely, PFLs willing to harvest trees may not have done so due to other factors. Thus, access to this portion of private forests is constrained by an infrequency of harvesting activity.

Efforts to compare survey responses from Huntingdon and Berks counties were complicated by the low numbers of respondents (37 for both). To allow response comparison between these counties, we conducted a hierarchical cluster analysis on all counties in the state to aggregate counties into groups. Hierarchical cluster analysis is used to identify homogeneous groups of cases based on selected variables. We analyzed 66 Pennsylvania counties based on population, county area, percent forest, and percent private forest.[1] These variables were chosen so clusters would reflect the level of parcelization or development of private forestland. Variables were standardized prior to analysis and separation between clusters was measured using squared Euclidean distance.

Cluster analysis indicated four distinct groups of counties, which we labeled "developed," "developed/developing," "developing/undeveloped," and "undeveloped." Berks County was identified as a member of the "developed/developing" group. This group included counties undergoing rapid development, but still had forestland available for harvesting. Huntingdon County was determined to be a member of the "undeveloped" group which included very rural and/or heavily forested counties.

PFL responses to opposition and commercial harvesting questions were compared among all four clusters of counties to determine if PFL attitudes and/or behavior differed (see Table 5-3). An ANOVA analysis indicated significant differences among clusters with regard to opposition ($p<0.001$) and harvesting behavior ($p=0.001$). Due to these significant differences, we used distinct values among respondents for opposition and

[1] Philadelphia County was excluded as it contains less than 0.1% of Pennsylvania's private forestland.

harvesting frequency when determining the influence of these factors on forestland in Berks and Huntingdon counties.

Table 5 - 3: PFL attitudes and behaviors regarding commercial harvesting by cluster

	County Cluster	
	"Developed/Developing" (including Berks County)	"Undeveloped" (including Huntingdon County
% of PFLs reporting commercial harvests within past 10 years	39.6%	44.9%
PFLs "Very Opposed" to harvesting	7.4%	3.9%
PFLs "Opposed" to harvesting	11.3%	8.1%
PFLs "Netiher Opposed nor Willing" to harvest(ing)	27.7%	29.0%
PFLs "Willing" to harvest	38.5%	41.9%
PFLs "Very Willing" to harvest	15.0%	17.2%
Mean opposition score (5pt scale)	3.42	3.61
Sample size (n)	666	653

As others have (Smith et al. 2001; Best & Wayburn 2001; Butler 2008), we found a significant relationship between acres owned by PFLs and their opposition and harvesting behavior. Statewide, PFLs owning small acreages are significantly and substantially more opposed to harvesting and less likely to have conducted commercial harvests than their counterparts owning larger properties (Figure 5-6). For instance, 38 percent of those PFLs with relatively small forested properties (i.e., less than 10 acres of forest) are opposed or very opposed to harvesting trees on their forestland. In contrast, only 7 percent of those PFLs owning 100 or more acres of forestland view harvesting in a similarly negative light. Harvesting behavior follows a similar trend with only 13 percent of PFLs with small properties (i.e., less than 10 acres of forest) having commercially harvested in the past 10 years while over 80 percent of their counterparts owning 1000 acres or more had done so.

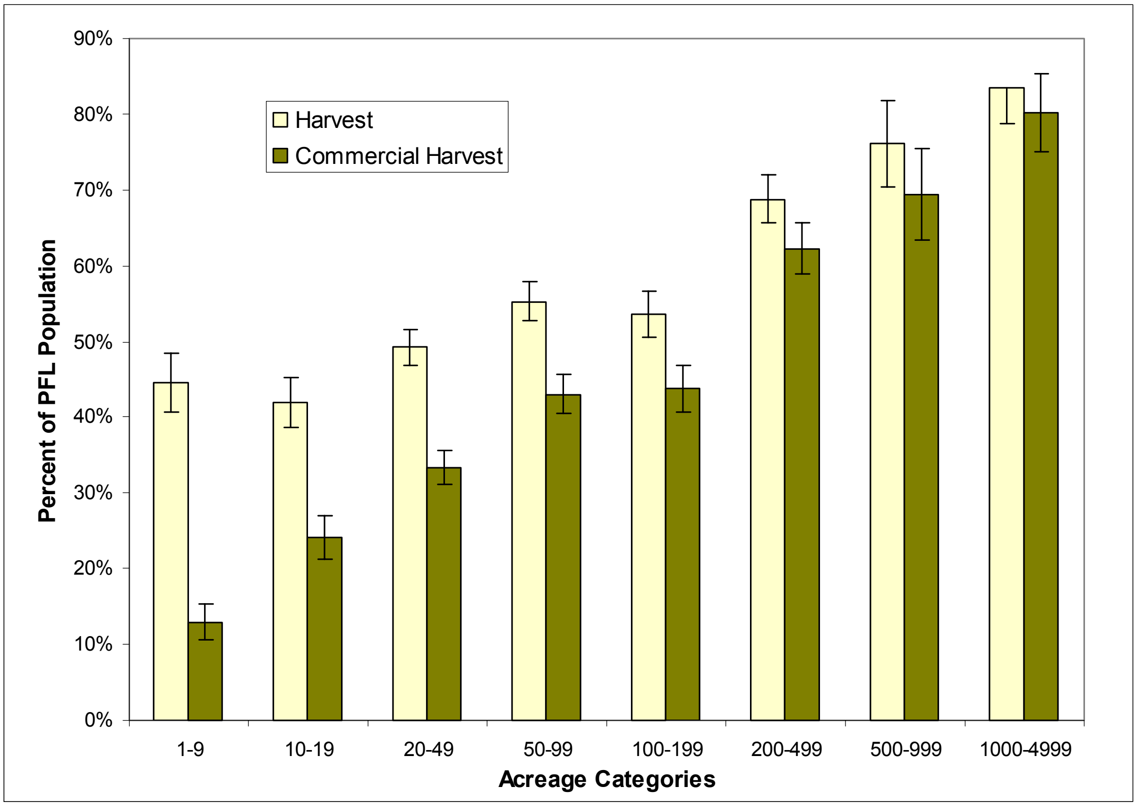

Figure 5 - 6: Distribution of Pennsylvania PFLs who have harvested trees and harvested trees commercially by acreage categories

To determine the influence of varying opposition and harvesting behavior on forestland access in these two counties, we first determined how forestland was parcelized among owners. In other words, how much forestland was owned by PFLs in the 1-9 acre class, 10-19 acre class, 20-49 acre class, etc.? If most of the forestland was owned by PFLs with large properties, lack of opposition and a high frequency of harvesting among these owners might limit timber access only slightly. On the other hand, if a substantial portion of forestland was owned by PFLs with small properties, the stronger opposition and infrequency of harvesting behavior among these owners could substantially limit timber access.

To determine forestland parcelization patterns in Berks and Huntingdon counties, we used the same landuse/landcover data available from PASDA (PALULC2000) in conjunction with digital parcel boundary data obtained from county GIS offices. All counties in Pennsylvania maintain records of parcels and owners through the county's tax assessment office. In 2006, approximately half of Pennsylvania's counties had digital versions of the spatial arrangement of parcels with owner information attributed (Metcalf 2006). Combining the forested pixels from the landuse/landcover data with parcel data allowed us to identify individual owners of private parcels and calculate exactly how much forest was contained on each parcel – essentially an enumeration of the PFLs in each county.

The USFS defines a PFL as a private, non-forest industry entity owning one (1) acre of contiguous forestland at least 10 percent stocked with trees (Alerich 1992). Pixels in the landuse/landcover data designated "forested" constitute 30 square-meter acres of forest, or approximately 0.22 acres. The stocking requirement was considered met if a pixel was designated forested as all such areas had to be at least 50 percent covered with canopy and therefore likely to be at least 10 percent stocked. Parcels with at least five or more contiguous pixels of forestland (1.11 acres) were selected as potential PFL parcels.

As recently detailed by Kittredge et al (2008), landowners often own more than one parcel of land making the number of parcels a poor proxy for PFL population size. As such, we dissolved all parcels based on the owner name attributes. Dissolving is a procedure by which separate polygons (e.g., parcels) are combined into one, multi-part polygon if they share a similar attribute (e.g., owner name). In other words, all parcels owned by "John J. Doe" would be considered a single property thus ensuring our results showed the total number of PFLs in the county, not simply forested parcels. Some data cleaning was required to ensure parcels owned by the same owner did in fact have identical owner attributes.

After dissolving, each parcel was attributed as either public (owned by a public entity), forest industry (owned by a forestry-related entity), or private based on the owner name. Forest industry included all known private, forestry-related entities. Public owners included all federal, state, county, and local entities. Public and forest industry lands were excluded from this analysis as our focus was on PFLs and the effects of their decisions. Further, the majority of public forestland follows harvesting allocation and scheduling rules.

All remaining private parcels with at least 5 contiguous pixels of forestland were then attributed as a PFL property. A zonal statistic was calculated in ArcGIS for each of these properties thus providing a count of pixels and an estimated acreage of forestland (i.e., $30m^2 * 0.0002471\ m^2/acre$) owned by each PFL. This final dataset allowed an enumeration of the PFL population and a detailed breakdown of the distribution of PFLs and forestland over acreage categories.

To combine survey results with these distributions, we calculated the percent of PFLs opposed to harvesting in each acreage category. Forestland in each acreage category was then assumed to be subject to the attitudes typical of the PFLs in that same acreage category. For example, if 100 acres of forestland was held on properties 1 to 10 acres in size and 75 percent of the owners in that category were opposed or very opposed to harvesting, 75 acres of the forestland was considered constrained due to opposition.

There is evidence in the literature that the percentage of PFLs intending to harvest remains relatively constant and closely reflects the percentage of PFLs who have previously harvested. Birch and Butler (2001) found in their 1994 study of New York PFLs that 39 percent had conducted harvests while 35 percent intended to do so in the future. Similarly, Turner, Finley, and Kingsley (1977) found the proportion of Delaware landowners intending to harvest remained constant from 1970 to 1974 despite individual landowners changing their minds. Stone (1970) suggested, too, that the percentage of PFLs intending to harvest may remain constant despite fluctuations in individual PFL intentions. These past findings are consistent with Fishbein and Ajzen's (1980) theory that past behavior is a strong predictor of future behavior. Thus, the percentage of PFLs who have harvested in the past 10 years is likely to reflect the percentage of PFLs who will do so in the next 10 years.

Similarly, we found evidence among respondents to the second panel mail survey (see Chapter Four) suggesting the percentage of PFLs with intentions to harvest closely reflected the percentage of PFLs who have harvested. Although future harvesting intentions were not measured during the first panel mail survey in 2006, they were measured during the second in 2008. These data indicated 25.8 percent of PFLs statewide had harvested in the last 10 years and 23 percent of PFLs statewide intended to harvest in the future. This, of course, does not imply the *same* PFLs are necessarily intending to harvest (although possible), which is consistent with previous findings (Stone 1970; Turner, Finley, and Kingsley 1977; Birch and Butler 2001).

Based on these findings and the consistency in past studies, we estimated the percentage of forestland likely to be harvested in the next 10 years by calculating the percent of PFLs who had commercially harvested in the past 10 years in each acreage category. For example, if 40 percent of the owners in the 1-9 acreage category had conducted a commercial harvest in the past 10 years, 60 percent of the forestland was considered constrained due to infrequency of harvesting. Again, this procedure does not suggest we are trying to predict *which* acres of forestland will or will not be harvested. Rather, we are estimating the percent of acres owned by landowners who harvest in the next 10 years will likely reflect the percent of acres owned by landowners who harvested in the past 10 years. Combining the PFL survey data with detailed acreage distributions allowed us to estimate how PFL attitudes and behaviors may constrain forestland.

Overlap of biophysical and social constraints

Biophysical and social constraints can and do overlap. For example, forestland that falls on an extremely steep slope may also be owned by a PFL who is very opposed to harvesting. Thus, the amount of constrained forestland is not equal to the sum of biophysically constrained acres and socially constrained acres; in reality, it will be less than this sum. As in a Venn diagram, some forestland will be constrained by biophysical factors, some by social, and some by both. While biophysical and social constraints are important to understand independently, the actual amount of constrained forestland is ultimately determined by the individual *and* combined affects of these factors.

To determine the overlap between social and biophysical constraints, we assigned unique attributes to each pixel of forestland. This attribution process allowed us to identify all the biophysical factors constraining each pixel (slope or proximity to stream, wetland, or road) and identify the size of the property that pixel fell on (which acreage category). All pixels were then categorized by the type of constraint(s) and the acreage size of its owner thus allowing an assessment of the combined affects of biophysical and social factors.

Results

Biophysical constraints

The majority of forestland in both counties is located on low slopes (Figure 5-7 and Table 5-4). In Huntingdon County, 61 percent of the forestland (185,787 acres) falls on slopes less than 20 percent and in Berks County 72 percent of the forestland (145,059 acres) fall on similar slopes. Limiting slopes (50% and greater) are only found on 2.7

percent of the forestland in Huntingdon County (8,223 acres) and 0.2 percent in Berks County (463 acres).

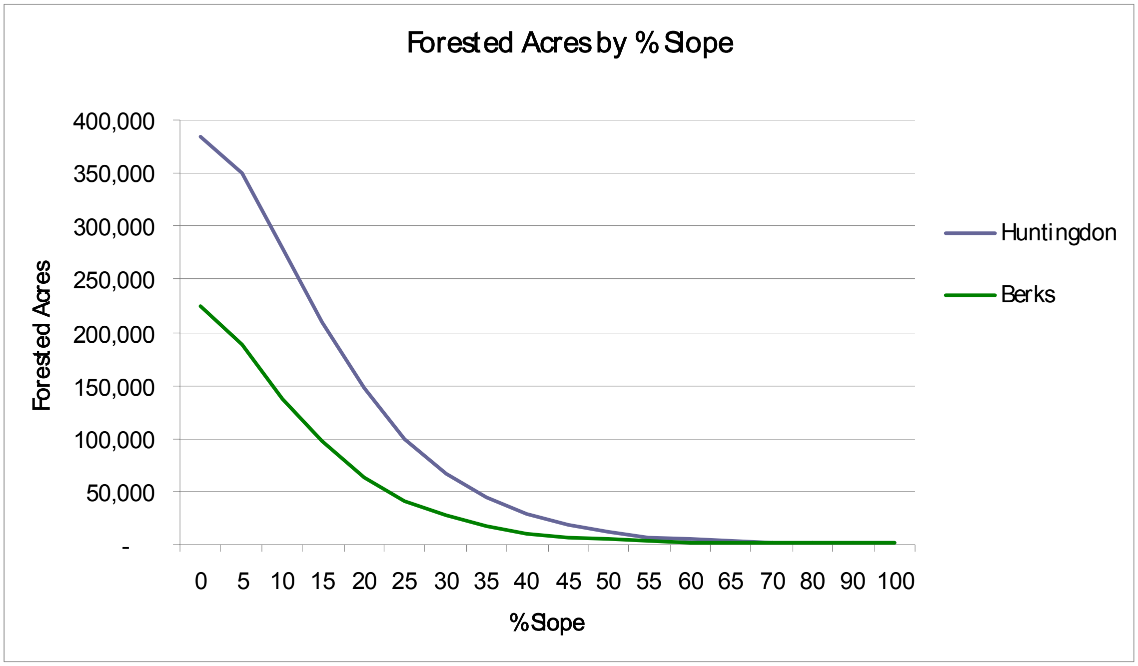

Figure 5 - 7: Forested acres by percent slope for Huntingdon and Berks Counties

Table 5 - 4: Forested acres by percent slope categories for Huntingdon and Berks Counties

		Huntingdon		Berks	
		Acres	%	Acres	%
% Slope	TOTAL	384,078	100%	225,152	100%
	0-10	104,857	27%	88,003	39%
	10-20	132,274	34%	73,844	33%
	20-30	80,126	21%	36,074	16%
	30-50	55,081	14%	22,698	10%
	50-70	9,268	2.4%	3,043	1.4%
	70-100	1,107	0.3%	368	0.2%

Similarly, relatively small portions of private forestland are found in proximity to roads, streams, and wetlands in both counties (Table 5-5). Only 0.5 percent of the private forestland in Huntingdon County (1,554 acres) and 2.9 percent of the forestland in Berks County (5,843 acres) is within 25 feet of roads. Slightly more private forestland, 2.5 percent in Huntingdon County (7,614 acres) and 3.2 percent in Berks County (6,447 acres), is found within 50 feet of streams. The 25 foot buffer around wetlands covered 0.7 percent of the private forestland in Huntingdon County (2,132 acres) and 2.7 percent of the forestland in Berks County (5,440 acres).

Table 5 - 5: PFL survey responses, private forestland distribution, and social constraints on forestland by acreage categories

	Berks		Huntingdon	
	Acres	Percent	Acres	Percent
Slope (50%) only	454	0.2%	8,131	2.7%
Roads only	5,563	2.8%	1,461	0.5%
NWI only	4,006	2.0%	1,588	0.5%
Streams only	4,969	2.5%	7,094	2.3%
Slope & Roads	7	0.0%	18	0.0%
Slope & NWI	3	0.0%	3	0.0%
Slope & Streams	5	0.0%	16	0.0%
Roads & NWI	68	0.0%	8	0.0%
Roads & Streams	208	0.1%	64	0.0%
NWI & Streams	1,256	0.6%	425	0.1%
Slope/Roads/NWI	-	0.0%	-	0.0%
Slope/Roads/Streams	-	0.0%	1	0.0%
Slope/NWI/Streams	1	0.0%	1	0.0%
Roads/NWI/Streams	27	0.0%	2	0.0%
Slope/Roads/NWI/Streams	-	0.0%	-	0.0%
Constrained Biophysically	16,567	8.2%	18,812	6.2%
Unconstrained Biophysically	184,904	91.8%	285,757	93.8%
TOTAL	201,471	100.0%	304,569	100.0%

Private forestland in both counties was sometimes constrained by two or more factors. As a result, the total private forestland constrained by biophysical factors is less than the sum of that affected by these individual factors (Table 5-5). Biophysical factors, as we measured them, combined to constrain 6.2 percent of the private forestland in Huntingdon County (18,812 acres) and 8.2 percent of the private forestland in Berks County (16,567 acres).

Social constraints

Opposition to harvesting by PFLs differed significantly among counties in Pennsylvania (Table 5-6). Nearly one fifth of PFLs (18.7%) from counties in the "developed/developing" cluster (including Berks County) were "opposed" or "very opposed" to harvesting trees from their forestland (11.3% and 7.4%, respectively). In contrast, 12 percent of PFLs from counties in the "undeveloped" cluster (including Huntingdon County) were "opposed" or "very opposed" (8.1% and 3.9%, respectively). A one-way ANOVA comparison of mean opposition scores showed a significant difference among clusters ($p<0.001$).

Similarly, reported harvesting behavior differed significantly among counties (Table 5-6). Nearly 40 percent of PFLs in the "developed/undeveloped" cluster (39.6%) reported having conducted a commercial harvest in the past 10 years. In the "undeveloped" cluster, 45 percent of PFLs reported commercial harvests in the same time period. A one-way ANOVA comparison of commercial harvesting frequency showed a significant difference among clusters ($p<0.001$).

In both "developed/developing" and "undeveloped" clusters, a strong relationship was found between acreage owned by PFLs and their attitudes and behaviors toward harvesting. PFLs owning fewer acres were more likely to oppose harvesting and less likely to have conducted commercial harvests. Regression analysis showed a significant log-linear relationship between acres of forestland owned and opposition score (Constant=2.616, B=0.226, R^2=0.112, F=289.99, p<0.001). Opposition was strong among PFLs owning relatively small properties, and lessened as acreage owned increased. Similarly, we found a significant log-linear relationship between acres of forestland owned and harvesting frequency (Constant=-0.029, B=0.109, F=335.59, p<0.001). Harvesting was uncommon among PFLs with small forests but increased quickly among owners of larger forests.

Due to this strong relationship, we assigned PFLs to acreage categories to assess the influence of opposition and harvesting frequency on forestland in our study counties. Based on the log-linear relationship, acreage categories were established to capture variation at the lower end of the acreage owned range. Acres of forestland owned ranged from one to 18,600 acres in the "developed/developing" cluster. In the "undeveloped" cluster, acres of forestland owned ranged from one to 15,500 acres. However, the majority of variation in opposition and harvesting frequency occurred below 100 acres. Thus we established acreage categories at 1 to 9.9, 10 to 19.9, 20 to 49.9, 50 to 99.9, and 100 or more acres to capture the majority of variation. For each acreage category we calculated the percent of PFLs opposed to harvesting and the percent PFLs who had conducted commercial harvests (Table 5-6, survey responses).

Table 5 - 6: PFL survey responses, private forestland distribution, and social constraints on forestland by acreage categories

			Acreage Category					
			1-9.9	10-19.9	20-49.9	50-99.9	100+	Total
Survey Responses	"Developed/ Developing" (including Berks County)	% PFLs Opposed	35.9%	25.1%	20.2%	8.0%	7.9%	18.7%
		% PFLs Reporting a Commercial Harvest	17.5%	27.1%	39.2%	45.0%	58.0%	39.6%
	"Undeveloped" (including Huntingdon County)	% PFLs Opposed	34.2%	19.2%	18.4%	5.3%	8.6%	11.9%
		% PFLs Reporting a Commercial Harvest	16.7%	21.1%	30.2%	47.1%	58.4%	44.9%
Forestland Distribution	Berks County	% Forestland	29.0%	15.1%	23.5%	15.0%	17.3%	100.0%
		Acres of Forestland	58,517	30,513	47,293	30,193	34,954	201,471
	Huntingdon County	% Forestland	6.8%	5.7%	12.4%	18.9%	56.2%	100.0%
		Acres of Forestland	20,795	17,330	37,704	57,589	171,151	304,569
Social Constraints on Forestland	Berks County	% Forestland constrained due to opposition	10.4%	3.8%	4.7%	1.2%	1.4%	21.5%
		% Forestland constrained due to infrequency of harvesting	24.0%	11.0%	14.3%	8.2%	7.3%	64.8%
	Huntingdon County	% Forestland constrained due to opposition	2.3%	1.1%	2.3%	1.0%	4.8%	11.5%
		% Forestland constrained due to infrequency of harvesting	5.7%	4.5%	8.6%	10.0%	23.4%	52.2%

Analysis of GIS parcel ownership and landuse/landcover data showed a population of 8,016 PFLs in Huntingdon County and 16,925 PFLs in Berks County. This analysis also allowed an enumeration of owners, percent owners, forested acres, and percent private forestland by acreage categories (Table 5-6, forestland distribution). The majority of private forestland in Huntingdon County (56.2%) was found on properties

100 acres in size or larger. Conversely, only 17.3 percent of the private forestland in Berks County was found on these large properties. Instead, the plurality of private forestland in Berks County (29.0%) was located in the smallest acreage category, “one to nine” acres.

Combining this distribution of private forestland with the opposition and harvesting behavior of PFLs by acreage category allowed us to estimate the influence on access (Table 5-6, social constraints). For example, in Huntingdon County, 6.8 percent of the private forestland was owned in the “one to nine” acreage category where 34 percent of owners are opposed to harvesting. Consequently, 2.3 percent of the private forestland in the county was constrained due to PFL attitudes. In total, PFL opposition to harvesting may be constraining 11.5 percent of the private forestland in Huntingdon County and 21.5 percent of the private forestland in Berks County.

Similarly, harvesting frequency within acreage classes allowed us to estimate the percentage of private forestland owned by PFLs likely to harvest in the next 10 years (Table 5-6, social constraints). For example, in Berks County, 29 percent of the private forestland was owned in the “one to nine” acreage class where 17.5 percent of PFLs reported harvesting in the past 10 years. If we assume the same percentage will harvest in the next 10 years, this means 24 percent of the private forest in the county is constrained due to infrequency of harvesting in this acreage category. In total, we estimate 52.2 percent of the private forestland in Huntingdon County and 64.8 percent of the private forestland in Berks County will be constrained in the next 10 years due to infrequency of harvesting.

Overlap of biophysical and social constraints

Analysis of the combined effects of biophysical and social constraints showed modest overlap in both percent and acres (Table 5-7 and Table 5-8). While biophysical constraints were measured using only one method, social constraints were estimated using first opposition to harvesting followed by harvesting behavior. Results are presented for analysis under both social constraint methods.

Table 5 - 7: Interaction of social and biophysical constraints (showing percent private forest affected)

			Acreage Categories					
			<10	10-19	20-49	50-100	100+	Total
Berks County	Biophysically constrained		2.63%	1.30%	2.09%	1.13%	1.08%	8.22%
	Socially constrained	Opposition	10.43%	3.80%	4.74%	1.20%	1.37%	21.54%
		Harvesting	23.82%	11.06%	14.32%	8.24%	7.29%	64.72%
	Overlap	Opposition	0.94%	0.33%	0.42%	0.09%	0.09%	1.87%
		Harvesting	2.16%	0.95%	1.27%	0.62%	0.45%	5.45%
	Total constrained	Opposition	12.1%	4.8%	6.4%	2.2%	2.4%	27.9%
		Harvesting	24.3%	11.4%	15.1%	8.7%	7.9%	67.5%
Huntingdon County	Biophysically constrained		0.5%	0.4%	0.8%	1.1%	3.4%	6.2%
	Socially constrained	Opposition	2.3%	1.1%	2.3%	1.0%	4.8%	11.5%
		Harvesting	5.7%	4.5%	8.7%	10.0%	23.6%	52.5%
	Overlap	Opposition	0.2%	0.1%	0.1%	0.1%	0.3%	0.7%
		Harvesting	0.4%	0.3%	0.5%	0.6%	1.4%	3.3%
	Total constrained	Opposition	2.7%	1.4%	2.9%	2.0%	7.9%	17.0%
		Harvesting	5.8%	4.6%	8.9%	10.5%	25.6%	55.3%

Table 5 - 8: Interaction of social and biophysical constraints (showing acres of private forest affected)

			Acreage Categories					
			<10	10-19	20-49	50-100	100+	Total
Berks County	Biophysically constrained		5,302	2,621	4,208	2,268	2,168	16,567
	Socially constrained	Opposition	21,008	7,659	9,553	2,415	2,761	43,397
		Harvesting	47,984	22,275	28,849	16,606	14,681	130,395
	Overlap	Opposition	1,903	658	850	181	171	3,764
		Harvesting	4,348	1,913	2,567	1,247	911	10,986
	Total constrained	Opposition	24,406	9,622	12,911	4,502	4,758	56,199
		Harvesting	48,939	22,982	30,490	17,627	15,938	135,976
Huntingdon County	Biophysically constrained		1,553	1,223	2,342	3,354	10,339	18,812
	Socially constrained	Opposition	7,112	3,327	6,938	3,052	14,719	35,148
		Harvesting	17,260	13,691	26,393	30,522	71,883	159,749
	Overlap	Opposition	531	235	431	178	889	2,264
		Harvesting	1,289	967	1,639	1,778	4,343	10,015
	Total constrained	Opposition	8,134	4,316	8,849	6,228	24,169	51,696
		Harvesting	17,524	13,948	27,096	32,098	77,880	168,546

When using opposition to harvesting to determine social constraints, the analysis indicated an overlap of 0.7 percent of the private forestland in Huntingdon County, and 1.9 percent in Berks County. In other words, while biophysical constraints in Huntingdon County accounted for 6.2 percent of the private forestland and social constraints (opposition to harvesting) accounted for 11.5 percent of the private forestland, 0.7 percent of the private forestland was constrained by both factors. Thus, using opposition as an indicator of social constraints, the total private forestland constrained totaled 17.0 percent in Huntingdon County and 27.9 percent in Berks County.

When harvesting behavior was used to determine social constraints, an overlap of 3.3 percent of the forestland was identified in Huntingdon County and 5.5 percent in

Berks County. Thus, using this method, the constrained private forestland totaled 55.3 percent in Huntingdon County and 67.5 percent in Berks County. This, too, may be an underestimation of the constrained private forestland as PFLs who reported harvests often only harvested a portion of their forestland (see discussion).

Discussion and Conclusion

While access to private forestland can be limited by either biophysical or social factors, or both, our analysis indicated only modest constraints from slope and proximity to water, wetlands, and roads. In a state with unregulated timber harvesting and a relatively small proportion of forestland found on steep slopes, biophysical conditions appear to limit access only slightly.

Buffers used in this analysis were relatively modest. Greater protection around streams and wetlands, afforded by regulation in other states, would restrict harvesting to a greater degree than in these two counties. However, BMPs in Pennsylvania allow harvesting within all buffers depending on the rate of removal (i.e., canopy disturbance) (DEP 2005). Larger buffers would cover more area, but the amount of private forestland constrained would likely be overestimated as harvesting is not completely restricted within these areas. This is especially true for forestland near roadways as there are no legal restrictions against harvesting in these areas, simply logistical complications.

Social factors appear to substantially affect access to private forestland in both Huntingdon and Berks counties, albeit to different levels. Consistent with the literature, our results indicate PFLs owning smaller properties are significantly more likely to oppose harvesting and less likely to conduct commercial harvests. Although this is true in both counties studied here, Berks County has more forestland owned by PFLs in these small acreage categories, thus increasing the influence of PFL attitudes and behaviors on access. For example, in Berks County 26.4 percent of the forestland is found on properties less than 10 acres in size. In contrast, only 6.8 percent of the forestland in Huntingdon County is found on properties in this acreage class. Even if opposition in this acreage class was constant across these two counties, substantially more forestland would be affected in Berks County. Compounding this effect, however, is the increased opposition to harvesting among PFLs in Berks County and similarly "developed/developing" counties.

As reported, we estimated social constraints to forestland access from two different perspectives: opposition and reported harvesting behavior. While similar in theory, these two estimates measure two different but somewhat complimentary perspectives on access constraints. Opposition measures indicate forestland that is off-limits due to PFL attitudes. However, forestland owned by PFLs unopposed to harvesting is not necessarily available as many other factors influence whether or not forestland is harvested. For example, a PFL may be very willing to harvest but owns immature trees, low-quality trees, species that may not have sufficient market value, or a variety of other reasons. While forestland owned by PFLs unopposed to harvesting is not constrained by this factor, reported harvesting over the past 10 years gives us an indication of how many PFLs overcame these other obstacles and conducted harvests. This provides our best estimate of how much forestland is owned by PFLs likely to harvest in the next 10 years if other factors do not change drastically (e.g., timber markets, regulatory framework).

The complimentary nature of these two measures shows how opposition limits harvesting as compared to other factors. While opposition is one of many factors limiting harvests on private forestland, not all forestland owned by PFLs opposed to harvesting is unlikely to be harvested. Figures 5-7 and 5-8 depict conceptual diagrams of forestland, and biophysical, social, and overlapping constraints affecting access in Berks and Huntingdon counties, respectively, according to our results. These diagrams show how various constraints combine to limit access to forestland for harvest. Biophysical constraints, while present, influence far fewer acres than either harvesting infrequency or opposition to harvesting in both counties.

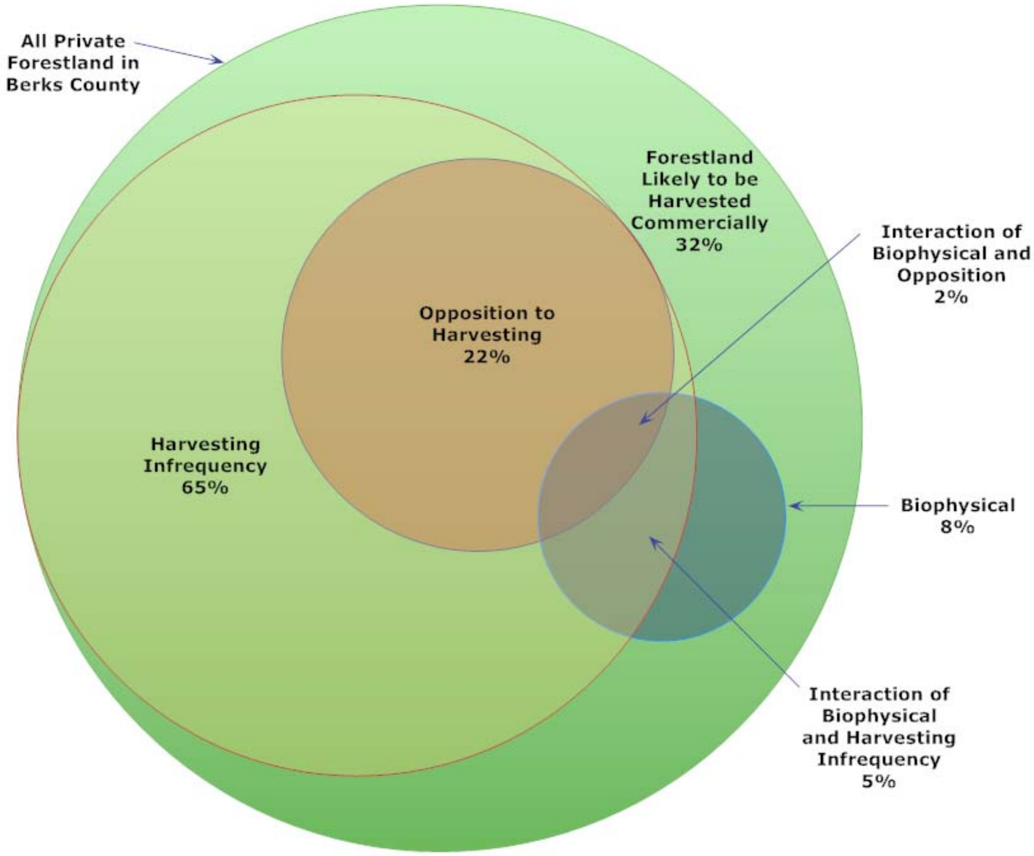

Figure 5 - 8: Conceptual diagram of private forestland in Berks County and estimated constraints from harvesting infrequency, opposition to harvesting, biophysical factors, and overlap among these variables

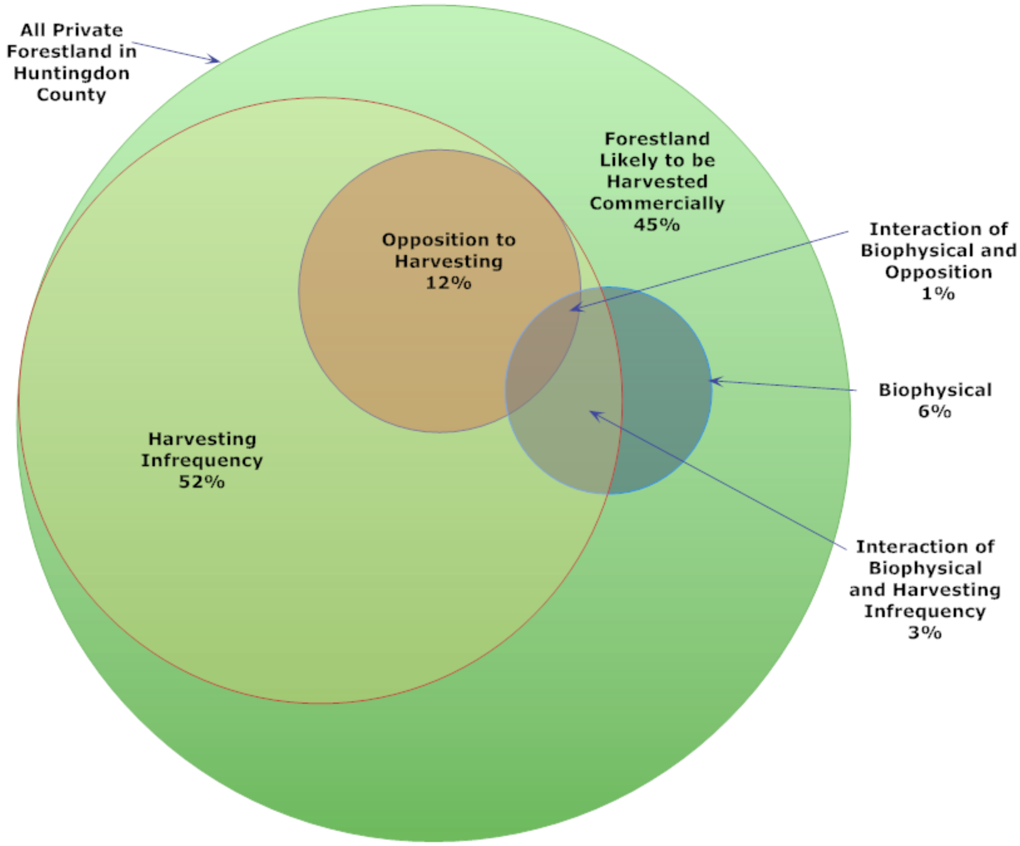

Figure 5 - 9: Conceptual diagram of private forestland in Huntingdon County and estimated constraints from harvesting infrequency, opposition to harvesting, biophysical factors, and interactions among these variables

These results indicate forestland is more constrained in Berks County (68%) than in Huntingdon County (55%). In both counties, however, biophysical constraints were heavily outweighed by social constraints. Opposition to harvesting among PFLs was a greater constraint in Berks County (22%) than in Huntingdon County (12%), but other factors seemed to limit harvesting to a greater degree in both counties. Results indicate that in Berks County 43 percent of the forestland is constrained by factors beyond opposition among PFL. In Huntingdon County, these other factors combined to constrain 40 percent of the forestland.

Overlap between biophysical and social factors was relatively minor. In Berks County, five percent of the forestland was constrained by harvesting infrequency and biophysical factors. Overlap between opposition and biophysical factors affected two percent of the private forestland in the county. In Huntingdon County, overlap between harvesting infrequency and biophysical factors both constrained three percent of the private forestland. Interaction between opposition and biophysical factors affected only one percent of the private forestland in the county.

These results indicated social factors limited access to forestland to a far greater degree than biophysical constraints. In fact, the overlap among these variables indicated over half of the forestland constrained by biophysical factors in Berks County (63%) was also constrained by harvesting infrequency. Further, 25 percent of the biophysically constrained forestland in Berks County was owned by PFLs who oppose harvesting. In Huntingdon County, 50 percent of the biophysically constrained forestland was also constrained by harvesting infrequency and 17 percent was owned by PFLs who opposed harvesting. These results suggest biophysical constraints, as measured, contribute only slightly beyond social factors to limiting access on private forestland.

It is important to note the remaining forestland (unconstrained by either social or biophysical factors) may not all be harvested in the next 10 years. While 44.7 percent of forestland in Huntingdon County and 32.5 percent of the forestland in Berks County may be owned by PFLs likely to conduct a harvest, these owners are unlikely to harvest *all* of their forestland in the next 10 years. In fact, according to our survey results, PFLs who reported conducting a commercial harvest often harvested only part of their forestland. When asked how many acres had been harvested in the past 10 years, PFLs reported a mean of 51 percent, meaning the average PFL who conducted a harvest only harvested approximately half of their forestland. As a result, the estimate of available forestland is likely high since it is possible only a portion of the forestland owned by PFLs willing to harvest will in fact be harvested in the next 10 years, barring major changes in market demand.

Social factors, as measured in our survey, may influence substantial amounts of forestland statewide. Although biophysical constraints were not measured statewide, we independently estimated social impacts on access given known opposition and harvesting behavior among PFLs and the distribution of forestland among these owners (Figure 5-10). Although the plurality of forestland was in ownerships 100 acres and larger, a significant portion was owned on smaller properties. Harvesting infrequency and opposition among owners of smaller properties is likely to substantially limit access across the state. Nearly 75 percent of the forestland is owned by PFLs who have not conducted a commercial harvest in the past 10 years. We estimate opposition constrains access to approximately 15 percent of this forestland.

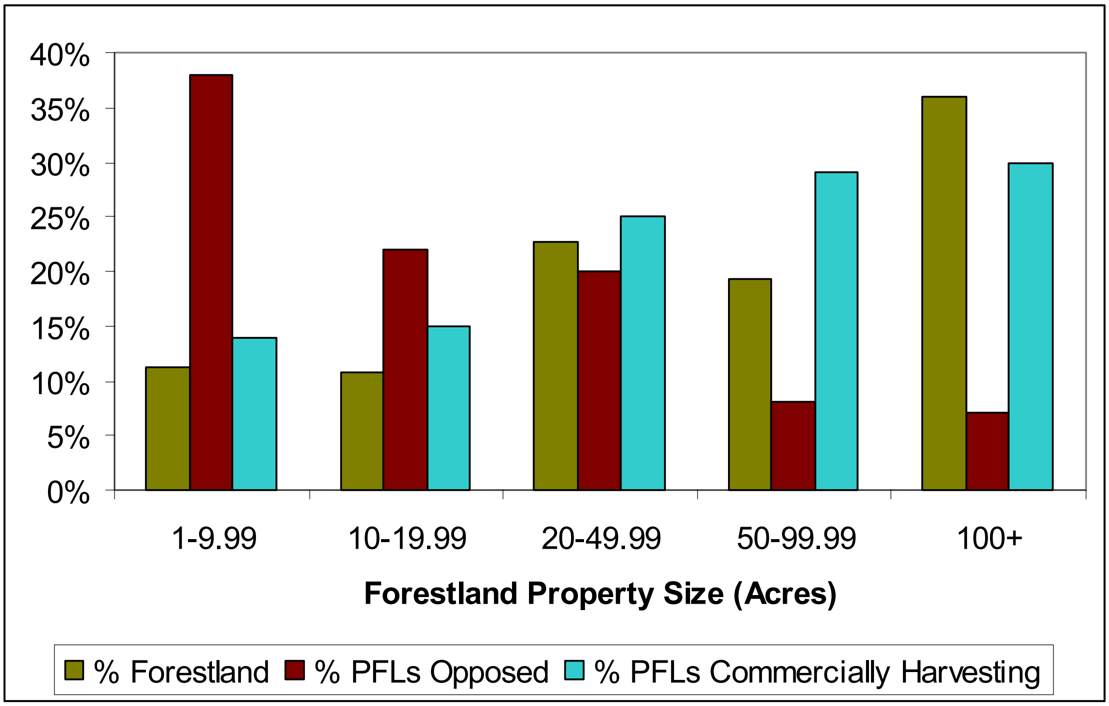

Figure 5 - 10: Statewide private forestland, PFL opposition to harvesting, and frequency of commercial harvests among PFLs by size (acres) of forestland property

Although results indicate social factors limit access to forestland, this analysis is limited as it employs forestland as a proxy for timber volume. Timber volume varies based on a variety of factors including site condition, species, management regimes, and myriad others. To be sure, timber volume is not evenly spatially distributed. Since this analysis measured access constraints to forestland, results may not be directly applicable to access to timber volume. Future research should attempt to bridge this gap. While this is an important caveat, we believe our conclusions regarding access to "generic" forestland moves our understanding of biophysical, social, and interactional constraints across the landscape forward. In our opinion, variation imposed by spatially explicit timber volume estimates will likely not reduce the strong influence of social factors on access.

These results suggest two important conclusions: (1) in developed and developing counties, more forestland is under the control of PFLs owning small properties than in less parcelized areas; and (2) PFLs in developed and developing areas are more opposed to harvesting and less likely to conduct harvests than their counterparts in less developed counties. Such factors likely work together in other counties across Pennsylvania to prevent access to forestland even while timber volumes continue to increase.

These results provide an important understanding of the variation in private forestland distribution across Pennsylvania and the potential impact of PFL attitudes and behavior on access to forest resources. While statewide estimates of private forestland distribution provide a picture of the average situation in the state, these results reflect significant variation among forested, rural areas of the state and more developed urban areas. Forestland holdings vary substantially across the state, as is clear from the distribution of forestland by size of forest holding [see Figure 5-11 (from McWilliams et al. 2007, p.15)]. Note, too, in Figure 5-11, areas with larger forest holding size are those areas of the state with large amounts of public ownership.

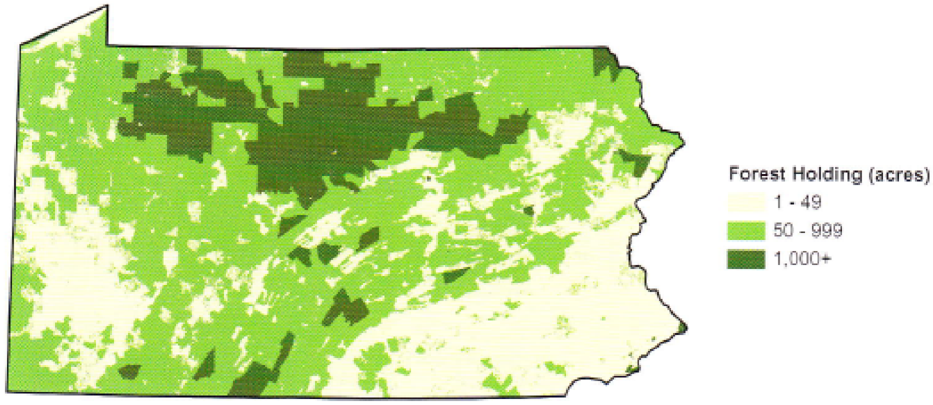

Figure 5 - 11: Distribution of forest holding size in Pennsylvania (from McWilliams et al. 2007, p.15)

North-central areas of the state are dominated by large properties, much of which is in public ownership, whereas most of the state is more parcelized. In fact, the influence of urban areas (i.e., Pittsburgh, Erie, Philadelphia and other development in the southeast of the state) extend across substantial forested areas of the state. This suggests access to private forestland is likely to be significantly and substantially constrained in these more parcelized areas of the state simply because more forestland is controlled by PFLs with smaller properties. Further, if PFLs in these more parcelized areas are more opposed to harvesting than their counterparts in more rural areas, constraints to access may be compounded.

These constraints to access should be considered as business, industry, and state and local governments plan their use of traditional forest resources and expand their use of emerging renewable energy resources (e.g., woody biomass for heat or co-generation facilities). In the US, especially in the East, most of the forestland is privately owned and decisions made by these owners will significantly influence supply of forest resources. Timber supply should not be viewed as a relative constant only changing as volume is accrued or lost, but rather as a variable fluctuating with changes in and interactions among parcelization patterns, PFL attitudes and behaviors, and market forces.

This study takes a small, but important step toward understanding and quantifying the constraints imposed by these factors. Future plans for utilization of these resources must account for such constraints or they run the risk of greatly overestimating supply. Future utilization of forest resources will require not only high-volume forest stands, but partnership and strong communication with those who own, live with, and care for private forests.

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Chapter 6

Conclusion

Across the United States, especially in the East, private forests are integral to the health of ecosystems, the strength of economies, and the well-being of people and communities. Understanding the owners of these private forests is essential to enduring future challenges to forest sustainability and changes in forest composition and distribution, both man-made and otherwise. This understanding will only be reached through careful and thorough methods of inquiry and only worthwhile if it informs outreach and assistance efforts to private forest landowners (PFLs) and affects policy efforts at all levels of government.

The composition, sustainability, and the mere existence of future forests depend not only on research of PFLs, but also, and perhaps more importantly, on stakeholders' abilities to engage PFLs in discussions and actions to improve forest stewardship. This dissertation establishes the beginning of efforts in Pennsylvania to refine the methods, results, and application of PFL research. To be valuable, however, this careful investigation of PFLs, their attitudes, values, beliefs, motivations, and decision making processes must lead to changes in outreach and assistance programming and be reflected in marked changes in private forest management. Efforts to quantify this chain of influence, beyond traditional measures such as management plans and contact hours, should be developed and supported.

While these Chapters have immediate implications for Pennsylvania stakeholders, discoveries and conclusions presented also directly affect PFL research in other states, nationally, and internationally. Historical inaccuracies of PFL population estimates should be assessed and corrected where needed. Current methods of PFL research in the United States must also be rectified such that estimates of PFL population size and other parameters reflect reality in an unbiased manner. Further, future studies employing quantitative methods should be carefully designed, with special attention to sampling and estimation procedures, not only to enable the best results possible, but also allow comparisons among studies and changes to be tracked over time. Much has been learned and discovered by past PFL researchers and the way forward will rest heavily on their work. However, if PFL research is to be built on a strong foundation, efforts among researchers, funding sources, and journal editors must insist upon clearly and carefully defined, unbiased sampling and estimation methods.

Focus on Methods

For many years, the United States Department of Agriculture Forest Service (USFS) has been the standard-bearer for methods of PFL research and population size estimation procedures. As established in Chapter Two, the USFS methods and results have been reported, replicated, and cited by many authors throughout USFS and peer-reviewed literature. Despite the ubiquitous presence of USFS results, their methods have not been critiqued or vetted by independent reviewers. Yet, while many researchers do not replicate USFS methods, the majority of PFL studies invariably cite USFS results. For example, few studies independently estimate PFL population size preferring instead to cite USFS estimates. Thus, the USFS methods and results have become accepted unquestioningly into PFL research and literature without thorough review.

While critiquing USFS research methods and estimation procedures were not among the initial goals of this study, much of our work has been necessarily focused on understanding these methods, identifying and troubleshooting problems, and modifying techniques for application at any geographic scale and/or sample size. Primarily, these efforts focused on the PFL population size estimation equation originally reported by Kingsley and Finley (1975) and repeated throughout USFS literature. The development of spatially explicit PFL databases (by combining digital parcel data with landuse/cover data) allowed detailed experimentation with the functionality and effectiveness of this equation under varying sampling designs.

Chapter Two detailed this analysis and established the parameters under which the USFS equation functions properly and those under which it does not. Importantly for the USFS, and others wishing to replicate their methods, results demonstrate that this equation should only be used in conjunction with simple random samples (SRS) of *forestland* drawn with replacement. As proven, when used with probability proportional to size (PPS) samples of PFLs, this equation produces deteriorating results as effective sample size deviates from actual sample size (i.e., the number of sampling points in an area deviates from the number of PFL properties selected by those points).

These conclusions call into question the validity of all past USFS estimates of PFL population size in Pennsylvania, other states, and the nation. While it is possible that effective sample size did not deviate from the actual sample size (the root of the error), this can only be established by those with access to USFS Forest Inventory and Analysis (FIA) plot locations and National Woodland Owner Survey (NWOS) databases. Future research, in conjunction with the NWOS, should detail the extent of this error and correct past estimates of PFL population size where possible.

More problematic, however, is the absence of a corresponding change to estimation methods used by NWOS after the shift in sampling techniques instituted under the Enhanced FIA sampling design. The introduction of the hexagonal grid system to the sampling protocol brought a fundamental shift in the method of sampling PFLs for NWOS. As detailed in Chapter Three, the changes to sampling methods did not herald a change in estimation procedures. Consequently, our results demonstrate that NWOS results obtained from samples collected under this new design are subsequently biased.

First, specifically, the interaction of hexagon boundaries with PFL property boundaries influences selection probabilities among PFLs such that two PFLs owning identical amounts of forestland could be treated unequally depending on the spatial arrangement of their property and hexagon boundaries. Further, and most problematic, the Enhanced FIA sampling design constitutes a two-stage design which is not corrected for under current NWOS estimation methods. We conclude this error has resulted in substantially low estimates of PFL population size and biased results toward characteristics found among larger PFLs in more forested areas.

More research is needed to fully understand the implications of these conclusions on past USFS results and current NWOS efforts to understand PFLs. Ideally, cooperative exploration of these issues with USFS researchers would enable the most detailed and comprehensive assessment of past impact. Through a cooperative effort a full understanding of these issues will be possible and inform a necessary re-design of NWOS estimation methods to complement the Enhanced FIA/NWOS sampling design.

In finding a solution, time is of the essence. We believe NWOS results will become more biased as forestland is further fragmented and lost. FIA/NWOS plots located in areas of the state undergoing rapid change are those plots most likely to become non-forested and thus discontinue contribution to NWOS samples. Results have shown these areas are disproportionately characterized by PFLs owning smaller properties. As forests are fragmented and lost in these areas, NWOS results will shift further toward those characteristics of PFLs in unfragmented, heavily forested areas. This, despite large populations of PFLs in these developed, albeit less forested areas.

The issues explored here highlight the need for clearly established human dimensions research of PFLs. USFS studies of PFLs, including the NWOS, have essentially supplemented the FIA. With a primary focus on the forest resource, PFL research has been an “add-on” where accuracy of methods and results were bound to suffer. Human dimension research of PFLs should be interdisciplinary, employ mixed methods, allow feedback among those methods, and clearly base estimation methods on sampling techniques used. This dissertation, and the study which enabled it, marks a recommitment to human dimensions research of PFLs by the PA DCNR Bureau of Forestry, Penn State, and hopefully beyond.

Implications of Results

Results presented in this dissertation begin an important exploration of Pennsylvania PFLs that will continue throughout the course of the parent study that extends over five years. As detailed in Chapter One, these results are drawn from one aspect of a mixed methods study and the first of three panels. Future reports will detail results from various methods (e.g., site visits to PFL properties, interviews with PFLs) employed over the course of all three panels, allowing changes to be detected over time. While much of this dissertation focused on methods and estimation techniques, the results presented provide an important first step toward understanding PFLs, specifically the impact of their decisions on timber supply and availability.

As discussed in Chapter Four, there are limitations to our survey results based on our sampling design. While spatially random points were placed over the private forestland in each Pennsylvania county, data were collected only once per individual PFL selected, not at each random point. As such, conclusions may be drawn regarding the PFL population; whereas they may not for private forestland. For example, these survey data allow calculations of how many PFLs engage in a behavior (e.g., the percentage of PFLs who are absentee owners), but do not allow calculations of how many acres of private forestland are affected by said behavior (e.g., the acres of private forestland owned by absentee owners).

Regardless of this limitation, data from the first statewide survey panel provide important baseline information about Pennsylvania PFLs' attitudes, values, behaviors, and sociodemographic profile. Additionally, these data allow regional analysis and comparisons demonstrating variation in PFL characteristics and contextual distinction. While not included in this dissertation, these data will allow segmentation of owners, analysis of outreach and stewardship programs (e.g., effectiveness and applicability of management plans among PFLs, contact rate for various programs).

Many of the results from this first survey panel confirm past conclusions about PFLs. While not matching exactly, the distribution of owners is very similar to previous estimates provided by the USFS; the majority of PFLs own small acreages and very few PFLs own very large properties. Confirmation reinforces the need for diverse programming and outreach efforts based on the target segment of PFLs. No one-size-fits-all approach exists for outreach to PFLs or for encouraging sustainable use and management of private forests. Any program must consider the variation in size of PFL properties across the state, the fact that owners of small properties view and manage their properties quite differently from owners of larger properties, and the logistical constraints to reaching such a vast, diverse, diffuse, and constantly overturning population.

These results also confirm past conclusions that most PFLs do not own for income-related objectives, including timber. PFLs are complex people with diverse interests, ownership objectives, and backgrounds. Although a focus on timber-resource availability is important, such a focus often shifts discussion from the non-timber orientation held by many PFLs. As others have found, these results confirm the diversity of ownership objectives and provide an important starting point for dialogue around wildlife, recreation, and cooperation among PFLs.

Some of the results from this first panel of mail surveys provide more in-depth exploration of traditional aspects of PFL behavior. For example, harvesting trees has long been treated as a uni-dimensional behavior; PFLs either harvest trees or not. However, results show most harvesting among PFLs is for personal use of wood (e.g., firewood, personal use of sawlogs). Segmentation of data based on personal or commercial harvesting allowed results to more accurately describe the attitudes, values, and behavior of those PFLs who supply timber to markets across the state and allow us to characterize their interactions with natural resource professionals.

Among commercially harvesting owners, results show PFLs are relatively removed from the decision to harvest – few commercial harvesters own explicitly for timber-oriented objectives and decisions seem to be tied to ownership transfers and outside influence rather than PFL planning. However, PFLs who view harvesting as incompatible with healthy forests are significantly less likely to harvest. These results suggest that while PFLs may not actively make decisions to harvest, they do actively make decisions *not* to harvest. The lack of planning among commercial harvesting (and all PFLs in general) is troublesome and suggests a need for further outreach or intervention to ensure the sustainability of private forests. Similarly, PFL descriptions of harvests (e.g. “cut most of the large trees, but left others”) should raise concerns about the prevailing type of harvest on private forestlands and the sustainability of such actions.

Importantly, results from this first round shed light on some previously unexplored aspects of PFLs. For example, the average age of PFLs has suggested an impending transfer of many acres of private forestland. Results indicate the majority of PFLs plan not only to leave their land to heirs, but plan to leave their land to *multiple* heirs. The impending transfer of private forests to children of current owners could bring a rash of parcelization, development, harvesting, or other changes. Future panels of this survey will address estate planning and provide estimates of how many PFLs have planned for the legacy of their forestland. If trends hold, it is likely most PFLs have secured their children’s futures rather than their forestland’s. Regardless of other differences, this is a unifying and important issue for all stakeholders concerned with the sustainability of Pennsylvania’s forests.

These results also provide an important contribution to current discussions of resource availability with regard to timber, biomass, and carbon sequestration. As discussed in Chapter Five, many assessments of resource availability simply provide caveats or “lip service” to the ownership matrix that complicates questions of access and instead focus solely on resource inventory data. Analysis of parcel data in conjunction with survey data has provided an important first step toward quantifying the influence of parcelization and PFLs on resource availability. The availability of high-quality timber volume, biomass tonnage, or acres for carbon sequestration is not simply a function of environmental variables, but rather a combination of environmental variables, parcelization patterns, PFL characteristics, and other contextual variables (e.g., markets, local ordinances, availability of loggers or mills). Despite being a seemingly obvious observation, this perspective is conspicuously absent from current discussions of resource availability. These results provide an important contribution to these discussions; however, more effort is needed to refine quantifications and measurement of these variables, their interactions, and their influence on resource availability.

Laying a Foundation

Perhaps the largest contribution of this dissertation is a sound foundation and model for future PFL research; both for the remainder of this study and for future studies in Pennsylvania and beyond. PFL studies have long been conducted using a variety of sampling, inquiry, and analysis methods. Consequently, consistency across studies has been elusive. Further, the majority of studies have long relied on a sole, un-reviewed source, the USFS, for PFL population size estimates, estimation techniques, and a baseline of data and trends among PFLs.

This dissertation lays a solid foundation for the remainder of this Pennsylvania study. Through years of trial, error, and experimentation, we have distilled the essential aspects for statistically valid sampling and analysis of PFL data. The Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry (BoF) has made significant investments toward understanding PFLs, private forest issues, and improving outreach, assistance, and stewardship. The years of work leading to this dissertation have provided a previously elusive foundation for all analysis, conclusions, and future investments. Anecdotal evidence has raised concerns with past conclusions, especially regarding population size. The analyses and conclusions in this dissertation ensure future conclusions will be objective, accurate, and reliable; no small step in what has thus far been a somewhat vague realm of PFL research. Because of this work we are now poised to successfully answer many of the major questions and address the major concerns regarding Pennsylvania PFLs.

This work also provides an important foundation for future PFL studies well beyond Pennsylvania. The sampling and estimation principles established in this dissertation provide a template for future PFL study design not only in Pennsylvania, but other states, nationally, and internationally. This dissertation, for the first time, provides an independent review of USFS methods and reveals significant problems. While further analysis is needed to quantify the impact of these errors, the conclusions presented here will allow future studies to design unbiased, independent estimates of PFL population size, PFL parameters, and private forestland parameters.

Additionally, this dissertation provides an important baseline of data and foundation of methods from which comparisons may be drawn. Comparisons and assessments of trends rely on consistency in methods or, at least, consistency in accuracy of results. Inconsistencies in PFL research methods have long prevented comparisons, even within the USFS, and because of this comparisons are often cautioned against. Future inferential studies should benefit from consistency in sampling and estimation methods distilled here. Further, future Pennsylvania studies will benefit from the baseline results concerning PFL attitudes, values and behaviors presented. Changes in these variables will be detectable and reportable as methods and/or accuracy will remain constant.

Much of the analysis regarding sampling and estimation methods relied heavily on digital spatial parcel data from some of Pennsylvania's counties. While the availability of this data is increasing, stakeholders concerned with almost any natural resource issue should work together to maximize the availability and accuracy of these data and their utilization. Information provided by these data is invaluable to those concerned with forestry, watersheds, wildlife, and well beyond; coordinated support is needed to ensure these data are available, updated, and utilized to their full potential.

Currently, these data exist almost solely because of investments made at the county level and utilization reflects this investment. Despite the clear utility in understanding landscape phenomenon, these data are rarely used for this purpose. Further, as the main impetus for their development is tax-related, it is rarely joined with other important spatial data such as landuse/landcover, watershed boundaries, or landscape level habitat analysis (e.g., GAP program). Natural resource stakeholders, defined broadly, would be remiss to allow the underutilization of these data to continue. Efforts should be made to improve funding for local offices to create and maintain these data, develop oversight and consistency across these offices, and ensure proper availability of these data to researchers investigating natural resource and land use phenomenon.

Although extremely important, the development and improved utilization of these data will not replace the need for careful sampling amd estimation procedures. PFL research will always focus both on PFLs and how much forestland their decisions impact. Quality parcel data will enable fast sampling procedures, clear calculations of selection probabilities, and careful tracking of parcelization trends. However, these data will not replace the need to carefully link sampling designs with estimation procedures. Even if these data allow samples of PFLs to be drawn in SRS fashion from the list of PFLs in an area, estimates of forestland parameters within such samples (i.e., how many acres are affected by PFL behavior) will require PPS estimation corrections.

Further, although these data will allow landscape level analysis of land use and forest parcelization changes, they will not replace the importance of continuing social research with PFLs. The world in which PFLs interact with their forestlands and make decisions is constantly changing. Research must continue to monitor the dynamics of PFL behavior amid changing economic, social, and environmental contexts. Research must also continue to inform outreach and assistance programs to enable flexibility, utilization of diverse tools, and maximize effectiveness.

The sustainability of forests will rely on a detailed understanding of and partnership with those who own forestland and ultimately decide their fate. We believe the research presented here provides an important and thus far absent foundation for current and future research of this important population. Further, the results from the initial panel of mail-surveys provide a reliable and statistically sound base-line of data for understanding Pennsylvania PFLs and will allow comparisons in coming years. These contributions are submitted with a strong commitment toward application. The results and conclusions here do not themselves constitute success, but provide important tools for, and mark a renewed commitment among, all stakeholders toward understanding PFLs and working in partnership for the sustainability of private forests.

Appendix PFL Study Questionnaire (Formatting adjusted)

PRIVATE FOREST LANDOWNERS OF PENNSYLVANIA
A study by the Human Dimensions Unit at Penn State

Please read each question and indicate your answer in the space provided. Your responses will be most useful if you read each question and follow directions carefully.

We have identified you as a private forest landowner in

Q1. Do you own at least one (1) acre of forestland in this county?

____ Yes → **If YES, this is "your county" for this survey.**

____ No

Q2. If NO, did you ever own forestland in this county?

____ No → **If NO, please SKIP AHEAD to Q4 below.**

____ Yes

Q3. If YES, did you do any of the following on your forestland immediately before getting rid of it?

Please CHECK ALL that apply:

A. ____ Subdivided
B. ____ Constructed roads
C. ____ Constructed buildings
D. ____ Clearcut
E. ____ Harvested trees
F. ____ Other, please specify: ________________________

Q4. Do you currently own forestland in another Pennsylvania county?

____ No → **If NO, please STOP here and return this**

____ Yes

Q5. If YES, in which Pennsylvania county do you own the most forestland?

____________________________ County

→ **This is "your county" for this survey.**

Q6a. How many <u>total acres</u> do you own in "your county" (all parcels)?

__________ number of acres

Q6b. About how many <u>total forested acres</u> do you own across all these parcels?

__________ number of acres

Q6c. How many parcels of forestland do you own in "your county?"

__________ number of parcels

Q7. How long have you owned your forestland?

__________ number of years

Q8. How did you acquire your forestland?

Please CHECK <u>ALL</u> that apply:

A. ____ Bought it
B. ____ Inherited it
C. ____ Got it as a gift
D. ____ Other, please specify: _________________________

Q9. From whom did you get your forestland?

Please CHECK <u>ALL</u> that apply:

A. ____ My parents, a spouse, or another family member
B. ____ Other individual
C. ____ Land investor/developer
D. ____ Corporation or business
E. ____ Local, state, or federal government
F. ____ Other, please specify: _________________________

Please remember: Throughout this survey we are only asking about your forestland in "your county."

Q10a. Was your forestland harvested for timber before you got it (within about 5 years)?

____ No ⇒ **If NO, please SKIP AHEAD to Q11a**

____ Yes

Q10b. If YES, how do you know your forestland was harvested before you got it?

Please CHECK ALL that apply:

A. ____ There was still evidence of a harvest (for example, freshly cut tree tops or stumps)
B. ____ Previous landowner told me
C. ____ I witnessed the harvest
D. ____ Other, please specify: ______________________________

Q10c. What type of harvesting took place?

Please CHECK ALL that apply:

A. ____ Clearcut
B. ____ Cut most of the large trees
C. ____ Cut trees of all sizes, but left a lot of trees
D. ____ Cut small trees, but left large trees
E. ____ Only cut a few select, large trees
F. ____ Cleared land for roads
G. ____ Cleared land for buildings
H. ____ Don't know
I. ____ Other, please specify: ________________________

Q11a. Why do you own your forestland?

Please CHECK ALL that apply:

A. ____ Land investment (I hope to sell all or part of my forestland at a profit)
B. ____ Hunting opportunities
C. ____ Camping, walking, or other recreation
D. ____ Growing timber for sale
E. ____ Personal uses of wood, such as firewood
F. ____ Enjoyment of owning forestland
G. ____ As an estate to pass on to my children
H. ____ Income other than from selling timber
I. ____ To enjoy wildlife
J. ____ Solitude
K. ____ It came with the property
L. ____ Other, please specify: ______________________

Q11b. From the list above, please pick the most important reason you own forestland?

Please WRITE IN the letter of the most important reason: ______________

Q12. What do you enjoy most about your forestland?

Q13. How often do you or members of your household visit your forestland?

Please CHECK one:

A. ____ I (or members of my family) live on my forestland
B. ____ At least once a week
C. ____ Monthly
D. ____ Several times a year
E. ____ Once a year
F. ____ Less than once a year
G. ____ Never

Q14. The following are activities some landowners do on their forestland. Please indicate if you have done each of the following on your forestland. ALSO, please indicate how likely you are to do each activity in the future, even if you haven't done that activity in the past.

1 = Very Unlikely (VU)
2 = Unlikely (U)
3 = Neither Likely nor Unlikely (N)
4 = Likely (L)
5 = Very Likely (VL)

Please CIRCLE "Yes" or "No" AND please CIRCLE a number for each activity:

FORESTLAND ACTIVITY	HAVE DONE ?			VU	U	N	L	VL
	circle one		*AND*	*circle one for each activity*				
A. Improve wildlife habitat	Yes	No	→	1	2	3	4	5
B. Improve fish habitat	Yes	No	→	1	2	3	4	5
C. Create a stream-side buffer	Yes	No	→	1	2	3	4	5
D. Reduce fire hazards	Yes	No	→	1	2	3	4	5
E. Harvest non-timber products for my own use	Yes	No	→	1	2	3	4	5
F. Harvest non-timber products for commercial sale	Yes	No	→	1	2	3	4	5
G. Hunt (by you or your family)	Yes	No	→	1	2	3	4	5
H. Recreate, besides hunting (by you or your family)	Yes	No	→	1	2	3	4	5
I. Lease to a club or organization	Yes	No	→	1	2	3	4	5

Q15. Do you post your forestland?
____ Yes
____ No

Q16. Would you allow the following activities to occur if you were asked?

Please circle either "Allow" or "Not Allow" for each activity:

A. Hunting on your land	Allow	Not Allow
B. Antlerless deer hunting on your land	Allow	Not Allow
C. Small game/bird hunting on your land	Allow	Not Allow
D. Friends to hunt on your land	Allow	Not Allow
E. Family to hunt on your land	Allow	Not Allow
F. Other recreation on your land	Allow	Not Allow
G. ATV use on your land	Allow	Not Allow
H. Public walking/hiking on your land	Allow	Not Allow
I. Horseback riding on your land	Allow	Not Allow

Q17. How likely are you to do any of the following with your forestland?

1 = Very Unlikely (VU)
2 = Unlikely (U)
3 = Neither Likely nor Unlikely (N)
4 = Likely (L)
5 = Very Likely (VL)

Please CIRCLE a number for each activity:

FORESTLAND ACTIVITY	VU	U	N	L	VL
	circle one for each activity				
A. Subdivide	1	2	3	4	5
B. Subdivide and sell	1	2	3	4	5
C. Sell as is	1	2	3	4	5
D. Sell a conservation easement	1	2	3	4	5
E. Leave to one child	1	2	3	4	5
F. Leave to more than one child	1	2	3	4	5
G. Establish a family corporation	1	2	3	4	5
H. Establish a trust	1	2	3	4	5
I. Clear land for a road	1	2	3	4	5
J. Clear land for buildings	1	2	3	4	5

Q18a. Please use the space below to describe your forestland in your own words. (Please think about trees, vegetation, soils, wetness, topography, and the overall condition of your forest)

Q18b. Could any of the following statements be used to describe your property?

Please CIRCLE "Yes" or "No" for each statement:

	STATEMENT	Yes	No
		circle one for each statement	
A.	There are drivable roads on my property	Y	N
B.	I can access my property directly from a road	Y	N
C.	There are beautiful views on my property	Y	N
D.	There is running water on my property	Y	N
E.	There are wetlands on my property	Y	N
F.	There is important wildlife on my property	Y	N
G.	There are important plants on my property	Y	N
H.	There is important wildlife habitat on my property	Y	N
I.	There is important plant habitat on my property	Y	N

The following questions ask about harvesting and management activities on your forestland.

Q19a. Have you cut trees from your property in the past ten (10) years?

____ No ⟹ **If NO, please SKIP AHEAD to Q28 on**

____ Yes

Q19b. If YES, during what year did you last cut trees from your property?

__________ year of the last cutting

Q19c. How many times have you cut trees from your property in the past ten (10) years?

__________ number of times

Q20. How many acres of your forestland have you cut trees from in the past ten (10) years?

__________ number of acres

Q21. What type of wood has been cut from your forestland in the past ten (10) years?

Please CHECK ALL that apply:

A. ____ Sawlogs for personal use
B. ____ Sawlogs for sale
C. ____ Veneer logs for sale
D. ____ Pulpwood
E. ____ Firewood for personal use
F. ____ Firewood for sale
G. ____ Other, please specify: ________________________

Q22. How were the cuts managed?

Please CHECK all that apply:

A. ____ Managed the harvest myself
B. ____ Got advice from Penn State Extension
C. ____ Got advice from a consulting forester
D. ____ Sold the timber directly to a timber company
E. ____ Got advice from an industry forester
F. ____ Got advice from a PA Bureau of Forestry forester
G. ____ Sold the timber directly to a logger
H. ____ Hired a consulting forester
I. ____ Other, please specify: ________________________

Q23a. What factors led to your decision to cut trees from your property?

Please CHECK all that apply:

A. ____ To allow seedlings to grow
B. ____ Needed the money
C. ____ To improve growing conditions for remaining trees
D. ____ To improve scenic quality
E.____ Approached by a buyer
F.____ To improve recreational opportunities
G. ____ To improve wildlife habitat
H. ____ Needed wood for my own use
I. ____ To salvage damaged trees
J. ____ To build a road
K. ____ Price was right
L.____ To improve hunting conditions
M. ____ To achieve objectives in my management plan
N. ____ To clear land for a building
O. ____ Trees were mature
P.____ Other, please specify: ________________________

Q23b. From the list above, which factor was most important to you in deciding to cut trees from your forestland?

Please WRITE IN the letter of the most important factor: __________

Q24. What type of cutting has been done <u>most</u> on your forestland in the past ten (10) years?

Please CHECK one:

A. ____ Clearcut
B. ____ Cut most of the large trees
C. ____ Cut trees of all sizes, but left a lot of trees
D. ____ Cut small trees, but left large trees
E. ____ Only cut a few select, large trees
F.____ Don't know
G. ____ Other, please specify:________________________

Q25. How happy are you with the outcome of the cuttings that took place on your forestland in the past ten (10) years?

Please CIRCLE one:

Very Unhappy	Unhappy	Neither Happy nor Unhappy	Happy	Very Happy

Q26. How would you describe the outcome of the cuttings that took place on your forestland in the past ten (10) years?

Please CHECK ALL that apply:

A. ____ I don't have certain types of wildlife/birds anymore
B. ____ Too many large trees were cut
C. ____ Wildlife habitat was improved
D. ____ Too many trees were cut
E. ____ Not enough trees were cut
F. ____ There are ruts left in the ground from the machinery
G. ____ Very few new seedlings are growing
H. ____ Too many trees of a certain species were cut
I. ____ Everything looks good; it's exactly what I wanted
J. ____ Too many of the remaining trees are the same species
K. ____ Trees that were left were damaged
L. ____ There are a lot of ferns
M. ____ Trees that were left were undamaged
N. ____ No valuable tree species was completely removed (there are at least some left)
O. ____ Tree that were left look healthy
P. ____ Most of the trees cut were of low quality
Q. ____ Streams were muddied during the harvest
R. ____ Given time, the trees that were left will become large, valuable trees
S. ____ It looks bad
T. ____ Temporary (skid) roads were cleaned up nicely
U. ____ I wish it had never happened
V. ____ Many new seedlings are growing
W. ____ Other, please specify: ___________________________

Q27. If you could change anything about the cuttings that took place on your forestland in the past ten (10) years, what would you change?

____

____

____

____

Q28. Are you opposed to cutting trees on your forestland?

Please CIRCLE one:

Very Opposed	Opposed	Neither Opposed nor Willing	Willing	Very Willing

Q29a. If there is any part of your forestland that you have not cut trees from, why haven't you?

Please CHECK ALL that apply:

A. ____ Concerned about harvesting impacts
B. ____ Concerned about doing damage to my property
C. ____ Concerned about water quality
D. ____ The land is too steep
E.____ Opposed to cutting in general
F.____ Recreation opportunities would be reduced
G. ____ Don't trust foresters
H. ____ Just not interested in harvesting timber
I. ____ Concerned about wildflowers
J. ____ Don't know how to manage a harvest
K. ____ Concerned about affecting neighbors
L.____ Don't have access to my property
M. ____ Scenic value would be reduced
N. ____ Can't find someone to do the work
O. ____ Concerned about endangered plants
P. ____ Too small of a property
Q. ____ Concerned about wildlife
R. ____ Local ordinances
S. ____ Hunting opportunities would be reduced
T. ____ Concerned about endangered animals
U. ____ No market for timber
V. ____ Don't trust loggers
W. ____ No market for pulpwood
X. ____ Don't trust the forest industry
Y. ____ Other, please specify: ________________________

Q29b. From the list above, please choose the main reason you have not cut trees from any or part of your forestland?

Please WRITE IN the letter of the main reason: __________

Q30. Have any of the following been done on your forestland in the past ten (10) years?

Please CHECK ALL that apply:

A. ____ Applied herbicides
B. ____ Controlled competing vegetation without herbicides
C. ____ Painted trees prior to harvest
D. ____ Erected a deer fence
E. ____ Planted trees
F. ____ Other, please specify: __________________________

Q31a. Do you have a written management or stewardship plan for any of your forestland?

____ No → **If NO, please SKIP AHEAD to Q32**

____ Yes

Q31b. If YES, when was it written?

_________ year written

Q31c. Who helped you write it?

Please CHECK ALL that apply:

A. ____ Cooperative Extension agent
B. ____ Natural Resources Conservation Service employee
C. ____ Consulting forester
D. ____ Industry forester
E. ____ PA Bureau of Forestry forester
F. ____ Friend, relative or neighbor
G. ____ Wrote it myself
H. ____ Other, please specify: ________________________

Q31d. What is the most important management objective in your plan?

____

Q31e. What management activities from your plan have you completed on your forestland in the past ten (10) years?

____

If you have a written management plan, please SKIP AHEAD to Q33a on the next page.

Q32. Why don't you have a written management plan?

Please CHECK all that apply:

A. ____ It would cost too much
B. ____ I don't have the time
C. ____ I don't know where to start
D. ____ I don't want a management plan
E. ____ What is a management plan?
F. ____ I'm not sure how a management plan would help me
G. ____ I would rather just make decisions as I go
H. ____ A management plan would not help me
I. ____ Other, please specify: ________________________

Q33a. The following are sources of help and information that some forest landowners use when making decisions about their forestland. Please indicate if you have used each of the following sources. ALSO, please indicate how likely you are to use each source in the future, even if you haven't used it in the past.

1 = Very Unlikely (VU)
2 = Unlikely (U)
3 = Neither Likely nor Unlikely (N)
4 = Likely (L)
5 = Very Likely (VL)

Please CIRCLE "Yes" or "No" AND please CIRCLE a number for each source:

SOURCE OF INFORMATION/HELP	HAVE USED ?			VU	U	N	L	VL
	circle one		*AND*	*circle one for each activity*				
A. Brochures or fact-sheets	Yes	No	→	1	2	3	4	5
B. Periodic newsletters	Yes	No	→	1	2	3	4	5
C. Classes or workshops	Yes	No	→	1	2	3	4	5
D. Books	Yes	No	→	1	2	3	4	5
E. The Internet	Yes	No	→	1	2	3	4	5
F. Consulting forester	Yes	No	→	1	2	3	4	5
G. Industry forester	Yes	No	→	1	2	3	4	5
H. PA Bureau of Forestry forester	Yes	No	→	1	2	3	4	5
I. Other government employee	Yes	No	→	1	2	3	4	5
J. Penn State Extension	Yes	No	→	1	2	3	4	5
K. Videos for home viewing	Yes	No	→	1	2	3	4	5
L. TV or radio programs	Yes	No	→	1	2	3	4	5
M. Friends or family members	Yes	No	→	1	2	3	4	5
N. Neighbors	Yes	No	→	1	2	3	4	5
O. Other forest landowners	Yes	No	→	1	2	3	4	5
P. Woodland Owners Association	Yes	No	→	1	2	3	4	5
Q. Loggers	Yes	No	→	1	2	3	4	5
R. Other:___________________	Yes	No	→	1	2	3	4	5

Q33b. From the list above, which source are you most likely to use in the future?

Please WRITE IN the letter of the source you are most likely to use:

____

Q34a. Do you want to do work on your forestland but are unable to for some reason?

____ No ⇨ **If NO, please SKIP AHEAD to Q35a**

____ Yes

Q34b. If YES, what work do you want to do on your forestland?

____
_

____
_

Q34c. What has prevented you from doing this work?

Please CHECK ALL that apply:

A. ____ My own physical health
B. ____ Can't find someone to do the work
C. ____ Don't know how
D. ____ Afraid of making a mistake
E. ____ Can't find the technical expertise
F. ____ Too expensive
G. ____ Not enough time
H. ____ Don't know the laws
I. ____ Law doesn't allow
J. ____ Concerned about affecting neighbors
K. ____ Concerned about causing damage to my property
L. ____ Concerned about reducing other values of my property
M. ____ Concerned about hurting myself
N. ____ Don't have the right equipment
O. ____ Don't have the right skills
P. ____ Don't have adequate access to my property
Q. ____ Haven't tried
R. ____ Other, please specify: ______________________________

Q34d. From the list above, please pick the main reason you haven't done this work.

Please WRITE IN the letter of the main reason: ___________

Q35a. How good a caretaker are you of your forestland?

Please CIRCLE one:

Poor Fair Good Excellent

Q35b. What activities do you do on your forestland that make you a good caretaker?

____

Q36. In what type of ownership is your forestland held?
Please CHECK one:
A. ____ Individual or joint ownership
B. ____ Family partnership or corporation
C. ____ Business partnership
D. ____ A forestry-related corporation
E. ____ A non-forestry-related corporation
F.____ Forest management company
G. ____ Timber investment management organization
H. ____ Non-profit organization
I. ____ Club or association
J. ____ Trust or estate
K. ____ Other, please specify: ________________________

Q37. How many miles is your primary residence from your forestland?
Please ENTER the number of miles (enter "0" if you live on or adjacent to your forestland):
__________ number of miles

Q38. Do you have any of the following on or adjacent to your forestland?
Please CHECK ALL that apply:
A. ____ Second home
B. ____ Camp
C. ____ Rental unit
D. ____ Business
E. ____ Barn
F.____ Farm
G. ____ Other structure, please specify: _________________________
H. ____ Small stream that is dry part of the year
I. ____ Small stream that is always flowing
J. ____ River
K. ____ Wetland
L. ____ Other, please specify: ________________________

Q39. Are you part of any of the following programs or organizations?
Please Check ALL that apply:
A. ____ PA Bureau of Forestry Stewardship Program
B. ____ Tree Farm
C. ____ County/Regional Woodland Owners Association
D. ____ Pennsylvania Forestry Association
E. ____ Pennsylvania Forest Stewards Volunteers
F. ____ CREP (Conservation Reserve Enhancement Program)
If YES to CREP, how many acres are enrolled? ____
G. ____ Watershed Association
H. ____ Environmental/Conservation Group
I. ____ Hunting/Sportsmen's Club

Q40a. How many neighbors share a property boundary with your forestland?

______ number of neighbors

Q40b. How many of these neighbors do you know on a first name basis?

______ number of neighbors

Q40c. How often do you interact with these neighbors?

Please CIRCLE one:

Never	Rarely	Sometimes	Often	Very Often

Q40d. How likely are you to cooperate with your neighbors in the following ways?

1 = Very Unlikely (VU)
2 = Unlikely (U)
3 = Neither Likely nor Unlikely (N)
4 = Likely (L)
5 = Very Likely (VL)

Please CIRCLE one number for each activity:

COOPERATIVE ACTIVITY	VU	SU	N	SL	VL
	circle one for each activity				
A. Allow your neighbors to hunt on your property	1	2	3	4	5
B. Allow your neighbors to recreate on your property	1	2	3	4	5
C. Coordinate trail building across your properties	1	2	3	4	5
D. Coordinate building access (road) to reduce cost	1	2	3	4	5
E. Share tools to reduce cost	1	2	3	4	5
F. Share large equipment to reduce cost	1	2	3	4	5
G. Improve wildlife habitat across your properties	1	2	3	4	5
H. Coordinate spraying herbicides to reduce cost	1	2	3	4	5
I. Share the cost of hiring labor	1	2	3	4	5
J. Sell timber together to get a better price	1	2	3	4	5
K. Hire a forester together to reduce cost	1	2	3	4	5

Now we would like to ask some general questions about forestry in Pennsylvania. Please think about Pennsylvania forests in general. Do not limit your responses to your forestland in "your county."

Q41. On a scale of 0 – 10, where 10 is very knowledgeable, how knowledgeable do you consider yourself about the following issues?

Please ENTER a number between 0 and 10 next to each issue:

	0 – 10	ISSUE
A.	_____	Pennsylvania's forests
B.	_____	General forest management
C.	_____	Forest ecology
D.	_____	Tree identification
E.	_____	Forestland taxes/incentives
F.	_____	Logging
G.	_____	Stream ecology
H.	_____	Wildlife ecology

Q42. How strongly do you agree with each of the following statements about forest ecology?

1 = Strongly Disagree (SD)
2 = Disagree (D)
3 = Neither Agree nor Disagree (N)
4 = Agree (A)
5 = Strongly Agree (SA)

Please CIRCLE a number for each statement:

STATEMENT	SD	D	N	A	SA
	circle one for each statement				
A. Cutting trees permanently harms the forest	1	2	3	4	5
B. Harvesting trees can improve the health of the forest	1	2	3	4	5
C. The size of a tree is a good indicator of age	1	2	3	4	5
D. Cutting trees can improve the forest	1	2	3	4	5
E. Any cutting of trees harms the water quality of nearby streams	1	2	3	4	5
F. Cutting only the large trees from a forest is better than clearcutting	1	2	3	4	5
G. Forests rarely recover from clearcutting	1	2	3	4	5
H. Cutting only the large trees from a forest is better than cutting some trees of all sizes	1	2	3	4	5
I. Forests are healthy when deer populations are high	1	2	3	4	5
J. Deer are not a threat to forest ecosystems	1	2	3	4	5
K. Ferns are not a threat to forest ecosystems	1	2	3	4	5
L. Deer eat ferns	1	2	3	4	5
M. Cutting trees usually results in soil erosion	1	2	3	4	5
N. Cutting trees usually destroys wildlife habitat	1	2	3	4	5

Q43. How strongly do you agree with each of the following statements about forests?

1 = Strongly Disagree (SD)
2 = Disagree (D)
3 = Neither Agree nor Disagree (N)
4 = Agree (A)
5 = Strongly Agree (SA)

Please CIRCLE a number for each statement:

STATEMENT	SD	D	N	A	SA
	circle one for each statement				
A. Neighboring landowners should work together to manage their forests	1	2	3	4	5
B. Humans shouldn't interfere with nature	1	2	3	4	5
C. Healthy forests are important to me	1	2	3	4	5
D. Forests have a right to exist for their own sake regardless of human concerns or use	1	2	3	4	5
E. The primary use of forests should be for products useful to humans	1	2	3	4	5
F. Humans should have more love, respect, and admiration for forests	1	2	3	4	5
G. You don't have to worry about the forest because mother nature will take care of the trees	1	2	3	4	5
H. People who own forestland have the right to use that forestland as they see fit	1	2	3	4	5
I. There is not much we can do to protect the forest	1	2	3	4	5

Q44. How strongly do you agree with the following statement? “Land that is not posted is open to recreational use”

Please CIRCLE one:

Strongly Disagree	Disagree	Neither Disagree nor Agree	Agree	Strongly Agree

Q45. What factors do you think are important to consider when managing a forest in Pennsylvania?

____

____

Q46. How important do you think it is to consider the following factors when managing a forest in Pennsylvania?

1 = Very Unimportant (VU)
2 = Unimportant (U)
3 = Neither Important nor Unimportant (N)
4 = Important (I)
5 = Very Important (VI)

Please CIRCLE one number for each factor:

	FACTOR	VU	U	N	I	VI
			circle one for each factor			
A.	The number of tree species	1	2	3	4	5
B.	Which tree species are present	1	2	3	4	5
C.	The size of the trees	1	2	3	4	5
D.	Which trees will produce quality seeds	1	2	3	4	5
E.	Number of seedlings present	1	2	3	4	5
F.	Types of other vegetation present	1	2	3	4	5
G.	Quality of the trees cut	1	2	3	4	5
H.	Quality of the trees not cut	1	2	3	4	5
I.	Deer populations	1	2	3	4	5
J.	Whether a management plan is written	1	2	3	4	5
K.	Whether an inventory has been done	1	2	3	4	5
L.	Slope of the land	1	2	3	4	5
M.	Type of soils present	1	2	3	4	5
N.	What time of year the trees are cut	1	2	3	4	5

Finally, we'd like to ask you a few questions about yourself and your family. All information will be treated confidentially and will never be linked with your name.

Q47. What is your gender?

____ Male ____ Female

Q48. In what year were you born?

__________ year you were born

Q49. What is your current employment status?
Please CHECK one:

A. ____ Full-time
B. ____ Part-time
C. ____ Retired
D. ____ Student
E. ____ Homemaker
F. ____ Non-employed (looking for work or laid off)

Q50. What was the highest grade of school you completed?
Please CHECK one:

A. ____ None
B. ____ Grade school
C. ____ Some high school
D. ____ Completed high school
E. ____ Some college/technical school beyond high school
F. ____ Completed college
G. ____ Graduate/prof. school

Q51. How do you describe yourself politically?
Please CIRCLE one:

Liberal	Moderate Liberal	Moderate	Moderate Conservative	Conservative

Q52. How many children do you have?

__________ number of children

Q53a. Currently, how many people, including yourself, live in your household?

__________ number of people

Q53b. How many are 5 years old or less? __________

Q53c. How many are 6 -18 years old? __________

Q53d. How many are 19 - 25 years old? __________

Q53e. How many are 26 - 59 years old? __________

Q53f. How many are over 60 years old? __________

Q54. How would you describe the following places?

1 = Large City (LC)
2 = Suburb of a Large City (SLC)
3 = Small City (SC)
4 = Suburb of a Small City (SSC)
5 = Rural Town or Village (RTV)
6 = Countryside (C)

Please CIRCLE one number for each place:

PLACE	LC	SLC	SC	SSC	RTV	C
A. Your current place of residence	1	2	3	4	5	6
B. The community where your land is	1	2	3	4	5	6
C. The place where you were born	1	2	3	4	5	6
D. The area you have spent most of your life	1	2	3	4	5	6

Q55. How long have you lived in your present community?

__________ number of years in community

Q56. Which of following are current sources of income in your household?
Please CHECK ALL that apply:

A. ____ Wages and/or salary
B. ____ Income from business
C. ____ Interest and/or investments
D. ____ Income from rental properties
E. ____ Supplemental security income
F. ____ Other disability benefits
G. ____ Social Security payments
H. ____ Retirement pension payments
I. ____ Unemployment
J. ____ Food stamps
K. ____ Public assistance/welfare
L. ____ Other, please specify

Q57. What was the total income of your household (before taxes) last year?
Please CHECK one:

M. ____ Less than $15,000
N. ____ $15,000 to $24,999
O. ____ $25,000 to $34,999
P.____ $35,000 to $49,999
Q. ____ $50,000 to $74,999
R. ____ $75,000 to $99,999
S.____ $100,000 to $149,999
T. ____ $150,000 or more

THANK YOU!

Those are all the questions we have.

Thank you very much for your time and cooperation in completing this survey!

Please return this completed questionnaire using the postage-paid envelope enclosed.

If you have any comments that you would like to share with us, please use the space below:

VITA

Alexander Leventon Metcalf

Education

Ph.D., Forest Resources
Dual Degree: Human Dimensions of Natural Resources and the Environment
Expected Graduation: August 2010
The Pennsylvania State University, School of Forest Resources, University Park, PA

M.S., Forest Resources, August 2006
The Pennsylvania State University, School of Forest Resources, University Park, PA

B.S., Environmental Science, May 2001
Juniata College, Huntingdon, PA

Research Experience

Mixed methods investigation of Pennsylvania private forest landowners
PA Department of Conservation and Natural Resources Bureau of Forestry
Future of Pennsylvania's forests
PA Department of Conservation and Natural Resources Bureau of Forestry
Wood products market analysis, Huntingdon County, PA
Huntingdon County Business and Industry
Pennsylvania timber availability assessment
PA Hardwood Development Council
Pennsylvania highlands conservation values assessment
US Forest Service
Flight 93 Memorial forest management plan
National Park Service
GIS support for Penn State cooperative extension/outreach and research
The Pennsylvania State University

Recent Professional Presentations

Metcalf, A.L., J.C. Finley, A.E., Luloff, R.C. Stedman. 2010. *Commercial harvesting decisions among private forest landowners: perceptions, parcelization, and predicting supply*. 16th Annual International Symposium for Society and Natural Resources. Corpus Christi, TX: June 6-10.

Metcalf, A.L. 2008. *Recreation as a catalyst for cooperation among private forest landowners.* 20th Northeastern Recreation Research Symposium. Bolton Landing, NY: March 30 – April 1.