Cost share payment and willingness to participate in Virginia's Pine Bark Beetle Prevention Program

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Abstract

Forest management practices which reduce southern pine beetle (SPB) risk benefit not only the landowners who perform them, but all those who draw benefits from southern pine forests in Virginia, especially other forest owners within the same region. One such management practice is pre-commercial thinning (PCT), which is particularly unattractive to non-industrial private forest (NIPF) landowners because of the substantial costs and delayed financial returns involved. Since the benefits to society generated by PCT are not fully realized by the individuals who might implement it, there may be a market externality in which PCT is underprovided across the landscape. The Pine Bark Beetle Prevention Program (PBBPP) has the potential to correct this externality by reimbursing a portion of the costs of PCT for landowners who qualify. However, cost share incentives have been criticized for being ineffectual on the basis that landowners substitute publicly funded reimbursement for private investment, without altering their management practices. To investigate the effect of the PBBPP cost share, a survey was sent to 1,200 NIPF landowners in seven counties across the Piedmont and Coastal Plain physiographic regions of Virginia, where southern pine is prevalent and SPB hazard is a relevant concern. To measure willingness to participate in the program, a referendum style question was used in which the offered cost share ranged from 20% to 90%. Results of discrete choice models estimated from survey data indicate that cost sharing has a significant, positive effect on willingness to participate overall, though increasing reimbursement above 60% is unlikely to affect participation. Some landowners are not responsive or are less responsive to cost sharing due to personal and property characteristics.

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Chapter 1. Introduction

Historically, the southern pine beetle (SPB), *Dendroctonus, frontalis* Zimmerman (Coleoptera: Curculionidae) has been one of the most destructive insect pests to pine forests in the southeast US. The importance of the SPB is highlighted by an outbreak from 1999-2002, during which the SPB caused over one billion dollars in timber losses (Clark and Nowak 2009). In the wake of this damage, the U.S. Forest Service (USFS) received funding from the Southern Pine Beetle Initiative directed towards proactive prevention of SPB outbreaks. State forestry agencies including the Virginia Department of Forestry received about $48 million to implement prevention and restoration efforts. A major focus of these efforts have been cost share incentives which include the Pine Bark Beetle Prevention Program (PBBPP) in Virginia, designed to encourage forest management practices that reduce SPB hazard (Nowak et al. 2008).

The SPB has earned all this attention and funding because of relatively brief, intense periods of damage, but SPB infestations are not always catastrophic. Their populations are highly variable and can remain at low, endemic levels for long periods of time, while retaining the potential to rapidly multiply to epidemic population levels when given favorable conditions (Mawby et al. 1989). The last large scale SPB outbreak in Virginia occurred in 1993 and caused an estimated $14 million in damage (Price et al. 1998). Virginia has not seen a major outbreak in the 17 years since, but SPB remains a relevant concern. In their assessment of tree mortality risk due to major insects and diseases, Krist et al. (2007) reported that significant outbreaks were expected in the near future. Meanwhile, the SPB continues to cause sporadic damage through smaller infestations, while retaining the potential to produce large scale losses.

A great deal of research devoted to the subject has established that thinning pine stands as a preventative measure is the best way to manage SPB risk (Nebeker and Hodges 1985, Burkhart et al. 1986, Brown et al. 1987). There is also evidence that "thinning has the potential of affecting the overall population dynamics of the SPB when applied over the landscape" (Nebeker, 2004). Commercial thinning of pines is a prevalent practice among many landowners because it can boost the diameter growth rate of the residual trees (Sword Sayer et al. 2004) and can provide a source of mid-rotation revenue during the long term forestry investment (Amateis, 2000). There are cases in which prolific natural pine reproduction results in juvenile stands which are so densely stocked that their growth stagnates (Grano, 1969). When this occurs in early stages of stand growth, commercial thinning is not an option because trees are not yet large enough to be merchantable. Landowners are faced with the decision either to leave these stands in a stagnated and unhealthy condition for many years, or to implement a pre-commercial thinning (PCT) in which felled trees are left on the ground. Although PCT can yield a beneficial growth boost to individual trees (Cain 1993, Haywood 2005), it entails a substantial cost and the financial returns may not be realized for many years. It is not surprising that Dubois et al. (1999) report that PCT is not a prevalent practice in the southeast U.S.

If the management practices of individual landowners influence the SPB risk faced by all forest landowners in their region, as suggested by Nebeker (2004), then the benefits of SPB risk reduction will not be fully realized by individuals. In the case of PCT, a portion of the benefits of risk reduction are external to market forces since there is no established method of penalty or compensation among landowners for risk reduction. Because of this externality, less thinning may be provided across the landscape than is socially optimal, in the absence of government intervention. Reducing the costs of PCT through cost sharing may be a way to correct this externality, if landowners are responsive to cost sharing. Cost sharing has been touted as a way to leverage public funding by "sharing the financial responsibility with landowners" (Nowak et al. 2008). However, similar forestry incentive programs have been the target of criticisms which suggest that landowners are unresponsive to them (Kluender et al. 1999, Cohen 1983). If true, these criticisms imply that incentive programs waste tax dollars by providing a bonus to some landowners while having no effect on the aggregate forest management practices which are their focus.

The objectives of this research are:

1) To identify landowner and forested property characteristics that are associated with participation in an incentive program for pre-commercial thinning in Virginia.

2) To understand the role of cost share payment, including the level of cost share payment in altering forest management practices.

3) To understand the policy implications of cost sharing, particularly in regard to the substitution and leveraging effects described in the literature.

To accomplish these objectives a theoretical model is developed to describe NIPF landowners' decision to conduct PCT, accounting for cost sharing. From this theoretical framework, empirical methods are used to model the participation decision using 2010 survey data from NIPF landowners in Virginia.

The remainder of this paper is organized as follows. Chapter 2 is a review of relevant literature pertaining to the biology of the SPB, forest management to mitigate SPB and previous analyses of NIPF landowner behavior to better understand the problem. Chapter 3 presents a theoretical model of the PCT decision, and chapter 4 describes the empirical methods used to estimate program participation. Chapter 5 is a discussion of empirical results. Finally, conclusions are laid out in chapter 6 along with practical implications for policy makers, landowners and program managers.

Chapter 2. Literature Review

2.1 The southern pine beetle: Lifecycle and forest management

A review of what is known about the SPB is appropriate because the effectiveness of cost sharing to mitigate the SPB depends not only on the economic effects of a cost share, but also its eventual impact on SPB populations. The SPB's potential to cause extensive damage is what has driven much of the scientific literature, yet often SPB populations exist at low, endemic populations which are fairly stable and cause little or no damage to forest resources. At other times SPB populations build up to epidemic levels during which they are difficult to control and cause devastating amounts of damage (Price et al. 1998). This interesting feature of SPB populations underscores the importance of understanding the SPB life cycle and interactions with its environment.

Mawby et al. (1989) develop an explanatory model of SPB damage in which they identify three distinct population stages: the low endemic level, the high transient epidemic level, and a threshold point at which a population transitions into epidemic levels. They find that the probability of an outbreak depends on the distance between the stable, endemic population level and the high, temporary epidemic level. They recommend the use of management practices such as felling wounded or lightning struck trees which lower the endemic level of SPB populations as well as practices such as thinning that raise the epidemic threshold.

Biological and environmental factors

The SPB is native to the southeast U.S., including parts of Virginia, and its range roughly follows that of loblolly pine (*Pinus taeda*)(Payne 1980). Although SPB has been observed to attack all pine species in its range, its preferred hosts are loblolly and shortleaf pine (*Pinus echinata*)(Thatcher and Barry 1982).

Since SPB is native to Virginia, it has associations with a wide range of organisms. Important predators include clerid beetles (Coleoptera: Cleridae) and various woodpeckers. Numerous parasitoids and mites also prey on the SPB, as well as pathogens. Survival of the SPB is sometimes reduced by competition from other phloem-feeding insects such as the southern pine sawyer (*Monochamus titillator*)(Berisford 1980). The SPB also has symbiotic associations with bacteria and fungi such as blue-stain fungi (*Ophiostoma minus*) which make nutrients more readily available to colonizing SPB. Engraver beetles (*Ips spp.*) and the black turpentine beetle (*Dendroctonus terebrans*) are often associated with SPB outbreaks (Thatcher and Barry 1982). These associations demonstrate the complexity of factors which influence SPB populations.

During endemic population conditions SPB infestations usually begin in a wounded or lightning struck tree (Ku et al. 1980) by “pioneer beetles” which identify a suitable host tree. Once the beetles successfully enter the phloem, pheromones are released along with other attractants produced by the host tree which signal surrounding beetles to concentrate attack on that tree. This process of concentrating attack within a short window of time contributes to the success of the SPB by overwhelming host defenses. As SPB concentrate on a suitable host tree, blue stain fungi and other microorganisms are introduced. To maintain the supply of suitable host material, SPB regulate their population levels through density dependent feedback. To avoid running out of host material, adults respond by reemerging from a tree that is densely populated and by depositing a smaller portion of their egg mass in densely populated trees. This regulation of host material helps avoid overpopulation and also drives the spread of the infestation by shifting adult beetles out of densely populated trees and into newly infested ones. As new beetles mature, they also emerge from infested trees to seek new hosts (Coulson 1980).

The literature suggests that climatic factors such as temperature and precipitation affect SPB populations (Michaels et al. 1984, Gumpertz, et al. 2000, Friedenberg et al. 2008). Gumpertz et al. (2000) find that certain measures of seasonal precipitation and temperature had a statistically significant effect when predicting an SPB outbreak at the county level, once other factors were controlled for. On the other hand, Turchin et al. (1991) point out that different studies reach opposite conclusions about the effect of climate on beetle populations. They conclude that SPB populations are driven by density dependent factors rather than climate conditions, and suggest predators, disease or host resistance as possible density dependent drivers. Later, Friedenberg et al. (2008) conclude that population dynamics are explained by both density dependent population regulation and variations in temperature extremes.

Forest management practices designed to mitigate SPB damage mainly involve manipulating the southern pine host population at the stand level. Understanding the interactions between beetles and the defense mechanisms of host trees is critical. A constitutive defense mechanism by the host trees to attack by SPB is exudation of oleoresin from severed resin canals, leading to the pitching out of attacking beetles. An induced defense involves the formation of a hypersensitive lesion around the wound to contain the attack (Hodges et al. 1979, Cook and Hain 1987, Lorio et al. 1995). Cook and Hain (1987) subjected loblolly and shortleaf pines to SPB attack, using lab raised beetles and mesh tenting to ensure a controlled attack. They did find that the hypersensitive lesions were significantly longer in successfully attacked shortleaf pines, but concluded that resin flow rate was more important in explaining a successful SPB attack. Strom et al. (2002) examined the progeny of loblolly pines that survived attacks by the SPB and found that the average oleoresin flow in these trees was 1.65 times higher than the average flow. They suggest that increased resin flow caused certain trees to survive SPB infestation rather than random chance.

Control and prevention

SPB infestations generally take on a circular, or "spot" shape which tend to expand only in one direction. Controlling an actively expanding spot can be costly as it involves not only cutting the currently infested trees but also a buffer of healthy trees (Nebeker 2004). Four common methods of direct control include cut and remove (cut the trees and remove them), cut and leave (cut the trees and leave them on the ground), cut and hand spray (cut the trees and spray with insecticide), and pile and burn (pile the cut trees and burn them) methods. Other techniques using aggregation inhibitor pheromones have been developed and can reduce the cost of controlling infestations in high value timber (Clarke et al. 1999, Salom et al. 1998).

Thinning pine stands has been widely recognized as the best way to manage for SPB risk, and clear guidelines have been established for doing so (Nebeker and Hodges 1985, Burkhart et al. 1986, Brown et al. 1987). Thinning has been shown to reduce both the probability of attack and the damage caused by SPB in at least three ways: by increasing the vigor of residual trees, by increasing the distance SPB must travel to attack fresh host trees, and by increasing airflow within the stand which helps disperse chemical signals used by the SPB (Nebeker and Hodges 1985, Brown et al. 1987, Johnson and Coster 1978).

Commercial thinning of pine stands is a prevalent silvicultural practice throughout the southeast, and for good reason. Aside from reducing SPB risk, a commercial thinning boosts the growth rates of the residual trees (Sword Sayer et al. 2004), which often increases their present value and provides an intermediate source of revenue from tree removals (Amateis 2000). Although commercial thinning operations often do provide immediate revenue or at least cover the operational costs involved, depressed timber prices can deter landowners from implementing them.

Prolific natural pine regeneration can result in densely stocked juvenile pine stands that are too young to be merchantable. When juvenile pine stands are densely stocked and the height of the juvenile trees fairly homogenous, the growth of the stand can become stagnated (Grano, 1969). A PCT can be implemented to restore the vigorous growth rate of a juvenile pine stand. Although this can increase the present value of timber by increasing individual tree growth rate, it generates substantial costs but no immediate revenue since trees do not yet have commercial value. Because of this, PCT is usually a less attractive option than commercial thinning, especially to NIPF landowners who may have limited capital to invest in their pine stands, and might not be able to wait for that investment to mature. As expected, PCT is not a prominent practice in the southeast (Dubois et al. 1999). Incentive programs in Virginia and other state incentive programs do target first commercial thinning in some cases, but this research focuses on cost sharing for PCT because of the consistently substantial costs of implementation.

Economics of southern pine beetle risk reduction

In economic terms, the justification for using public resources to reimburse landowners is that by doing so, a market failure in the form of an externality is being corrected so that society as a whole is better off. For the market failure justification to be valid in the case of the PBBPP, two assumptions must be true. One, there must be a valid expectation that the market does fail to provide the optimal level of PCT. Two, cost sharing must have an impact on the management decisions of NIPF landowners. The validity of the first assumption is explored in this review of the existing literature. Testing the second assumption empirically is a primary research goal.

If thinning a high hazard stand has value to other members of society who have no established means of compensating its owner for hazard reduction, an externality can be expected in which thinning is underprovided (Figure 1). The existing literature does suggest that SPB hazard reduction in one stand affects the hazard level in other stands within the same region.

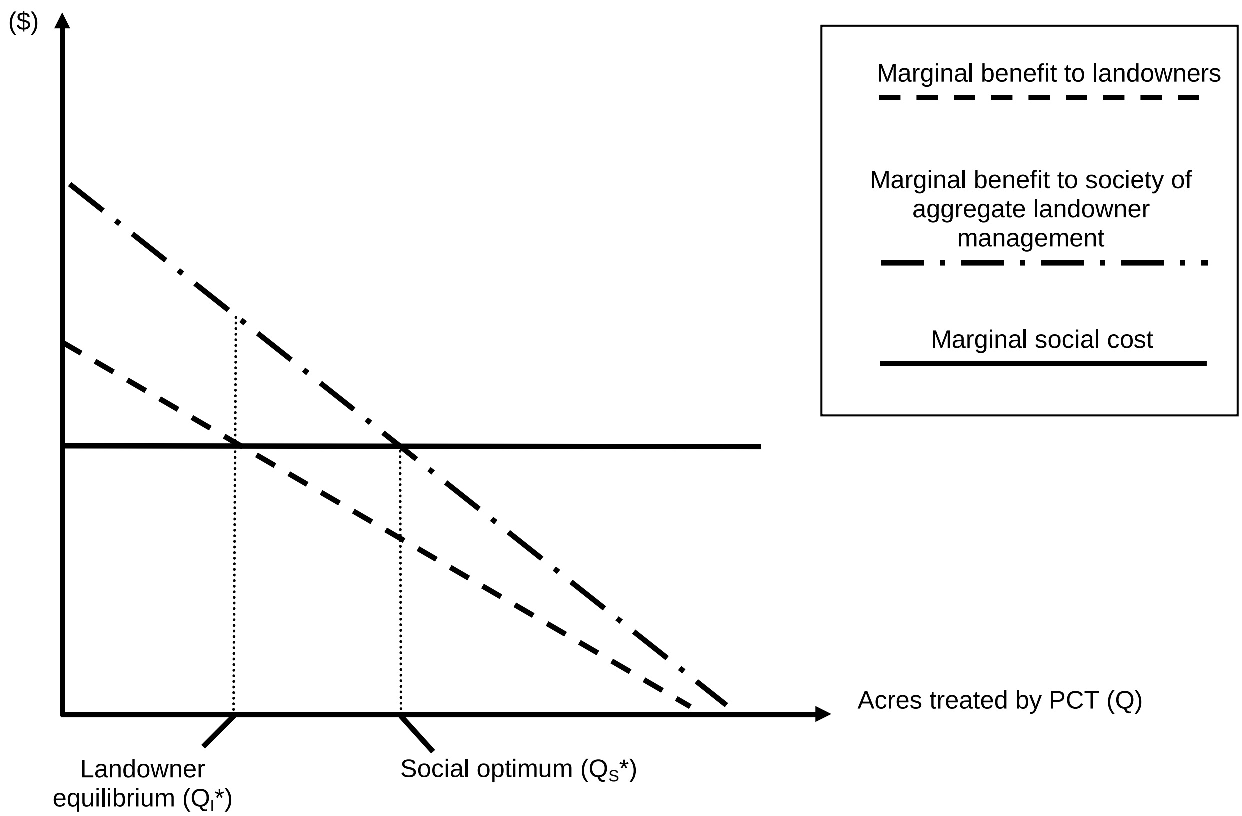

Figure 1. Theoretical example of the marginal costs and benefits of pre-commercial thinning without cost sharing. (This example shows that when the benefits of large scale southern pine beetle risk reduction generated by thinning treatments are external to market forces, thinning is underprovided.)

Johnson and Coster (1978) studied two SPB infestation areas and found an interesting relationship among stand density, probability of attack upon a tree adjacent to an infestation, and overall SPB infestation size. When overall SPB infestation size was small, the results of their study supported the conclusions of a previous study by Gara and Coster (1968) that in more dense stands there is a greater probability that the beetles in an infested tree will begin to colonize an adjacent tree. However, Johnson and Coster (1978) also found that stand density or the distance between trees has "reduced importance" on the probability that beetles will colonize an adjacent tree when the infestation is a large one.

Modeling SPB populations has been used to estimate the effects of specific factors and as predictive tools. Hedden and Billings (1979) studied the rate of expansion of individual infestations (spots) from 1975 to 1977 in east Texas. They found that spot size and basal area had significant, positive correlations with the expansion rate of infestations. They also noted an interesting phenomenon they had failed to control for: "mean rates of summer spot growth varied among years in direct relation to area wide beetle population levels in east Texas," and recommended that future models control for beetle population levels. Responding to this recommendation, Reed et al. (1981) found that the number of spots per thousand acres of host for the entire region was an important factor in modeling spot spread. Paine et al. (1984) recognize the "dynamic relationship" between beetle population and physiological condition of trees explicitly in their conceptual model of bark beetle infestations. Turchin et al. (1991) use time series and regression analyses to model SPB populations in east Texas from 1973 to 1987, concluding that density dependent factors were the principle drivers of SPB population. Gumpertz et al. (2000) report the presence of both spatial and temporal autocorrelation in their model of SPB outbreak in North Carolina, South Carolina, and Georgia.

Given these results, it is apparent that the management practices of each individual landowner have some influence on the SPB risk faced by all forest landowners in his or her region. Without a means of penalty or compensation between forest landowners, we expect the market to fail in providing the optimal amount of PCT across the landscape because some of the benefits to society are unrealized by the individual landowners who make the decision to PCT their pine stands. Reducing the costs which NIPF landowners face through a cost sharing program could be one way to correct for this externality, if landowners respond to the cost share by altering their management decisions (Figure 2).

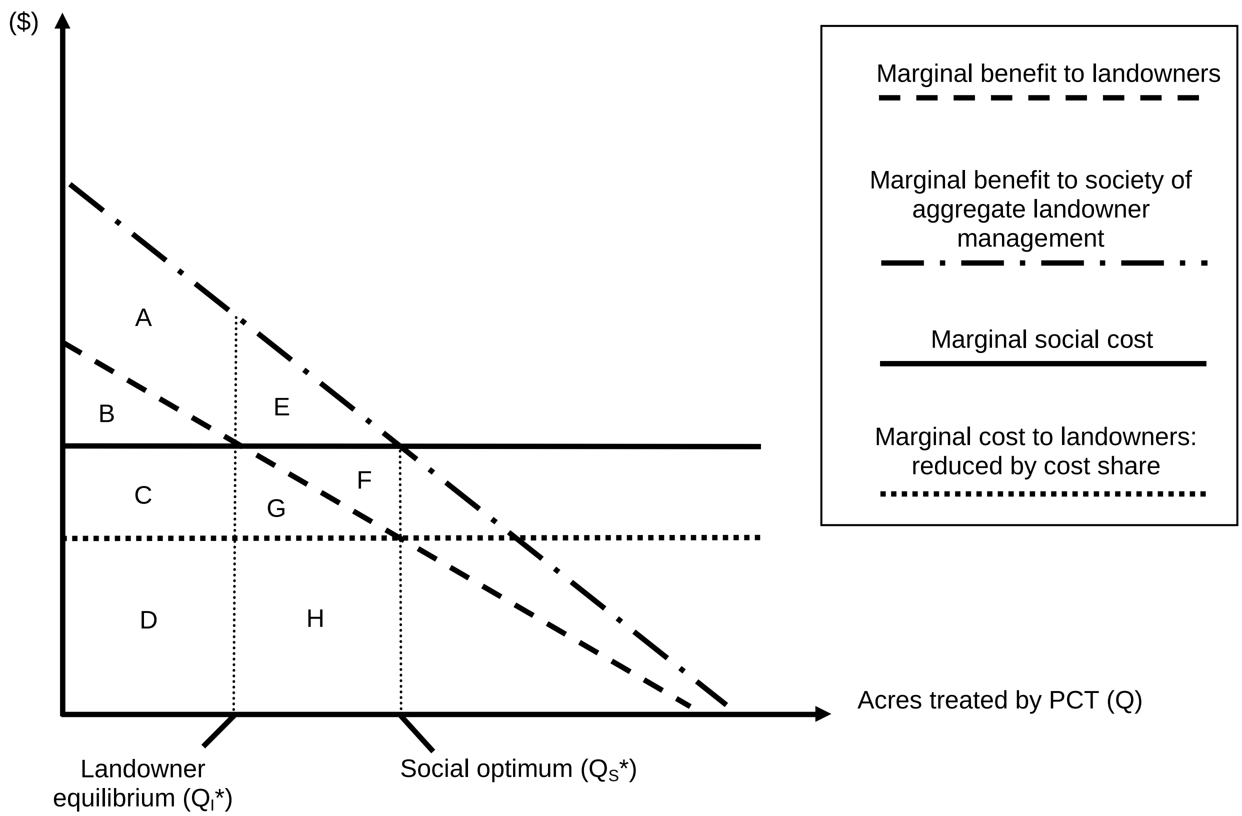

Figure 2. Theoretical example of the marginal costs and benefits of pre-commercial thinning with cost sharing. (Cost sharing has the potential to correct the risk reduction externality. Without cost sharing: A+B is the net benefit to society of pre-commercial thinning where A is the net benefit of large scale SPB risk reduction, and B is the net benefit of thinning to landowners. C+D is the total cost to society, which is borne entirely by landowners without cost sharing.

With an optimal level of cost sharing: A+B+E are the net benefits to society where E is the increase in net benefit due to large scale SPB risk reduction. C+D+F+G+H are the total costs to society, of which C+G+F are paid by cost share reimbursement. G is the net benefit to landowners of newly enrolled acres, and C is cost share funding substituted for private investment. D+H are thinning costs borne by landowners under cost sharing.)

2.2. Econometric analysis of non industrial private forest landowners

Given support in the SPB literature for the expectation of an externality, this review turns to the literature which investigates NIPF landowner decisions. Previous analyses of NIPF landowner decisions are numerous. Amacher et al. (2003) and Beach et al. (2005) provide valuable reviews of this field of literature.

The decisions made by NIPF landowners are driven by a complex set of factors which can include profit maximization, non timber amenity benefits, preferences, personal characteristics, and physical characteristics of their land which can vary widely. These complex decisions are of great interest when trying to predict, alter, or describe forest management in the southeast, since NIPF landowners make up close to 70% of land ownership in many states (Amacher et al. 2003).

Within this larger literature, review is focused on those studies which analyze various forestry incentive programs. The subject of the majority of these studies are cost share programs designed to boost long run timber supply by subsidizing tree planting and site preparation on NIPF lands. The justification of cost sharing is hotly debated in the literature by two opposing camps. One of these decries cost sharing as a waste of public resources on the basis that landowners are not responsive to it, because they substitute cost share dollars for their own investment dollars which they would have spent regardless of cost sharing (Kluender et al. 1999, Cohen 1983), or that cost sharing leads to deadweight loss (Boyd et al. 1988). These studies call for policy makers to reconsider the continued provision of cost share dollars. The opposing camp supports the continuation of cost sharing on the basis that landowners are responsive to cost sharing, and argue that substitution is not really occurring (DeSteiguer 1984, Hardie and Parks 1996, Lee et al. 1992). Others fall in between these two views, reporting results which suggest that some amount of substitution occurs, or that substitution occurs under certain circumstances (Zhang and Flick 2001, Mehmood and Zhang 2002, Kline et al. 2002). Other studies investigate important factors in the decision to participate in cost share programs and do not address the issue of substitution. These studies generally conclude that cost sharing had or can be expected to have a positive impact on NIPF management (Bell et al. 1994, Ovaskainen et al. 2006, Romm et al. 1987, Royer and Moulton 1987), although some do not address variations in cost, but focus on other factors (Nagubadi et al. 1996, Rossi et al. 2010).

Existing studies on forestry incentive programs raise valid questions about the impacts of cost sharing, but are not directly applicable to the situation of a cost share directed at pre-commercial thinning to reduce SPB hazard. Although pre-commercial thinning is similar to the reforestation decision in that it involves making a long term investment in forestry, fewer alternative uses are available for a densely stocked juvenile pine stand than are available immediately after timber harvest. Furthermore, thinning is less prevalent than reforestation because while it may beneficial in many cases, it is not strictly necessary. The reforestation decision is relevant after every harvest and always relevant to open land. The motivation behind cost sharing is a market externality involving hazardous risk reduction rather than timber supply outcomes.

Two studies were found in the literature, which are fairly similar to the case of cost sharing to reduce SPB risk (Ovaskainen et al. 2006, Rossi et al. 2010). Ovaskainen et al. (2006) used survey data to examine the effect of cost sharing and information assistance on timber stand improvements in privately owned lands in Finland. The timber stand improvements in question included PCT, cleaning of seedling stands, and restoration thinnings of juvenile stands. They found that cost sharing and assistance had positive impacts on both the probability and intensity of stand improvements, though cost sharing especially increased quantities treated while information provision were "more typically triggering effects" (52) to invest in stand improvement.

Rossi et al. (2010) conducted two surveys in the southeast U.S. to assess cost share programs targeted at SPB prevention. One of these surveys was sent to cost share program participants, while the other was sent to NIPF landowners randomly selected from county tax data. Unfortunately the second survey yielded a fairly low response rate, which Rossi et al. (2010) suggest was due to the heavy cognitive burden of the choice experiment involved. Despite this difficulty, comparisons of key variables between the two groups of survey respondents, as well as evaluations given by actual cost share program participants provide useful insights into program implementation. The main differences reported between cost share participants and non participants were landholding size, gender, management intensity, and forest/conservation organization membership. Cost share participants were more often male, and had larger landholdings. Forest management and organization membership were more prevalent among cost share participants. Program participants reported a high level of satisfaction with their experience, and 99% indicated a willingness to participate again. Forestry officials and consultants are identified as critical to program success. While this study is valuable to program implementation, it lacks the ability to speak to the important policy questions of landowner responsiveness and the potential for substitution which are raised in previous literature examining forestry incentive programs.

This analysis of the impact of cost sharing attempts to answer these questions by using a focused analysis of landowner responsiveness to cost share expenditures for PCT in Virginia. The level of cost share is examined in greater detail than in previous work, simple spatial interactions among landowners are explored, and the effect of debt is estimated in a predictive model of willingness to participate in the PBBPP.

Chapter 3: Conceptual model of the pre-commercial thinning decision

To guide the empirical analysis, a conceptual model is presented of a landowner facing the decision to participate in a cost share program for PCT. The primary motivation for this decision is financial returns from the increased timber growth associated with thinning. So, a key component in the conceptual model is discounted net revenue from the sale of timber, which is a function of forest condition as well as management costs. It has been recognized that non-timber amenity benefits also drive landowner behavior (Hartman 1976). Amenity benefits are included, also as a function of forest condition. Participation in the program involves a substantial expenditure for PCT, of which some portion is reimbursed by the incentive payment within the short term. A landowner's personal finances, as described using annual income and debt level should also be important components for at least two reasons. The state of a landowner's personal finances affects their ability to engage in the long term investment of thinning, while simultaneously influencing their motivation to generate financial revenue from their land.

Omitting the option to participate in the cost share program, an individual landowner's indirect utility (V) is given as the following function:

$$V(R, I, D_0, F_0) = V[R(F_0), I, D_0, \phi(F_0)] \qquad (1)$$

Where R is the discounted net revenue generated from the property, which in this case is assumed to be primarily generated from timber, I is exogenous income, D_0 is an initial debt level, F_0 is the initial condition of the forest and ϕ are the non-timber amenity benefits derived from forested land. If PCT is a relevant consideration, assume that F_0 is a juvenile pine stand which is densely stocked.

The continuously discounted flow of costs and revenues associated with forested land could be represented across an infinite time frame following the Faustmann formulation, (Amacher et al. 2009, chapter 2). To avoid the strong assumption that PCT will be a relevant consideration for every future rotation, the first rotation decision where it is relevant, is separated from subsequent rotations in which PCT may not be relevant. The discounted net revenue function for the first rotation without thinning is,

$$R(F_0) = pQ(T, S, F_0)e^{-rT} \tag{2}$$

where p is the constant timber price, r is the discount rate, Q is the merchantable volume growth of timber as a function of the number of years until the first harvest rotation (T), site quality (S), and initial forest conditions (F_0) relevant to the first rotation only.

Discounted net revenues from subsequent rotations in which thinning is not a relevant consideration is,

$$R(F_0) = \left(\frac{pQ(t, S)e^{-rt} - C_{EST}}{(1 - e^{-rt})} \right) e^{-rT} \tag{3}$$

where Q is the merchantable volume growth of timber as a function of (t), the rotation length of subsequent rotations, and site quality (S). The term C_{EST} is the periodic cost of forest establishment after harvest.

Combining equations (2) and (3) gives discounted net revenues from all future rotations,

$$R(F_0) = pQ(T, S, F_0)e^{-rT} + \frac{pQ(t, S)e^{-r(T+t)} - C_{EST}e^{-rT}}{(1 - e^{-rt})} \tag{4}$$

Amenity benefits to the landowner can also be expressed as a discounted flow of future benefits over an infinite time frame:

$$\phi(F_0) = \int_0^\infty b[F_0(z), z]e^{-rz}dz \qquad (5)$$

where *b(.)* is the periodic amenity benefit provided by the land, *z* is a variable of integration representing time periods 1,…,∞, and *F(z)* is the condition of the forest at each point in time, which begins as a densely stocked juvenile pine stand (F_0).

A landowner who chooses to participate in the PBBPP faces different management costs, timber growth rate, amenity benefits, and may face a different debt level than the landowner who does not. The indirect utility function for participating landowners is:

$$V(R, I, D_{PCT}, F_{PCT}) = V[R(F_{PCT}), I, D_{PCT}, \phi(F_{PCT})] \qquad (6)$$

where D_{PCT} is the debt level after paying for a PCT which, for some landowners may be higher than D_0, and F_{PCT} is the residual forest condition after PCT. Revenue generation under program participation is included in our model of discounted cost and revenue flows as,

$$R(F_{PCT}) = -C_{PCT} + pQ(T, S, F_{PCT})e^{-rT} + \frac{pQ(t, S)e^{-r(T+t)} - C_{EST}e^{-rT}}{(1 - e^{-rt})} \qquad (7)$$

where the term C_{PCT} is the cost of a PCT implemented in the current time period, which changes the initial condition of the forest, thereby increasing timber growth rate by changing growth function input F_0 to F_{PCT}: $Q(T,S,\boldsymbol{F_{PCT}})$. Along with costs and revenues, we also expect PCT to alter the amenity benefits provided by the forest by increasing visibility and maneuverability for recreation within the stand, as well as improving the appearance of the individual trees. The amenity benefit function is now,

$$\phi(F_{PCT}) = \int_0^\infty b[F_{PCT}(z), z]e^{-rz}dz \qquad (8)$$

where forest condition *F(z)* begins as a thinned juvenile stand.

Participation in the PBBPP will improve an individual landowner's welfare if:

$$V\left(R, I, D_{PCT}, F_{PCT}\right) > V\left(R, I, D_0, F_0\right) \quad (9)$$

or

$$V\left[-C_{PCT} + pQ\left(T, S, F_{PCT}\right)e^{-rT} + \frac{pQ\left(t, S\right)e^{-r(T+t)} - C_{EST}e^{-rT}}{\left(1 - e^{-rt}\right)} + \int_0^{\infty} b\left[F_{PCT}(z), z\right]e^{-rz}dz, I, D_{PCT}\right] >$$

$$V\left[pQ\left(T, S, F_0\right)e^{-rT} + \frac{pQ\left(t, S\right)e^{-r(T+t)} - C_{EST}e^{-rT}}{\left(1 - e^{-rt}\right)} + \int_0^{\infty} b\left[F_0(z), z\right]e^{-rz}dz, I, D_0\right] \quad (10)$$

and we expect them to be willing to participate in the PBBPP if (10) is true.

Across a population of landowners among which the factors of equation (10) vary, define

$$Pr(\textit{willing to participate}) = f\left(R\left(F_0\right), I, D_0, \phi\left(F_0\right)\right) \quad (11)$$

as the probability that equation (9) holds for any given landowner within the relevant population. This probability is a function of the same inputs identified in equation (1), and is analogous to the probability that equation (10) holds for a given landowner.

Clearly, lowering C_{PCT} can be expected to increase the utility associated with program participation and the PCT involved, but the amount of cost reduction necessary for (10) to be true is not clear, and likely varies across a population of NIPF landowners among which the factors of equation (10) vary. It is also unclear how far C_{PCT} can be lowered before ceasing to affect adoption of PCT.

$$\frac{\partial P(PCT)}{\partial C_{PCT}} \leq 0 \quad (12)$$

As personal income increases, the willingness to pay for the costs of PCT should also increase, all else being equal,

$$\frac{\partial P(PCT)}{\partial I} \geq 0 \quad (13)$$

The expected effect of debt poses a more complex question. On one hand increasing debt levels might be expected to burden landowners financially, making them less likely to participate. On the other hand increasing debt levels might indicate an increasing willingness to spend, making landowners more likely to participate.

$$\frac{\partial P(PCT)}{\partial D} = ? \tag{14}$$

Since PCT increases the visibility and maneuverability within a stand and improves the health and appearance of residual trees, landowners with preferences for amenity benefits may be more likely to participate.

Other interesting analytical questions are raised by the conceptual model about how cost sharing might impact forest conditions on a large scale. On densely stocked sites with low productivity, the present value of harvest revenue might not warrant the cost of a PCT, even if diameter growth and forest health are increased. Similarly, expectations of low local timber prices could mean that the present value of harvest revenue is not increased enough by thinning to justify the costs involved. As costs are reduced, PCT could become economically optimal across a broader forested land base in which site quality and local timber prices are variable.

This conceptual model of landowner decision making highlights the importance of understanding how cost interacts with other factors within the established microeconomic framework to affect willingness to participate in the PBBPP. Through empirical analysis we seek to better understand these questions in order to shed light on how individual landowner decisions alter hazardous forest conditions on a large scale.

Chapter 4. Empirical methods

4.1 Survey design and implementation

Since the actual utility levels of equation (10) cannot be directly measured, the empirical approach is to estimate the probability that a given landowner adopts PCT according to equation (11). The econometric method used was the logit function,

$$Pr(\textit{willing to participate}) = \frac{e^{\beta x}}{1+e^{\beta x}} \qquad (17)$$

where β are the coefficients estimated, and *x* is a vector of explanatory variables from equation (10). The logit function is appropriate for estimating probability because it can never be less than zero or greater than 1, and only approaches these extreme values as β*x* approaches ±∞ (Wooldridge 2009, chapter 17).

Landowner data describing willingness to participate in the PBBPP, and data describing the inputs to equation 8 were collected from a 2010 mail survey sent to 1,200 households within the Piedmont and Coastal Plain regions of Virginia where southern pine management is prevalent. Since we used tax parcel data maintained at the county level to identify landowners, it was necessary to first select relevant counties for inclusion in the survey. Seven counties were selected (Figure 3) on the basis of land area classified as medium to high hazard for SPB infestation (Figure 4) by the USDA Forest Service, Forest Health Technology Enterprise Team[1] (FHTET) (FHTET SPB Risk Map, v1.0). Within these seven counties, the survey mailing list was drawn as a random sample from county tax parcel records with 5 or more contiguous acres[2] of pine cover, as delineated by the Virginia Forest Cover Type Map 2005: Level 2 (Virginia Department of Forestry, Division of Resource Information).

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[1] At least 16% of the land area in each of these counties has been categorized as having a high or medium SPB hazard level as determined by FHTET

[2] 5 acres was chosen because this is the minimum pine stand acreage required to qualify for the PBBPP

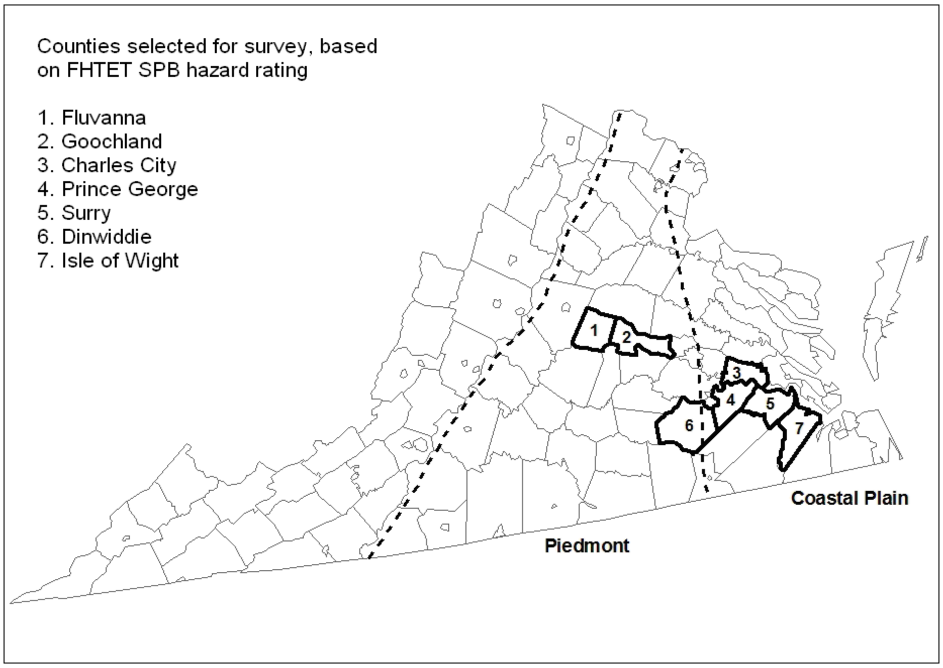

Figure 3. Virginia counties selected for inclusion in the survey.

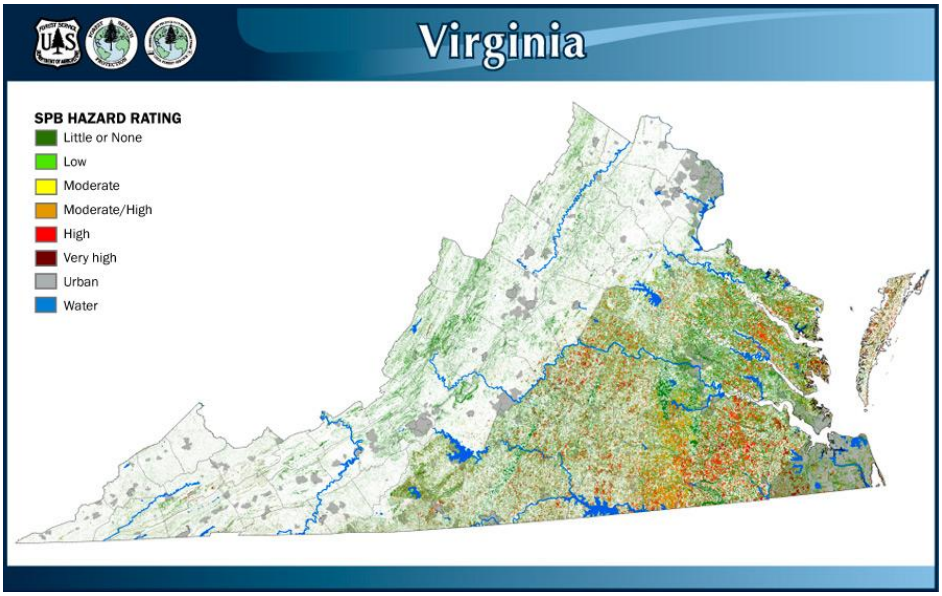

Figure 4. Southern pine beetle Hazard Map for Virginia (USDA Forest Service, Forest Health Technology and Enterprise Team).

Survey design and implementation followed the "Tailored Design Method" described by Dillman et al. (2009) which includes a notice letter, questionnaire with cover letter, reminder post card, and replacement questionnaire with cover letter. In total, 512 of the original 1,200 questionnaires were received for a final response rate of 42.7% of which 354 were used for logistic regression, once missing data was discarded. This response rate is somewhat higher than is reported in previous landowner surveys in the southeast (Bell et al. 1994, Conway et al. 2003, Zhang et al. 2006, Rossi et al 2010), with the exception of Vokoun et al. (2010) who reported a response rate of 45%.

In designing the questionnaire, the goal was to make it clear, unambiguous and as brief as possible in order to capture accurate responses and avoid non response bias. Explanation was included as to why questions were asked, and we attempted to order questions in a logical, conversation like flow. Previous econometric analyses of NIPF landowner behavior guided the choice of questions (Amacher et al. 2003, Beach et al. 2005). One-on-one cognitive interviews were conducted with NIPF landowners, and forestry professionals, following the recommendation of Dillman, et al. (2009). These interviews provided further insights on what to ask, and how questions would be interpreted.

4.2 Descriptive statistics of survey respondents

Landowner and property characteristics found by this survey (Table 1) describe a population which is wealthier, better educated, older (often retired), and more male dominated than the average population in Virginia (U.S. Census Bureau. 2000). In general, these descriptive statistics are similar to those found in earlier studies (Conway 2002, Conway et al. 2003, Rossi et al. 2010, Joshi and Arano 2009), especially with regards to age, gender, income, and education. One notable difference is our average size of forest land holdings, which was 236 acres. This average acreage is higher than several previous NIPF landowner surveys conducted in Virginia (Conway 2002, Conway et al. 2003, Sullivan et al. 2005) which reported average forest land acreages between 36 and 125 acres, though these surveys did not report a sampling emphasis on pine ownership. The median of forest land in this survey was 95 acres, which, when compared to the mean acreage of 236 indicates the influence of large outliers (maximum forest land reported was 8,000 acres). A recent survey of NIPF landowners in the southeast U.S. (Rossi et al. 2010) reported a mean value of 558 acres of forest land, which they also attributed to large outliers in their sample.

Table 1. Descriptive statistics of survey respondents (units in parentheses).

Variable	Mean	S.D.	Min/Max
Cost share & willingness to participate			
Cost share (%)	54.93	23.10	20 / 90
Willingness to participate (1=yes)	0.62		
Property characteristics			
Forest land (ac)[A]	235.75	576.09	5 / 8,000
Pine forest (1=yes)	0.53		
Mixed forest (1=yes)	0.39		
Pine or mixed forest (1=yes)	0.88		
Crop land (ac)	52.41	100.35	0 / 749
Adjacent pine stands (1=yes)	0.73		
Landowner characteristics			
Age (years)	64.61	12.20	26 / 94
Gender (1 = female)	0.26		
College (1=yes)	0.54		
Resides off forest (1=yes)	0.43		
Aesthetic or env. pref. (1=yes)	0.39		
Income < $60,000 (1=yes)	0.34		
Income $60,000 to $99,999 (1=yes)	0.31		
Income >$100,000 (1=yes)	0.35		

[A] Median value of forest land = 95 acres

Follow up questions within our questionnaire gauged why survey respondents were willing, or unwilling to participate (Figures 5 and 6). The most prevalent reason to participate was for a commercial value improvement, though other reasons were frequently indicated. The most prevalent reason not to participate was the lack of capital available to invest in PCT. A substantial portion (36%) of landowners said the financial benefits did not outweigh the costs[3]. Very few said that SPB risk was not a concern on their land. Based on these responses, it appears that landowners were evaluating the decision to PCT primarily as a financial investment, but with substantial secondary reasons like SPB risk reduction, and aesthetic, environmental and wildlife improvements. It also appears that most landowners take SPB risk seriously, but that some are constrained by limited capital. The average cost share among respondents who were unwilling to participate was 48.7%, while the average cost share among those willing to participate was 59.0%. With this difference in mind, increased cost share payment may be responsible for changing PCT from a poor investment to a sound investment in the eyes of some NIPF landowners, as well as decreasing the short term capital necessary to make that investment. Other landowners may view PCT as an irrelevant and unnecessary cost, regardless of cost sharing, or may be wary of inviting government involvement with their personal property, as indicated by open ended responses in the survey.

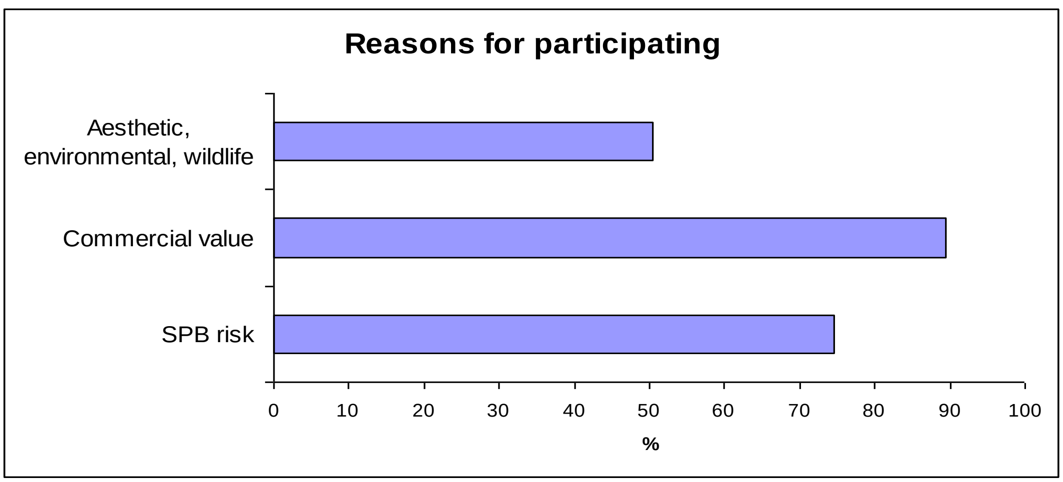

Figure 5. Reasons survey respondents indicated for participating in the pre-commercial thinning cost share program.

[3] An average cost of $110 per acre for PCT was provided in the questionnaire. This cost was based on VDOF records of the actual costs per acre of 478 PCT treatments performed in Virginia from 2004 to 2009, which averaged to $112.16 per acre.

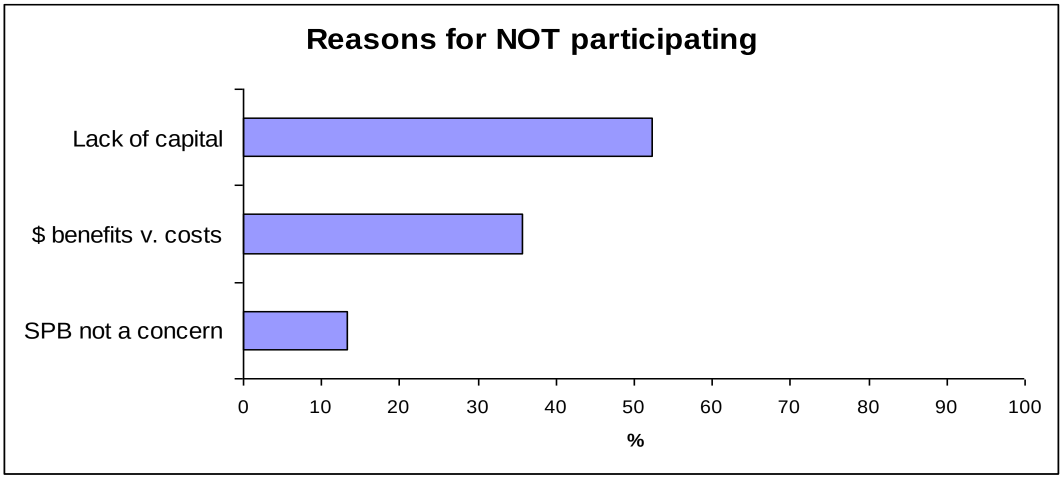

Figure 6. Reasons survey respondents indicated for not participating in the pre-commercial thinning cost share program.

Landowner education has been recognized as a supplemental and even alternative policy tool to cost sharing (Bell et al. 1994). Responses to several questions about landowner familiarity with the PBBPP, SPB management, and the costs and benefits of PCT (Figure 7) may provide some insight into the utility of further landowner education efforts. It appears that most respondents view SPB risk as a concern, and are at least somewhat familiar with it. However, about 41% (n=503) report that they know very little about SPB risk. While most of our landowners know something about SPB risk, efforts to educate them further could be beneficial. Comments reveal that at least some landowners are eager to learn more[4]. It is somewhat surprising that 74% of landowners reported being unfamiliar with the PBBPP[5] especially given their high average landholding and frequent participation in other incentive programs. In fact 37% had previously participated in other forestry cost share programs. The lack of familiarity with the PBBPP could be due to the fact that PCT considerations are encountered less frequently

[4] Paraphrased comment: "did not know much about SPB risk, wish you had provided more information on how to recognize and handle these beetles."
[5] Familiarity levels were qualified with descriptions. For instance "Not Familiar" with the PBBPP was qualified with this description- "I didn't know there was a cost share program available in Virginia for pre-commercial thinning."

than other forestry activities. For instance, PCT is commonly a consideration after prolific natural regeneration or after tightly spaced plantings with high survival rates, whereas replanting is a consideration after each harvest.

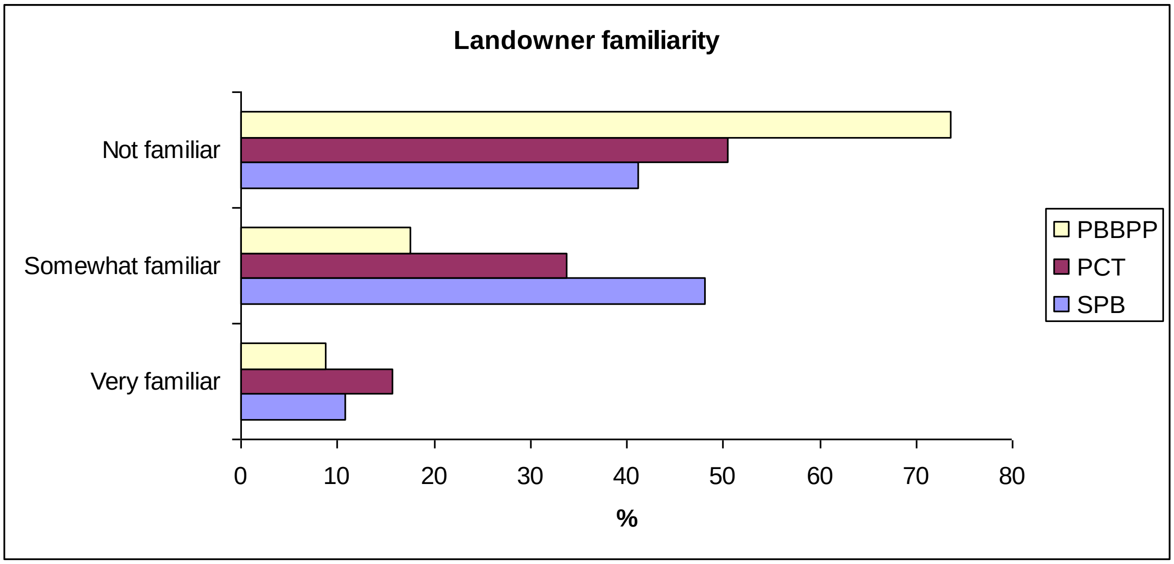

Figure 7. Survey respondents' familiarity with the Pine Bark Beetle Prevention Program (PBBPP), pre-commercial thinning (PCT), and the southern pine beetle (SPB).

Chapter 5. Results and discussion

5.1 Logistic regression results

A logistic regression was used to estimate the ceteris parabis effects of cost sharing and other key variables on program participation (Table 2). The dependent variable was a discrete variable equal to one if the responding landowner was willing to participate in the cost share program for pre-commercial thinning, and equal to zero otherwise.

Three classes of explanatory variables were included in the model to measure and control for the effects of cost sharing, property characteristics, and the personal characteristics of landowners. Forest land size was included in the model because larger acreages of forestland may entail greater tax burdens as well as commercial opportunities for timber production due to economies of scale. Crop land size was included in the model to account for differing opportunities available to landowners involved in agriculture as well as differing experience with actively managing their land. SPB infestations have the potential to spread between pine stands on adjacent ownerships, so the presence of adjacent pines was included to measure their effect on participation. College education was included because of the possibility that landowners with a college education have different perspectives on SPB risk reduction, government incentive programs, or long term financial investments then those without. Off forest residence was included because landowners who live on their forested property could be more knowledgeable about its condition and find it easier to engage in active management. Preferences for aesthetic or environmental quality were included because a PCT could potentially improve these qualities by increasing visibility and forest health. Income and debt were included in the model because they could impact the ability and interest in program participation because of the substantial up front cost involved and potential for positive financial returns in the long run.

Cost share, forest and crop land holdings, adjacent pine stands, college education, preferences, and a low debt level had a significant effect on willingness to participate at the 10% level or better, ceteris parabis (Table 2). Estimated effects for those variables with strong a priori expectations such as forest and crop land holdings, aesthetic/environmental preferences, and a low debt level were not surprising. However, there was not evidence that age, off forest residence, or income have a significant effect on willingness to participate, which is different from some previous studies of NIPF landowner behavior (Kuuluvainen et al. 1996, Romm et al. 1987, Joshi and Arano 2009).

Table 2. Logistic regression results of the Overall Model, dependent variable is willingness to participate in the cost share program.

Logistic Regression Results (n=354)	Dep. Var: Willing to Participate (1=yes)	
Variable	Coefficient Estimate	S.E.
Constant	-2.4864***	0.9039
Cost Share (%)	0.0228***	0.0054
Property characteristics		
ln(Forest land)	0.2032*	0.1158
Crop land	0.0033*	0.0017
Pine adjacent to property (1=yes)	0.7216**	0.2876
Landowner characteristics		
Age (years)	-0.0065	0.0109
College education (1=yes)	0.7308***	0.2601
Resides off forest (1=yes)	-0.3521	0.2555
Aesthetic or env. pref. (1=yes)	0.5255*	0.2692
Income $60,000 to $99,999	0.2051	0.3044
Income >$100,000	0.3062	0.3178
Debt (non zero) < $10,000	0.9277**	0.4685
Number of observations = 354		* Significant at 10%
Log likelihood = -198.863		** Significant at 5%
Likelihood ratio $\chi 2$ statistic for model = 63.21***		*** Significant at 1%

Cost Sharing

Cost sharing should not have a negative effect on participation, though whether or not it has a significant, positive effect is not clear a priori. One argument is that cost sharing should have a positive effect by lowering the cost that landowners incur by investing in a PCT. Another argument is that cost sharing should not affect participation because landowners not interested in a PCT are not interested in a cheaper PCT, while interested landowners will only receive a bonus for a decision they have already made. We find that cost sharing does have a positive overall effect on participation significant at the 1% level. This result supports the view that landowners respond to a higher investment return and is consistent with the perception of PCT as an investment seen in the responses to follow up questions (Figure 5).

Property Characteristics

Forest and crop landholding size, as well as adjacent pine stands were significant predictors of landowners' willingness to participate. Acres of forestland had a positive effect on probability of participation, significant at the 10% level and consistent with a priori expectations and previous studies (Hardie and Parks 1996, Nagubadi et al. 1996, Straka and Doolittle 1988, Kline et al. 2000). Perhaps landowners with larger acreages of forest land have greater commercial opportunities for timber production as well as higher tax burdens, so management intensity increases as forest landholding size increases. A natural logarithm transformation was used for acres of forest land to reduce the influence of outliers on the coefficient estimates (Cramer 1991).

Acres of crop land also had a positive effect on willingness to participate at the 10% level. This result is comparable to other studies which have found farming to be a significant factor for explaining NIPF landowner decisions (Kuuluvainen and Salo 1991, Hyberg and Holthausen 1989, Hardie and Parks 1996). Landowners with large crop land holdings may have a greater interest and ability to manage their forest land because of experience managing crop land.

The presence of adjacent pine stands as measured by a binary dummy variable had a positive effect on willingness to participate, significant at the 5% level. It is possible that landowners who have pine stands adjacent to their property which they do not own or manage perceive a greater risk or liability associated with SPB infestation than landowners whose wooded property is isolated from other pine stands. It is also possible that landowners gain information or access to contractors from neighboring pine ownerships. Although the causal relationship is not clear, the presence of pine on adjacent ownerships does significantly impact willingness to participate and may have important implications to program implementation. Several previous studies have also found that landowners are sensitive to the forest condition of adjacent ownerships (Vokoun et al. 2010, Swallow and Wear 1993, Koskela and Ollikainen 2001, Amacher et al. 2004).

Landowner Characteristics

Although education has been a significant factor explaining NIPF behavior in other studies (Straka and Doolitte 1988, Dennis 1989, 1990, Kline et al. 2000), the expected sign was not clear in this case. Landowners in our survey who had a college education were more willing to participate than those without, and this effect was significant at the 1% level. Landowners with a college education may have a better understanding of, or trust for incentive programs than those without a college education. Education may also facilitate an understanding of the long term benefits of PCT and SPB risk.

Landowners who expressed a preference for aesthetic and environmental quality were more willing to participate than those who did not, and this effect was significant at the 10% level. Landowners who indicated this preference may place a positive value on the open stand conditions and healthy trees expected to result from a PCT. Kuuluvainen et al. (1996) found a similar variable- “multi objective ownership” to be a significant factor in predicting NIPF landowner behavior.

Landowners with a low, but non-zero debt level were more willing to participate than those with high debt levels and those who indicated that they had no debt whatsoever, and this effect was significant at the 5% level. This result is consistent with the a priori expectation of debt as a financial burden that should reduce willingness to participate in an activity which landowners may view as a substantial expenditure. Perhaps landowners with a low level of debt are not financially burdened by it, but perhaps those who have reduced their debt to zero are unwilling to take on a positive level of debt, which could deter them from investing in PCT.

There was not evidence that age, income, or living off forested property had a statistically significant effect on willingness to participate. Several previous studies have found these factors to be significant in explaining various NIPF landowner decisions (Kuuluvainen et al. 1996, Romm et al. 1987, Joshi and Arano 2009), though others have failed to find evidence that they are significant.

5.2 A closer look at cost sharing

The estimation results (Table 2) allow for a comparison of the relationship between cost sharing and willingness to participate among landowners with different characteristics. For instance, the estimated relationship between cost share and willingness to participate for landowners with large landholdings[6] is clearly weaker than for our average landowner (Figure 8). The relationship is even weaker for landowners with large landholdings and a college education. Landowners who are interested in the PBBPP because of their personal and property characteristics may care less about its cost than our average landowner.

[6] Landowners with large landholdings were those who had greater than 497 acres of forest land, and 180 acres of crop land, the 90th percentile values reported in the survey.

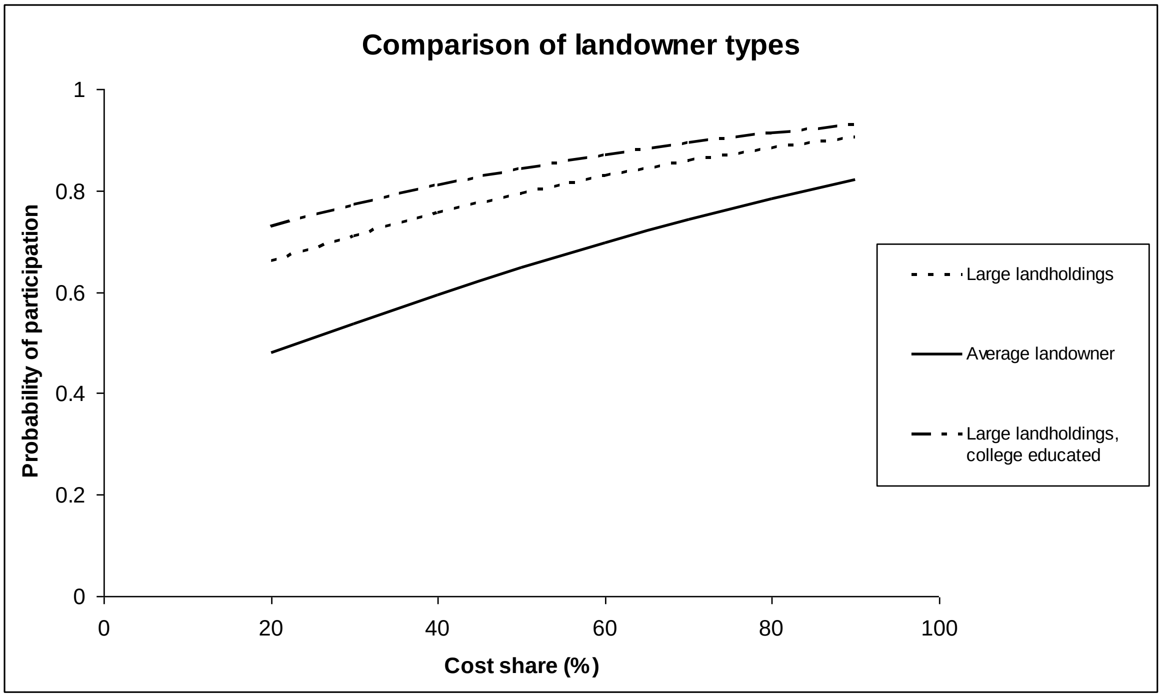

Figure 8. The estimated relationship between cost share level (%) and probability of participation in the cost share program for our average landowner, landowners with large landholdings, and landowners with large landholdings and a college education.

The raw data describing willingness to participate at each level of cost share (Figure 9) prompted investigation of the effects of cost share in greater detail by estimating models for two separate subsets of landowners. One subset is composed of respondents who were offered a cost share of 50% or less, while the other subset of respondents were offered a cost share of 60% or greater.

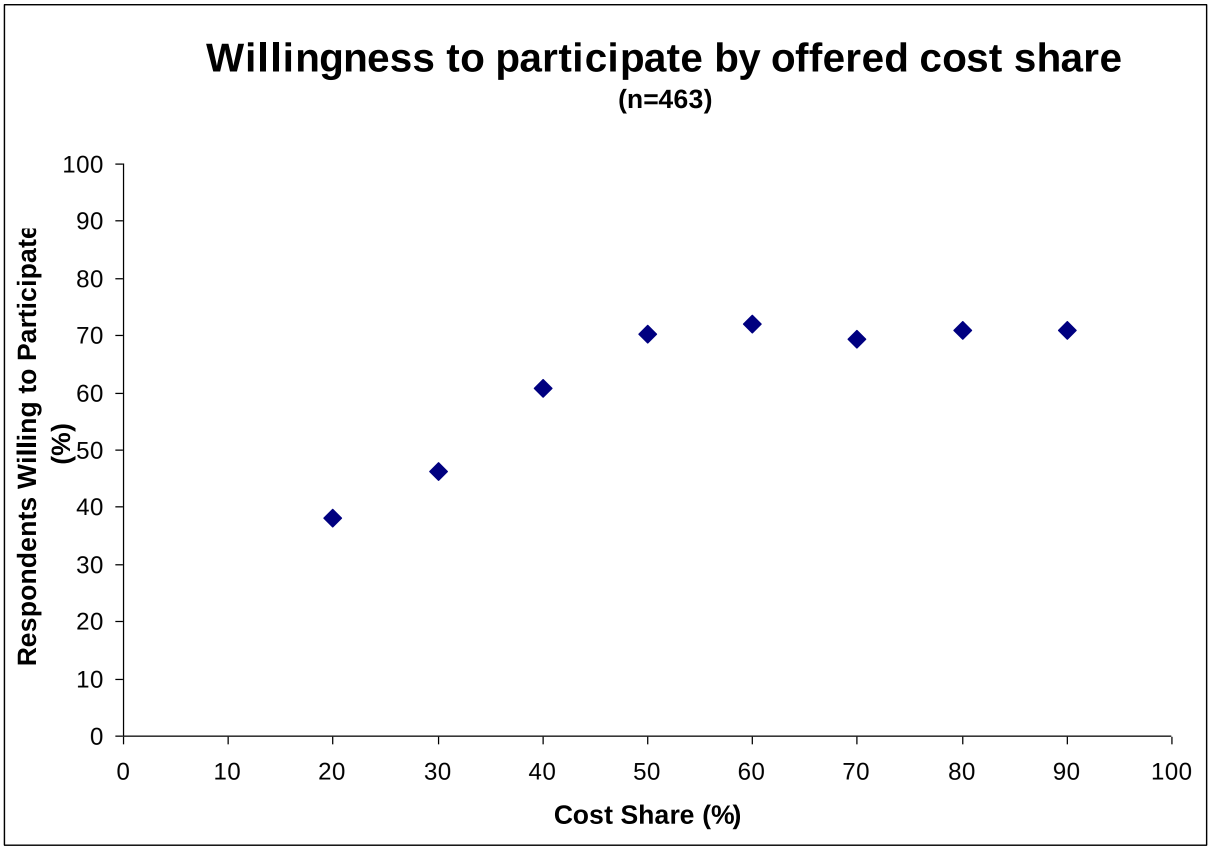

Figure 9. The raw data describing average willingness to participate by the cost share level offered.

In the low cost share model (Table 3), cost share had a positive effect on willingness to participate, which was significant at the 5% level. Acres of crop land, preferences, and low debt level were significant factors in the overall model, but were not significant at the 10% level in the low cost share model. The coefficient estimates for crop land and low debt level were higher in the low cost share model, but their standard errors were also higher. The lower number of observations (n=172) in this model may be the cause of the increased standard errors for these estimates.

Table 3. Logistic regression results of the Low Cost Share Model, which was estimated using a subset of the survey data in which offered cost share was 50% or less. The dependent variable is willingness to participate in the cost share program.

Low cost share (50% or less) (n=172) Dep. Var: WTP (1=yes)		
Variable	Coefficient Estimate	S.E.
Constant	-3.9780***	1.4718
Cost Share (%)	0.0368**	0.0164
Property characteristics		
ln(Forest land)	0.3083*	0.1713
Crop land (ac)	0.0037	0.0024
Pine adjacent to property (1=yes)	0.8841**	0.4292
Landowner characteristics		
Age (years)	0.0026	0.0164
College education (1=yes)	0.8661**	0.3871
Resides off forest (1=yes)	-0.4827	0.3637
Aesthetic or env. pref. (1=yes)	0.4045	0.3770
Income $60,000 to $99,999	-0.1578	0.4208
Income >$100,000	0.1235	0.4541
Debt < $10,000	1.0035	0.6843
Number of observations = 172	* Significant at 10%	
Log likelihood = -99.4160	** Significant at 5%	
Likelihood ratio χ^2 statistic for model = 38.12***	*** Significant at 1%	

In the high cost share model (Table 4) we did not find evidence that increases in cost share level had any effect on willingness to participate at the 10% level. The standard error for the cost sharing coefficient estimate was similar to that of the low cost share model, as was the number of observations (n=182). However, the coefficient estimate itself was not statistically different from zero. In fact, in this high cost share level model there was not evidence that any of our explanatory variables had a significant effect on willingness to participate at the 10% level, with the exception of aesthetic and environmental preferences. It may be the case that most of the variables used in these models have reduced importance in explaining willingness to participate in the program when the costs of participation are low, as suggested by lower coefficient estimates. Conversely, some landowners may be free to act on their preferences when the financial costs of doing so are low.

Table 4. Logistic regression results of the High Cost Share Model, which was estimated using a subset of the survey data in which offered cost share was 60% or greater. The dependent variable is willingness to participate in the cost share program.

High cost share (60% or greater) (n=182)	Dep. Var: WTP (1=yes)	
Variable	Coefficient Estimate	S.E.
Constant	-0.7916	1.6124
Cost Share (%)	0.0059	0.0164
Property characteristics		
ln(Forest land)	0.1094	0.1628
Crop land (ac)	0.0026	0.0024
Pine adjacent to property (1=yes)	0.6671	0.4106
Landowner characteristics		
Age (years)	-0.0097	0.0158
College education (1=yes)	0.3951	0.3804
Resides off forest (1=yes)	-0.1298	0.3798
Aesthetic or env. pref. (1=yes)	0.7066*	0.4063
Income $60,000 to $99,999	0.6718	0.4658
Income >$100,000	0.6103	0.4740
Debt <$10,000	0.8683	0.6865
Number of observations = 182	* Significant at 10%	
Log likelihood = -95.4799	** Significant at 5%	
Likelihood ratio χ^2 statistic for model = 19.04*	*** Significant at 1%	

The results of these models indicate that when the cost of PCT is reduced by 60% or greater, marginal increases in cost share level have little effect on willingness to participate (Figure 10). Once the cost of PCT reaches a low enough level, it appears that most landowners who have an interest in the PBBPP will participate. Other landowners may simply be uninterested in the program and unwilling to participate, regardless of the costs involved.

Perhaps these landowners are averse to government involvement with their personal property, are not convinced that PCT will yield any positive return on investment, or do not have the buying power to implement the thinning, since cost sharing is structured as a reimbursement paid after satisfactory completion of PCT operations.

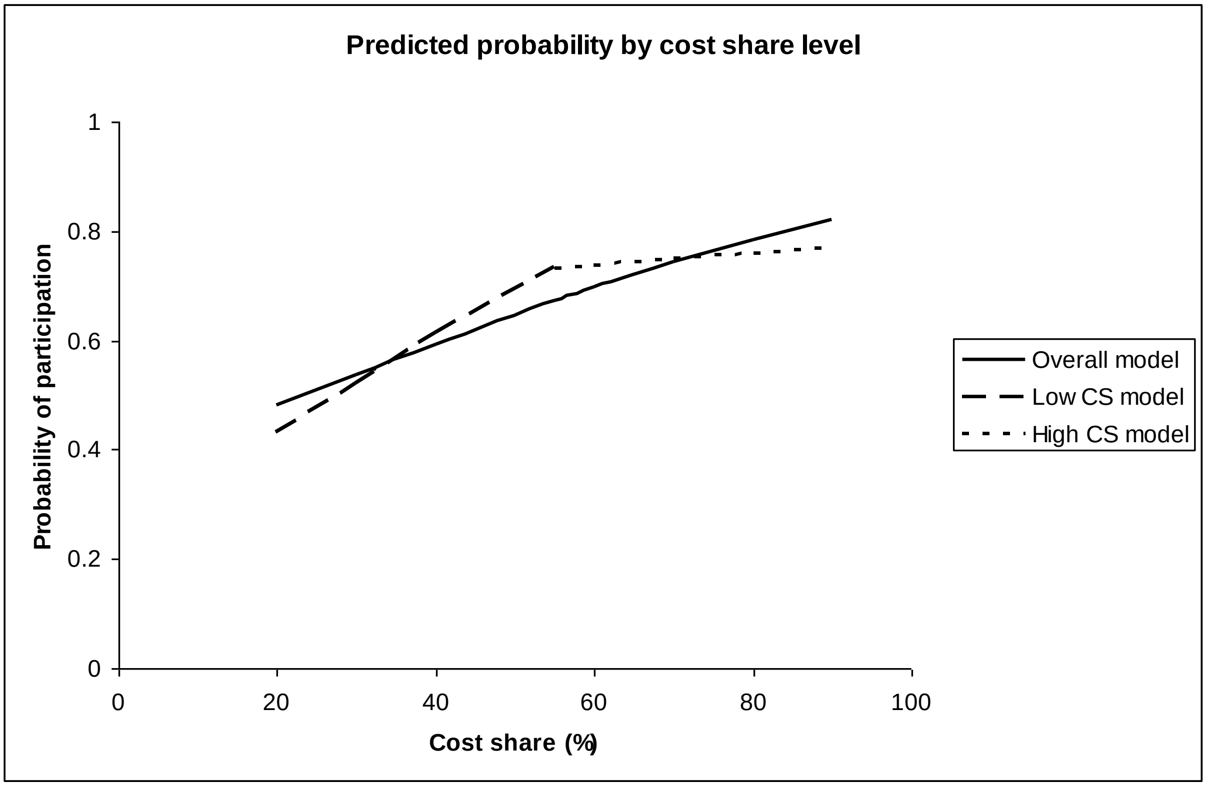

Figure 10. The estimated relationships between cost share level (%) and probability of participation in the cost share program for our average landowner from the Low Cost Share Model, the High Cost Share Model, and the Overall Model.

5.3 Marginal effects

Calculating and comparing the effect on the probability of participation from small changes in the explanatory variables using estimated model parameters provides a more explicit way to describe willingness to participate (Table 5). Marginal effects also allow for an evaluation of the practical importance of variables, along with the statistical significance already reported. The response probability used in this study is the logit function (Equation 17), so the partial effect of a small change in an independent variable on the probability of participation depends on the magnitude of that variable and of all other explanatory variables. Here, we follow a common method of calculating marginal effects[i] in the forest economics literature (Hyberg and Holthausen 1989, Dennis 1990, Bell et al. 1994, Nagubadi et al. 1996, Royer 1987) which is to set all explanatory variables to their mean values and calculate the marginal effects for the "average landowner." For simplicity in the remainder of this section, the percent change in probability that a landowner will be willing to participate is referred to as a change in the probability of participation. The marginal effects estimated in the overall model of cost sharing are discussed first, followed by notable differences in the marginal effects calculated from the low cost share and high cost share models.

Table 5. Marginal effects of the explanatory variables on willingness to participate.

Marginal Effects Dep. Var: Willing to Participate (1=yes)				
Variable	Interpretation	Overall model	Low cost share	High cost share
Cost Share (%)	$(\%\partial y)/\partial x =$	0.0050***[A]	0.0091**[B]	0.0011[C]
Property characteristics				
ln(Forest land)	$(\%\partial y)/(\%\partial x) =$	0.0446*	0.0760*	0.0199
Crop land	$(\%\partial y)/\partial x =$	0.0007*	0.0009	0.0005
Adjacent pine stands (1=yes)	$(\%\partial y)/\partial x^D =$	0.1664**	0.2175**	0.1312
Landowner characteristics				
Age (years)	$(\%\partial y)/\partial x =$	-0.0014	0.0006	-0.0018
College education (1=yes)	$(\%\partial y)/\partial x^D =$	0.1615***	0.2117**	0.0722
Resides off forest (1=yes)	$(\%\partial y)/\partial x^D =$	-0.0779	-0.1189	-0.0237
Aesthetic or env. pref. (1=yes)	$(\%\partial y)/\partial x^D =$	0.1128**	0.0987	0.1240
Income \$60,000 to \$99,999	$(\%\partial y)/\partial x^D =$	0.0445	-0.0390	0.1153
Income >\$100,000	$(\%\partial y)/\partial x^D =$	0.0660	0.0304	0.1055
Debt (non zero) < \$10,000	$(\%\partial y)/\partial x^D =$	0.1732**	0.2232*	0.1296

[A] Mean value = 55.3 (%)
[B] Mean value = 33.8 (%)
[C] Mean value = 75.5 (%)
[D] For a discrete change from 0 to 1

* Significant at 10%
** Significant at 5%
*** Significant at 1%

The marginal effect of cost sharing estimated in the overall model is 0.0050, meaning that probability of participation changes at a rate of 0.50 percentage points per one percent change in cost share, for marginal changes in cost share level. If this rate continued for a 10% increase in cost share from its mean value, 55% to 65%, the probability of participation would increase 0.050, or 5.0 percentage points. Because of the natural log transformation of forest landholding size, its marginal effect, 0.0446 is interpreted as a percent change in the probability of participation for a marginal percent change in forest landholding size. If this rate of change holds for a 100% change[7] in forest landholding size, or a doubling of forest land from its mean value of 97 acres[8], the probability of participation would increase by 4.46 percentage points. Probability of participation increases at a rate of 0.0007 per acre of crop land holdings when crop land increases marginally from its mean value of 53 acres. If this rate of change holds for a 53 acre increase in crop land, the probability of participation will increase by 3.71 percentage points. A doubling of crop land from its mean value has a somewhat smaller effect on the probability of participation than does a doubling of forest land from its mean value.

Factors represented by binary dummy variables do not allow calculation of truly marginal effects, because there cannot be marginal changes in these variables. Instead, the difference in probability when these variables change from 0 to 1 is reported as their marginal effect. The probability of participation for landowners with pine on adjacent ownerships is 16.64 percentage points higher than those whose property is bordered by other land types. The probability of participation for landowners with a college education is 16.15 percentage points higher than for

[7] A 100% change in forest landholding size is a reasonable change given the wide range and variation of forested acreage within our data. Forested acreage ranged from a minimum value of 5 acres to a maximum value of 8,000 acres with a standard deviation of 576 acres.

[8] The mean value of forest land was 236 ac. The mean value of ln(forest land) was about 4.57, which translates to about 97 acres when the anti-log is taken. This mean value is less influenced by large outliers and is fairly close to the median of forest land which is 95 acres.

landowners without. Landowners who expressed preference for aesthetic or environmental quality are more likely to participate by 11.28 percentage points than those who did not express this preference. While the marginal effect of this preference is statistically different from zero at the 5% level, it is the lowest probability change calculated for a discrete explanatory variable. Landowners with a positive level of debt less than $10,000 are more likely to participate than others by 17.32 percentage points, which is the strongest probability change calculated for a discrete explanatory variable. The marginal effects calculated in the overall model for age, off forest residence, and income level are not statistically different from zero.

The marginal effect of cost sharing calculated in the low cost share model (Table 3) is 0.0091, which represents a somewhat higher rate of change in probability of participation than was estimated in the overall model. If this rate holds for a 10% increase in cost share from its mean value of 34% (in the low cost share subset) to 44%, the probability of participation increases by 9.1 percentage points. In the high cost share model, the marginal effect was not statistically different from zero. The higher marginal effect of cost sharing from the low model and the non-significant marginal effect from the high cost share model indicate that cost sharing has a stronger effect on probability of participation when the costs of thinning are high.

The marginal effects of forest land, pine on adjacent ownerships, college education, and low debt level were also higher in the low cost share model than in the overall model, but were not statistically different from zero in the high cost share model. These differences in marginal effects across the three models support the implication that they are important factors in predicting participation when costs are high, but have less importance when thinning costs are substantially reduced. The marginal effect of a low debt level in the low cost share model, is statistically significant at the 10% level, and demonstrates that a low debt level is important when costs are high, despite the fact that the coefficient estimate was not statistically different from zero. The marginal effect of preferences for aesthetic or environmental quality was not statistically different from zero in the low cost share model, but in the high cost share model the marginal effect of preference was greater than in the overall model. While other factors may have decreased importance in predicting participation when costs are low, these preferences have a stronger marginal effect when costs are low, perhaps because landowners are free to act on their preferences once costs are lowered.

5.4 Large scale implications of cost sharing

So far, the results of the econometric analysis have been discussed in terms of an individual landowner's willingness to participate. However, the externality involving SPB risk reduction is a large scale problem, and its outcome depends on the aggregation of many individual landowner decisions. The relationship between cost sharing and willingness to participate estimated in this study can be used to evaluate some of the large scale effects involved in cost sharing. One such effect is the potential for cost sharing to leverage public funding by "sharing financial responsibility with landowners" (Nowak et al. 2008). Another is the potential substitution effect in which landowners receive a bonus for management they would have implemented anyway (Kluender et al. 1999, Cohen 1983). Other large scale aspects of cost sharing elude evaluation. Since the societal benefits of risk reduction through increased thinning across the landscape are unknown, the social optimum acreage to be thinned, net benefits to society, and deadweight loss of cost sharing cannot be calculated.

A few assumptions are necessary to scale up the estimated probabilities for large scale analysis. These assumptions are:

1) Landowners are identical and have the personal and property characteristics of the average landowner in our survey.

2) The probability of participation estimated for an individual landowner under a given cost share level is translated to the proportion of the relevant population which participates under a given cost share level.

3) The relevant population of landowners who would qualify for the thinning cost share in Virginia is 1,000. This is a strong assumption, and there is little basis available to support or oppose it, but only the magnitudes of cost share effects are sensitive to it.

4) The total cost of PCT is assumed to be $110 per acre. This assumption is based on records of actual costs per acre of 478 PCT treatments enrolled in the cost share program in Virginia from 2004 to 2009 which averaged to $112.16 per acre.

5) 46 acres are treated per landowner. This assumption is also based on records of actual PCT treatments enrolled in the cost share program which averaged to 45.8 acres.

While the magnitude of large scale cost share effects like substitution and leveraging are sensitive to assumptions 3-5, the relationships shown between these effects and cost share level are not sensitive to these assumptions concerning population, cost of thinning, and acreage treated per landowner.

Under assumptions 1-5, a curve estimating the marginal benefits of PCT to landowners can be plotted (Figure 11). This marginal private benefit curve (*MPB*) is calculated as follows,

MPB = [*P*(*cost share*)][*Relevant Population*][*acres treated per landowner*]

or,

$$MPB = \left(\frac{e^{\hat{\beta} x}}{1 + e^{\hat{\beta} x}} \right) (1{,}000)(46)$$

where, P is the estimated probability of participation which is a function of cost share level, $\hat{\beta}$ are the estimated coefficients of the low and high cost share models (low & high cost share model tables) and x is the vector of explanatory variables used to estimate probability of participation. Cost share level is varied from 0% to 90% and all other explanatory variables are set at the mean values reported in our survey.

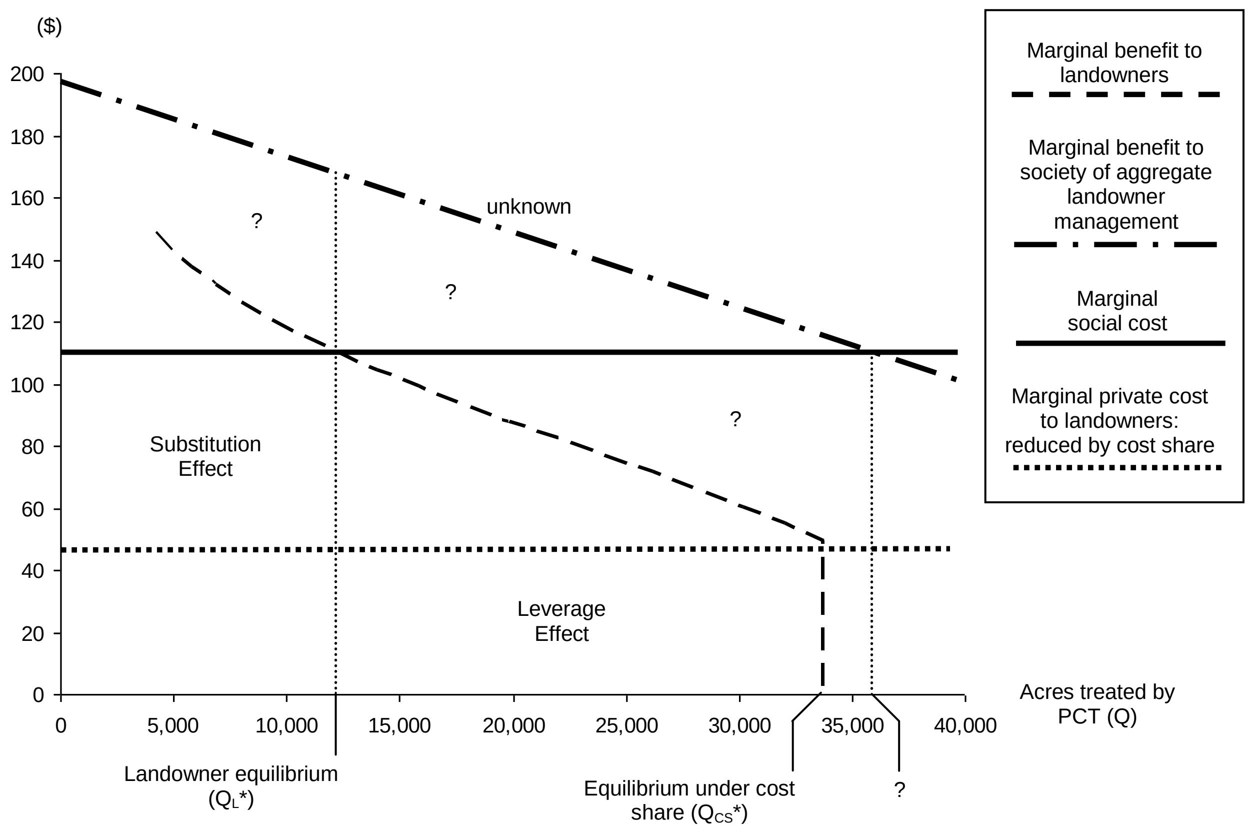

Figure 11. The marginal costs and benefits of pre-commercial thinning. (The marginal benefits ($) to landowners of increasing acres treated by pre-commercial thinning (Q) are plotted using the estimated relationship between cost share level and probability of participation, together with assumptions about landowner population size, acreage per landowner, total cost, and the simplifying assumption that all landowners are identical to our average landowner. Marginal benefits to society of pre-commercial thinning are unknown, as are net benefits, and potential deadweight loss. However the substitution effect and leverage effect of cost sharing can be calculated.)

Since estimation results show that marginal increases in cost share level beyond 60% do not have a significant effect on participation, a cost share level of 60% represents a corner solution to maximize net benefits when the marginal benefits to society are high (Figure 11) and budget constraints are not binding on the cost share program (meaning that qualified landowners are not turned away due to lack of funding). However, the benefits to society are not explicitly known, which means that a 60% cost share level could over provide thinning, resulting in deadweight loss.

The leverage effect (*L*) here refers to thinning investments made by private landowners on acres enrolled because of incentive payments (Figure 12) and is calculated,

$$L = (Q_{CS} - Q_L)(MPC)$$

where Q_{CS} is the total number of acres thinned under cost sharing, Q_L is the total number of acres thinned in the absence of cost sharing, and *MPC* is the marginal private cost of thinning- the portion of the marginal social costs of thinning not paid by cost sharing. This leverage effect is maximized at a cost share level of about 50%.

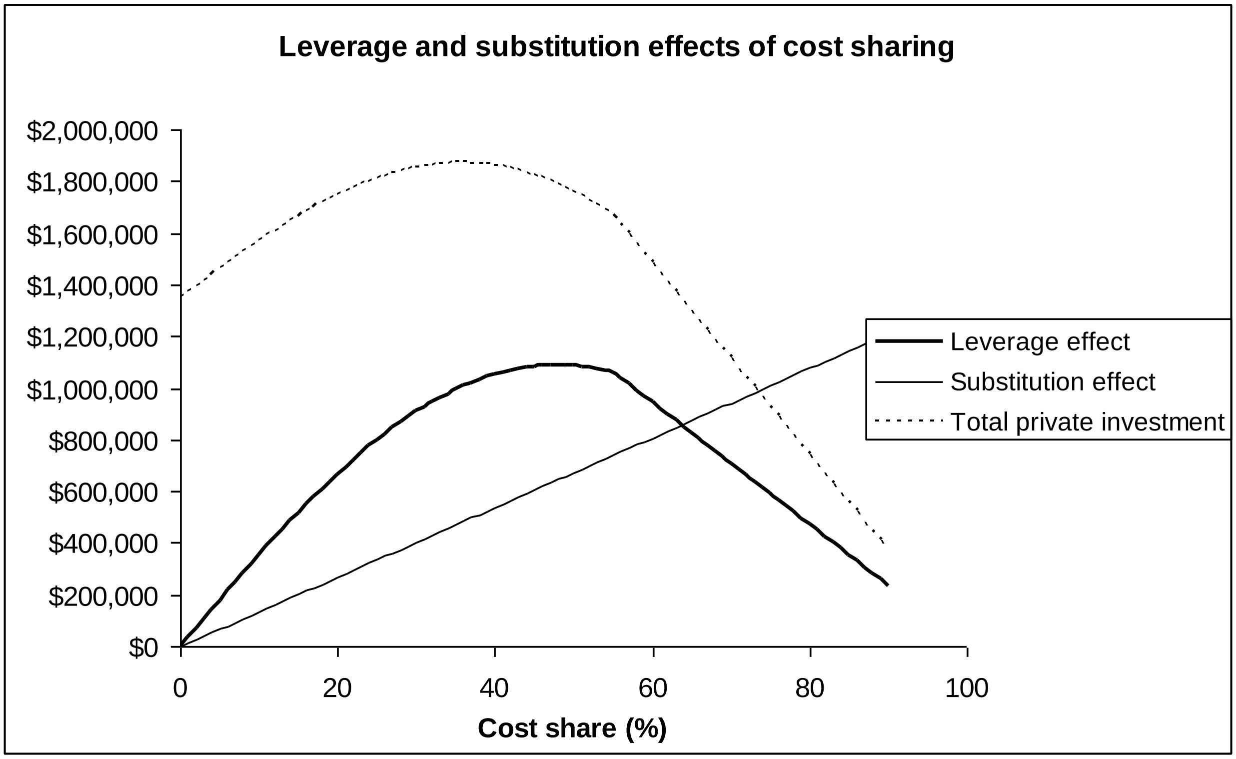

Figure 12. The leverage effect, substitution effect, and total private investment associated with cost sharing. (These are plotted over increasing cost share levels. The magnitudes ($) shown depend on assumptions about landowner population size, acreage per landowner, and total cost. However, the relationships shown (i.e. cost share level at which total private investment peaks) do not depend on these assumptions.)

If there are a positive number of landowners who would choose to PCT in the absence of cost sharing, than a substitution effect must be present since cost sharing does not influence management on these acres, but is likely to be accepted as payment for them. The substitution effect (*S*) was calculated,

$$S = Q_L\left(MSC - MPC\right)$$

where *MSC* is the marginal social cost of PCT, which under assumption (4) is $110 per acre. The amount of public investment in thinning substituted for private investment increases linearly as the level of cost share increases.

As cost share level increases from zero, newly enrolled acreage increases, stimulating private investment. This newly enrolled acreage expands as marginal private costs are decreased by cost sharing, but the proportion of thinning costs paid by landowners also decreases. As a result, the costs borne by landowners on newly enrolled acreage peaks at a cost share level of about 50%, and is referred to as the leverage effect. Simultaneously, substitution of public investment for private investment is occurring on lands that would have been thinned without incentive payments, dampening the effect of cost sharing. This causes the total investment in thinning made by landowners to peak at a lower cost share level (around 40%) than the leverage effect.

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[i] $P(WTP=1)=y$

$\beta x=\beta_0+\beta_1 x_1+\beta_2 x_2 \ldots$

$$\frac{\partial y}{\partial x_n}=\left(\frac{e^{\beta x}}{\left(1+e^{\beta x}\right)^2}\right)\beta_n=y(1-y)\beta_n$$ Where x_n is a continuous variable.

Marginal effects for dummy variable x_1 which is equal to one or zero.

$$P_0=\left(\frac{e^{\beta_0+\beta_1 0+\beta_2 x_2}}{\left(1+e^{\beta_0+\beta_1 0+\beta_2 x_2}\right)}\right)$$ Where x_1 is set to zero.

$$P_1=\left(\frac{e^{\beta_0+\beta_1+\beta_2 x_2}}{\left(1+e^{\beta_0+\beta_1+\beta_2 x_2}\right)}\right)$$ Where x_1 is set to one.

$$\frac{\partial y}{\partial x_1}=P_1-P_0$$

Chapter 6. Conclusions and implications

This study examines the role of a cost share payment in the decision to pre-commercially thin a densely stocked juvenile stand. The lack of penalty or compensation mechanisms among landowners for management practices which alter southern pine beetle risk leads to an externality in which the practice of pre-commercial thinning may be underprovided in the absence of government intervention. This externality could be corrected by leveraging public funding through a cost share program, if landowners respond to the incentive. To study the potential for cost sharing to influence landowner management, a referendum style survey was conducted to gauge landowners' willingness to participate in the program under varying levels of cost share reimbursement. A wider and more detailed range of cost share payment levels were used than have been in previous studies of cost share incentives. The results of an empirical analysis of this survey provide insights on responsiveness of landowners to cost sharing in the specific case of the pine bark beetle prevention program in Virginia. The marginal benefits to society of increased thinning across the landscape are unknown, so the optimal acreage to be thinned, optimal cost share level, and potential deadweight loss of cost sharing (Boyd et al. 1988) are also unknown.

Across the population of landowners surveyed, cost sharing had a positive overall effect on willingness to participate that was both statistically significant and practically important. Perhaps the strongest implication of this research is that if the cost share incentive is rescinded, policy makers should expect to see 64% less thinning of juvenile densely stocked pine stands, than at the current cost share level of 60%. To the extent that southern pine beetle risk reduction is external to market forces, rescinding the cost share will result in increased risk on a large scale, which could result in the loss of property value to individual landowners and seriously threaten local economies dependent on timber.

The results of this study also indicate that landowners are more likely to participate when pine is present on adjacent ownerships. When other pine stands are adjacent, landowners may gain experience from observing these stands and communicating with their neighbors. These landowners may also perceive an increased level of risk and liability from seeing or hearing about southern pine beetle infestations. They may be more informed about active management practices and have better access to contractors. Regardless of the causal relationships involved, this phenomenon offers valuable information for program implementation. Program enrollment is expected to be higher in areas with abundant, contiguous pine ownership. The large scale benefits of southern pine beetle risk reduction could also be higher in these areas, and targeting them is recommended to boost the efficiency of the cost share program.

A closer examination of the effects of different levels of cost sharing revealed that increasing reimbursement levels beyond 60% is unlikely to change program participation, and is not recommended. On the other hand, reducing the cost share level below 50% will reduce program participation if program budget constraints are not binding. If program budget constraints are binding and qualified landowners must be denied incentive payments, program administrators can use the results of this study to weigh the tradeoffs involved in reducing the cost share level.

A number of property characteristics and personal characteristics of landowners, such as landholding size, education and others, were found to significantly influence willingness to participate. Cost sharing appears to carry less importance when other factors have a strong positive influence on willingness to participate. The substitution effect of which the cost share literature warns (Kluender et al. 1999, Cohen 1983) seems to be at work within a portion of the population surveyed, dampening the impact of cost sharing. Despite this result, narrowing the eligibility parameters of the cost share program based upon the property and personal characteristics of landowners is difficult to accomplish and may be seen as unfair. Targeting certain types of landowners may be more feasible than restricting others. To some degree, landowners with larger landholdings may be good targets for program implementation since they are more likely to participate and may have more acreage in need of thinning. However, landowners with very large landholdings show a weaker response to cost sharing, and may be more likely to implement a thinning without a cost share incentive. While the existing program limit of $10,000 per landowner per year does not exclude any type of landowner, it does effectively limit the acreage they can treat, which to some extent should limit incentive payments given to landowners with large landholdings. In cases where a landowner has large acreages that could benefit from thinning, the $10,000 limit may become binding and encourage efficiency and treatment of additional acres not covered by cost sharing, as noted by Nowak et al. (2008).

The probability of participation estimated in this study depends on the assumption that landowners know about the program and whether they qualify for it, since the survey provided them with this information. However, according to survey responses this may not be the case since 74% of landowners in our sample area indicated that they did not know there was a cost share available in Virginia for pre-commercial thinning, even though 36% of respondents had previously participated in other forestry incentive programs such as the Reforestation of Timberlands program, the Conservation Reserve Program, or the Environmental Quality Incentives Program. Furthermore, results suggest that a substantial portion of landowners are not interested in the program even when costs are greatly reduced through cost sharing. If increased participation is desirable, education and program marketing efforts should be considered along with cost sharing offers.

The intent of this study is to understand the implications of changes to Virginia's Pine Bark Beetle Prevention Program, especially regarding impacts on program participation. This analysis cannot identify an "optimal" level of cost sharing in the normative sense. In order to provide such a recommendation, knowledge of the explicit effects of regional changes in forest management on southern pine beetle risks and hazards is required. Empirically estimating these effects could be a productive direction for future research. In addition, development of a stand value optimization model could provide insights on how individual budget constraints and varying levels of cost affect the financial viability pre-commercial thinning. Modeling forest management decisions at the stand level could also shed light on the forest conditions which can be expected to follow a pre-commercial thinning on non-industrial private forest lands, and provide a useful tool for discussing management options with individual landowners.

Literature Cited

Amacher, G., C. Conway and J. Sullivan. 2003. Econometric analyses of nonindustrial forest landowners: Is there anything left to study?. *Journal of Forest Economics*. 9(Dec.): 137-164.

Amacher, G., E. Koskela and M. Ollikainen. 2004. Forest rotations and stand interdependency: ownership structure and timing of decisions. *Natural Resource Modeling*. 17(1), 1-43.

Amacher, G., M. Ollikainen and E. Koskella. 2009. Economics of forest resources. The MIT Press, Cambridge, London, 397 p.

Amateis, R. 2000. Modeling response to thinning in loblolly pine plantations. *Southern Journal of Applied Forestry*. 24(1), 17-22.

Beach, R., S. Pattanayak, J. Chang, B. Murray and R. Abt. 2005. Econometric studies of non-industrial private forest management a review and synthesis. *Forest Policy and Economics*. 7(3), 261-281.

Bell, C., R. Roberts, B. English and W. Park. 1994. A logit analysis of participation in Tennessee's Forest Stewardship Program. *Journal of Agricultural and Applied Economics*. 26(2): 463-472.

Berisford, C. 1980. Natural enemies and associated organisms. In: The southern pine beetle. Thatcher, R., J. Searcy, J. Coster and G. Hertel (eds.). US Department of Agriculture. Forest Service. Science and Education Administration Technical Bulletin 1631. 266 p.

Boyd, R., B. Daniels, R. Fallon and W. Hyde. 1988. Measuring the effectiveness of public forestry assistance programs. *Forest Ecology and Management*. 23(4), 297-309.

Brown, M., T. Nebeker and C. Honea. 1987 Thinning increases loblolly pine vigor and resistance to bark beetles. *Southern Journal of Applied Forestry*. 11(1), 28-31.

Burkhart, H., H. Haney, J. Newberry, W. Leuschner, C. Morris and D. Reed. 1986. Evaluation of thinning for reduction of losses from southern pine beetle attack in loblolly pine stands. *Southern Journal of Applied Forestry*. 10(4): 105-108.

Cain, M. 1993. Ten-year results from precommercial strip-thinning: paradigm lost or reinforced?. *Southern Journal of Applied Forestry*. 17(1), 16-21.

Clarke, S., S. Salom, R. Billings, C. Berisford, W. Upton, Q. McClellan and M. Dalusky. 1999. A scentsible approach to controlling southern pine beetles: two new tactics using verbenone. *Journal of Forestry*. 97(7), 26-31.

Clarke, S. and J. Nowak. 2009. US For. Serv., Portland OR. Forest insect and disease leaflet 49.

Cohen, M. 1983. Public cost-share programs and private investment in forestry in the south. In: Royer, J. and C. Risbrudt. (Eds.), Symposium proceedings, Non-industrial private forests: A review of economic and policy studies, Duke University, Durham, NC. 181-188.

Conway, C., G. Amacher, J. Sullivan and D. Wear. 2003. Decisions nonindustrial forest landowner make: an empirical examination. *Journal of Forest Economics*. 9(3), 181-203.

Conway, C. 2002. Testing the reservation price behavior of nonindustrial forest landowners. PhD dissertation, Virginia Tech Department of Forestry, Blacksburg, VA. USA.

Cook, S. and F. Hain. 1987. Susceptibility of trees to southern pine beetle, *Dendroctonus frontalis* (Coleoptera: Scolytidae). *Environmental Entomology*. 16(1), 9-14.

Coulson, R. 1980. Population dynamics. In: The southern pine beetle. Thatcher, R., J. Searcy, J. Coster and G. Hertel (eds.). US Department of Agriculture. Forest Service. Science and Education Administration Technical Bulletin 1631. Washington DC, 266 p.

Cramer, J. 1991, The logit model: an introduction for economists. Edward Arnold, London. 110 p.

Dennis, D. 1989. An economic analysis of harvest behavior: integrating forest and ownership characteristics. *Forest Science*. 35(4), 1088-1104.

Dennis, D. 1990. A probit analysis of the harvest decision using pooled time-series and cross-sectional data. *Journal of Environmental Economics and Management*. 18(2), 176-187.

DeSteiguer, J. 1984. Impact of cost-share programs on private reforestation investment. *Forest Science*. 30(3), 697-704.

Dillman, D., J. Smyth and L. Christian. 2009. Internet, mail, and mixed-mode surveys: the tailored design method. *John Wiley and Sons*. 499 p.

Dubois, M., C. Erwin and T. Straka. 1999. Costs and cost trends for forestry practices in the South. *Forest Landowner*. 58, 3-11.

Friedenberg, N., S. Sarkar, N. Kouchoukos, R. Billings and M. Ayres. 2008. Temperature extremes, density dependence, and southern pine beetle (Coleoptera: Curculionidae) population dynamics in east Texas. *Environmental Entomology*. 37(3), 650-659.

Gara, R. and J. Coster. 1968. Studies on the attack behavior of the southern pine beetle III. Sequence of tree infestation within stands. *Contrib. Boyce Thompson Inst*. 24, 77-86.

Grano, C. 1969. Precommercial thinning of loblolly pine. *Journal of Forestry*. 67(11), 825-827.

Gumpertz, M., C. Wu and J. Pye. 2000. Logistic regression for southern pine beetle outbreaks with spatial and temporal autocorrelation. *Forest Science*. 46(1), 95-107.

Hardie, I. and P. Parks. 1996. Program enrollment and acreage response to reforestation cost-sharing programs. *Land Economics*. 72(2), 248-260.

Hartman, R. 1976. The harvesting decision when a standing forest has value. *Economic Inquiry*. 14, 52–58.

Haywood, J. 2005. Influence of precommercial thinning and fertilization on total stem volume and lower stem form of loblolly pine. *Southern Journal of Applied Forestry*. 29(4), 215-220.

Hedden, R. and R. Billings. 1979. Southern pine beetle: factors influencing the growth and decline of summer infestations in east Texas. *Forest Science*. 25(4), 547-556.

Hodges, J., W. Elam, W. Watson and T. Nebeker. 1979. Oleoresin characteristics and susceptibility of four southern pines to southern pine beetle (Coleoptera: Scolytidae) attacks. *Canadian Entomologist*. 111(8), 889-896.

Hyberg, B. and D. Holthausen. 1989. The behavior of non-industrial private forest landowners. *Canadian Journal of Forest Research*. 19, 1014-1023.

Johnson, P. and J. Coster. 1978. Probability of attack by southern pine beetle in relation to distance from an attractive host tree. *Forest Science*. 24(4), 574-580.

Joshi, S., and K. Arano. 2009. Determinants of private forest management decisions: a study on West Virginia NIPF landowners. *Forest Policy and Economics*. 11, 118-125

Kline, J., R. Alig and R. Johnson. 2000. Fostering the production of nontimber services among forest owners with heterogeneous objectives. *Forest Science*. 46(2), 302-311.

Kline, J., B. Butler and R. Alig. 2002. Tree planting in the South: what does the future hold?. *Southern Journal of Applied Forestry*. 26(2), 99-107.

Kluender, R., T. Walkingstick and J. Pickett. 1999. The use of forestry incentives by nonindustrial forest landowner groups: is it time for a reassessment of where we spend our tax dollars?. *Natural Resources Journal*. 39(4), 799-818.

Koskela, E. and M. Ollikainen. 2001. Optimal private and public harvesting under spatial and temporal interdependence. *Forest Science*. 47(4), 596-607.

Krist, F. Jr., F. Sapio and B. Tkacz. 2007. Mapping risk from forest insects and diseases. U.S. For. Serv. FHTET 2007-06. 115 p.

Ku, T., J. Sweeney and V. Shelburne. 1980. Site and stand conditions associated with southern pine beetle outbreaks in Arkansas: a hazard-rating system. *Southern Journal of Applied Forestry*. 4(2), 103-106.

Kuuluvainen, J., H. Karppinen and V. Ovaskainen. 1996. Landowner objectives and nonindustrial private timber supply. *Forest Science*. 42(3), 300-309.

Kuuluvainen, J., and J. Salo. 1991. Timber supply and life cycle harvest of nonindustrial private forest owners: an empirical analysis of the Finnish case. *Forest Science*. 37(4), 1011-1029.

Lee, K., H. Kaiser, and R. Alig. 1992. Substitution of public for private funding in planting southern pine. *Southern Journal of Applied Forestry*. 16(4), 204-208.

Lorio, P., F. Stephen and T. Paine. 1995. Environment and ontogeny modify loblolly pine response to induced water deficits and bark beetle attack. *Forest Ecology and Management*. 73(1-3), 97-110.

Mawby, W., F. Hain and C. Doggett. 1989. Endemic and epidemic populations of southern pine beetle: implications of the two-phase model for forest managers. *Forest Science*. 35(4), 1075-1087.

Mehmood, S. and D. Zhang. 2002. Causes for continuation of state-cost share programs for nonindustrial private forest landowners. *Forest Science*. 48(3), 471-478.

Michaels, P. 1984. Climate and the southern pine beetle in Atlantic Coastal and Piedmont regions. *Forest Science*. 30(1), 143-156.

Nagubadi, V., K. McNamara, W. Hoover and W. Mills Jr. 1996. Program participation behavior of nonindustrial forest landowners: a probit analysis. *Journal of Agricultural and Applied Economics*. 28(2), 323-336.

Nebeker, T. 2004. Advances in the control and management of the southern pine bark beetles. In: Southern forest science: past, present and future. Rauscher, H. and K. Johnsen (eds.). U.S. For. Serv. Gen. Tech. Rep. SRS-75. U.S. For. Serv., South. Res. Stn., Asheville, NC. 155-160.

Nebeker, T. and J. Hodges. 1985. Thinning and harvesting to minimize site and stand disturbance and susceptibility to bark beetle and disease attacks. In: Branaham, S. and Thatcher, R. (Eds.), Integrated Pest Management Research Symposium, Proceedings. GTR-SO-56. U.S. Department of Agriculture, Forest Service, Southern Research Station, New Orleans, LA. 263–271.

Nowak, J., C. Asaro, K. Klepzig and R. Billings. 2008. The southern pine beetle prevention initiative: working for healthier forests. *Journal of Forestry*. 106(5), 261-267.

Ovaskainen, V., H. Hanninen, J. Mikkola and E. Lehtonen. 2006. Cost-sharing and private timber stand improvements: a two-step estimation approach. *Forest Science*. 52(1), 44-54.

Paine, T., F. Stephen and H. Taha. 1984. Conceptual model of infestation probability based on bark beetle abundance and host tree susceptibility. *Environmental Entomology*. 13(3), 619-624.

Payne, T. 1980. Life history and habitats. In: The southern pine beetle. Thatcher, R., J. Searcy, J. Coster and G. Hertel (eds.). US Department of Agriculture. Forest Service. Science and Education Administration Technical Bulletin 1631. 266 p.

Price, T., C. Doggett, J. Pye and B. Smith. 1998. A history of southern pine beetle outbreaks in the southeastern United States. Tech. rep., South. For. Insect Work. Group, Georgia Forestry Commission, Macon, GA. 71 p.

Reed, D., H. Burkhart, W. Leuschner and R. Hedden. 1981. A severity model for southern pine beetle infestations. *Forest Science*. 27(2), 290-296.

Romm, J., R. Tuazon and C. Washburn. 1987. Relating forestry investment to the characteristics of nonindustrial private forestland owners in northern California. *Forest Science*. 33(1), 197-209.

Rossi, F., D. Carter, J. Alavalapati and J. Nowak. 2010. Forest landowner participation in state-administered southern pine beetle prevention cost-share programs. *Southern Journal of Applied Forestry*. 34(3), 110-117.

Royer, J. 1987. Determinants of reforestation behavior among southern landowners. *Forest Science*. 33(3), 654-667.

Royer, J. and R. Moulton. 1987. Reforestation incentives: tax incentives and cost sharing in the south. *Journal of Forestry*. 85(8), 45-47.

Salom, S., R. Billings, C. Berisford, S. Clarke, Q. McClellan, M. Dalusky, T. Robinson, and J. Johnson. 1998. Basis for technology transfer of inhibitor-based suppression tactics for the southern pine beetle. *Southern Journal of Applied Forestry*. 22(1), 24-34.

Straka, T. and S. Doolittle. 1988. Propensity of nonindustrial private forest landowners to regenerate following harvest: relationship to socioeconomic characteristics, including innovativeness. *Resource Management and Optimization*. 6(2), 121-128.

Strom, B., R. Goyer, L. Ingram Jr., G. Boyd and L. Lott. 2002. Oleoresin characteristics of progeny of loblolly pines that escaped attack by the southern pine beetle. *Forest Ecology and Management*. 158(1-3), 169-178.

Sullivan, J., G. Amacher and S. Chapman. 2005. Forest banking and forest landowners forgoing management rights for guaranteed financial returns. *Forest Policy and Economics*. 7, 381-392.

Swallow, S. and D. Wear. 1993. Spatial interactions in multiple-use forestry and substitution and wealth effects for the single stand. *Journal of Environmental Economics and Management*. 25(2), 103-120.

Sword Sayer, M., J. Goetz, J. Chambers, Z. Tang, T. Dean, J. Haywood and D. Leduc. 2004. Long-term trends in loblolly pine productivity and stand characteristics in response to thinning and fertilization in the West Gulf region. *Forest Ecology and Management*. 192(1), 71-96.

Thatcher, R. and P. Barry. 1982. Southern pine beetle. U.S. Dep. Agric. For. Insect and Dis. Leaflet 49, 7 p.

Turchin, P., P. Lorio, A. Taylor and R. Billings. 1991. Why do populations of southern pine beetles (Coleoptera: Scolytidae) fluctuate?. *Environmental Entomology*. 20(2), 401-409.

U.S. Census Bureau. 2000. American Community Survey. Available at: http://www.census.gov/acs/www/; accessed April 17, 2010.

Vokoun, M., G. Amacher, J. Sullivan and D. Wear. 2010. Examining incentives for adjacent non-industrial private forest landowners to cooperate. *Forest Policy and Economics*. 12(2), 104-110.

Wooldridge, J. 2009. Introductory econometrics: a modern approach, fourth edition. *South-Western Cengage Learning*. 865 p.

Zhang, D. and W. Flick. 2001. Sticks, carrots and reforestation investment. *Land Economics*. 77(3), 443-456.

Zhang, D., A. Hussain and J. Armstrong. 2006. Supply of hunting leases from non-industrial private forest lands in Alabama. *Human Dimensions of Wildlife: An International Journal*. 11(1), 1-14.

APPENDIX A. Log of sample selection process

Mailing List Log
Landowner list is derived from lists of tax parcel ownership. The tax parcels are maintained at the county level.

County Selection

Virginia Counties with less than 16% of land area classified as medium or high hazard for SPB were dropped, leaving these 19 counties:

County	Physiographic Region
Charles City	Coastal Plain
Gloucester	Coastal Plain
Isle of Wight	Coastal Plain
King and Queen	Coastal Plain
Matthews	Coastal Plain
Prince George	Coastal Plain
Southampton	Coastal Plain
Surry	Coastal Plain
Sussex	Coastal Plain
Amelia	Piedmont
Brunswick	Piedmont
Buckingham	Piedmont
Cumberland	Piedmont
Fluvanna	Piedmont
Goochland	Piedmont
Lunenburg	Piedmont
Mecklenburg	Piedmont
Dinwiddie	Piedmont/Coastal Plain
Greensville	Piedmont/Coastal Plain

Out of these, tax parcel data was available from these 7 counties:

County	Physiographic Region
Charles City	Coastal Plain
Isle of Wight	Coastal Plain
Surry	Coastal Plain
Prince George	Coastal Plain
Fluvanna	Piedmont
Goochland	Piedmont
Dinwiddie	Piedmont/Coastal Plain

Parcel Selection

Convert Virginia Cover Type Map to Shapefile

http://www.dof.virginia.gov/gis/dwnld-2005-for-cov-I-faq.shtml info and metadata
http://webhelp.esri.com/arcgisdesktop/9.2/tutorials/Spatial_23.htm
Conversion tool box
From Raster tool set
Raster to Polygon tool

Input raster = VFCM raster
Leave Field as "VALUE"
Name: "pine_poly.shp"
In attribute table, "GRIDCODE" is the cover type, 8 = pine
Delete all polygons with GRIDCODE ≠ 8

Software:
ESRI ArcCatalog 9.3.1
ESRI ArcMap 9.3.1
ArcGIS Desktop 9.3.1

<u>Surry County</u>   Shapefile name: "SurryParcel"
1) Delete parcels without a name attached
Copy the shapefile and rename "SurryParcel_cleaned**"**
In attribute table sort by OWNERNAME1, scroll to the top and delete parcels without owner names (~60 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** SurryParcel_cleaned, **Output:** surry_pine
3) Union Surry Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input SurryParcel_cleaned **and** surry_pine > **Run Output:** surry_pine_Union
Start Editing, Open surry_pine_Union **attribute table and delete all Gridcode ≠ 8**
Check: surry_pine_Union **should now perfectly overlap with** surry_pine, **except that** surry_pine_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in surry_pine_Union **named** pine_acres
Start editing surry_pine_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing surry_pine_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename surry_pine_Union **to** surry_pinegt4ac
FINISHED
<u>Charles City County</u>   Shapefile name: "CharlesCity"
1) Delete parcels without a name attached
Copy the shapefile and rename "charles_city_cleaned**"**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~84 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** charles_city_cleaned, **Output:** charles_city_pine
3) Union Charles City Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input charles_city_cleaned **and** charles_city_pine > **Run Output:** charles_city_Union
Start Editing, Open charles_city_Union **attribute table and delete all Gridcode ≠ 8**
Check: charles_city_Union **should now perfectly overlap with** charles_city_pine, **except that** charles_city_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in charles_city_Union **named** pine_acres
Start editing charles_city_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**

Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing charles_city_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename charles_city_Union **to** charles_city_pinegt4ac
FINISHED

Goochland County   Shapefile name: "Goochland_Parcels_with_ownership"
1) Delete parcels without a name attached
Copy the shapefile and rename "goochland_cleaned**"**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~28 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** goochland_cleaned, **Output:** goochland_pine
3) Union Goochland Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input goochland_cleaned **and** goochland_pine > **Run Output:** goochland_Union
Start Editing, Open goochland_Union **attribute table and delete all Gridcode ≠ 8**
Check: goochland_Union **should now perfectly overlap with** goochland_pine, **except that** goochland_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in goochland_Union **named** pine_acres
Start editing goochland_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing goochland_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename goochland_Union **to** goochland_pinegt4ac
FINISHED

Isle of Wight County Shapefile name: "Isle of Wight Parcel Info"
1) Delete parcels without a name attached
Copy the shapefile and rename "isleofwight_cleaned**"**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~409 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** isleofwight_cleaned, **Output:** isleofwight _pine
3) Union Isle of Wight Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input isleofwight_cleaned **and** isleofwight _pine > **Run Output:** isleofwight_Union
Start Editing, Open isleofwight_Union **attribute table and delete all Gridcode ≠ 8**
Check: isleofwight_Union **should now perfectly overlap with** isleofwight_pine, **except that** isleofwight _Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in isleofwight_Union **named** pine_acres
Start editing isleofwight_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing isleofwight_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename isleofwight_Union **to** isleofwight_pinegt4ac
FINISHED

Dinwiddie County   Shapefile name: "DinwiddieParcels"
1) Delete parcels without a name attached
Copy the shapefile and rename "dinwiddie_cleaned**"**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~569 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** dinwiddie_cleaned, **Output:** dinwiddie_pine
3) Union Dinwiddie Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input dinwiddie_cleaned **and** dinwiddie_pine > **Run Output:** dinwiddie_Union
Start Editing, Open dinwiddie_Union **attribute table and delete all Gridcode ≠ 8**
Check: dinwiddie_Union **should now perfectly overlap with** dinwiddie_pine, **except that** dinwiddie_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in dinwiddie_Union **named** pine_acres
Start editing dinwiddie_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing dinwiddie_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename dinwiddie_Union **to** dinwiddie_pinegt4ac
FINISHED

<u>Prince George County</u>   Shapefile name: "PrinceGeorgeParcels"
1) Delete parcels without a name attached
Copy the shapefile and rename "prncgrge_cleaned**"**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~75 parcels)
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** prncgrge_cleaned, **Output:** prncgrge_pine
3) Union Prince George Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input prncgrge_cleaned **and** prncgrge_pine > **Run Output:** prncgrge_Union
Start Editing, Open prncgrge_Union **attribute table and delete all Gridcode ≠ 8**
Check: prncgrge_Union **should now perfectly overlap with** prncgrge_pine, **except that** prncgrge_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in prncgrge_Union **named** pine_acres
Start editing prncgrge_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing prncgrge_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename prncgrge_Union **to** prncgrge_pinegt4ac
FINISHED

Fluvanna   Shapefile name: “Fluvanna”
1) Delete parcels without a name attached
Copy the shapefile and rename “flvnna_cleaned**”**
In attribute table sort by NAME, scroll to the top and delete parcels without owner names (~644 parcels)
1a) Project Spatial Data
Imported coordinate system from nearby Dinwiddie County Parcel Data (dinwiddie_cleaned)
NAD_1983_StatePlane_Virginia_South_FIPS_4502_Feet
2) Clip pine_poly
Toolbox > Analysis Tools > Extract > Clip
Input: pine_poly, **Clip feature:** flvnna_cleaned, **Output:** flvnna_pine
3) Union Fluvanna Parcels with Pine Polygons
Toolbox > Analysis Tools > Overlay > Union
Input flvnna_cleaned **and** flvnna_pine > **Run Output:** flvnna_Union
Start Editing, Open flvnna_Union **attribute table and delete all Gridcode ≠ 8**
Check: flvnna_Union **should now perfectly overlap with** flvnna_pine, **except that** flvnna_Union **has parcel divisions and landowner info**
4) Recalculate Acreage
Help > areas, calculating in table
Create new short integer field in flvnna_Union **named** pine_acres
Start editing flvnna_Union
Right click pine_acres **heading, and Calculate Geometry use coordinate system of the data source**
Check: compare calculated acreage with measure tool acreage
5) Delete parcels with less than 5 acres of pine
Start editing flvnna_Union
Open attribute table, sort by pine_acres, **delete all polygons with** pine_acres < 5
Rename flvnna_Union **to** flvnna_pinegt4ac
FINISHED

APPENDIX B: Survey Instrument

Pine Bark Beetle Prevention Program: Virginia Forest Landowner Survey 2010

Forest Condition

We are interested in gauging the condition of the forest growing on your property.

Please answer the following questions for **all** the property you own in Virginia.

1. Approximately how many acres of each type of land use are on your property?

Please estimate these acreages as well as you can

_____ Acres of **Forest**

_____ Acres of **Crop Land**

_____ Acres of **Pasture**

_____ Acres of **Residential Land**

_____ Acres of **Another Land Use** *(Please Specify)*:

____

☐ Check this box if you cannot estimate these acreages

If there are less than 5 acres of forest on your property, we ask that you please **indicate this on question 1** and **return the survey now**. In order for this study to be statistically valid, it is **VERY IMPORTANT** that we receive your questionnaire.

Only proceed if there are 5 acres or more of forest on your property

2. How did you acquire your property?

Check all that apply and write the percentage of land that you acquired in that way.

	%
☐ Inherited……………………………….…………………...	____
☐ Purchased…………………... …………………………...	____
☐ Other *(Please Specify)*..……………………………………	____

____

3. When did you first acquire property with at least 5 acres of forest on it?

_____ Year(s) Ago

4. Does your land contain at least 5 acres of pine that was planted or established <u>within the past ten years</u>?

- ☐ Yes
- ☐ No
- ☐ Unsure

5. What types of forest are present on your property?
Check all that apply.

- ☐ Mostly or all Pines
- ☐ Mostly or all Hardwoods (or non-Pine)
- ☐ A fairly even mix of Pines and Hardwoods (or non-Pine)
- ☐ Other *(Please Specify)*: ______________________________
- ☐ Unsure

6. Who owns the land adjacent to yours? (Not including roads)
Check all that apply

- ☐ Private
- ☐ Industry
- ☐ Public/Government

7. What types of land are adjacent to your property?
Check all that apply

- ☐ Pine Forests
- ☐ Hardwood (or non-Pine) Forests
- ☐ Developed Land (*ex: houses, stores, industrial use*)
- ☐ Farm or Pasture Land
- ☐ Other *(Please Specify)*: ______________________________

Landowner Awareness

*For questions 8 through 10: Select the answer that **best** describes your familiarity with forest risks and pre-commercial thinning.*

8. How familiar are you with southern pine beetle risk?

□	Very Familiar	I know which trees are preferred by southern pine beetles, recognize when a forest is vulnerable, and would know how to handle an outbreak on my land.
□	Somewhat Familiar	I know southern pine beetles can be a risk to pine stands and I'd recognize beetle damage if I saw it.
□	Not Familiar	I don't know very much about southern pine beetle risk.

9. How familiar are you with the costs and benefits of pre-commercial thinning *(trees are too small to be sold)* for a young, densely stocked forest?

□	Very Familiar	I have a good idea of the cost to thin non-merchantable trees, how many trees to leave and how much faster the trees could grow, and the risks that would be reduced.
□	Somewhat Familiar	I could make a "ball park" estimate of pre-commercial thinning costs, and/or how it might improve the value and health of the forest.
□	Not Familiar benefit	I don't know how much a pre-commercial thinning might cost, and/or I've never heard that it could the health or value of the trees.

10. How familiar were you with the Virginia Department of Forestry cost-share program for pre-commercial thinning before receiving this survey?

□	Very Familiar	I had heard about the cost share program, and knew most of the details.
□	Somewhat Familiar	I knew about the cost share program, but didn't know if I was eligible or how the program worked.
□	Not Familiar	I didn't know there was a cost share program available in Virginia for pre-commercial thinning.

Pre-commercial thinning cost-share payments

We are interested in how Virginia forest landowners such as yourself respond to cost share offers from the Virginia Department of Forestry.

<u>BACKGROUND INFORMATION</u>

Currently, the Virginia Department of Forestry provides cost-share dollars to support the costs of pre-commercial thinning where appropriate. Some researchers have concluded that pre-commercial thinning of young, densely stocked southern pine stands would significantly reduce damages in the event of a southern pine beetle outbreak.

Some forestry professionals recommend pre-commercial thinning of young, densely stocked pine stands because it can speed up the growth of the trees which can result in larger, more valuable trees. However, it is not always clear how much tree growth will be improved on a given stand and whether the growth improvement outweighs the costs involved. You may be able to write off a portion of the costs involved with pre-commercial thinning at tax time.

Based on records of forest landowners who have hired contractors to perform pre-commercial thinning operations in the past, the average cost was about **$110 per acre**.

11. If you had a young, 25 acre pine stand and pre-commercial thinning was recommended by a forestry professional, would you pay $110 per acre ($2,750 total) to have a contractor perform a pre-commercial thinning on that stand if the VDOF offered to reimburse 50% ($1,375 in this case) of the costs involved?

- ☐ Yes
- ☐ No

STOP — IF **YES**, PLEASE ANSWER QUESTIONS **12** and **13**.
IF **NO**, PLEASE SKIP TO QUESTION **14**.

Only answer if you answered YES to Question 11

12. For what reasons would you have the pre-commercial thinning done which was discussed in question 11?

Check all that apply

- ☐ To reduce the risk of southern pine beetle infestation
- ☐ To increase the future commercial value of the forest
- ☐ To improve the scenic beauty, environmental quality, and/or wildlife benefits of the forest.
- ☐ Other *(Please Specify)*:

____

13. Would you have the pre-commercial thinning done which was discussed in question 11 if the VDOF was not able to offer you any reimbursement?

- ☐ Yes
- ☐ No

GO TO QUESTION 15

Only answer if you answered NO to Question 11

14. For what reasons would you NOT have the pre-commercial thinning done which was discussed in question 11?

Check all that apply

- ☐ The financial benefits might not outweigh the costs
- ☐ Southern pine beetle risk is not a major concern on my land
- ☐ I would prefer to do the thinning myself
- ☐ I don’t have the money to spend on pre-commercial thinning right now
- ☐ Other *(Please Specify)*:

____

PLEASE CONTINUE

15. On your land, how would you rate the risk of losing timber to fire, insects, ice damage, or other natural occurrences?

Please circle one rating for each

	Low Risk		Moderate Risk		High Risk	Don't Know
A. Fire	1	2	3	4	5	☐
B. Insect Damage	1	2	3	4	5	☐
C. Ice Damage	1	2	3	4	5	☐
D. Wind Damage	1	2	3	4	5	☐

Forest Management

We are interested in the management activities of Virginia forest landowners because they have an important impact on southern pine beetle hazard.

Please answer the following questions for **all** property you have owned.

16. Have you cut more than <u>half an acre</u> of trees on your property in the past?

☐ Yes

☐ No

STOP — IF **YES**, PLEASE ANSWER QUESTIONS **17** and **18**.
IF **NO**, PLEASE SKIP TO QUESTION **19**.

Only answer if you answered YES to Question 16

17. When was the last time trees were cut on your property?

________ Year(s) ago

18. For what reasons have you cut trees on your property?
(including most recent cutting and all previous cuttings)

Check all that apply

- ☐ Income from sale of timber
- ☐ Forest Health
- ☐ Aesthetic Reasons
- ☐ Firewood
- ☐ Clearing Land (*ex: for house/building site, or agricultural use)*

GO TO QUESTION 20

Only answer if you answered NO to Question 16

19. Why haven't you had trees cut on your property?

Check all that apply

- ☐ Environmental, Scenic Beauty, or Wildlife reasons
- ☐ Recreational Use (such as hunting or hiking)
- ☐ Trees are not accessible
- ☐ Trees are not mature
- ☐ Desire to preserve the forest for future generations
- ☐ Lack of knowledge about timber markets, prices, or procedures
- ☐ Other *(Please Specify)*:

____

PLEASE CONTINUE

20. Do you plan on cutting trees on your property at any point in the future?

- ☐ Yes
- ☐ No

IF **YES**, PLEASE ANSWER QUESTIONS **21** and **22**.
IF **NO**, PLEASE SKIP TO QUESTION **23**.

Only answer if you answered YES to Question 20

21. Approximately when do you expect to cut trees from your property (again)?

In _______ year(s)

22. For what reasons do you plan to cut trees on your property?

Check all that apply to any future cuttings

- ☐ Income from sale of timber
- ☐ Forest Health
- ☐ Aesthetic Reasons
- ☐ Firewood
- ☐ Clearing Land (*ex: for house/building site, or agricultural use)*

GO TO QUESTION 24

Only answer if you answered NO to Question 20

23. Why are you NOT planning to cut trees on your property in the future?

Check all that apply

- ☐ Environmental, Scenic Beauty, or Wildlife reasons
- ☐ Recreational Use (such as hunting or hiking)
- ☐ Trees are not accessible
- ☐ Desire to preserve the forest for future generations
- ☐ Lack of knowledge about timber markets, prices, or procedures
- ☐ Other *(Please Specify)*:

____

PLEASE CONTINUE

24. Which of the following would you consider to be the main reasons that you own forest land?

Check all that apply

- ☐ Scenic Beauty or Environmental Reasons
  (Examples: protection of wildlife habitat, water quality, protection against soil erosion)
- ☐ Income from Timber Production
- ☐ Land Investment
- ☐ Recreation
  (Examples: hunting, fishing, hiking, bird watching)
- ☐ Estate for Future Generations
- ☐ For Privacy / Rural Setting
- ☐ Other *(Please Specify)*

  ____

25. Have you ever performed (or hired a contractor to perform) any of these management practices?

Check all that apply

- ☐ Commercial Thinning *(Sold some or all of the trees that were cut)*
- ☐ Pre-Commercial Thinning *(trees were too small to be sold)*
- ☐ Prescribed/Controlled Burning
- ☐ Replanting
- ☐ Herbicide Application
- ☐ Developed Management or Stewardship Plan
- ☐ Other *(Please Specify)*:

  ____
- ☐ None of the above
- ☐ Unsure

26. Have you ever received assistance or advice about managing your forest from any of the following?

Check all that apply

- ☐ County Forester
- ☐ Private Consultant
- ☐ Timber or Paper Company
- ☐ Other *(Please Specify)*:

  ____

- ☐ None of the above

27. Have you ever participated in the pre-commercial thinning cost share program offered by the Virginia Department of Forestry?

- ☐ Yes
- ☐ No

28. Have you ever participated in any of the landowner incentive programs listed below?

Check all that apply

Tax Credits

- ☐ Land Use Tax
- ☐ Riparian Buffer Tax Credit

Cost Shares

- ☐ Pine Bark Beetle Prevention Program (PBBPP)
- ☐ Reforestation of Timberlands (RT)
- ☐ Conservation Reserve Program (CRP)
- ☐ Environmental Quality Incentive Program (EQIP)

Conservation Easements

- ☐ Forest Legacy Program (FLP)
- ☐ Wetland Reserve Program (WRP)
- ☐ Tomorrow Woods Land Conservation Incentive Program

Other Incentive Programs

- ☐ Other *(Please Specify)*:

  ____

- ☐ None of the above

29. Are you a member of any forestry or conservation organizations?

- ☐ Yes
- ☐ No

If Yes, Please Specify: ______________________

____

Demographics

A few basic details about your land and household are necessary for statistical validity.

30. Are you living on your forested property (or one of your forested properties)?

- ☐ Yes
- ☐ No

Only answer if you answered NO to Question 30

31. Where are you currently living?

Please write out:

City/County ______________________

State *(if outside Virginia)* ______________________

Country *(if outside the U.S.)* ______________________

32. Do you own multiple properties that are not connected to each other?

- ☐ Yes
- ☐ No

33. What is your age?

______ years

34. What is your gender?

- ☐ Female
- ☐ Male

35. Are you presently:

- ☐ Unemployed
- ☐ Employed
    - o Part time
    - o Full time
- ☐ Retired

36. What is your primary source of income?

Check all that represent a substantial source of income

- ☐ Timber Harvesting on own land
- ☐ Farming of own land
- ☐ Employment not associated with your land

  Occupation: ______________________
- ☐ Other *(Please Specify)*:

  ____

37. What was your approximate gross family income (before taxes) in 2009?

- ☐ Less than $20,000
- ☐ $20,000 to $39,999
- ☐ $40,000 to $59,999
- ☐ $60,000 to $79,999
- ☐ $80,000 to $99,999
- ☐ $100,000 to $119,999
- ☐ $120,000 to $139,999
- ☐ $140,000 or greater

38. Please estimate your total amount of household debt.

(*Total of home mortgages, car or other loans, credit card balances, etc*.)

- ☐ None
- ☐ Less than $10,000
- ☐ $10,000 to $29,999
- ☐ $30,000 to $59,999
- ☐ $60,000 to $99,999
- ☐ $100,000 to $149,999
- ☐ $150,000 to $199,999
- ☐ $200,000 or greater

39. What is the highest level of education that you have completed?

- ☐ No Formal Education
- ☐ Elementary School
- ☐ Junior High School
- ☐ High School
- ☐ Some College
- ☐ College or higher (*Please specify highest degree and major*)

____

Thank you for helping us with this study! If you have any other comments, please write them in the space provided on the next page.

Questions and Comments

Please insert your completed questionnaire into the pre-stamped, self addressed envelope included with this questionnaire and place it in the mail.