ABSTRACT

ESTEVEZ, RAFAEL CHRISTOPHER. A Cost and Benefit Analysis of the North Carolina Southern Pine Beetle Prevention Program. (Under the direction of Dennis Hazel and Robert Bardon.)

The North Carolina Southern Pine Beetle Prevention Program (NCSPBPP) was authorized and funded under the USDA Forest Service Forest Health Protection program in 2005. The objective of the NCSPBPP is to encourage eligible forest landowners in North Carolina to improve forest health and reduce the threat and severity of southern pine beetle (SPB) attack through technical assistance and cost-sharing of precommercial thinning (PCT) of young pine stands (North Carolina Division of Forest Resources [NCDFR], 2006). A process evaluation and a cost and benefit analysis (CBA) of the NCSPBPP were undertaken to provide a program overview, quantify program benefits and associated costs, and construct a set of recommendations for program improvement.

A process evaluation of the NCSPBPP was conducted for the 2006–2007 North Carolina fiscal year. The evaluation focused on program implementation, stand characteristics reporting, and the landowner application process. Site visits, informal interviews, field data sheet reporting (FDSR) of stand characteristics, and application processing time (APT) were used for the process evaluation. The CBA pertained only to the cost-sharing and personnel portion of the NCSPBPP during the same time period. A sample of 180 treated stands of loblolly pine was utilized to quantify benefits from PCT. An incremental analysis of with and without PCT was commenced to estimate the program's net benefit to society. PCT incremental gain, program net benefit, and benefit-cost ratio for the entire program were calculated using a growth and yield model, PLANTYLD, SPB infestation probabilities (Daniels et al., 1979), SPB spot severity modeling (Reed et al., 1981), SPB expected timber volume loss equations (Burkhart et al., 1986), Timber Mart-South 2006 prices, and real discount rates of 4 and 10 percent. The process evaluation identified high turnover rate of SPB Foresters, SPB Foresters' being utilized outside the scope of the program, and deficient program documentation as major program challenges.

These challenges can result in poor resource utilization and documentation that is insufficient to quantify program impacts. The program net benefit was estimated to be $680,414.19 to $818,019.97 with an associated program cost of $1,755,817.24. The benefit-cost ratio was within the range of 1.42 to 1.55. These results indicated that society was better off due to the NCSPBPP.

Recommendations for program administration include instituting incentives to retain SPB Foresters, guaranteeing position funding, changing supervisory responsibility for the SPB Foresters from the District Forester to the NCDFR Pest Control Department head, encouraging collaboration with other NCDFR personnel and other forestry-related agencies, and mandating a complete field data sheet (FDS) with all management and consultant plans prior to landowner-funding approval. The program's net benefit would be increased by eliminating SPB Forester positions in Region III, removing eastern white pine as an eligible species due to the low probability of SPB attack, and targeting landowners with pine stands that are more than 6 years old, have greater than 1,500 TPA, and are on highly productive soils. Research efforts also yielded an unplanned positive impact by identifying program challenges during the process evaluation, which gave program managers the opportunity to address obstacles earlier on.

A Cost and Benefit Analysis of the North Carolina Southern Pine Beetle Prevention Program

by
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BIOGRAPHY

Rafael Christopher Estevez was born on October 27, 1982 in Miami, FL to Rafael Angel Estevez and Guadelupe Estevez. He spent most of his early childhood in Davie, FL. Here, Rafael exhibited his strong entrepreneurial spirit and love for plants at an early age by establishing a small nursery with his older brother, propagating various tropical and medicinal plants. Later, Rafael attended Leesville Road Middle and High School. He joined the cross-country team, was chess club champion, and was an active participant in computer club, quiz bowl, and DECA. Rafael attended various state and local competitions for geography and marketing.

After high school, Rafael enrolled at North Carolina State University in the Fall of 2001 in the Forest Management program. Rafael earned a B.S. in Forest Management and graduated Summa Cum Laude and Valedictorian of the Class of 2005. Throughout his undergraduate career, Rafael earned several scholarships and awards for his academic achievement, including the Crescent Resources/Duke Power Scholarship, the Edwin F. Conger Academic Scholarship, the Multicultural Student Affairs Academic Award, and various undergraduate research grants. Rafael conducted undergraduate research under the supervision of Dr. Erin Sills for the Sustainable Woodlands Project and for the Eastern NC Christmas Tree Growers Association for three years during his undergraduate studies. He gathered information regarding consumer behavior, existing suppliers, market structure, and willingness to pay on various non-timber forest products (NTFPs), including pine straw, longleaf pine needle baskets, medicinal plants, Christmas greenery, wetland, and native plant propagation. Rafael worked for the ENCCTGA on topics such as consumer demographics and behavior, Eastern NC Christmas tree production statistics, a cost analysis for Eastern NC Christmas tree production, and quantifying the potential of Christmas greenery in the NC Hispanic market. He presented his findings at the NCSU Undergraduate Research Symposium, submitted several articles to the Eastern NC Christmas Tree Growers Association's newsletter, and published landowner pamphlets that included information regarding his research. Rafael was also an active member of the International Society of Tropical Foresters (ISTF) and the NCSU Forestry Club, in which he was elected Treasurer.

These experiences led Rafael to pursue a Master of Science in Forest Management with a minor in Economics at North Carolina State University. During his graduate studies, Rafael accepted an internship with the City of Raleigh in North Carolina. Early in the internship, Rafael worked with the Planting Coordinator to administer the NeighborWoods program, which received the City's Environmental Award and the Sir Walter Raleigh Award in 2009. Rafael became later involved in revising the city's Urban Forestry Policy and Standards Manual and conducted research to construct recommendations to improve Raleigh's City Tree Ordinance. He also completed cost and benefit, payback, and lifecycle analyses for sustainability project proposals and was part of a team that was instrumental in the Raleigh Parks and Recreation Department being awarded over $500,000 in sustainability grants. Rafael plans to pursue a Master's in Business Administration and is working towards a career in renewable energy and sustainability. Currently, Rafael holds the Eastern Region Forester position with Progress Energy.

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Furthermore, I would like to thank my family and friends for their continued loving support and understanding. To my wonderful wife, who has given me the motivation, emotional conditioning, and physical support throughout my academic journey. Lastly, I would like to acknowledge God for giving me the strength and wisdom to complete my research.

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INTRODUCTION

Widespread southern pine beetle (SPB) outbreaks caused unprecedented damage in the Southeast from 1999 to 2003 (Coulson & Stephen, 2006; Nowak, 2004), which resulted in an estimated economic loss of $1 billion dollars (Nowak et al., 2008) and affected almost 1 million acres of forestland (Nowak, 2004). This pest is considered the most serious threat to pine forest health in the Southeastern region of the United States (Thatcher & Barry, 1982). The SPB, *Dendroctonus frontalis* Zimmermann, is endemic to the Southeast (Figure 1). SPB outbreaks are cyclical, sporadic, and potentially highly devastating (Meeker, Dixon, & Foltz, 1995) (Figure 2 and 3). This pest plays a quintessential role in changing the landscape and creating economic hardship for many forest landowners. The SPB has also threatened the survival of the red-cockaded woodpecker (*Picoides borealis* [Vieillot]), an endangered species, by destroying forests that serve as vital habitat (Nowak et al., 2008).

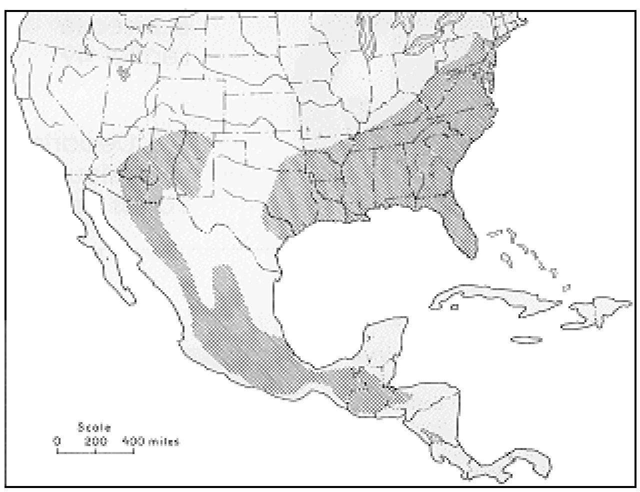

Figure 1: A map of the southern pine beetle natural range which is indicated by the shaded areas.

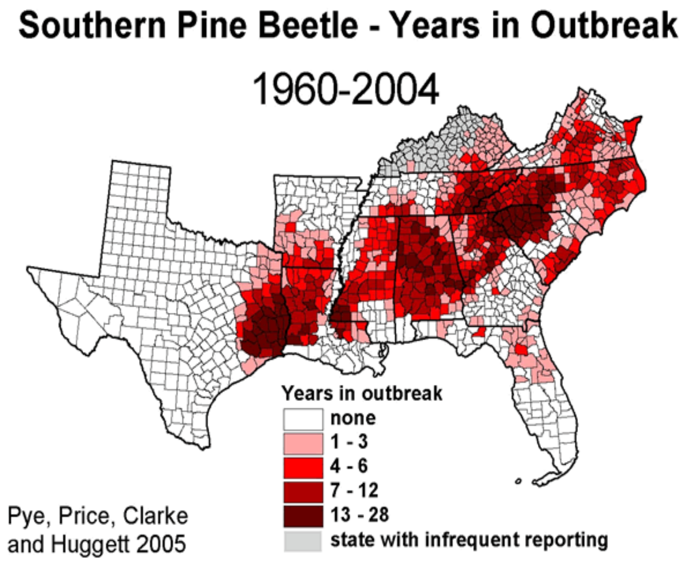

Figure 2: Outbreak frequency of the southern pine beetle from 1960 to 2004 across the Southeast.

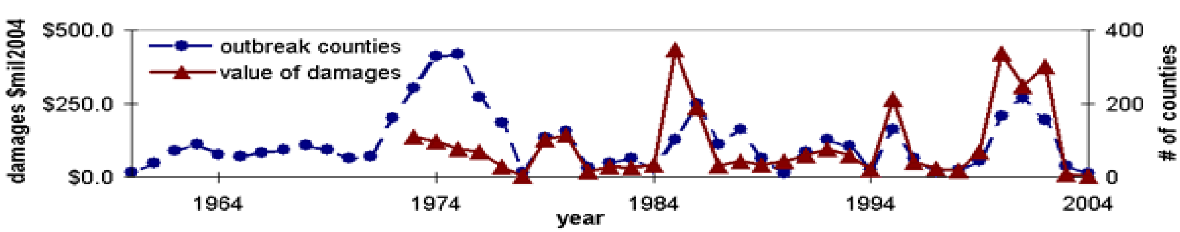

Figure 3: Timber loss trends and frequencies of counties in the Southeast impacted by southern pine beetle outbreak from 1960 to 2004.

In the past, common SPB suppression methods included cut and leave, cut and hand-spray, cut and remove, and pile and burn. These efforts have been very effective in minimizing resource losses and halting the expansion of SPB infestations (Billings & Varner, 1986; Redmond & Nettleton, 1990). Generally, SPB infestations are candidates for suppression methods when more host species is available, more than 10 trees currently infested, freshly attacked trees are present, and the infestation is expanding (Hedden & Billings, 1979; Billings, 1980). SPB suppression programs are effective in reducing resource losses but will not prevent the onset of an SPB outbreak (Clarke & Billings, 2003). Widespread SPB devastation and a renewed interest in a more proactive management approach to promoting healthier forests prompted the funding and creation of the SPB Prevention and Restoration Program administered by the U.S. Forest Service (Nowak et al., 2008).

The U.S. Forest Service Forest Health Protection (FHP) and the Southern Research Station (SRS) have been funded by the SPB Initiative (SPBI) to spearhead SPB preventive efforts in all of the 13 Southeastern states and 12 national forests. FHP allocated $48 million dollars to state forestry agencies during the federal fiscal years of 2003–2008 to help implement the SPB Prevention and Restoration program (Nowak et al., 2008). Program frameworks vary because states were given flexibility in allocating funds. These funds are being used to educate landowners about the impacts of SPB infestations, develop SPB hazard rating and mapping systems, and help manage non-industrial private forests and state-owned land (Nowak et al., 2008).

The North Carolina Southern Pine Beetle Prevention Program (NCSPBPP) is administered by the North Carolina Division of Forest Resources (NCDFR). The program’s objective is to encourage eligible nonindustrial landowners in North Carolina to improve forest health and reduce the threat and severity of SPB attacks through technical assistance and cost-sharing of recommended prevention practices (NCDFR, 2006). The NCSPBPP budget consists of several components including program marketing, forest health education, personnel, and cost-share funding for approved forest prescriptions. This paper’s primary foci were on providing an overview and process evaluation of the NCSPBPP and quantifying the benefits and costs associated with the cost-share and personnel portions of the program pertaining to precommercial thinning (PCT). A cost and benefit analysis (CBA) based on landowners who completed the program and on program implementation for the 2006–2007 state fiscal year are documented in this paper.

NCSPBPP Process Evaluation

A process evaluation of the NCSPBPP provided valuable insight and an insider perspective of the interworking of the program's administration and implementation. This evaluation was prompted by the difficulty of collecting treated stand characteristics data for the CBA. Because poor stand characteristics documentation hindered the quantifying of program benefits, a process evaluation was initiated to better understand the reasons for this shortfall. The process evaluation included participant observation and informal interviews with eight of the SPB Foresters during site visits to several NCDFR districts. An overview of the program's administration and implementation was constructed to place the CBA into context and explain how costs and benefits were derived. Stand characteristics data were compiled, and processing times for landowner reimbursement and program completion were quantified as part of the process evaluation.

Site visits were conducted in eight of the 13 NCDFR districts to document program processes and identify observed program challenges. Districts 2, 4, 5, 6, 7, 9, 10, and 11 were visited based on the availability of the SPB Forester to be interviewed, while the other five NCDFR districts were not visited because of scheduling conflicts and time constraints. Topics discussed during the informal interview included landowner response and acceptance of the program, landowner demographics in their particular NCDFR district, landowner motivation to participate in the program, the relationship between landowners and the NCDFR, program shortfalls, areas for program improvement, the administrative processes in handling landowner applications, the dependency of other types of NCDFR officials to help administer the program, perceived benefits to landowners participating in the program, and tree contractor activity. Responses were recorded, compiled, and summarized in this paper.

The second half of the process evaluation was primarily focused on landowner data-gathering efforts and the landowner application process. Field data sheet reporting (FDSR) and application processing time (APT) were introduced to determine the consistency and completeness of landowner data collection and the duration needed to process a landowner's SPB application—from when PCT was completed to when the landowner was reimbursed. For each SPB landowner application, a management plan was required prior to full approval by the NCDFR. A management plan can include a field data sheet (FDS), which may expedite data collection by listing the mandatory data collection fields. However, many landowner management plans prepared by forestry consultants omitted an FDS. An analysis was conducted to determine how the completeness and consistency of stand characteristics data obtained from management plans was affected by the presence or absence of an FDS. Diameter at breast height (dbh), average tree height, soil classification, slope, and landform were examined. The core analysis was focused on a subsample of 192 treated stands completed during the study period and excluded landowners without an acquired management plan. APT was created to gauge personnel efficiency in processing landowner paperwork needed to close a project after the stand has been treated. APT was recorded for 121 landowners for which data were obtained, and the results are summarized in this paper.

Program Cost and Benefit Analysis

Commonly neglected during the program's lifecycle are regularly conducted program evaluations. The program evaluation process is sometimes disregarded due to lack of available resources, inadequate technical expertise, or weak accountability standards. Although often viewed as a low priority, program evaluation is vital in understanding previous program frameworks, what contributed to their success or failure, benefits and costs associated with a particular program, and program validation. The general intention of a CBA is to help social decision making by facilitating better allocation of resources (Boardman et al., 2006). An efficient incentive program must generate benefits to society greater or at least equal to the costs (Kronrad & Morzuch, 1985). The development of a CBA was undertaken to gain a greater understanding of derived benefits and program costs based on a societal perspective, quantify a benefit-cost ratio for the program, and offer program recommendations to increase program efficiency.

The CBA framework was designed to underestimate benefits and overestimate program costs and was based on a similar study conducted by Burkhart et al. (1986) regarding the effect of thinning on SPB expected timber volume loss. This type of framework generates the presence of low SPB activity and does not take into account the economic effects that are associated with SPB epidemics. SPB epidemics in the South are commonly seen as large-scale catastrophes (Price et al., 1998). These catastrophes can affect timber market prices and increase price risk. Prices drop precipitously in the short run because of a glut of material available to timber buyers, lower quality of the salvage material, and the added costs associated with salvage harvesting (Prestemon et al., 2001). After an SPB outbreak in Louisiana and Texas during 1984–1985, prices were negatively affected for 15 months because of salvage logs (Holmes, 1991). SPB epidemics are also associated with greater production risk by creating larger unforeseen volume and quality losses. This framework would typically underestimate SPB losses, the bias is negligible for a situation where salvage is infeasible and SPB infestations are small and scattered (Burkhart et al., 1986).

Under the NCSPBPP, PCT is the primary forestry prescription approved. The CBA focused on the treatment's benefits of higher-valued timber products and reduction in SPB expected timber volume loss. Other program benefits due to PCT, which may include wildlife habitat improvement, enhanced aesthetics, reduced fire risk and fuel load, and a decrease in timber price and production volatility due to less frequent SPB outbreaks, were not included in the CBA due to lack of data and to resource constraints.

Southern Pine Beetle History and Management Overview

Research on the SPB has included lifecycle, population dynamics, tree species susceptibility, hazard rating systems, and preventive forest management prescriptions. The SPB is one of more than 12 American species of bark beetles found in North and Central America and is considered a primary pest due to the susceptibility of numerous types of coniferous species throughout its natural range (Thatcher et al., 1980). SPBs attack living conifers by feeding on the phloem tissue and depositing their eggs in S-shaped galleries beneath the bark. Stressed, dying, and suppressed trees are normally targeted first, but during periods of epidemics, healthy and vigorous trees can be overwhelmed and killed effortlessly.

Aggregated SPB populations in expanding infestations are known as spots (Clarke & Billings, 2003). NCDFR personnel conduct aerial surveys with follow-up ground checks across North Carolina and usually during late June to early July, fall, and winter after hardwood leaf fall to record spot occurrence (Anderson & Doggett, 1980). During initial ground checks conducted in North Carolina from 1973 to 1975, the average spot size was found to be 1.356 acres (Doggett & Tweed, 1994). SPB epidemic intervals are regionally dependent in North Carolina (Doggett & Tweed, 1994) and normally short-lived throughout its natural range (Thatcher et al., 1980). Epidemics and spot spread are believed to be correlated with favorable stand conditions such as high host density, poor vigor, stressed host species (Lorio, 1968; Hicks, Coster, & Watterston, 1978), and lightning strikes.

Shortleaf pine, *Pinus echinata,* and loblolly pine, *Pinus taeda*, are considered to be the most susceptible and preferred by SPB (Thatcher & Barry, 1982; Clarke & Nowak, 2009). In a study conducted during 1973 through 1975 in North Carolina, *Pinus echinata* was the species most frequently killed based on total volume and quantity of available host species. Loblolly pine, which is the most abundant pines species in North Carolina, was ranked second in total volume killed (Anderson & Doggett, 1980). The SPB has also infested other coniferous species, such as pitch pine (*Pinus rigida*), Eastern white pine (*Pinus strobus*), longleaf pine (*Pinus palustris*), Virginia pine (*Pinus virginiana*), Slash pine (*Pinus elliotti*), table mountain pine (*Pinus pungens*), and spruce pine (*Pinus glabra*) (Thatcher et al., 1980). Pine forests totaling 8.4 million acres in the South are at risk of having 25% or more of the standing live basal area (BA) greater than 1 inch in diameter killed by SPB activity in the next 15 years (Krist, Sapio, & Tkacz, 2007).

Supported by the FHP and state funding, SPB stand hazard maps were developed and released in 2008 for each of the 13 states in the Southern region. These maps are intended to better prioritize and target areas for funding through the SPB Prevention and Restoration Program (Nowak et al., 2008). Hazard rating systems can also offer forestry prescription recommendations. Based on a hazard rating system developed for East Texas, the following prescription recommendations were constructed: stands that are rated moderate to high hazard with an average height of greater than 60 feet should be considered for harvest and replanted with a more SPB-resistant pine species such as slash pine; moderate to high hazard stands with an average height of less than 60 feet should be thinned to 70–80 square feet of basal area per acre; extreme hazard stands are recommended for harvest and conversion to hardwood; and resistant pine species and stands with a low to moderate rating with an average height of less than 60 feet generally would not require any treatment for SPB protection (Hicks et al., 1978).

Preventing outbreak populations and creating forest conditions that adversely affect SPB outbreaks once they occur is believed to be the most effective method of managing SPB populations (Thatcher et al., 1980; Belanger, Hedden, & Lorio, 1993; Clarke, 2001). Stand structure is thought be a major factor in estimating the probability of spot initiation and rate of spread (Nowak et al., 2008). The predominant strategy of the SPB Prevention and Restoration Program is to thin stands early. Thinning is a preferred method for altering the stand structure and reducing SPB susceptibility because of lower intraspecific competition (Nowak et al., 2008). Thinning can increase tree growth, shorten the length of the rotation, increase forage for livestock or wildlife, and reduce the risk of timber losses due to fire, insects, diseases, and weather (Mann & Lohrey, 1974). A PCT study conducted by Cain (1993) concluded that crop trees grew substantially faster than did unthinned plots and that PCT improved wildlife habitat. Precommercial thinning plots were also better suited for early sawtimber production, and commercial loggers preferred to perform intermediate thinnings in these plots. Precommercial thinning can also be profitable without SPB being a factor. Precommercial thinning was found to be justified if the stand stocking was greater than 5,500 to 6,500 trees per acre and if was followed by an aggressive commercial thinning program (Franklin & Lloyd, 1997).

ESSAY ONE: NORTH CAROLINA SOUTHERN PINE BEETLE PREVENTION PROGRAM PROCESS EVALUATION

A process evaluation of the North Carolina Southern Pine Beetle Prevention Program (NCSPBPP) was undertaken to place the cost and benefit analysis (CBA) into context and to identify challenges that were encountered when gathering program information for the CBA. Constructing an overview of the program provides background information on how costs and benefits are derived and offers a detailed account of program administration and implementation, which can be used to improve similar program frameworks and future program replication.

Poor documentation of stand characteristics of treated stands hindered conducting the CBA. Consistent and complete stand characteristic data collection from each treated stand is vital in quantifying program impacts, such as SPB expected timber volume losses and changes in timber product classes. Incomplete data documentation does not affect the overall social and economic impact of the program, but this impediment can hinder research efforts in program justification, quantifying economic efficiency and effect, and identifying program aspects that can be improved upon. The CBA framework was tailored to what stand characteristics could be collected consistently from treated stands and was constrained by feasible methods that could be utilized.

Stand-characteristics requirements when met were approved by a North Carolina Division of Forest Resources (NCDFR) official that inspected the stand before funding approval. Specific stand characteristics documentation was not an explicit program requirement. A process evaluation was initiated to document the program processes and assess the reasons for the lack of complete and consistent stand characteristics documentation.

Southern Pine Beetle Prevention Program Background

The NCSPBPP, administered by NCDFR, started to enroll landowners in 2005 and was funded by federal grants from the Southern Pine Beetle Prevention and Restoration Program. Precommercial thinning (PCT), first pulpwood thinning, prescribed burning, replanting lower density stands, and planting less susceptible pine species (such as longleaf pine) are the primary preventive methods being used by state-administered programs. The number and type of approved methods varies by state. For example, the Florida SPB Prevention Program (FSPBPP) has approved first pulpwood thinning, PCT, and prescribed burning for cost-share funding, whereas the NCSPBPP has approved only PCT for cost-share funding.

Treatment area prioritization and personnel needs also differ among state programs. The Texas Forest Service has placed a special emphasis on targeting counties that are considered having a high to moderate SPB hazard rating. Florida, North Carolina, and Texas also use SPB hazard maps to preferentially treat stands, whereas other states may treat stands based on need and SPB outbreak history (Nowak et al., 2008). Typically, SPB prevention programs fund a coordinator position, and sometimes an assistant coordinator position, to administer the program and rely heavily on other forest service staff to help with program implementation. In contrast, the NCSPBPP hired 13 forester positions and an SPB coordinator.

Availability of cost-share funds and rates vary among states. The FSPBPP limits funding to 44 northern counties where SPB is found historically, yet the NCSPBPP has made cost-shares dollars available to each of the 100 counties in the state, regardless of SPB activity and perceived SPB risk. The cost-share rates for approved practices can also differ. The Texas SPB Prevention Program pays up to $10,000 annually per landowner, with a 50% cost-share rate. In contrast, the FSPBPP pays a flat rate of $50 per acre for first pulpwood thinning, up to $50 per acre for PCT, and $8 per acre for prescribed burning. The SPB initiative has brought about the hazard reduction and the thinning of over 500,000 acres, educated several thousand landowners about SPB-related issues, and expanded our knowledge base of SPB through funded research projects (Nowak et al., 2008).

North Carolina Southern Pine Beetle Prevention Program Implementation

Program Structure

The NCSPBPP is divided into three major components: personnel, cost-share, and education. The personnel and cost-share portions are the primary foci of this paper. These components were allocated approximately one million dollars for personnel costs and one million dollars for cost-share spending out of the three million dollars for the NCSPBPP given to the state during the state fiscal year of 2006–2007.

The NCDFR Pest Control Department head was responsible for overseeing and executing the new prevention program. NCDFR created 13 new SPB Forester positions, one for each NCDFR district (Figure 4), and an SPB program coordinator position located in the Central Office in Raleigh, NC to manage outreach efforts to minority and limited resource landowners.

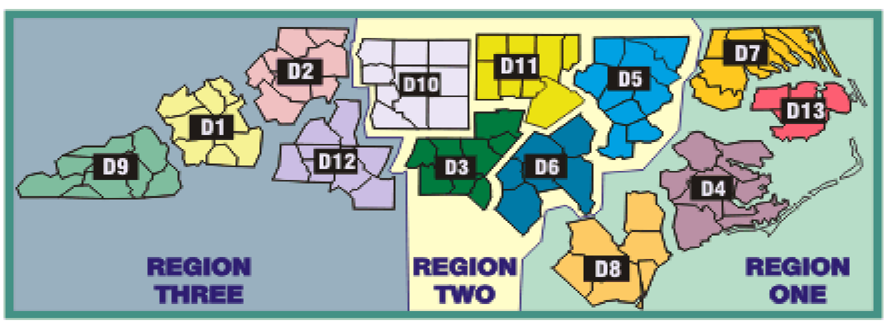

Figure 4: A map of North Carolina Division of Forest Resources regions and districts.

The primary duties of the SPB Forester include educating landowners about the new program, encouraging landowner participation, processing SPB landowner applications, inspecting potential stands to gather stand characteristics, overseeing tree contractors, surveying and mapping treated stands, and promoting overall forest health. Training requirements for an SPB Forester, which is a two-year period, were similar to those of a Service Forester. The SPB Forester was housed in each district office and reported to the

District Forester for daily tasks. The SPB coordinator's primary functions were to encourage minority landowners and limited-resource landowners to participate in the NCSPBPP, through networking and attending community events. These positions were based on soft monies and could be eliminated if funding was discontinued.

Program Promotion and Education

A consultant firm was contracted to launch a marketing campaign to promote forest health and landowner participation. Various methods were tested, such as publishing newspaper articles about the program and purchasing radio, newspaper, and television advertisements. About $800,000 was spent on these efforts, and each SPB forester was also encouraged to find innovative methods to reach at-risk landowners. Methods utilized include aerial photos, compiling landowner lists from other federally or state funded forestry programs, windshield inspections between appointments, coordinating with other NCDFR county personnel, demonstration plots, and contacting the local media to generate publicity.

SPB educational efforts were integrated in both the marketing and personnel portions of the program. Marketing efforts were intended to generate interest about SPB and the NCSPBPP, but they also provided general information regarding this well-studied insect. The SPB foresters and the SPB coordinator routinely educated landowners about the importance of the SPB and why it is essential to manage their forests to promote good forest health as part of the NC SPB educational initiatives while implementing the program.

Landowner Program Guidelines and Requirements

Commonly, PCT is completed mechanically or by manual-labor crews. Eligibility requirements included being a nonindustrial private landowner located in North Carolina and owning at least five acres of forestland in North Carolina, a written management plan, other cost-share funds cannot be spent on the same acre for forestry practices, and a candidate stand must meet certain stand characteristics criteria (Table 1), which was verified by a NCDFR representative.

Table 1: NCSPBPP pre-stand characteristics and post-stand characteristics eligibility requirements stated in the program handbook of 2006.

Type of Tree	Practice	Max. Age Crop Trees	Pre-Treatment Condition	Post-Treatment Condition
Southern Yellow Pine	Precommercial Thinning	12 years	700+ pine stems / acre	300–450 stems / acre, depending upon age; 450 at age 3-9, down to 300 at age 10+
White Pine	Precommercial Thinning	30 years	700+ pine stems / acre or 150+ square feet of basal area	300–450 stems / acre or 90 square feet of basal area or less

The cost-share reimbursement rate was 70/30, in which the landowner pays 30% of the costs and the NCDFR pays the remaining 70%. Landowners can be reimbursed up to $8,000 per year per ownership. Prior to the 70/30 cost-share rate, the rate for landowners was 50/50 and up to $5,000 at the end of the 2005 state fiscal year. The cost-share rate was adjusted upward as of July 1, 2006 to encourage landowner participation. Each approved prescription was completed within one calendar year if an extension was not approved by the NCDFR. Participating landowners were obligated to maintain treated stands for 10 years, based on the stipulations outlined in the previously approved management plan. If a landowner failed to do so, he or she may be required to return received cost-share dollars to the State of North Carolina and other financial penalties may apply.

Landowner Application Process

Participating landowners begin the enrollment process by having an NCDFR official assess a potential candidate stand. This official, which usually was an SPB Forester, a County Ranger, an Assistant County Ranger, or a Service Forester, evaluated the stand by establishing several plots to identify species, age, diameter at breast height (DBH), average tree height, TPA, basal area per acre, site index (SI), volume range, stand quality, understory species, if desirable reproduction was present, landform, and a site description for slope, soils, aspect, and drainage. These data were later recorded in the management plan and usually were compiled on the field data sheet (FDS) if included.

A management plan is required with each landowner application. A landowner may ask an NCDFR official or a forestry consultant to prepare and submit a management plan on his or her behalf. The enrolling landowner must also fill out a basic application that requires personal and property information, such as name, address, social security number, PCT rate, and the number of acres to be treated. This application and management plan were then submitted jointly to the Central Office for NCDFR funding approval.

After administrative approval, the landowner must complete the PCT within a year, in the absence of an extension. A PCT contractor was hired at a set rate, which was preapproved by the NCDFR. The agency set rates for PCT as low ($80/acre), medium ($120/acre), and high ($200/acre). A list of PCT contractors was usually kept at the district office and furnished to inquiring landowners upon request.

During treatment, a NCDFR official can make site visits to monitor the work in progress. When the PCT was completed, a NCDFR representative, usually a SPB Forester, accurately measured the treated area for billing and inspected the completed work to ensure that post-treatment stand characteristics criteria are satisfied. However, no post-treatment stand characteristics are officially recorded. Written documentation, which may include a map of the treated area and proof of payment to the tree contractor, was then submitted to the NCDFR Central Office for landowner reimbursement. Once the landowner was reimbursed, the application was considered complete.

<u>Program Process Evaluation</u>

The process evaluation was conducted through participant observations, informal interviews, quantifying the effectiveness of data collection methods, and measuring participating landowner application processing times for landowners that completed PCT and were reimbursed with cost-share funds during the study period. In the evaluation, 8 of the 13 NCDFR districts were visited, with the other 5 districts not being visited due to scheduling conflicts and time constraints. Landowner management plans were compiled to analyze program documentation efforts. The administrative staff within the NCDFR provided landowner processing-time information for analysis. Each SPB Forester was informally interviewed. Questions asked during the interview pertained to landowner demographics, program decision-making, program acceptance in their particular district, identifying qualifying landowners, administrative processes, treatment costs and tree contractor behavior, the relationship between NCDFR and landowners, realized program benefits and associated costs, areas for program improvement, and program limitations.

A metric created to estimate stand-characteristics data-collection completeness and consistency was field data sheet reporting (FDSR), which is described in more detail in the following section. Application processing time (APT) was used to quantify the time needed to complete an SPB landowner application after PCT was completed in the field. Findings from the program process evaluation were used to construct comprehensive recommendations, with the intention of assisting the NCDFR by identifying areas for improvement in program implementation, funding utilization, and data collection efforts.

Field Data Sheet Recording (FDS Reporting)

Stand characteristics and program documentation were recorded primarily in the landowner management plan. An FDS was usually included in a management plan prepared by an NCDFR official, unlike plans prepared by forestry consultants on behalf of the participating landowner. This type of sheet was intended only as a guide in which stand characteristics were recorded before PCT and is not a requirement for cost-share funding approval. Landowner management plans that included an FDS were compared with management plans that did not use an FDS, to analyze stand-characteristics data-recording consistency and completeness. Each stand was counted individually even if a landowner management plan contained multiple stands.

Stand characteristics examined were average diameter at breast height, average tree height, soil classification, slope, and landform. These stand characteristics are commonly used in SPB risk models to determine SPB expected timber volume loss and SPB hazard ratings. Each stand characteristic category was given a score of 1 if specific data were recorded for it; otherwise, 0. The core analysis was focused on a subsample of 192 treated stands that completed the program during the state fiscal year of 2006–2007. Of those stands, 136 included an FDS and 56 did not.

Application Processing Time (APT)

Dates used for APT were provided by administrative staff within the NCDFR. This benchmark was created to gauge personnel efficiency in processing landowner paperwork needed to close a project after the necessary documents are submitted to show that treatment has been completed. The 15th was the set day used if the day was not listed, but the month and year were provided. No studies were found in the literature of similar programs using this metric for a comparison. One hundred twenty-one landowners were sampled for APT.

<u>Program Process Evaluation Results</u>

Landowner Participation and Program Interest

Based on participant observations during site visits and on informal interviews with the SPB Foresters, landowner participation and program interest seem to be higher in NCDFR districts having landowners with a strong relationship with the NCDFR, good timber markets, productive timberland, rural areas, and abundant loblolly pine. NCDFR Districts 3 and 5 had the greatest number of participating landowners during the study period. These districts have few urban centers and plentiful loblolly pine. Also, timber pricing in the eastern part of the state where these districts are located was higher than in the western part of the state, based on Timber Mart-South 2006 annual average stumpage prices (Timber Mart-South, 2006). Program participation in some districts was limited by landscapes' being highly fragmented due to urban development and large tracts of industrial lands, which are ineligible. Landowners in districts with significant urban development, such as NCDFR Districts 10 and 11, were less likely to enroll because of the high potential of capitalizing on appreciating real estate prices within the 10-year period required by the program for the land to remain in trees and because of smaller tract sizes, as reported by the SPB Foresters during informal interviews. The SPB Forester in District 10 reported difficulty encouraging loggers and tree contractors to conduct forestry prescriptions on small tracts. To entice tree contractors and loggers by larger economies of scale, the District 10 SPB Forester organized these landowners to conduct forestry prescriptions at the same time. Landowners with less than 30 acres of timberland were less likely to be receptive to managing for mitigating SPB risk (Molnar, Schelhas, & Carrie, 2007), which is consistent with larger forest landowners' tending to be more likely to implement forest management practices (Mayfield, Nowak, & Moses, 2006). Observations indicated that the cost-share rate's being increased from 50/50 and a ceiling of $5,000 annually to 70/30 and a ceiling of $8,000 annually seemed to have generated greater program interest and given NCDFR personnel greater confidence to encourage landowners to enroll in the program.

Landowner Motivation

During site visit interviews, SPB Foresters were asked what motivated landowners to enroll in the program. Answers varied between districts, but timber production, wildlife management, and aesthetics were cited several times. Aesthetics seem to have had a greater weight in landowner decision making in urban districts, due to the impracticality of timber production on smaller tracts. Also, landowners seem to have little to moderate concern with SPB risk in general. The literature corroborated with the foresters' answers. In the South, many landowners have little interest in mitigating SPB impacts and are unaware of SPB being a source of timber losses (Molnar, Schelhas, & Holeski, 2003; Mayfield et al., 2006). The majority of landowners with less than 15 acres are slightly aware to unaware of SPB as a source of timber losses and have slight to no interest in mitigating SPB impacts (Molnar et al., 2003).

Program Implementation and the SPB Forester

The SPB Forester position was observed to be experiencing high turnover, although the exact rate of turnover was not quantified. Causes noted during the site visits were funding uncertainty and the availability of other permanent job opportunities within the organization, such as a Service Forester position. This high turnover created significant program delays due to the agency's having to find qualified replacements and then train them. SPB Foresters were also found to be utilized differently in each NCDFR district. Commonly, the SPB Forester was acting as a Service Forester in an assigned county in addition to duties pertaining to the NCSPBPP. Service Forester is a permanent state position that typically addresses general concerns of forest landowners in a district and not just issues relating to SPB and forest health.

SPB Foresters were also found to be involved at various stages of the landowner application process and collaborated with other NCDFR personnel regularly. Other NCDFR personnel were essential in promoting the program, encouraging landowners to participate, and completing the landowner application process.

Forestry consultants played a critical role in landowner enrollment. In some districts, such as district 3, over one third of landowner applications sampled were submitted by a forestry consultant on behalf of the landowner. Forestry consultants work in the best interest of the landowner by utilizing their professional expertise to increase financial returns and to promote better forest management. This group of professionals is incentivized to seek out government subsidies to boost their clients' financial returns and lower treatment costs paid by their clients.

Tree Contractors

Observed during site visits, PCT in each district was being primarily completed by manual-labor crews instead of mechanically. New contractors entering the market were rare, and many existing contractors only recently added PCT to their company services or emphasized this service due to the NCSPBPP. Future program funding uncertainty discouraged many tree contractors from investing in new employees and equipment. However, many existing tree contractors already possessed the necessary equipment required for PCT, so little additional investment in equipment was needed.

Most of the NCDFR districts had an ample list of tree contractors providing PCT in their area, which allowed landowners to complete projects in a timely manner. Far fewer tree contractors were present in the western districts than in the eastern districts. However, project delays were seldom due to the lack of tree contractors being available and were usually attributed to the landowner.

Field Data Sheet Reporting Results

Approximately 71% of treated stands sampled were included in a landowner management plan where an FDS was included. Table 2 and Figure 5 and 6 compare the availability of stand characteristics of treated stands according to whether the landowner management plan included an FDS.

Table 2: Percentage of treated stands in a landowner management plan, with or without a field data sheet, that included reporting data for stand characteristic category.

Data Availability of Treated Stands in a Management Plan		
Stand Characteristic Category	Availability with FDS (%)	Availability without FDS (%)
Average DBH	97.06%	12.50%
Average Tree Height	97.06%	16.07%
Soil Classification	92.65%	10.71%
Slope	77.21%	7.14%
Landform	13.24%	1.79%

NCDFR districts 1, 4, 6, 8, 12, and 13 did not have landowner management plans without an FDS included for comparison. Landowner management plans were not provided from district 9.

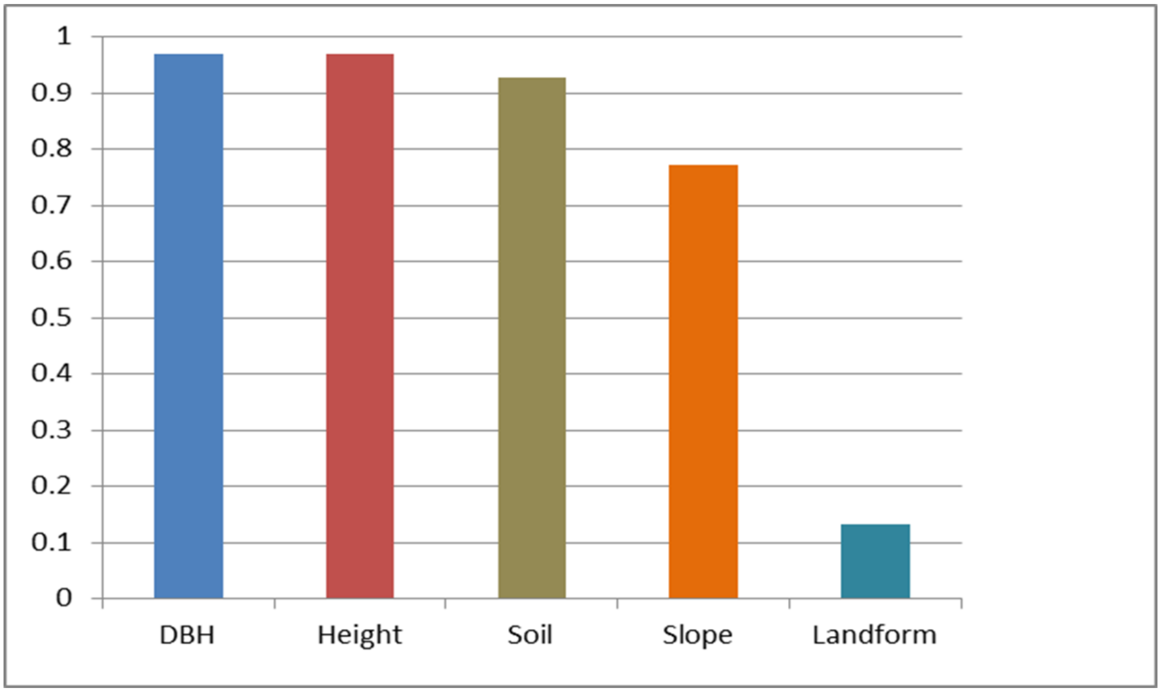

Figure 5: Percentage of treated stands in a landowner management plan with a field data sheet for which the given stand characteristics data were provided.

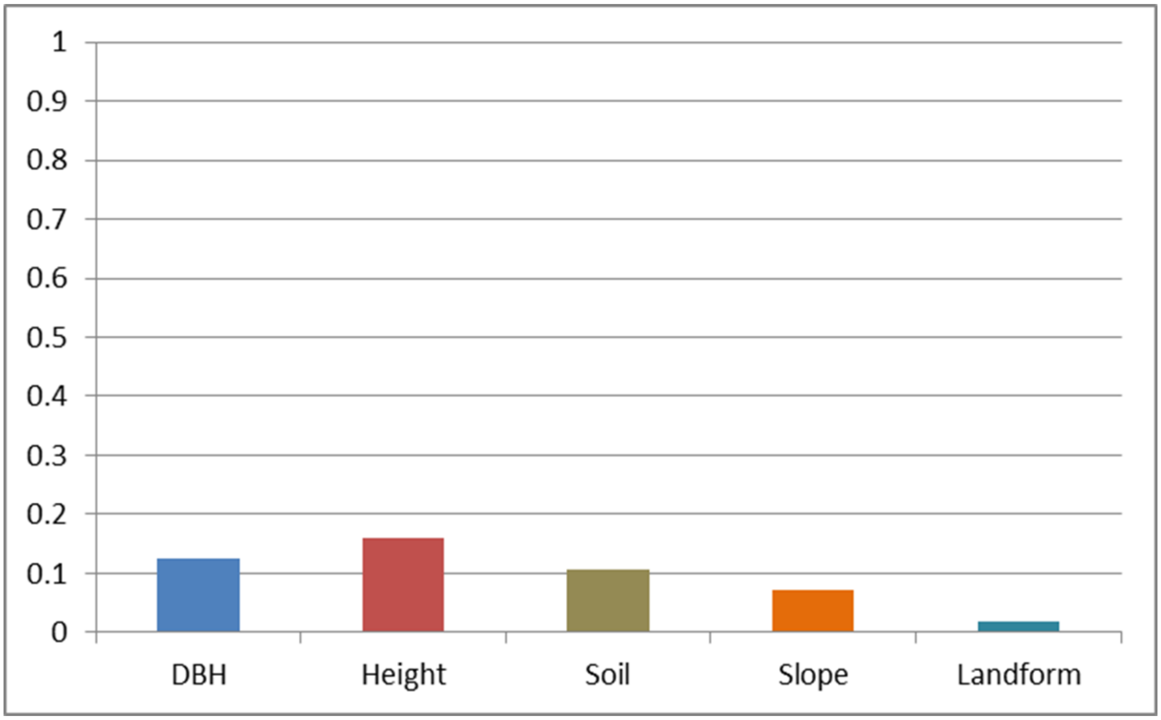

Figure 6: Percentages of treated stands in a landowner management plan without a field data sheet for which the given stand characteristics data were provided.

Generally, each stand characteristic category was reported more frequently when an FDS was included. Landform data were seldom collected even where an FDS was used.

Application Processing Time Results

The application processing time was found to be 59.5 days or ~2 months with a standard deviation of 56 days and a median of 46 days. The median is a better description of the APT data because the distribution of APT values is rightly skewed. In general, NCDFR districts closer to the Central Office in Raleigh, NC tended to have a lower APT. No further comparisons were conducted.

<u>Program Process Evaluation Discussion</u>

NCSPBPP Program Challenges

Program challenges identified from early site visits were (1) a high turnover rate for SPB Foresters, this position is being leveraged in other areas that are not program related, and (2) deficient accounting of stand characteristics for enrolled stands. Several recommendations were constructed to address these issues.

The high employee turnover undermined the NCSPBP program. Recurring upfront costs accrued during the hiring process and training period diverted program resources. Each time a new SPB Forester was hired, a period of time was needed for him/her to build professional relationships and creditability among landowners and to familiarize himself/herself with the existing social demographics, geography, and other NCDFR personnel working in their district. Also, more disruptions and delays may have occurred when transitioning from old to new hires because of the lack of knowledge transfer of existing projects undertaken by the previous SPB Forester.

SPB Forester duties on a day-to-day basis were under the direct oversight of the District Forester in each NCDFR district. This posed a potential program challenge in some cases because several SPB Foresters were being utilized for general NCDFR operations instead of exclusively for NCSPBPP. It is unknown the magnitude of this impact on program results that may have occurred due to diverting program personnel resources for NCDFR general tasks.

Another program challenge was documentation of stand characteristics before and after treatment. An NCDFR representative was not explicitly required by the program to record each stand characteristic analyzed for FDS reporting before treatment. This individual can use various inventory methods to determine if a particular stand met program requirements. A plot method was commonly used to make this determination. The number of plots taken varied based on the NCDFR official conducting the assessment. Commonly, NCDFR representatives would take as many plots as he or she deemed necessary to accurately reflect the stand characteristics of a particular candidate stand. This method was sufficient in determining whether a stand exceeded the threshold requirements of the program, but it may be lacking in providing robust data for deriving research conclusions about possible program impacts. No post-treatment stand characteristics were documented, but documentation by an NCDFR official evaluating stand characteristics after treatment was common.

Based on FDS reporting results, information consistency and completeness were identified as areas for program improvement. Collection of stand characteristics data was sporadic among districts and especially in landowner management plans containing no FDS.

Program Process Evaluation Recommendations

The program process evaluation resulted in the following five recommendations:

- Institute incentives to retain SPB Foresters by offering higher pay comparable to NCDFR permanent positions such as a Service Forester position, and administratively discourage SPB Foresters from filling those positions immediately.
- SPB Forester positions would be on a contract basis, and funding for that time period would be guaranteed.
- Change supervisory responsibilities of the SPB Foresters to the NCDFR Pest Control Department head instead of the District Foresters.
- Encourage collaboration between county-level personnel or other forestry-related governmental agencies and forestry outreach groups, such as Cooperative Extension, and SPB Foresters, to increase efficiency in reaching eligible and at-risk landowners.
- Mandate inclusion of an FDS with all landowner management and consultant plans and require all data fields to be properly provided on this sheet prior to landowner funding approval.

The first three recommendations encourage measures, such as higher pay and greater job security, to retain SPB Foresters. Pay comparable to that of a Service Forester would help compensate SPB Foresters for the uncertainty associated with funding. Also discouraging SPB Foresters internally from transitioning to a permanent position immediately should also improve program results. Shifting day-to-day oversight of SPB Foresters to the Central Office would give greater authority to the NCDFR Pest Control Department head in directing and spearheading NCSPBPP efforts on a local level and minimize opportunities for SPB Foresters to be utilized for general tasks.

The fourth recommendation encourages collaboration between SPB Foresters and other NCDFR personnel. This is critical in gaining access to landowner relationships already established by county-level officials. Precommercial thinning is associated with an upfront expense that is usually carried to the end of the rotation. This can discourage many forest landowners, which tend to be cost adverse, from conducting PCT. Having a strong relationship with landowners is vital to building creditability and convincing these individuals to make this type of investment with the promise of higher future returns due to better quality timber and reduced SPB risk.

Collaborating with other forestry-related governmental agencies and outreach groups, such as North Carolina Cooperative Extension, can help promote the program and reach receptive landowners seeking forestry assistance. These types of agencies and groups tend to have high landowner interaction and cater to individuals interested in managing their forest landholdings. Collaboration among these groups, agencies, and the NCDFR can be a feasible method in disseminating program information among their constituents more effectively.

The final recommendation pertains to program documentation and program data-gathering efforts. Data gathering was shown to be inconsistent among districts. For various stand characteristics, such data can be essential in evaluating SPB risk and program impacts. By requiring an FDS for each landowner management plan and ensuring that each stand characteristic field is recorded prior to funding approval, data-gathering should improve. Concentrating stand-characteristics information on one sheet within the landowner management plan would streamline the auditing process. Reviewing the FDS could alert NCDFR officials more promptly to data parameters missed during the initial stand assessment or excluded from the management plan altogether.

No program process evaluation recommendations pertaining to APT were given because of the lack of baseline data for comparison. Findings in this study regarding APT create the necessary baseline for future evaluations. Having an effective process in place for reimbursing landowners is vital in encouraging them to participate in the program, maintaining an excellent public image, and maintaining high landowner satisfaction.

Program Process Evaluation Conclusion

Forestry officials and lawmakers are being more proactive by promoting SPB prevention efforts through state-operated cost-share programs and forest-health education initiatives. The program process evaluation for the NCSPBPP revealed several obstacles to program implementation and documentation and proposed a remedy for each. The greatest impediments were high turnover of SPB Foresters, which could be addressed by SPB Foresters being given greater financial incentives and being internally encouraged to postpone taking permanent positions; SPB Foresters' being utilized for general tasks, which calls for changing the position to which they directly report; and inconsistent data collection, which suggests requiring a FDS to be filled out properly in each landowner management plan prior to funding approval. Research efforts also yielded an unplanned positive impact on program implementation. The previously identified program challenges of high turnover rate of SPB Foresters and their being used for general tasks were brought to the attention of program managers, who then addressed them early during research efforts, thus improving program efficiency for subsequent years.

ESSAY TWO: NORTH CAROLINA SOUTHERN PINE BEETLE PREVENTION PROGRAM COST AND BENEFIT ANALYSIS

Cost and Benefit Analysis General Application and Theory

Commonly, the government offers subsidies to landowners in the form of cost-share programs to internalize positive externalities provided by environmental improvements such as clean water, wildlife habitat improvement, enhanced aesthetics, and carbon sequestration. Economists usually justify government interference in the free markets as preventing market failures, such as positive or negative externalities. Based on the assumption that forest landowners do not invest the necessary capital, state and federal cost-sharing and tax-incentive programs have been instituted (Kronrad & Morzuch, 1985).

Publicly funded forestry cost-share programs can have the following objectives: (1) provide incentives for private landowners to implement some specific practice(s) to better manage their forests, and (2) produce more benefits derived from forests to society, which may include improving ecosystem services, producing superior forest products, fueling renewable energy, preserving recreation areas, and mitigating insect and disease outbreaks.

Federal, state, and local agencies document program benefits, costs, and accomplishments, in part to present to policymakers and legislative bodies to justify initiation of government funding or continued funding of a program or project. Cost and benefit analysis (CBA) is an effective method to document and quantify different parameters in one concise analysis. Executive Order 12291, issued by President Ronald Reagan in early 1981, mandated the general use of CBA by the U.S. federal government, which was reaffirmed by President Clinton in Executive Order 12866 in 1994 (Boardman et al., 2006). CBA has been used in the past to justify or suggest elimination of preexisting forestry practices and incentive programs (Kronrad & Morzuch, 1985; Clarke & Billings, 2003).

In a general sense, CBA is a policy-assessment technique to quantify all consequences of a policy in monetary terms. CBA is intended to facilitate better decision making to more efficiently allocate societal resources. There are three major types of cost and benefit analysis: *ex ante* CBA, *media res* CBA, and *ex post* CBA. *Ex ante* analysis is useful in determining whether resources should be allocated to a particular project or program under consideration. This type of CBA is usually the least accurate. *Media res* analysis is conducted during the life of a project or program. This type of analysis can suggest possible shifts of resources to alternative uses and can lead to project or program termination. Conducting a CBA at the end of a project or program, *ex post* CBA, is commonly the most accurate and can contribute in determining the value of proposed projects and programs that are similar (Boardman et al., 2006).

CBA benefits society by enabling better-informed decision makers and more efficient resource allocation. A well-formulated CBA can break down the relevant costs and benefits and present the analysis findings in the best comprehensive set of information to policymakers (Williams, 2008). Conducting a CBA can also introduce accountability into decisions that affect whole communities and encourages people to be aware of the environmental and human costs of what they do (Schmidtz, 2001). CBA also creates greater regulatory transparency and helps government agencies set priorities for different projects and programs (Alder & Posner, 1999). This tool remains relevant through the continuous development of new empirical methods to evaluate benefits and costs.

However, CBA can also have many pitfalls and sometimes is not the most appropriate tool for government (Williams, 2008). Some pitfalls may include the following:

- Difficulty of aggregating individual effects across the relevant population (Williams, 2008; Boardman et al., 2006),
- Can be hampered due to lack of data (Alder & Posner, 1999),
- Costly to measure benefits and costs, requires a level of expertise, includes intangible elements that cannot be measured (Williams, 2008),
- Does not produce morally relevant information (Alder & Posner, 1999),
- May have goals other than efficiency that are relevant (Boardman et al., 2006),
- May include distribution-of-wealth issues regarding willingness to pay (WTP) and willingness to accept (WTA) (Boardman et al., 2006),

- Greatly influenced by the discount rate and relevant costs and benefits chosen by the analyst.

The very premise of CBA, Pareto efficiency, is argued by many economists and philosophers as being inappropriate when deciding the wellbeing of individuals.

Alternative methods to CBA include cost-effectiveness analysis, cost-utility analysis, and multigoal analysis. Cost-effectiveness analysis can be used when two programs have similar or the same goal(s). Cost-utility analysis is commonly used in health economics because the benefits are usually measured in non-monetary units (Williams, 2008). Multigoal analysis can be used also when comparing alternatives based on relevant goals instead of just efficiency (Boardman et al., 2006). Despite some of the disadvantages of CBA and alternative techniques, these methods are commonly used by government agencies to evaluate proposed government programs and projects and have aided lawmakers for decades in weighing alternative uses and allocation of scarce public resources.

At the request of North Carolina Division of Forest Resources (NCDFR) officials, a *media res* analysis was conducted to evaluate the net benefits of the North Carolina Southern Pine Beetle Prevention Program (NCSPBPP). This program addressed the classic economic problem of market failure due to underproduction of a positive externality. In this case, the benefits generated from precommercial thinning (PCT), which includes the reduction of expected timber volume loss caused by the southern pine beetle (SPB) in treated stands and adjacent parcels. PCT increases the tree vigor of residual crop trees (Cain, 1993), reduces the probability of SPB infestation and severity of spread once an SPB infestation is initiated, produces higher-quality timber products (Cain, 1993), enhances aesthetics, and improves wildlife habitat (Mann & Lohrey, 1974; Cain, 1993). This market failure in the free markets justified government intervention through offering forest landowners subsidies, but this measure does not address how to allocate societal resources efficiently.

The objectives of CBA of the NCSPBPP are to quantify program net benefits to society, gain greater insight into program benefits and costs, identify feasible program shifts to achieve better resource utilization, and provide documentation for continuing program funding or termination. This CBA can also be used to compare the NCSPBPP to other SPB prevention programs operating in other Southeastern states and to regional programs. This could lead to the identification of "best practices" for SPB prevention efforts in the Southeast. This would improve the uniformity among states, achieve better resource utilization, and provide a basic framework for future SPB prevention programs.

<u>North Carolina Southern Pine Beetle Prevention Program</u>

The NCSPBPP is a cost-share program that partially reimburses PCT costs for landowners whose stands may be at risk of SPB attack. This program targeted, with PCT, young overstocked pure pine and pine hardwood mix forests. The NCDFR started implementing the program in May 2005 with an initial budget of three million dollars.

Program Structure and Eligibility

The program is divided into three major components: personnel, cost-share payments, and education. Only the personnel and cost-share portions are being evaluated, due to resource constraints and lack of data available to quantify the educational component. The NCDFR hired 13 SPB foresters and an outreach coordinator to administer and implement the state's SPB prevention program.

The program provides annually for position support, which may include office supplies, energy use, uniforms, office space, and transportation needs. The federal program funds also matches 50/50 with state funds for other NCDFR personnel acting as support staff. These personnel may include County Rangers, Assistant County Rangers, and Service Foresters. Job duties for these positions and SPB Foresters also included SPB educational initiatives. The benefits of these initiatives were excluded, but not all associated costs from the CBA. Educational costs were associated with the marketing and personnel portions of the program. Segregating educational costs from personnel costs proved to be difficult because it is unknown how much time and personnel resources were spent by program personnel to educate landowners. The CBA was a snapshot of the study fiscal year, whereas educational benefits tend to be long term, thus, educational benefits were excluded from the CBA. As a result of excluding educational benefits and including some educational costs in the analysis, program costs would be overestimated while program benefits would be underestimated.

Approximately one million dollars was set aside for landowner cost-sharing payments for PCT. PCT is the only approved forestry prescription under the program, which is mainly completed through mechanical methods or by manual-labor crews. Program eligibility requirements included being a non-industrial private landowner of at least five acres of forestland in North Carolina and having a preapproved written management plan, and the exclusion of acres already subsidized by other cost-share monies. A candidate stand must meet certain pretreatment criteria that are verified prior to enrollment by a NCDFR official. To qualify, candidate stands must have a minimal level of trees per acre (TPA) or basal area, meet the age limits, and have greater than 70% of stems consisting of eligible pine species. Detailed information on both pre-stand characteristic and post-stand characteristic requirements is depicted in Table 1 in Essay 1.

The cost-share reimbursement rate was 70/30, in which the landowner pays 30% of the PCT costs and the NCSPBPP covers the remaining 70%. Landowners can be reimbursed for treatment costs up to $8,000 annually per ownership. The cost-share rate was previously 50/50 and provided up to $5,000 annually for treatment costs. The cost-share rate was adjusted to the current rate on July 1, 2006 to provide greater financial incentive for landowner enrollment. Each approved landowner application must be completed within one calendar year if an extension is not approved by the NCDFR. Participating landowners must maintain treated stands for at least 10 years and meet the stipulations outlined in their approved landowner management plans. If a landowner fails to do so, he or she may be obligated to return reimbursed cost-share dollars to the State of North Carolina, and other financial penalties may apply.

<u>NCSPBPP CBA Framework</u>

An incremental analysis of with and without PCT was conducted to quantify costs and benefits associated with the NCSPBPP. The framework was constructed to determine the net program benefit or loss generated from the NCSPBPP in regards to society and the benefit-cost ratio of the program. Society was defined as all citizens of North Carolina.

Landowner Study Sample Demographics

To be included in the incremental analysis, landowners must have completed the program during the 2006–2007 state fiscal year (July 1, 2006–June 30, 2007). Landowners could have enrolled either during the same period or in a prior period. Landowners that were enrolled in the program during the study period but had not completed until after the study period were excluded from the analysis to keep the starting point of realized benefits consistent.

Completion status was given to landowners that completed PCT in the field and were reimbursed with costs-share monies from the NCDFR. Several parameters were analyzed. They include total acres, average tract size and range, stand establishment, stand age, site index (SI), trees per acre (TPA), and species. A total of 212 treated stands were sampled from across the state for the CBA, but primarily from the Piedmont and Coastal Plain. Of those stands, 32 (15%) were excluded from the analysis due to missing data, incomplete data, modeling restrictions, or consisting of a different pine species from loblolly pine, such as white, shortleaf, or longleaf pine. The remaining 180 treated stands, consisting of 6,241 acres of loblolly pine, were analyzed.

CBA Standing Benefits

Program benefits initially considered for the CBA included a reduction in expected timber volume loss caused by SPB, improved foraging habitat for wildlife and livestock (Cain, 1993; Mann & Lohrey, 1974), enhanced aesthetics, higher-valued timber products due to PCT, mitigated SPB suppression costs, preserved recreational areas, decreased price volatility due to less frequent and severe SPB epidemics, and jobs created due to an increase in tree-contractor activity and investment. A reduction in expected timber loss and higher-valued timber products were the primary benefits included in the CBA. These two benefits combined were defined as the “timber benefit” and were perceived to have significant impact on societal benefits and could be estimated utilizing the available landowner data set provided by the NCDFR. The remaining benefits of PCT considered for analysis were excluded because of insufficient data and resource constraints.

During the site visits conducted for the process evaluation, wildlife and aesthetics were identified as values that motivated landowners to participate in the program. However, based on the data set provided by the NCDFR, it was unclear the extent to which these values affected the landowner decision-making process. Improving wildlife habitat by prescribing PCT may benefit some species but harm others depending on their preferred habitat. Thus, the benefit or possible cost derived from this effect on wildlife would depend on how society values an increase in particular species' populations as a result of habitat improvement.

Southern pine beetle epidemics can influence timber price risk and volatility due to an oversupply of beetle-damaged wood. Generally, the beetle-damaged wood is removed through suppression and recovery efforts. SPB infestations recorded in Texas during the 1990s on several national forests were treated with cut and remove as the preferred method (Clarke & Billings, 2003). This technique sometimes can quickly generate an ample supply of beetle-damaged wood, causing downward pressure on local and regional timber prices in the short term. The price of pulpwood often falls to unprofitable levels when wood yards are being overrun with infested wood. During extreme SPB outbreaks, producers suffer a dead weight loss when infested trees are felled and left in the forest (Molnar et al., 2003). Forest landowners are faced not only with the loss of timber volume due to SPB tree-related mortality but with receiving lower prices for their timber. The benefit of mitigating SPB epidemics is significant, but the CBA framework assumed minimal SPB activity throughout the stand rotation. This would underestimate program benefits.

Based on observations during site visits and discussion with NCDFR officials, job creation as a result of increased tree-contractor activity and investment was considered to be unsubstantial. Therefore, a job multiplier was not taken into account in the CBA. Most tree contractors in each district were preexisting and had already acquired the equipment needed to perform PCT. Tree contractors included PCT to their list of services that they already provided. These contractors are also cautious to add new employees and equipment. This is because government-funded cost-share programs are frequently discontinued and reinvented due to constant changes in the political landscape and available funding. By excluding a job multiplier from the analysis, derived program benefits would be lower.

CBA Standing Costs

The costs of PCT, personnel which included costs associated with educational initiatives, position support, supplies and equipment, overhead, and other necessities were provided by NCDFR and were included in the CBA. Precommercial thinning costs were not separated between NCDFR and participating landowner because society as a whole bears the total costs. Also, the above costs associated with implementing the program were segregated into program enrollment and completion costs, to account for the different time periods in which costs were incurred. Higher fire- and ice-damage risk and costs associated with filling out paperwork, meeting with NCDFR officials, and locating a tree contractor to work with the landowner were excluded from the analysis. These costs were disregarded because of lack of available data to quantify time spent on landowner tasks and the perceived minimal increase in risk due to elevated fuel loads and the higher susceptibility of treated stands to ice damage after PCT was performed.

Program Net Benefit to Society

The program's net benefit to society was derived from the present values (PVs) of stands enrolled in the program minus program costs and the net present values of the same stands if the status quo would persist. Present values of stands account for SPB expected timber volume loss, which is estimated based on a deterministic approach, and for gains in product classes achieved by PCT.

$$\textit{Societal Program Net Benefit} = \underbrace{\left\{ \textit{(with PCT) PV} - \textit{(without PCT) PV} \right\}}_{\text{“Timber Benefit”}} - \textit{Program Costs PV}$$

The net benefit per participating landowner was summed to estimate the net benefit of the program to society. The benefit-cost ratio for the program was also calculated to determine the economic value of benefits generated by each dollar spent for the NCSPBPP.

The CBA framework assumes that PCT would have not occurred for participating landowners unless cost-share dollars were available, participating landowners' primary objective is timber production, timber volume loss due to SPB activity is not salvaged, and participating landowners practiced even-aged management. The cost of PCT, which generally occurs early in the rotation, is not usually recovered until the stand is harvested. Many forest landowners tend to minimize costs. This phenomenon may be attributed to the higher rate of return that is required by landowners for longer-term investments (Bullard et al., 2002) and to the capital requirement needed for conducting stand treatments. Thus, landowners tend to minimize their costs during the beginning of the rotation because of the low liquidity associated with this asset class, the higher rate of return expected because of a long investment horizon, and the risk attributed to price volatility and potential timber losses from insects, disease, fire, and other natural disasters. These factors can discourage many nonindustrial forest landowners from investing in PCT. However, by easing the financial burden on landowners through cost-sharing, the amount of work accomplished would increase, sometimes beyond the cost-share plan (Nowak et al., 2008). Other essential CBA assumptions are described in more detail later in this essay.

Cost and Benefit Analysis Methodology

Program Benefit Analysis

The timber benefit was quantified by mirroring a study conducted by Burkhart et al. (1986), which was an evaluation of thinning practices to reduce expected timber volume loss resulting from SPB. This model was considered deterministic rather than stochastic (Burkhart et al., 1986). Burkhart et al. (1986) employed the Cao et al. (1982) stand model for growth and yield forecasting, an SPB infestation probability model developed by Daniels et al. (1979) coupled with an SPB spot severity model from Reed et al. (1981), and an expected volume loss equation for calculating expected timber volume loss related to SPB activity over the entire rotation (Burkhart et al., 1986). The stand model of Cao et al. (1982) was not leveraged when forecasting future stand characteristics and harvest volumes, which initiated a growth and yield model selection process.

Growth and Yield Model Selection and Comparison

A growth and yield model comparison was conducted among Tauyield (TAULYLD), PLANTYLD, and NATYLD software packages to analyze the possible variability of average height, trees per acre (TPA), basal area, diameter at breast height (DBH), and volume among the different models. LOBDSS and PTAEDA2 software packages were also considered for this analysis, but they were rejected due to comparison and application limitations. This experimental design was intended to mimic young loblolly pine stands on different site indices of 60, 70, 80, and 90, all for base age 50 years, that were precommercially thinned at age 5 and harvested at age 35 with no further intermediate treatments. Under the NCSPBPP, loblolly pine stands under 10 years old were thinned to 450 TPA to meet post-treatment program requirements, which was set for the theoretical stands.

Growth and Yield Model Comparison Methodology

NATYLD, TAULYLD, and PLANTYLD were selected due to their similar input variables and output categories. TAULYLD required site index (SI) to be inputted at base age 25 years, but this was remedied by obtaining the SI equations for the model and making the appropriate conversions (Amateis et al., n.d.). The site index conversions from base age 50 years to base age 25 years can be found in Table 3. PTAEDA2 was excluded because of its having different input variables from the other selected models, which might have introduced unintended variability. PLANTYLD was chosen as a baseline model to draw comparisons and conclusions. As a result, the numeric values from TAULYLD and NATYLD were reported as the differences from those generated by PLANTYLD. PLANTYLD predictions are depicted as actual predicted numeric values in the results section.

Table 3: Site indices for base age 50 years converted to base age 25 years, which were inputted in the TAULYLD growth and yield model.

Base Age 50 Years	Converted to Base Age 25 Years
60	43.07518045
70	49.63124847
80	56.11167845
90	62.52669596

Species, initial TPA, SI, initial and harvest age, initial basal area, hardwood competition, thinning regime, and site location were required inputs for each of the models. Values inputted for each selected model are listed below, which were necessary in constructing model comparisons.

NATYLD

- Initial Trees per Acre: 450, 4500
- SI: 60, 70, 80, 90
- Initial Age: 5
- Harvest Age: 35
- Initial Basal Area: 1
- No Hardwood Competition and Thinning
- Loblolly Pine as Species

PLANTYLD

- Initial Trees per Acre: 450
- SI: 60, 70, 80, 90
- Initial Age: 5
- Harvest Age: 35
- No Hardwood Basal Area
- Loblolly Pine as Species
- Upland/Piedmont

<u>TAULYLD</u>

- SI: 60, 70, 80, 90 at Base Age 25 years after Conversion
- Initialized Existing Plantation Unthinned
- At Age 5 with 450 Trees per Acre
- Loblolly Pine as Species
- Can Compare: Average Height, Diameter at Breast Height, Basal Area, and Volume

A run was conducted for each model for site indices of 60, 70, 80, and 90, resulting in an initial 12 runs. However, NATYLD's initial TPA input variable was adjusted to 4,500 TPA because the NATYLD model contains a mortality function that drastically decreases the TPA to unrealistic levels at the beginning of the rotation. A total of 16 runs were conducted for the final model comparisons, and the adjusted NATYLD results are presented separately as NATYLD REV. Growth and yield estimates were reported for each 5-year interval beginning at age 5 and ending at age 35 when the stand was harvested.

Growth and Yield Model Comparison Results

Tables 4 through 8 display the deviation from PLANTYLD at each age, the absolute value of the deviation across the entire rotation, the average deviation for all ages, and the actual data generated from PLANTYLD, which is depicted in the last column of each table. The actual raw data sets outputted by NATYLD, PLANTYLD, and TAULYLD are in Appendix A. Graphs were also generated for each output category and are presented in Appendix B.

TAULYLD predicted higher average heights and volume for site indices of 60 and 70 than did PLANTYLD. However, TAULYLD generated lower estimates for TPA, basal area, DBH, and volume for site indices 80 and 90. As site index increased for different categories, TAULYLD's variability compared to PLANTYLD increased for basal area and diameter at breast height, but it decreased for average height and TPA. As age increased, TPA and basal area had increased variability for TAULYLD. Volume estimates had the same behavior except at site index 60.

NATYLD's forecasted output values were lower than those of the base model in most categories, such as average height, TPA, basal area per acre, and volume. The only exception was DBH, for which NATYLD generated higher estimated values. When adjusting TPA initially to 4,500 for NATYLD REV, the basal area per acre, average height, and volume remained unchanged compared to the NATYLD unadjusted. The only two categories that differ were DBH and TPA.

The adjustment enabled NATYLD REV to predict DBH with lower variability compare to PLANTYLD, but the estimated DBH values were less than those forecasted by PLANTYLD. As the site index increased for NATYLD, the variability for DBH decreased compared to PLANTYLD. NATYLD REV was found with the opposite effect; as the site index increased also did the variability in DBH compared to PLANTYLD. For the trees per acre category, NATYLD and NATYLD REV had similar trends for variability changes due to site index. As the site index increased the variability for TPA against the base model decreased. NATYLD and NATYLD REV experienced higher variability for basal area and volume compared to the base model as the site index and age level increased.

Table 4 depicts the results of the comparisons of average height among the different models for various site indices.

Table 4: Average height per acre comparisons for SI 60, 70, 80, and 90 with base age 50 years.

Year	Average Height (ft)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
SI 60			
5	-5	n/a	9
10	-3.3	1.62	19.3
15	-0.9	2.5	26.9
20	1.4	2.3	32.6
25	1.8	2.94	37.2
30	2.1	3.5	40.9

Table 4 (continued)

Year	Average Height (ft)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
35	1.9	4.93	44.1
Total of Absolute Values of Differences	**16.4**	**17.79**	n/a
Average Difference	**-0.29**	**2.97**	n/a
SI 70			
5	-7.7	n/a	11.7
10	-4	0.75	23
15	-1	0.72	32
20	0.1	1.63	38.9
25	1.5	1.25	44.5
30	0.9	2.93	49.1
35	1.1	3.4	52.9
Total of Absolute Values of Differences	**16.3**	**10.68**	n/a
Average Difference	**-1.3**	**1.78**	n/a
SI 80			
5	-7.5	n/a	12.5
10	-5.7	-0.62	26.7
15	-2.3	-0.53	37.3
20	-0.4	0.56	45.4
25	0	1.44	52
30	0.6	1.25	57.4
35	0	2.89	62
Total of Absolute Values of Differences	**16.5**	**7.29**	n/a

Table 4 (continued)

Year	Average Height (ft)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
Average Difference	**-2.19**	**0.83**	n/a
Site Index 90			
5	-9.4	n/a	14.4
10	-6.7	-1.94	30.7
15	-3.8	-1.86	42.8
20	-2.2	-1.77	52.2
25	-0.8	-0.9	59.8
30	-1.1	-0.04	66.1
35	-1.6	0.81	71.6
Total of Absolute Values of Differences	**25.6**	**7.32**	n/a
Average Difference	**-3.66**	**-0.95**	n/a

Table 5 depicts the results of the comparisons of trees per acre among the different models for various site indices.

Table 5: TPA comparisons for SI 60, 70, 80, and 90 with base age 50 years.

Year	**TPA**			
	NATYLD – PLANTYLD	NATYLD REV – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
SI 60				
5	0	4050	n/a	450
10	-367	368	-22	449
15	-400	43	-34	449
20	-410	-63	-56	449
25	-416	-115	-86	449
30	-417	-143	-123	447

Table 5 (continued)

Year	TPA			
	NATYLD – PLANTYLD	NATYLD REV – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
35	-414	-159	-161	442
Total of Absolute Values of Differences	**2424**	**891**	**482**	n/a
Average Difference	**-346.29**	**-11.5**	**-80.33**	n/a
SI 70				
5	0	4050	n/a	450
10	-366	382	-22	449
15	-398	56	-36	449
20	-408	-49	-59	448
25	-407	-95	-87	442
30	-398	-115	-115	430
35	-383	-118	-140	412
Total of Absolute Values of Differences	**2360**	**815**	**459**	n/a
Average Difference	**-337.14**	**10.17**	**-76.5**	n/a
SI 80				
5	0	4050	n/a	450
10	-364	396	-22	449
15	-395	73	-37	447
20	-398	-25	-56	439
25	-387	-62	-77	423
30	-366	-71	-96	399
35	-341	-65	-115	372
Total of Absolute Values of Differences	**2251**	**692**	**403**	n/a
Average Difference	**-321.57**	**41**	**-67.17**	n/a
SI 90				

Table 5 (continued)

Year	TPA			
	NATYLD – PLANTYLD	NATYLD REV – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
5	0	4050	n/a	450
10	-363	411	-23	449
15	-387	96	-33	441
20	-380	7	-45	423
25	-359	-21	-58	397
30	-334	-25	-76	368
35	-306	-18	-93	338
Total of Absolute Values of Differences	**2129**	**578**	**328**	n/a
Average Difference	**-304.14**	**75**	**-54.67**	n/a

Table 6: Basal area per acre comparisons for SI 60, 70, 80, and 90 with base age 50 years.

Year	Basal Area (ft^2/ac)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
SI 60			
5	-3	n/a	4
10	-18	12	28
15	-32	1	57
20	-44	-11	84
25	-54	-22	106
30	-62	-35	125
35	-69	-49	140
Total of Absolute Values of Differences	**282**	**130**	n/a
Average Difference	**-40.29**	**-17.33**	n/a
SI 70			
5	-5	n/a	6
10	-28	7	39

Table 6 (continued)

Year	Basal Area (ft^2/ac)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
15	-50	-9	76
20	-66	-23	108
25	-78	-36	133
30	-85	-50	152
35	-88	-62	164
Total of Absolute Values of Differences	**400**	**187**	n/a
Average Difference	**-57.14**	**-28.83**	n/a
SI 80			
5	-8	n/a	9
10	-41	1	52
15	-69	-17	96
20	-87	-32	131
25	-97	-44	156
30	-100	-55	171
35	-98	-65	179
Total of Absolute Values of Differences	**500**	**214**	n/a
Average Difference	**-71.43**	**-35.33**	n/a
SI 90			
5	-11	n/a	12
10	-55	-6	66
15	-88	-29	117
20	-106	-43	153
25	-113	-52	176
30	-112	-60	188
35	-105	-68	192
Total of Absolute Values of Differences	**590**	**258**	n/a
Average Difference	**-84.29**	**-43**	n/a

Table 7: DBH per acre comparisons for SI 60, 70, 80, and 90 with base age 50 years.

Year	DBH (in)			
	NATYLD – PLANTYLD	NATYLD REV – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
SI 60				
5	-0.7	-1.1	n/a	1.3
10	1.4	-1.9	0.7	3.4
15	4.9	-1.7	0.3	4.8
20	7.9	-1.5	0	5.8
25	10.3	-1.2	-0.1	6.6
30	12.3	-1	-0.1	7.2
35	13.9	-0.8	0	7.6
Total of Absolute Values of Differences	**51.4**	**9.2**	**1.2**	n/a
Average Difference	**7.14**	**-1.35**	**0.13**	n/a
SI 70				
5	-1	-1.4	n/a	1.3
10	0.9	-2.5	0.4	3.4
15	4.1	-2.5	-0.1	4.8
20	7.1	-2.3	-0.4	5.8
25	9.7	-2	-0.3	6.6
30	11.7	-1.8	-0.3	7.2
35	13.2	-1.6	-0.2	7.6
Total of Absolute Values of Differences	**47.7**	**14.1**	**1.7**	n/a
Average Difference	**6.53**	**-2.12**	**-0.15**	n/a
SI 80				
5	-1.3	-1.7	n/a	1.9
10	0.3	-3.1	0.2	4.6
15	3.5	-3.2	-0.4	6.3

Table 7 (continued)

Year	DBH (in)			
	NATYLD – PLANTYLD	NATYLD REV – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
20	6.6	-3	-.5	7.4
25	9.1	-2.7	-0.5	8.2
30	11	-2.6	-0.5	8.9
35	12.6	-2.4	-0.4	9.4
Total of Absolute Values of Differences	**44.4**	**18.7**	**2.5**	n/a
Average Difference	**5.97**	**-2.83**	**-0.35**	n/a
SI 90				
5	-1.6	-2	n/a	2.2
10	-0.3	-3.6	-0.1	5.2
15	2.9	-3.9	-0.7	7
20	6	-3.6	-0.8	8.1
25	8.5	-3.5	-0.8	9
30	10.5	-3.3	-0.7	9.7
35	12.1	-3.2	-0.6	10.2
Total of Absolute Values of Differences	**41.9**	**23.1**	**3.7**	n/a
Average Difference	**5.44**	**-3.52**	**-0.62**	n/a

Table 8 provides the results of the comparisons of volume per acre among the different models for various site indices.

Table 8: Volume per acre comparisons for SI 60, 70, 80, and 90 with base age 50 years.

Year	Volume (ft^3/ac)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
SI 60			
5	-13	n/a	14
10	-129	211.6	197
15	-285	295.1	556
20	-434	320.6	985
25	-578	296.9	1423
30	-721	210.2	1843
35	-854	52.2	2226
Total of Absolute Values of Differences	**3014**	**1386.6**	n/a
Average Difference	**-430.57**	**231.1**	n/a
SI 70			
5	-23	n/a	25
10	-244	200.7	326
15	-549	224.8	880
20	-836	174.2	1514
25	-1089	67.7	2133
30	-1290	-92.1	2680
35	-1422	-302.1	3122
Total of Absolute Values of Differences	**5453**	**1061.6**	n/a
Average Difference	**-779**	**45.53**	n/a
SI 80			
5	-39	n/a	41
10	-404	187.3	500
15	-894	162.3	1290
20	-1325	62.3	2145
25	-1646	-75	2916
30	-1841	-252.7	3535

Table 8 (continued)

Year	Volume (ft^3/ac)		
	NATYLD – PLANTYLD	TAULYLD – PLANTYLD	PLANTYLD
35	-1912	-481.6	3985
Total of Absolute Values of Differences	**8061**	**1221.2**	n/a
Average Difference	**-1151.57**	**-66.23**	n/a
SI 90			
5	-63	n/a	65
10	-619	116.2	730
15	-1326	5.2	1793
20	-1886	-147	2866
25	-2248	-313.2	3774
30	-2425	-527.7	4466
35	-2449	-816.9	4949
Total of Absolute Values of Differences	**11016**	**1926.2**	n/a
Average Difference	**-1573.71**	**-280.57**	n/a

Growth and Yield Model Effects on SPB Risk Analysis

Expected timber volume loss as a result of SPB activity is calculated using an approach similar to Burkhart et al. (1986) and is greatly impacted by basal area, TPA, DBH, and volume forecasts. The initial probability of an SPB infestation based on equations developed by Daniels et al. (1979) increases with pine basal area. Basal area also influences the dynamics of the severity level and growth of SPB infestations. Seen in the SPB infestation probability model (Daniels et al., 1979), a higher total basal area inputted in the SPB spot severity model (Reed et al., 1981) resulted in greater tree mortality per day due to SPB. Two other input variables to the spot severity model are TPA and DBH. As the TPA increases, more trees are assumed to have been attacked. Last, increasing the stand volume was assumed to result in a higher expected SPB timber volume loss. Each growth and yield model generated different estimates for basal area, TPA, DBH, and volume, which can fundamentally influence the final CBA.

Growth and Yield Model Final Selection

The North Carolina State University Managed Pine Plantation Growth and Yield Simulator (PLANTYLD) was selected to forecast future harvest volumes of pine and hardwood pulpwood, pine chip-n-saw, and pine sawtimber by inputting variables such as age, initial and post-treatment TPA, and site index with base age 50 years. This model was chosen because it accommodated the data set provided by NCDFR, practical use, user-friendliness, and the ability to modify the model to generate required output parameters on an annual basis. TAULYLD would generally produce lower expected SPB timber volume losses due to lower stand volume predictions on the more productive sites, TPA, and basal area predictions. However, expected SPB timber volume loss results would be slightly closer on less productive sites because TAULYLD predicted higher stand volume than did PLANTYLD for those sites. Generally, NATYLD would generate significantly different results due to predicting lower values for stand characteristic categories and different site index levels. The probability of initial SPB attack, SPB spot severity, and expected SPB timber volume loss would all be affected by the lower forecasts in contrast to PLANTYLD. NATYLD, which is based on natural stand data, is not the best fit for the CBA because it is unreliable for stands under 20 years old, which is explicitly mentioned when running the program, and tended to have excessive tree mortality and dbh estimates. However, reliable results from NATYIELD have been obtained down to age 10 (Franklin & Lloyd, 1997).

PLANTYLD Growth and Yield Model Methodology

Age, TPA, site index with base age 50 years, tree species, region, mixed hardwood competition, and percentage of hardwood basal area to the total basal area were inputted into the PLANTYLD growth and yield model. The lower estimates for TPA and site index were used because parameter ranges were commonly found for these stand characteristics, unlike age. By selecting the lower TPA and site index, program benefits would be underestimated. If a landowner enrolled more than one distinct stand based on differences in age, site index, tree species, and trees per acre for the same SPB landowner application, separate simulations were conducted for each. Treated stands comprised only of loblolly pine were selected for the analysis. Piedmont, upper coastal plain, and lower coastal plain are selectable regional classifications in PLANTYLD. Regional classification was based on the county where the treated stand is located.

Percentage of hardwood basal area was assumed to default to zero if the NCDFR provided no data to indicate any hardwood competition or if there were insufficient data for a reasonable estimation. Based on site observations and discussions with SPB Foresters, enrolled stands tended to consist of some type of hardwood, but hardwood competition usually was scattered and sparse. Hardwood competition estimations were derived by utilizing pine and hardwood basal areas that were given on the field data sheet (FDS) or found in the landowner management plan. If the estimated hardwood basal area was greater than 30% of the total basal area, then the percentage of hardwood basal area was set to 30% because it would have not met program requirements otherwise. All of the hardwood competition was removed for simulations that pertained to enrolled stands where PCT was conducted. Hardwood competition categories found in the model were excurrent, decurrent, or mix of both excurrent and decurrent hardwood species. Based on the provided data, the quantity of each hardwood species was unclear. Therefore, mix of excurrent and decurrent hardwood species was selected when an enrolled stand consisted of both pine and hardwood. The hardwood was assumed to be the same age as the pines because timber harvesting of a particular stand usually occurs at the same time for both the pine and hardwood species.

The growth and yield projections were reported starting at year 10, or at the treatment year if the age was greater than 10, until age 45. Output parameters included age, basal area, DBH, average height, pine volume, and hardwood volume. Projections were initiated at year 10 because the SPB seldom attacks pine stand less than 10 years old and with a basal area of less than 60 square feet per acre (Anderson & Doggett, 1980). Expected volume loss was assumed to be zero during the prior years. Modeling for stands with PCT included a harvest age of 35 years, thinning to 450 TPA if the stand was younger than 10 years old or to 300

TPA if the stand was at least 10 years old, and no future intermediate treatments. To mimic stand conditions without PCT, a separate run was conducted for each participating landowner, which included no additional thinning or intermediate treatments and harvesting at age 35.

Harvest volumes were converted to cubic feet from MBF per acre for pine sawtimber. Timber Mart-South prices for pine chip-n-saw, pine pulpwood, and hardwood pulpwood were converted to cubic feet to match the model output. The conversion factors used were 95 ft^3 per cord and 185.19 ft^3 per MBF. Expected SPB timber volume loss was subtracted from the total harvest of merchantable timber. This condition implies that tree growth within the stand was not affected by tree mortality due to SPB and that the volume loss is not realized until harvest. In moderate to severe SPB epidemics, surviving trees may increase in growth due to less competition for resources, which may partially offset some of the timber volume losses due to tree mortality from SPB. The adopted conditions are appropriate in representing a landscape with minimal and sporadic SPB activity.

Some participating landowners that completed the program during the study period were excluded from the analysis because of modeling restrictions or incomplete data. Growth and yield projections were not obtained for stands composed of shortleaf, longleaf, and white pine. Each participating landowner must have documented age, site index, type of pine species, and TPA to forecast future growth and yield values. A total of 360 simulations were conducted for this study.

<u>SPB Risk and Expected Timber Volume Loss Analysis</u>

The SPB risk and expected timber volume loss analysis contained three components: the annual SPB infestation probability equation from Daniels et al. (1979), the SPB spot spread severity model of Reed et al. (1981) to determine trees killed per day, and SPB expected volume loss equations obtained from Burkhart et al. (1986). All three components work in unison to estimate the total expected SPB timber volume loss for both with and without PCT for the entire rotation. Other expected SPB loss models are available, such as

CLEMBEETLE and TAMBEETLE, but were not used in this study because they require more input parameters for estimating SPB expected timber volume loss then were available.

Annual SPB Infestation Probabilities

To estimate annual SPB infestation probabilities, the logistic probability function developed by Daniels et al. (1979) was selected due to its simplicity, the study data set limitations, and lack of specific stand-characteristics databases available relating to SPB infestations in North Carolina. The probabilities generated from this function may be combined with outbreak severity estimates to predict SPB expected value losses (Daniels et al., 1979). That function also provides a continuous measure of incidence, which may be differentiated into risk categories, predicts infestation probabilities for stands with low susceptibility, and provides probabilities that can be used in sophisticated decision models, such as forest simulators (Reed, Hedden, & Daniels, 1982). However, Daniels et al. (1979) SPB infestation probability function excluded the effect of SPB activity in prior years (Reed et al., 1982), derived from limited temporal SPB data, and based on non-plantation forest stands only due to insufficient data obtained for plantation stands (Daniels et al., 1979).

The following equation was used to calculate annual SPB infestation probabilities acquired from Daniels et al. (1979). The regression coefficients used in the equation varied depending on whether disturbed or undisturbed conditions existed (Table 9). The following equations and variables definitions are from Daniels et al. (1979).

$$\hat{p} = 1/[1 + e^{-(b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k)}]$$

where: $\hat{p}$ = the estimated value of p; $0 \leq p \leq 1$
e = the base of the natural logarithm
b_i = the ith estimated regression coefficient ($i = 0, 1, 2, \ldots, k$)
x_i = the ith variable associated with outbreak probability ($i = 0, 1, 2, \ldots, k$).

Table 9: Undisturbed and disturbed stand regression coefficients obtained by Daniel et al. (1979).

Stand type	B_o	B_1	B_2
Undisturbed	-8.599	0.044	3.309
Disturbed	-9.998	0.088	4.801

Regression estimates for undisturbed stands were used for years PCT was absent. Disturbed-stand coefficients were used in the year following the treatment year. X_1 and X_2 were the only two parameters inputted into the Daniels et al. (1979) model. X_1 was defined as the total basal area in m^2/ha of the stand, whereas X_2 is the proportion of pine basal area to the total basal area. X_2 was set no lower than .7 to meet program requirements if hardwood basal area was present. Both parameters had to be converted to m^2/ha from ft^2/ac because the latter unit applied to growth and yield model outputs for basal area. Annual SPB infestation probabilities were later divided by the average stand size of 15 acres obtained from Knight (1978) to covert these probabilities to per acre (Burkhart et al., 1986). It was assumed that stands are not susceptible to SPB infestation until year 10.

SPB Severity Spot Model

The SPB spot severity model estimated the number of trees killed during spot initiation and the number killed per day after infestation begins (Reed et al., 1981). The following equations are from Reed et al. (1981).

$$\ln(TK/D) = 3.43457 + 0.96545 \ln AT - 2.84669 \ln DBH - 22.13668 TBA/DBH^2 + 0.073662 TBA + 0.55764 POP$$

$\ln(TK/D)$ = the predicted natural logarithm of trees killed per day
$\ln AT$ = the natural logarithm of the number of attacked trees at the start of the simulation period
DBH = the mean DBH of the stand (cm) at the start of the year
TBA = the total basal area of the stand (m^2/ha) at the start of the year
POP = the number of spots per 405 ha (1,000 ac) of host type for the entire region during the year being examined.

$$TK/D = \exp(\ln(TK/D) + (s^2_{y \cdot x}/2))$$

TK/D = the estimated number of trees killed per day
$\ln(TK/D)$ = the predicted logarithm of the number of trees killed per day
$s^2_{y \cdot x}$ = the mean square error of the estimate ($\ln(TK/D)$).

The initial number of trees attacked was set to 5% of the TPA. The mean standard error was given as 0.53 (Reed et al., 1981); thus, S^2_{y*x}, the mean square error of the estimate, was determined to be $(0.53)^2$. Diameter at breast height and total stand basal area estimates provided by PLANTYLD were converted, the former from inches to centimeters and the latter from square feet per acre to square meter per hectare, before being input into the SPB spot severity model. The SPB population levels used were 0.5, 1, and 2 spots per 1,000 acres of host species, termed Infestation One, Infestation Two, and Infestation Three, respectively.

SPB Expected Timber Volume Loss

SPB expected timber volume loss was calculated using the corresponding equation from Burkhart et al. (1986). This equation is displayed below with parameter definitions from Burkhart et al. (1986).

$$VL = \sum_{j=k}^{r} (P_j)(D \times TKD_j + AT_j)(V_j/N_j)$$

VL = expected volume loss over rotation due to SPB infestations
r = rotation length
k = age at which stand first becomes susceptible to SPB attack
P_j = probability of infestation at year j
D = number of days of spot expansion
TKD_j = trees killed per day at year j
AT_j = initial number of attacked trees at year j
V_j = volume/ac at year j
N_j = number of stems/ac at year j

Initial trees attacked (At_j) was assumed to be 0.05 of an acre when a spot was initiated. D was set at 45 days, and stands were not attacked until age 10. Rotation length, defined as r, was the harvest age of 35 years minus the age when the stand was treated if the stand age was initially greater than 10; otherwise r was equal to 25—the difference between 10 and 35—since the stand does not become susceptible until year 10. Thus, k must be defined as being greater or equal to 10 for stands younger than 10 years old.

Annual SPB infestation probabilities, represented by P_j, were generated from the Daniels et al. (1979) probability model. The SPB spot severity model (Reed et al., 1981) produces numerical values for trees killed per day on an annual basis, which is defined as TKD_j. Last, annual trees per acre and volume estimates from PLANTYLD were inputted for N_j and V_j. By following this method developed by Burkhart et al. (1986), SPB expected volume loss for both with PCT and without PCT were determined.

Projected Prices and Present Values

2006 Timber Mart-South average stumpage prices for eastern and western regions of North Carolina were used in the CBA (Table 10). In the study sample, only District 12 was considered to be in western region of NC. The remaining NCDFR districts with participating landowners were in the eastern region. These prices were not compounded into the future, which indicated no real price increases during the rotation. Final harvest values were then calculated by taking the total merchantable volume from the model and subtracting the expected timber volume loss due to SPB. This net volume was then multiplied by a weighted price based on the product class distribution at harvest. Harvest values for both with and without PCT were then converted to present values (PVs) by discounting with real discount rates of 4 percent (Fitzsimmons & Harou, 1981; Row, Kaiser, & Sessions, 1981; De Steiguer, Hedden, & Pye, 1987) and 10 percent (Fitzsimmons & Harou, 1981; Kronrad & Morzuch, 1985; De Steiguer et al., 1987).

Table 10: 2006 Timber Mart-South average stumpage prices for western and eastern North Carolina.

Product	**Western Region**	**Eastern Region**
Pine Sawtimber	$217.00	$310.00
Pine Chip-N- Saw	$49.52	$66.05
Pine Pulpwood	$12.53	$16.27
Hardwood Pulpwood	$13.77	$10.26

Program Cost Analysis

Societal costs considered were PCT costs and program administration costs, which included personnel, position support, supplies and equipment, overhead, and miscellaneous. Program administration costs were further divided into two categories: program enrollment costs and program completion costs. These costs are incurred by the NCDFR for administering the program and exclude costs generated by interested landowners, such as time to fill out program paperwork, meeting with NCDFR officials, and locating possible tree contractors.

Program enrollment and program completion costs were segregated to account for those landowners whose enrollment or completion did not occur within the study period. Landowners that did not enroll within six months of the beginning of the study period (July 1, 2006) had their enrollment costs compounded forward by a year. Enrollment costs were excluded for landowners that enrolled during the study period but did not complete. Generally, the initial program year may incur costs that would be higher than in subsequent years because of startup costs and early implementation inefficiencies. Program enrollment and completion costs from the 2006–2007 NC fiscal year, rather than costs generated during the initial program year of 2005, were applied to each participating landowner to better reflect the typical long-term costs of the program.

Program Enrollment vs. Program Completion Costs

Program enrollment costs included

- Identifying and researching parcels that may qualify for cost share.
- Contacting landowners and informing them of program information.
- Conducting onsite inspections of parcel to see if stand(s) meet program requirements.
- Surveying and conducting plot measurements to collect stand-characteristics data.
- Writing a landowner management plan with recommendations and prescriptions.
- Filling out cost share application and sending it to the central office to be processed.
- Helping the landowner find a contractor to conduct PCT.
- Position support expenses and personnel costs.

Program completion costs included

- Monitoring contractors and job quality.
- Inspecting completed projects to ensure that they meet program requirements.
- Estimating acres of PCT for cost-share reimbursement.
- Processing forms for landowner reimbursement.
- Roll-up of results and accomplishments to state and federal levels.
- Position support expenses and personnel costs.

Three different program enrollment and program completion cost weights were developed based on a survey of SPB foresters during administrative site visits, to which six SPB Foresters responded. These weights were developed due to the lack information available for determining if program enrollment or program completion costs carried the greater weight on total program administration costs. The different weights were 70% program enrollment costs and 30% program completion costs, 50% program enrollment costs and 50% program completion costs, and 30% program enrollment costs and 70% program completion costs.

To calculate program enrollment and completion costs for the study period, landowners had to be segregated by those who enrolled and completed in the study period (E/C), enrolled but did not complete during the study period (E/NC), and enrolled prior to the study period but completed during the study period (PE/C). Program enrollment and completion costs are assumed to be perfectly uniform among all groups of landowners. Table 11 depicts the associated costs embedded in the expense information provided by NCDFR.

Table 11: Program enrollment and completion costs for each group of landowners accounted for in budget expenditures from July 1, 2006 to June 30, 2007.

Landowner Enrolled/Completed (E/C)	$E_c + C_c$
Landowner Prior Enrolled/ Completed (PE/C)	C_c
Landowner Enrolled/ Not Completed (E/NC)	E_c

$$Total\ Program\ Administration\ Expenditures = (E_c + C_c) * E/C_{Acres} + C_c * PE/C_{Acres} + E_c * E/NC_{Acres}$$

Different weight equations for program enrollment and completion costs

E_c/C_c *(70/30):* $E_c = (.7/.3)C_c$

E_c/C_c *(50/50):* $E_c = C_c$

E_c/C_c *(30/70):* $E_c = (.3/.7)\ C_c$

Program enrollment and completion costs were solved by using systems of equations.

E/NC landowners were adjusted to reflect the tendency of NCDFR personnel to overestimate the initial number of acres to ensure that sufficient funds were allocated for treatment (Figure 7). Based on landowner data of all completed projects since 2005, which was a sample of 273 landowners, NCDFR personnel tended to overestimate the number of acres actually treated with PCT by 15.47% or 5.7 acres on average. As a result, a total of 9,086 enrolled acres was adjusted to 7,680.71 acres.

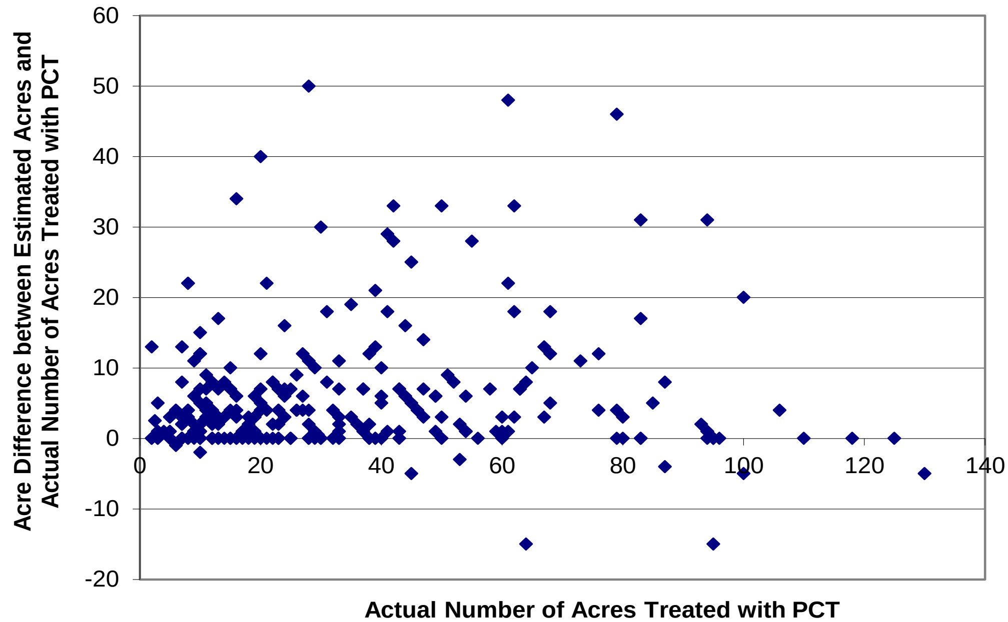

Figure 7: A comparison of the estimated and actual quantities of treated acres.

Program Net Benefit Analysis

Program incremental benefits were calculated by subtracting without PCT present values from with PCT present values to capture the "timber benefit," which reflected the gain in higher product classes and the decrease in SPB expected timber volume loss due to PCT. The program and treatment costs were then subtracted from the sum of all program incremental benefits to determine the program net benefit. A benefit-cost (B/C) ratio was calculated by dividing the present values of the timber benefit by the societal costs. If the B/C ratio is greater than one, landowners and society are benefiting from and better off with the program than with the status quo.

CBA Sensitivity Analysis

A sensitivity analysis was undertaken to analyze the effects of variability for age, site index, and TPA on the incremental gain from PCT with a real discount rate of 4 and 10 percent. PCT incremental gain (timber benefit) is defined as the difference in present values from with and without PCT. The timber benefit was based on Infestation One (0.5 spots per 1,000 acres of host species) for the sensitivity analysis. Enrollment period was also examined and served as a dummy variable. A score of zero was given to all landowners that completed within the study period and PE/C landowners having program enrollment costs not compounded to the present. A score of one was given to PE/C landowners having their program enrollment costs compound by the appropriate real discount rate one year to the present. Enrollment period was included in the analysis to identify any correlations involving the timber benefit and the different landowner groups. Microsoft Excel's regression analysis package was utilized for the calculations, and the confidence level was set to 95%. This software package performed a linear regression by utilizing least square methods to determine the best-fit line.

Cost and Benefit Analysis Results

Study Sample Statistics

The average treated stand for all participating landowners was approximately 34 acres, with minimum 2 acres and maximum 130 acres. A breakdown of stand establishment statistics can be found in Table 12. Species composition for the entire study sample is shown in Table 13.

Table 12: Stand establishment amount of acres and percentage of the total by category.

Stand Establishment	Acreage	Percentage of Study Sample
Natural Regeneration	1,902.5	27%
Plantation	4,373	61%
Unknown or Missing	853.5	12%

Table 13: Species composition for the entire study sample, reported in total acres and percentage of total acres.

Species	Acreage	Percentage of Study Sample
Loblolly Pine	6,448.0	90.22%
Longleaf Pine	589.0	8.24%
White Pine	38.5	0.54%
Shortleaf	6.0	0.08%
Mixed (White, Virginia, and Shortleaf)	2.0	0.03%
Unknown	63.5	0.89%

Stand age for the 180 treated stands included in the CBA ranged from 2 to 13 years, averaging 7.67. Site index with base age 50 ranged from 56 to 105 with an average of 81.53, whereas TPA ranged from 300 to 5,000 with an average of 1,473.46.

Total Program Expenditures and PCT Costs

Total program implementation expenditures, program enrollment, and program completion costs are depicted in Table 14 and Table 15.

Table 14: Program implementation expenditures and PCT costs provided by the NCDFR for fiscal year 2006–2007.

Item	Cost
Personnel	$593,519.86
Services (Utilities/Vehicle/Travel/Contractors)	$153,661.56
Supplies	$64,403.27
Equipment	$125,257.73
Other	$730.08
Overhead	$93,813.17
Subtotal	**$1,031,385.67**
PCT Costs (Division and Landowner Costs)	$724,431.57
Total Program Costs	**$1,755,817.24**

Table 15: Program enrollment and completion cost estimates for 70/30, 50/50, and 30/70 weights.

E/C Split ($/acre)	70/30	50/50	30/70
Enrollment Costs	$72.92	$56.58	$37.16
Completion Costs	$31.25	$56.58	$86.70

SPB Infestation Probability Curves

SPB infestation probability curves are depicted in Figure 8 for stands with the same age and TPA in the Upper Coastal Plain. One stand had a site index of 70 with a base age 50, and the other stand had a site index of 90 with a base age 50. For both SI levels, the SPB infestation probability was lower after PCT treatment. On average, simulations without PCT had higher probabilities of SPB infestation than with PCT. This is similar to what Hedden concluded in his 1983 study, that the probability of SPB infestation for a particular stand is low, and SPB infestation probabilities are higher at the end of the rotation for thinned plots.

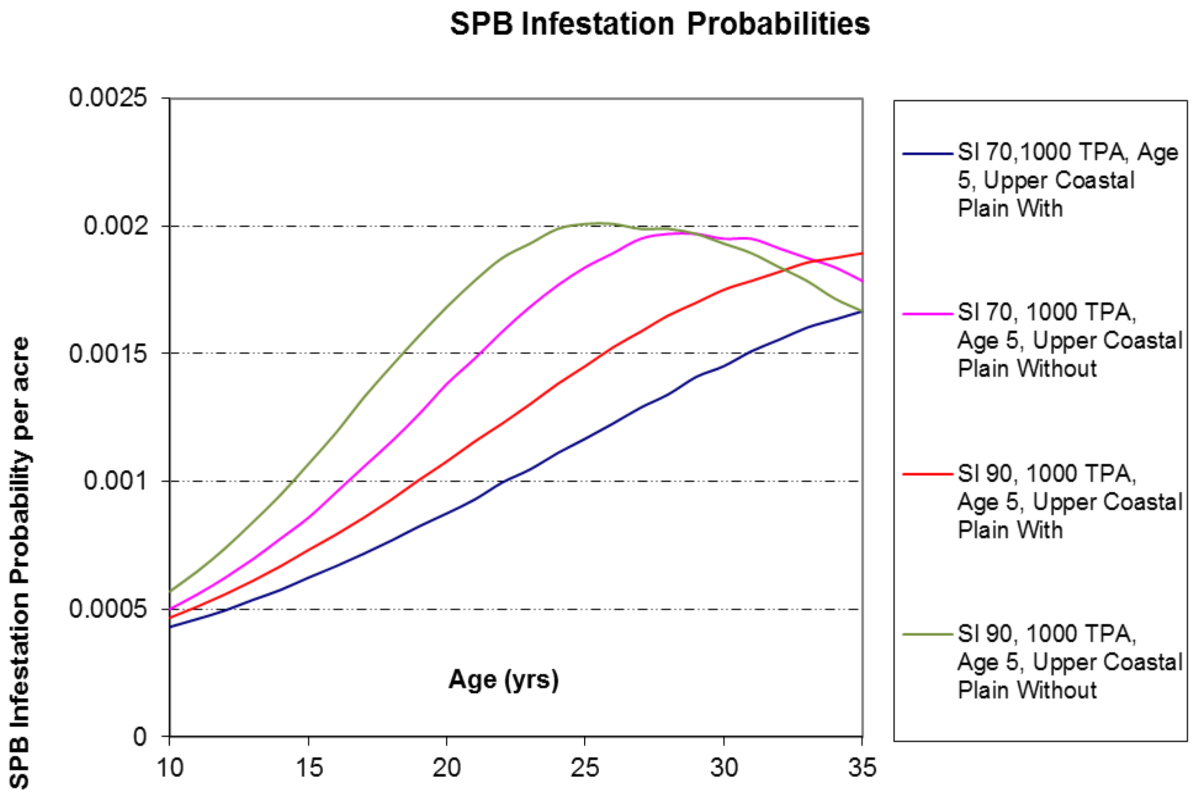

Figure 8: SPB infestation probabilities with and without PCT in the Upper Coastal Plain for stands 5 years old and having 1,000 TPA, but with different site indices (SI base age 50 years) of 70 and 90.

Program Net Benefits

The NCSPBPP generated a societal net benefit of $680,414.19 to $818,019.97 based on a real discount rate of 4% for the NC fiscal year of 2006–2007. This is equivalent to $109.02 to $131.07 per acre. All program net benefit values were negative with a 10% real discount rate. Based on the average between low and high infestation levels, SPB expected timber volume loss was 4.67 ft^3 per acre with PCT and 5.12 ft^3 per acre without PCT. This represents an approximate 9% reduction in SPB expected timber volume loss if treatment is undertaken. These results are similar to those in Hedden (1983) and Burkhart et al. (1986).

Hedden determined that SPB expected timber volume loss was always lower on thinned plots due to lower SPB infestation probabilities and lower spot damage. Burkhart et al. (1986) concluded a net present value gain of $8.19 with a real discount rate of 4% as a result of thinning to reduce SPB timber volume losses. Burkhart et al. (1986) also showed that higher realized gains were on more productive sites, higher thinning intensities, and during elevated SPB population levels. Thinning practices will reduce timber losses due to SPB activity but will not eliminate them entirely (Hedden, 1983).

Benefit-Cost Ratios (B/C Ratios)

The benefit-cost ratios (B/C ratios) varied by SPB population level and weighting of program enrollment and completion costs. Different B/C ratios with corresponding real discount rates are depicted in Figure 9 given an infestation level of 0.5 spot per 1,000 acres of host species. The B/C ratios were from 1.42 to 1.55 at a 4% real discount rate for the NCSPBPP. The program did not pass the B/C test at a real discount rate of 10%, due to the negative program net benefit. However, the program passed the test when the real discount rate was 5.2% for all levels and failed at 5.8% for all different weightings of program enrollment and completion costs. North Carolina was the first state to conduct a CBA for its SPB prevention program, and the literature contains very few economic analyses of similar forestry programs. Social Efficiency (SE) ratios for the Forestry Incentives Programs (FIP) in Massachusetts were determined to be 2.62, 1.77, and 0.89 for real discount rates of 4, 6.625, and 10 percent, respectively (Fitzsimmons & Harou, 1981). The SE ratio is similar to the benefit-cost ratio. This type of ratio compares social benefits to social costs and is a great tool to evaluate the efficiency of government programs (Kronrad & Morzuch, 1985). Fitzsimmons and Harou (1981) study indicated that program costs may be greater than the program benefits at a real discount rate of 10 percent which was similar to the NCSPBPP CBA. For an SPB suppression program in the National Forests in Texas during the 1990s, an economic analysis was conducted and concluded an overall B/C ratio of 3.55 (Hicks et al., 1978). The NCSPBPP CBA generated a smaller B/C ratio than other forestry programs, but this may be due to the overestimation of program costs by not segregating educational costs from the total, by underestimating program benefits because of minimal SPB activity, and by selecting lower TPA and site indices.

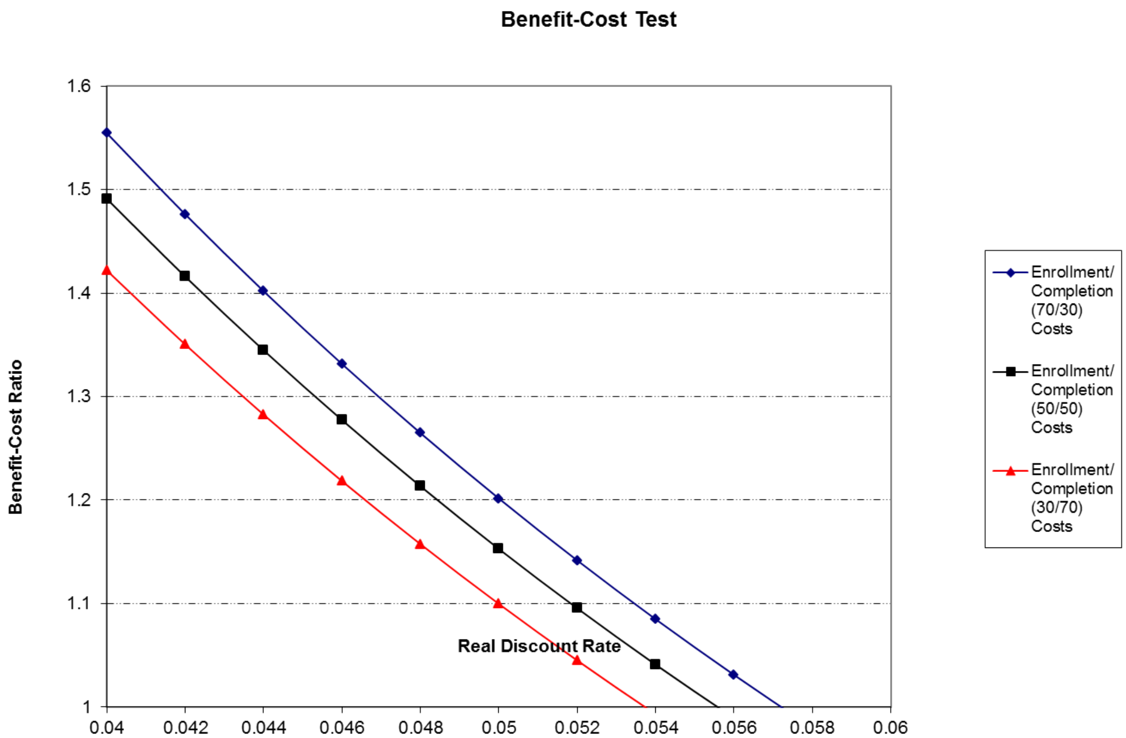

Figure 9: Benefit-cost ratio based on SPB Infestation Level 1 (.5 spots per 1000 acres of host species) varying by real discount rate.

PCT Incremental Gain "Timber Benefit" Results for Age, TPA, and SI Categories

PCT incremental present value gains are shown for various age categories (2–5, 6–9, and 10+ years), TPA values (<700, 701–1500, 1501–3000, 3001 +), and SI values (60–69, 70–79, 80–89, 90+) at 4% and 10% real discount rates in Tables 16–18. TPA, age, and site index were assumed to have normal distributions. Category ranges were chosen to ensure sufficient landowner data to formulate reasonable conclusions. The more productive sites, with an age of at least 6 years and at least 1,500 TPA, will yield the highest timber benefit if PCT is performed.

Table 16: Average timber benefit present values for all SPB infestation levels by age and with 4% and 10% real discount rates.

Age Category	Timber Benefit PV $/ac	
	4% Real Discount Rate	10% Real Discount Rate
2 to 5	$264.17	$47.31
6 to 9	$359.02	$77.07
10+	$487.29	$126.87

Table 17: Average timber benefit present values for all SPB infestation levels by SI, with base age 50 and with 4% and 10% real discount rates.

SPB infestation level	Timber Benefit PV $/ac	
	4% real discount rate	10% real discount rate
SI 60 or lower	$215.76	$49.90
SI 70 (70-79)	$245.83	$55.69
SI 80 (80-89)	$361.76	$80.38
SI 90+	$642.85	$149.77

Table 18: Average timber benefit present values for all SPB infestation levels by TPA, with 4% and 10% real discount rates.

TPA	Timber Benefit PV $/ac	
	4% real discount rate	10% real discount rate
<700	$190.41	$45.74
701-1500	$305.47	$70.19
1501-2800	$514.15	$114.58
2801+	$631.18	$135.82

Targeting older stands may increase the fire risk after PCT because it leaves a greater amount of debris that could serve as fuel compared to younger PCT stands. But pine stands more than 10 years old are at greater risk to SPB infestation than are younger pine stands. Productive and overstock pine stands are very vulnerable to SPB attack because they usually have a high basal area. Based on Burkhart et al. (1986), average and better sites would see a reduction in SPB expected timber volume loss. The general conclusion was that as the site quality increased, also did the benefits of decreasing SPB expected timber volume losses (Burkhart et al., 1986).

Sensitivity Analysis Results

The intercept, age, site index, and TPA were found to be statistically significant with an alpha level of .05 based on the low p-values for the t-test. Enrollment period was not statistically significant, which was expected and reinforces that enrollment period does not influence PCT incremental gain. These findings are valid for real discount rates of both 4 and 10 percent. Sensitivity analysis results for a real discount rate of 4% are shown in Tables 19–26.

Table 19: Linear regression output of multiple r, r^2, adjusted r^2, standard error, and the number of observations generated by the Microsoft Excel Regression Analysis Tool based on a 4 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Regression Statistics	
Multiple R	0.91
R Square	0.83
Adjusted R Square	0.83
Standard Error	84.39
Observations	180

Table 20: Linear regression output of degrees of freedom, sum of squares, mean squares, and f-test generated by the Microsoft Excel Regression Analysis Tool based on a 4 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*
Regression	4	6376922.01	1593436.74	223.80	1.14E-67
Residual	175	1246577.73	7123.29	n/a	n/a
Total	179	7623499.74	n/a	n/a	n/a

Table 21: Linear regression output of regression coefficients, standard error, t-values, and p-values generated by the Microsoft Excel Regression Analysis Tool based on a 4 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Characteristic	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	-1319.79	71.83	-18.37	1.07E-42
Age	30.58	2.31	13.22	4.02E-28
SI	15.20	0.86	17.63	1.14E-40
TPA	0.14	0.0082	17.92	1.77E-41
Enrollment Period	1.96	13.48	0.14	0.88

Table 22: Linear regression output of 95% confidence interval values for the line intercept, age, site index, TPA, and landowner type generated by the Microsoft Excel Regression Analysis Tool based on a 4 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Characteristic	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1461.56	-1178.02	-1461.56	-1173.02
Age	26.02	35.15	26.02	35.15
SI	13.50	16.90	13.50	16.90
TPA	0.13	0.16	0.13	0.16
Enrollment Period	-24.64	28.58	-24.64	28.58

Sensitivity analysis results for a real discount rate of 10% are shown below:

Table 23: Linear regression output of multiple r, r^2, adjusted r^2, standard error, and the number of observations generated by the Microsoft Excel Regression Analysis Tool based on a 10 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Regression Statistics	
Multiple R	0.90
R Square	0.82
Adjusted R Square	0.82
Standard Error	22.54
Observations	180

Table 24: Linear regression output of degrees of freedom, sum of squares, mean squares, and f-test generated by the Microsoft Excel Regression Analysis Tool based on a 10 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

ANOVA	*Df*	*SS*	*MS*	*F*	*Significance F*
Regression	4	423154.97	105788.74	208.20	2.16E-65
Residual	175	88919.38	508.11		
Total	179	512074.36			

Table 25: Linear regression output of regression coefficients, standard error, t-values, and p-values generated by the Microsoft Excel Regression Analysis Tool based on a 10 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Characteristic	*Coefficients*	*Standard Error*	*t Stat*	*P-value*
Intercept	-335.33	19.18	-17.47	3.10E-40
Age	11.32	0.61	18.33	1.34E-42
SI	3.50	0.23	15.22	7.10E-34
TPA	0.031	0.0022	14.36	2.10E-31
Enrollment Period	1.01	3.60	0.28	0.77

Table 26: Linear regression output of 95% confidence interval values for the line intercept, age, site index, TPA, and landowner type generated by the Microsoft Excel Regression Analysis Tool based on a 4 percent real discount rate, a dependent variable of PCT incremental gain, and independent variables of age, site index, TPA, and enrollment period.

Characteristic	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-373.19	-297.47	-373.19	-297.47
Age	10.10	12.54	10.10	12.54
SI	3.05	3.95	3.05	3.95
TPA	0.027	0.035	0.027	0.035
Enrollment Period	-6.09	8.11	-6.09	8.11

Cost and Benefit Analysis Discussion

Program recommendations were constructed to improve economic efficiency and increase program net benefits. The first program recommendation is stated below.

- Reclassify SPB forester positions in NCDFR districts 1, 2, 9, and 12 to a Forest Health Forester and have these positions focus on overall forest health instead of just SPB or eliminate these positions altogether.

The total number of acres of enrolled stands participating in the program was found to be considerably lower in Region III, NCDFR districts 1, 2, 9, and 12, which represented about 3% of the total number of acres in the initial study sample, than in the other two regions. This low figure may be attributed to poor timber markets for white pine, development pressure from new retirement communities and vacation home construction, low incidence of SPB-infested white pine stands, lack of abundance of loblolly pine and other commercially valuable southern yellow pine species, or lower emphasis by forest landowners on timber production.

Reclassifying the SPB Forester in Region III to a Forest Health Forester would be a more appropriate title when addressing various forest health issues instead of just SPB and communicate a broader classification to their constituents. Benefits generated from keeping these forester positions in their respective districts to lead educational initiatives and mitigate other threats to forest health is unknown and was out of the scope of the CBA. The CBA findings support elimination of the four SPB Forester positions in Region III due to the lack of stands being enrolled in the program and the higher program administration costs associated with enrolling these few stands. Eliminating these four positions could increase program net benefit by $182,621.50 due to personnel savings, which would be an increase of 22%. This back-of-the-envelope calculation is based on the assumptions that cost-share monies would be spent on similar stands elsewhere and that each SPB Forester position has similar program costs.

- Eastern white pine should be excluded from the program due to the low risk from SPB losses. Efforts should be concentrated on loblolly pine due to its higher merchantable value and SPB risk susceptibility.

Loblolly pine is very susceptible to SPB mortality (Anderson & Doggett, 1993). But those researchers ranked eastern white pine as less susceptible than shortleaf pine, loblolly pine, Virginia pine, pitch pine, and longleaf pine.

- Target those stands that are at least 1,500 TPA, greater than 6 years old, 30 acres or larger, and on highly productive soils (90 + SI base age 50).

Incremental findings of the CBA concluded that stands at least 1,500 TPA, older than six years, or on highly productive soils had the greatest timber benefit. Out of the scope of the CBA, forest landowners with 30 acres or more of timberland were found to have greater interest in managing SPB risk and were more proactive when using preventive practices (Molnar et al., 2007). This type of landowner should be targeted also by the NCSPBPP to increase program enrollment.

Based on results from the sensitivity analysis, age had the greatest impact on the PCT incremental gain, whereas TPA had the lowest impact. Site index had the second greatest bearing on PCT incremental gain, which was significantly greater than TPA. These findings were valid for real discount rates of 4 and 10 percent. To provide the most accurate estimates for PCT incremental gain, accurate field estimates for SI and age are more important than for TPA. The “best fit” line equations generated from the linear regression analysis are depicted below for real discount rates of 4 and 10 percent.

$$\text{PCT Incremental Gain}_{\text{for } 4\%} = -1319.79 + 30.58(\text{Age}) + 15.20(\text{SI}) + .14(\text{TPA})$$

$$\text{PCT Incremental Gain}_{\text{for } 10\%} = -335.33 + 11.32(\text{Age}) + 3.50(\text{SI}) + .031(\text{TPA})$$

These equations are intended for forecasting PCT incremental net gain estimates that would enable program managers and personnel to better target stands that would yield the most timber benefit. This estimation tool could also be useful to NCDFR officials by providing more information to share with landowners in predicting financial gains with PCT.

Cost and Benefit Analysis Conclusion

The NCSPBPP generated $818,019.97 of net benefits, reduced SPB expected timber volume loss by 9%, and had a 1.55 benefit-cost ratio, but there is room for improvement with better data collection, excluding eastern white pine as an eligible species, and landowner targeting. As indicated by other forestry programs' benefit-cost ratios, program benefits could potentially be higher. Narrowing the focus of funds and resources on the most productive and highly susceptible stands may raise equity issues but is economical. This analysis can also be utilized as a benchmark to other state-administered SPB prevention programs in the South and help identify "best practices" among the different SPB cost-share programs. Building a long-term relationship with the landowner is important in maintaining overall forest health by encouraging landowners to conduct future commercial thinnings, which may greatly improve program net benefits by producing higher-quality timber and maintaining a lower SPB risk of infestation and spread. This program is essential in opening dialogue between forest landowners and NCDFR personnel by offering incentives, which can be the first step of many in promoting good forest practices.

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APPENDICES

Appendix A: Growth and Yield Model Comparison Raw Data

PlantYld

Model: PlantYld
SI: 60
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
5	11	450	1.3	9	4	14
10	22	449	3.4	19.3	28	197
15	31	449	4.8	26.9	57	556
20	38	449	5.8	32.6	84	985
25	44	449	6.6	37.2	106	1,423
30	49	447	7.2	40.9	125	1,843
35	53	442	7.6	44.1	140	2,226

Model: PlantYld
SI: 70
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
5	12	450	1.6	11.7	6	25
10	26	449	4	23	39	326
15	36	449	5.6	32	76	880
20	45	448	6.7	38.9	108	1,514
25	51	442	7.4	44.5	133	2,133
30	57	430	8	49.1	152	2,680
35	62	412	8.5	52.9	164	3,122

Model: PlantYld
SI: 80
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
5	14	450	1.9	12.5	9	41
10	30	449	4.6	26.7	52	500
15	42	447	6.3	37.3	96	1,290
20	51	439	7.4	45.4	131	2,145
25	59	423	8.2	52	156	2,916
30	65	399	8.9	57.4	171	3,535
35	70	372	9.4	62	179	3,985

Model: PlantYld
SI: 90
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
5	16	450	2.2	14.4	12	65
10	34	449	5.2	30.7	66	730
15	47	441	7	42.8	117	1,793
20	58	423	8.1	52.2	153	2,866
25	66	397	9	59.8	176	3,774
30	74	368	9.7	66.1	188	4,466
35	80	338	10.2	71.6	192	4,949

TaulYld

Model: TauYield
SI: 60
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
5						
10	22	428	4.1	20.92	40	408.6
15	31	415	5.1	29.4	58	851.1
20	38	393	5.8	34.9	73	1,305.6
25	43	363	6.5	40.14	84	1,719.9
30	47	326	7.1	44.4	90	2,053.2
35	51	286	7.6	49.03	91	2,278.2

Model: TauYield
SI: 70
TPA_0 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
10	25	427	4.4	23.75	46	526.7
15	35	413	5.5	32.72	67	1,104.8
20	43	389	6.3	40.53	85	1,688.2
25	49	355	7.1	45.75	97	2,200.7
30	54	315	7.7	52.03	102	2,587.9
35	59	272	8.3	56.3	102	2,819.9

Model: TauYield
SI: 80
TPA$_0$ 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
10	28	427	4.8	26.08	53	687.3
15	39	410	5.9	36.77	79	1,452.3
20	49	383	6.9	45.96	99	2,207.3
25	56	346	7.7	53.44	112	2,841
30	62	303	8.4	58.65	116	3,282.3
35	67	257	9	64.89	114	3,503.4

Model: TauYield
SI: 90
TPA$_0$ 450

Year	Dominant Height	TPA	Average DBH	Average Height	Basal Area	Vol. (ft^3)
10	30	426	5.1	28.76	60	846.2
15	43	408	6.3	40.94	88	1,798.2
20	54	378	7.3	50.43	110	2,719
25	62	339	8.2	58.9	124	3,460.8
30	69	292	9	66.06	128	3,938.3
35	75	245	9.6	72.41	124	4,132.1

NatYld

Model: NatYield
SI: 60
TPA$_0$ 450

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	450	1	1	0.6
10	16	82	10	68	4.8
15	26	49	25	271	9.7
20	34	39	40	551	13.7
25	39	33	52	845	16.9
30	43	30	63	1,122	19.5
35	46	28	71	1,372	21.5

Model: NatYield
SI: 60
TPA_0 700

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	700	1	1	0.5
10	16	127	10	68	3.9
15	26	76	25	271	7.8
20	34	60	40	551	11
25	39	52	52	845	13.6
30	43	47	63	1,122	15.6
35	46	44	71	1,372	17.2

Model: NatYield
SI: 70
TPA_0 450

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	450	1	2	0.6
10	19	83	11	82	4.9
15	31	51	26	331	9.7
20	39	40	42	678	13.8
25	46	35	55	1,044	17.1
30	50	32	67	1,390	19.7
35	54	29	76	1,700	21.7

Model: NatYield
SI: 70
TPA_0 700

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	700	1	2	0.5
10	19	129	11	82	3.9
15	31	79	26	331	7.8
20	39	62	42	678	11.1
25	46	54	55	1,044	13.7
30	50	49	67	1,390	15.8
35	54	46	76	1,700	17.4

Model: NatYield
SI: 80
TPA_0 450

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	450	1	2	0.6
10	21	85	11	96	4.9
15	35	52	27	396	9.8
20	45	41	44	820	14
25	52	36	59	1,270	17.3
30	58	33	71	1,694	19.9
35	62	31	81	2,073	22

Model: NatYield
SI: 80
TPA_0 700

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	700	1	2	0.5
10	21	131	11	96	3.9
15	35	81	27	396	7.9
20	45	64	44	820	11.2
25	52	56	59	1,270	13.9
30	58	51	71	1,694	16
35	62	48	81	2,073	17.6

Model: NatYield
SI: 90
TPA_0 450

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	450	1	2	0.6
10	24	86	11	111	4.9
15	39	54	29	467	9.9
20	50	43	47	980	14.1
25	59	38	63	1,526	17.5
30	65	34	76	2,041	20.2
35	70	32	87	2,500	22.3

Model: NatYield
SI: 90
TPA_0 700

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	700	1	2	0.5
10	24	134	11	111	3.9
15	39	83	29	467	7.9
20	50	67	47	980	11.3
25	59	59	63	1,526	14.3
30	65	53	76	2,041	16.2
35	70	50	87	2,500	17.9

NatYld Rev

Model: NatYield
SI: 60
TPA_0 4500

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	4500	1	1	0.2
10	16	817	10	68	1.5
15	26	492	25	271	3.1
20	34	386	40	551	4.3
25	39	334	52	845	5.4
30	43	304	63	1,122	6.2
35	46	283	71	1,372	6.8

Model: NatYield
SI: 70
TPA_0 4500

Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	4	4500	1	2	0.2
10	19	831	11	82	1.5
15	31	505	26	331	3.1
20	39	399	42	678	4.4
25	46	347	55	1,044	5.4
30	50	315	67	1,390	6.2
35	54	294	76	1,700	6.9

Model: NatYield
SI: 80
TPA_0 4500

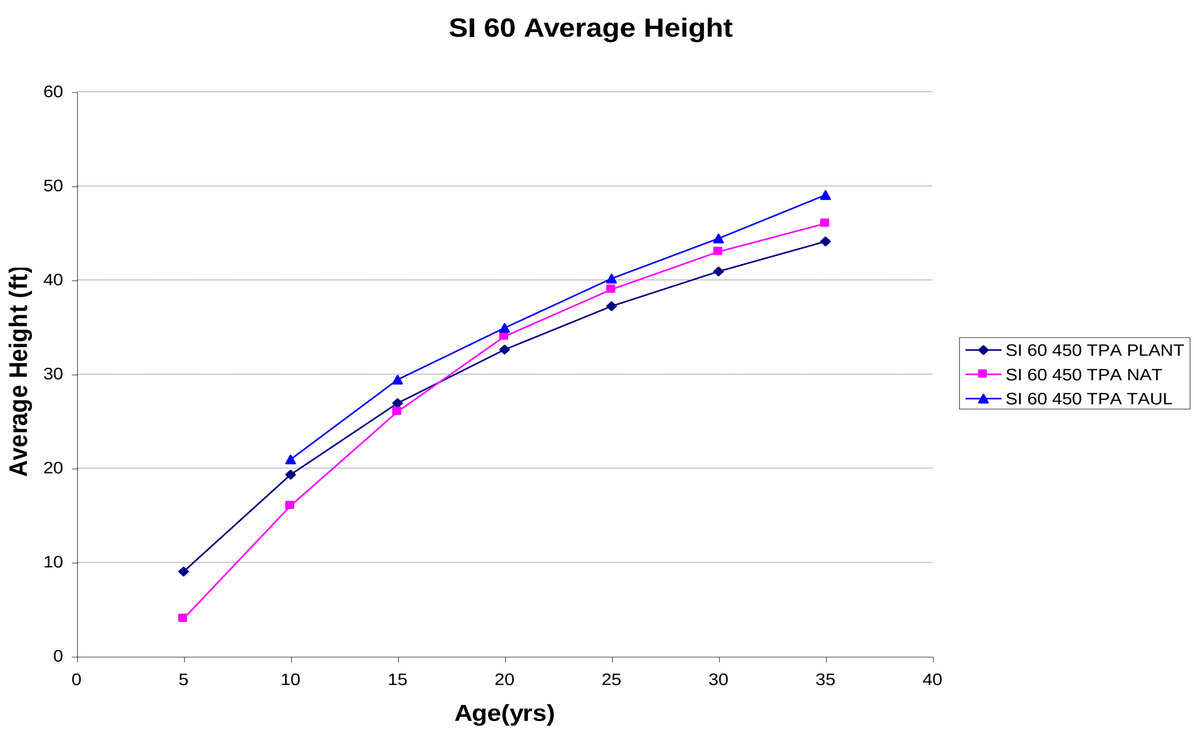
Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	4500	1	2	0.2
10	21	845	11	96	1.5
15	35	520	27	396	3.1
20	45	414	44	820	4.4
25	52	361	59	1,270	5.5
30	58	328	71	1,694	6.3
35	62	307	81	2,073	7

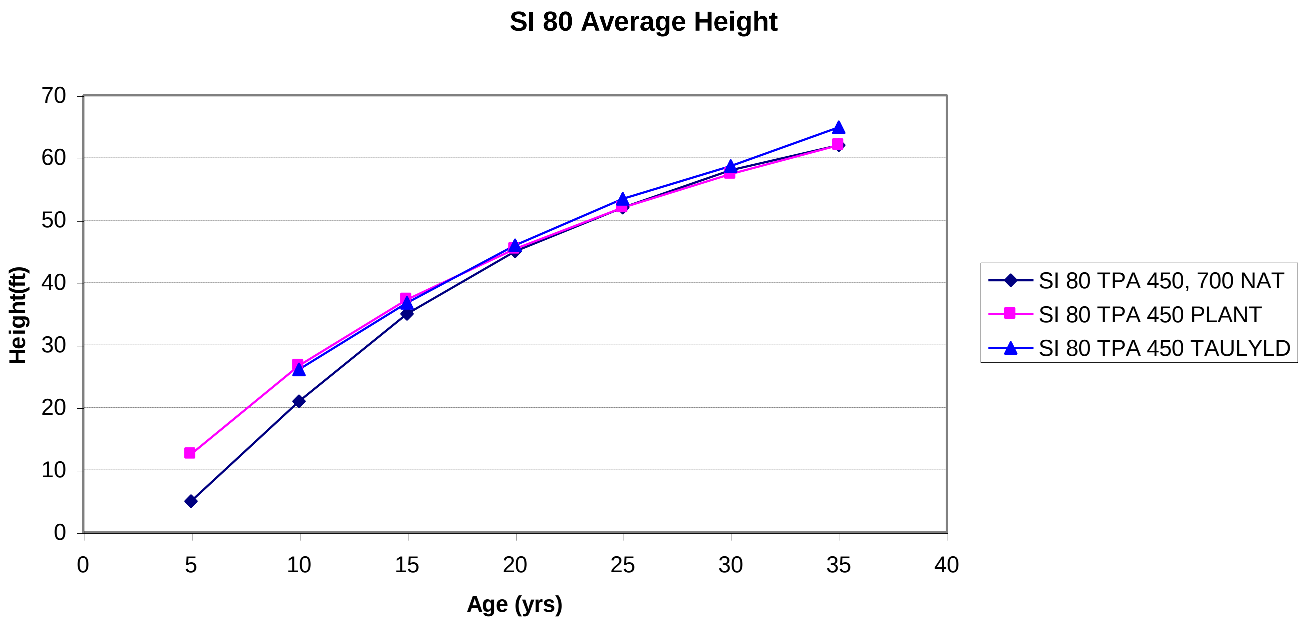
Model: NatYield
SI: 90
TPA_0 4500

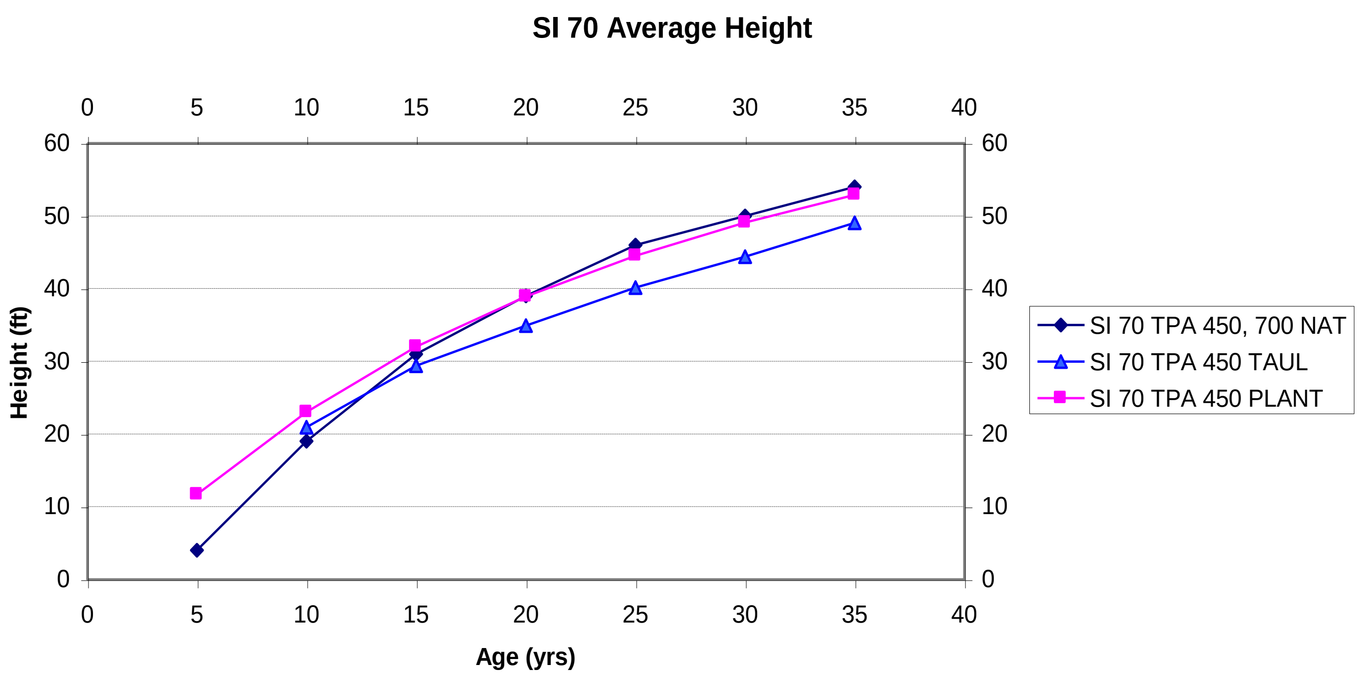
Year	Average Height	TPA	Basal Area	Vol. (ft^3)	Average DBH
5	5	4500	1	2	0.2
10	24	860	11	111	1.6
15	39	537	29	467	3.1
20	50	430	47	980	4.5
25	59	376	63	1,526	5.5
30	65	343	76	2,041	6.4
35	70	320	87	2,500	7

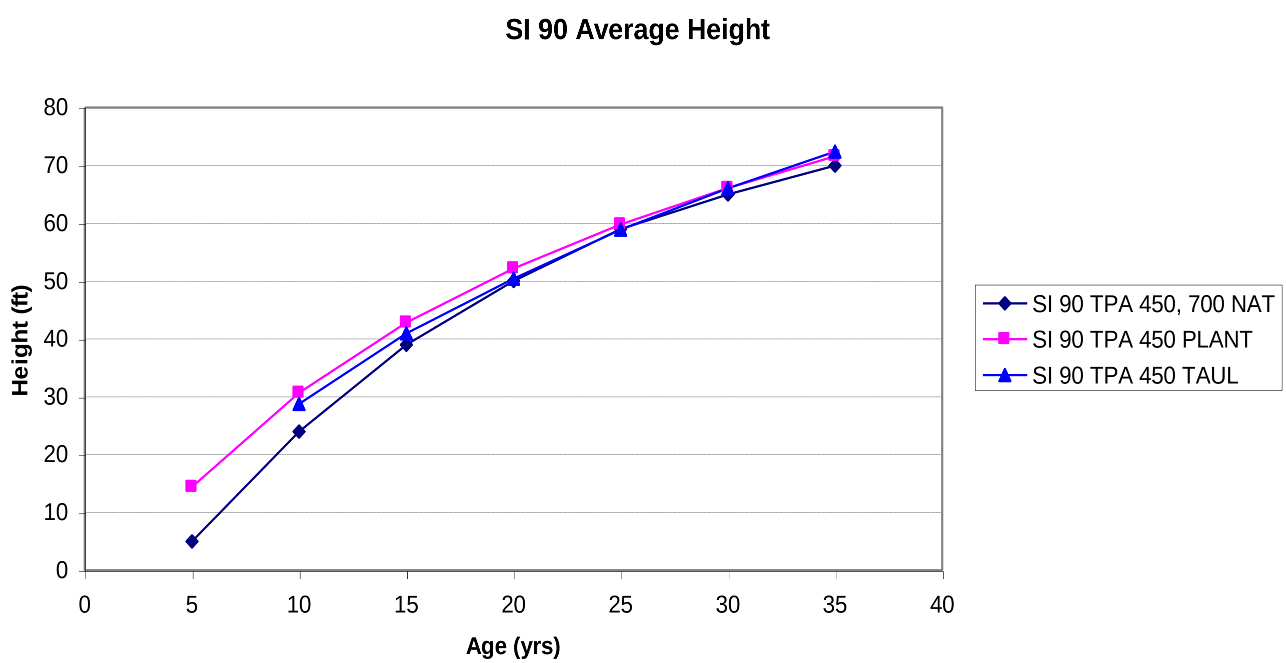
Appendix B: Growth and Yield Model Comparison Graphs of Raw Data for Output Variables Average Height, TPA, Basal Area, DBH, and Volume

<u>Average Height Growth and Yield Model Comparison Raw Data Graphs</u>

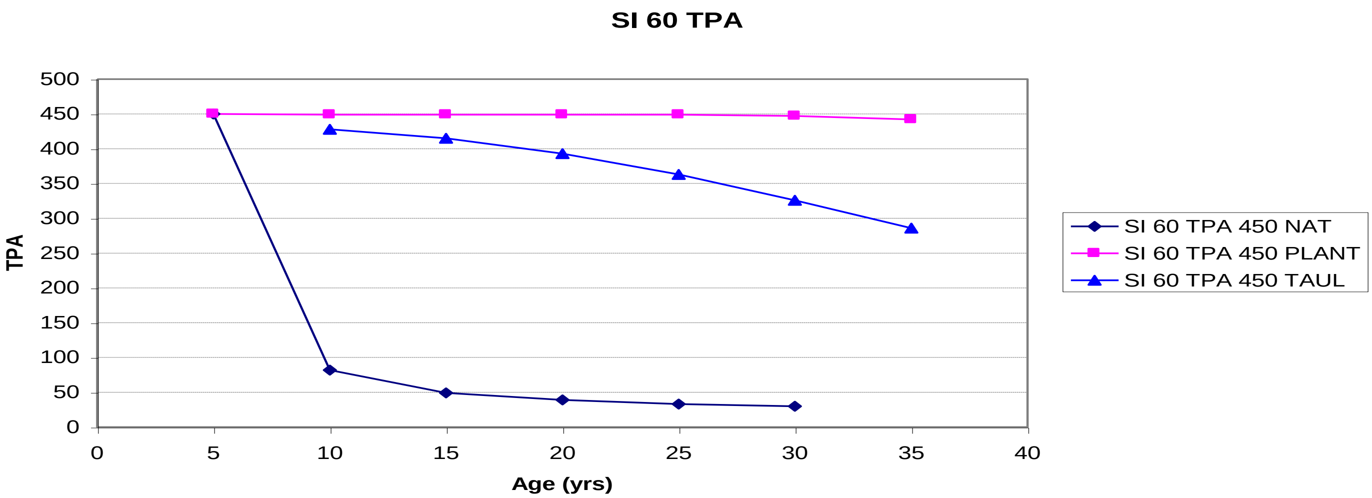


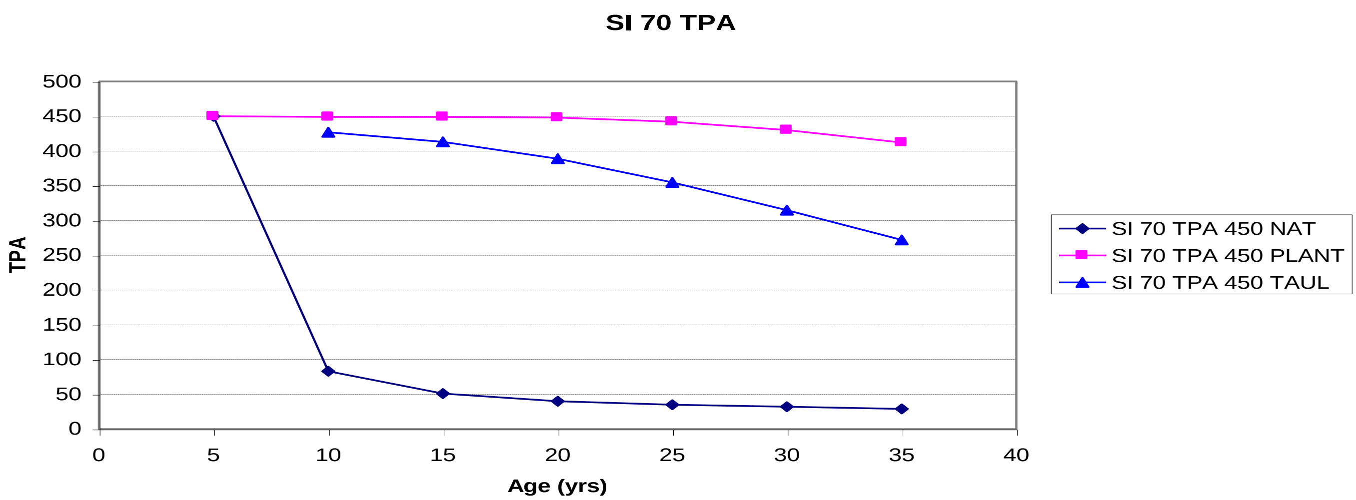

SI 80 Average Height
70
60
50
40
30
20
10
0
Height(ft)
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 80 TPA 450, 700 NAT
SI 80 TPA 450 PLANT
SI 80 TPA 450 TAULYLD

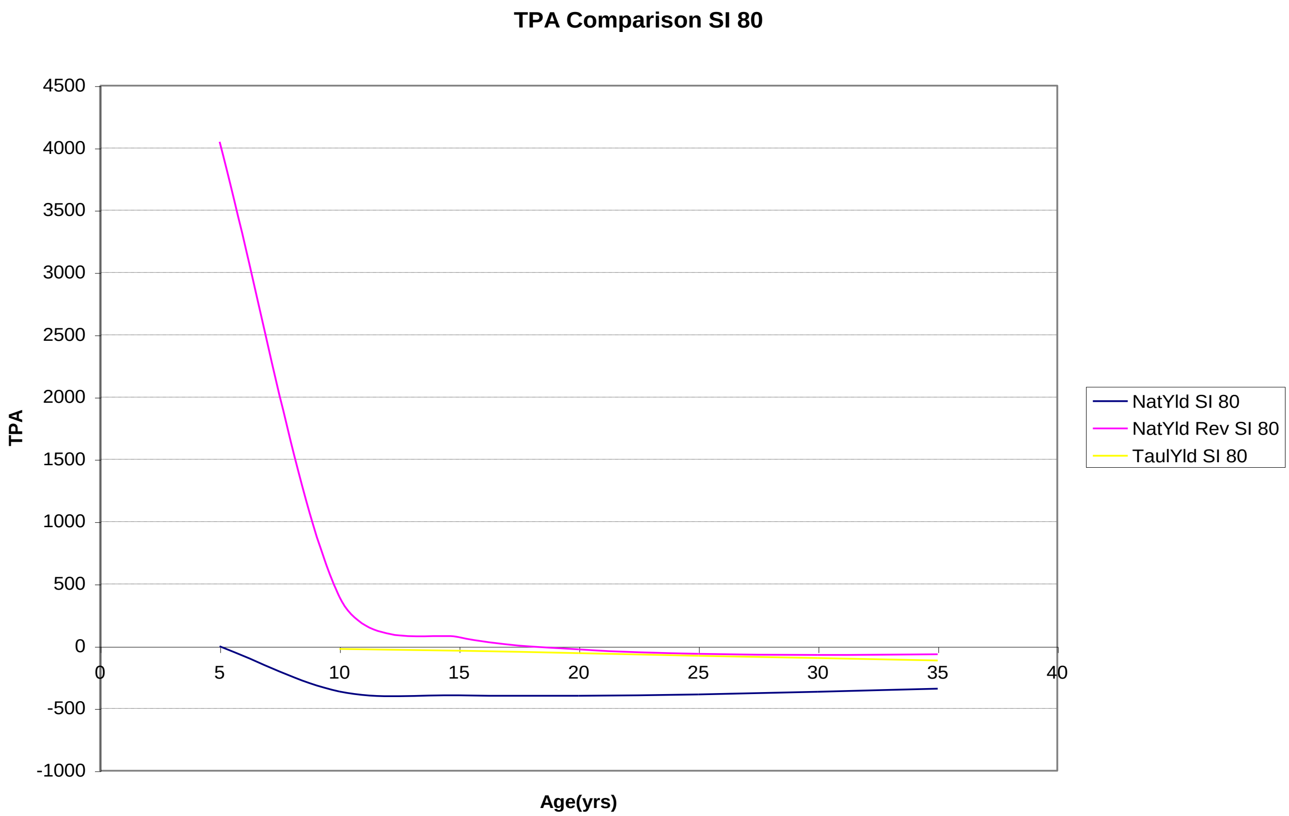

SI 70 Average Height
0
5
10
15
20
25
30
35
40
60
50
40
30
20
10
0
Height (ft)
Age (yrs)
SI 70 TPA 450, 700 NAT
SI 70 TPA 450 TAUL
SI 70 TPA 450 PLANT

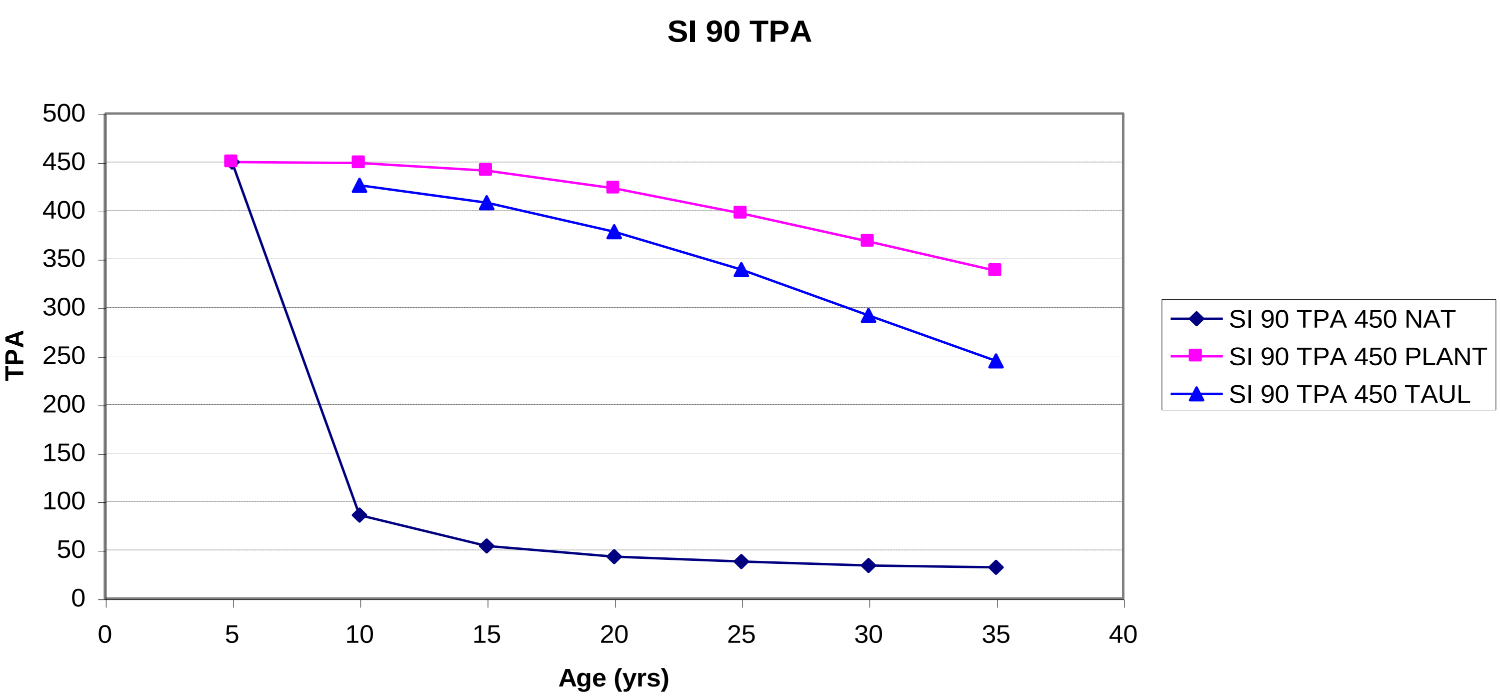

SI 90 Average Height
Height (ft)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 90 TPA 450, 700 NAT
SI 90 TPA 450 PLANT
SI 90 TPA 450 TAUL

Growth and Yield Model Comparison TPA Raw Data Graphs

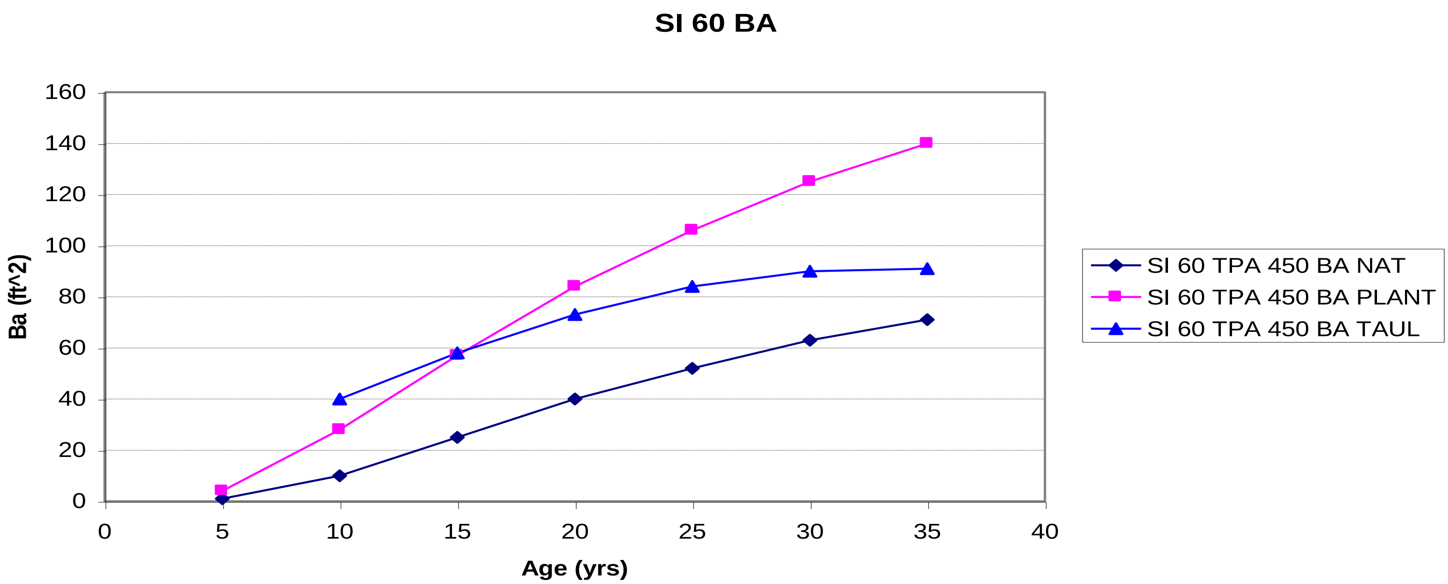


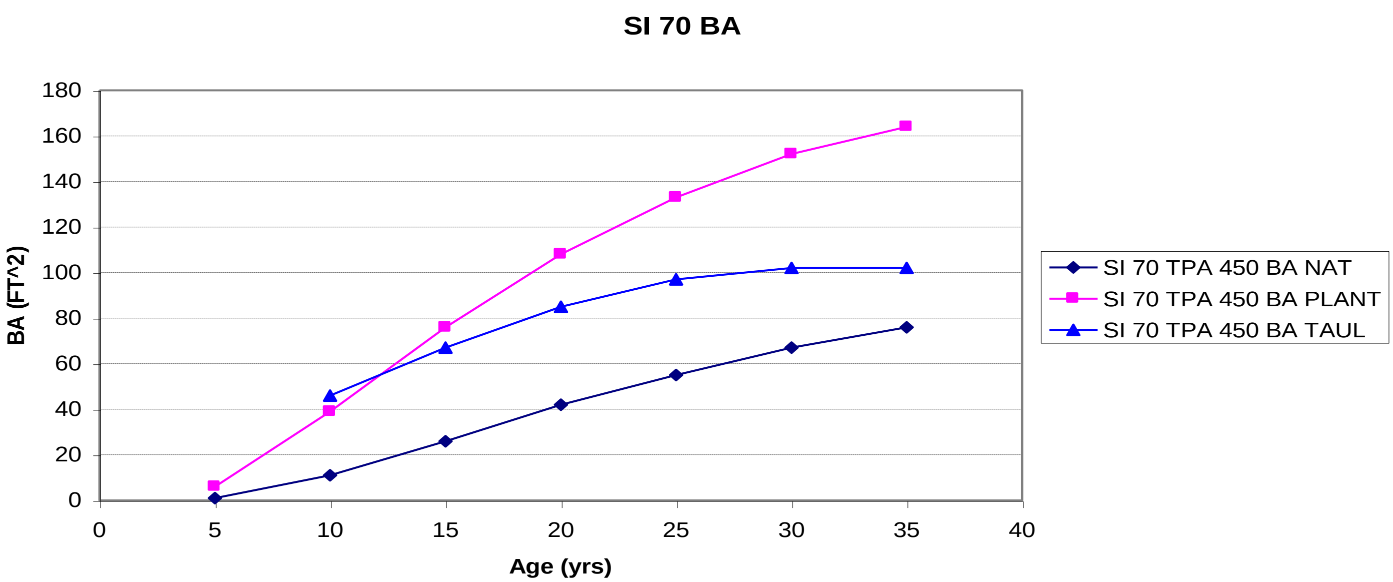


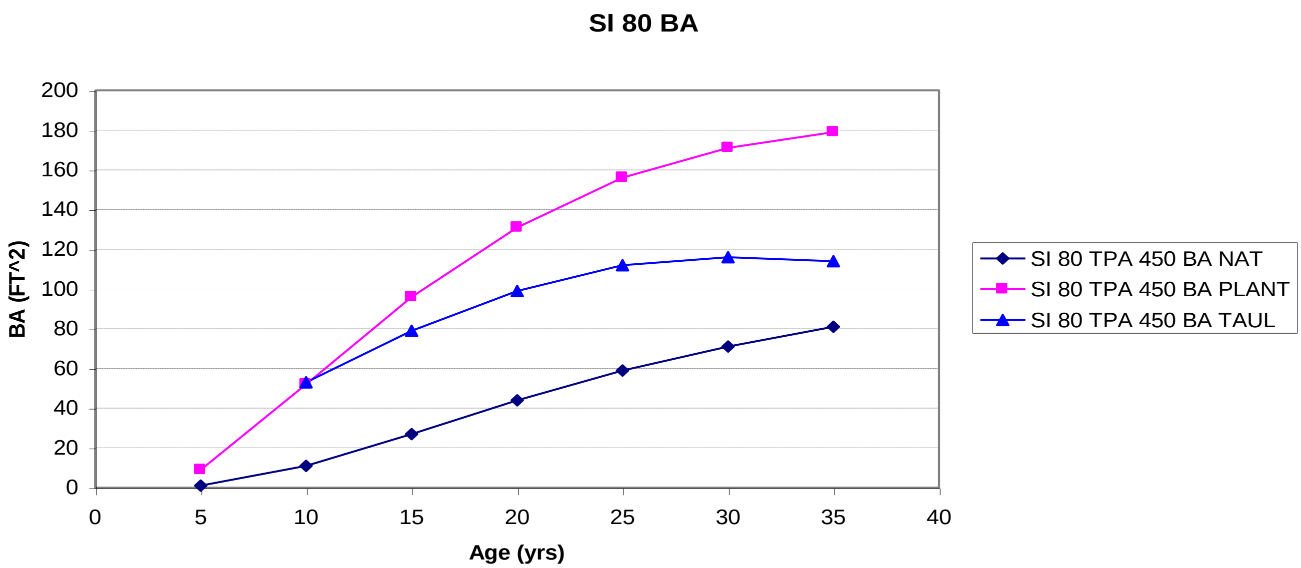

TPA Comparison SI 80
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
TPA
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 80
NatYld Rev SI 80
TaulYld SI 80

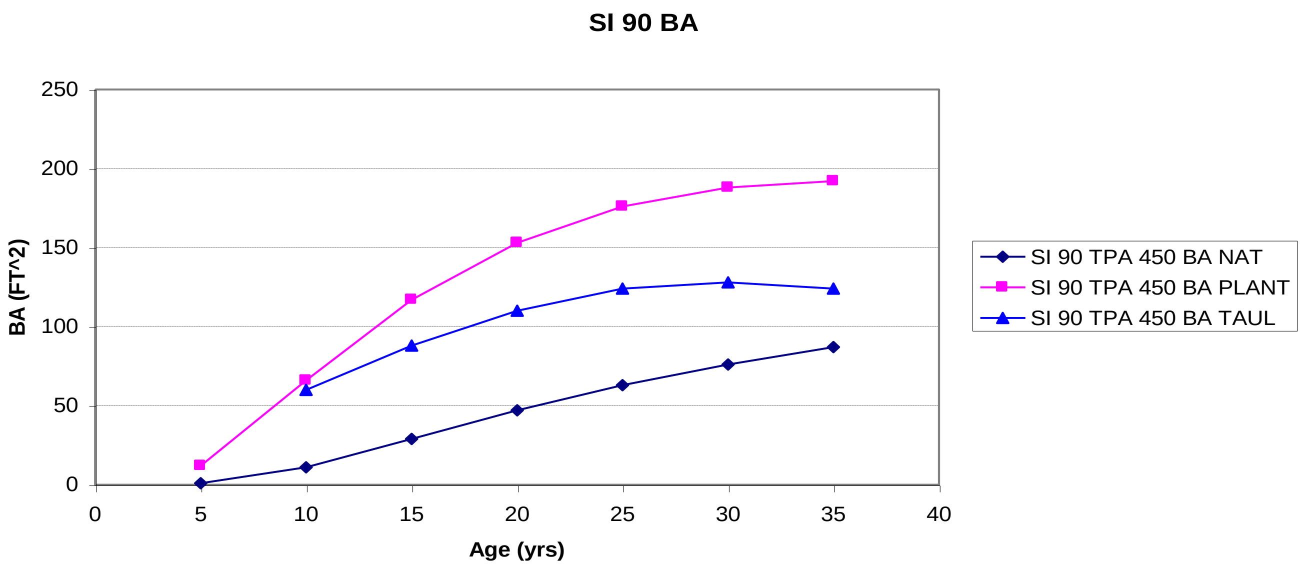

SI 90 TPA
500
450
400
350
300
250
200
150
100
50
0
TPA
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 90 TPA 450 NAT
SI 90 TPA 450 PLANT
SI 90 TPA 450 TAUL

Growth and Yield Model Comparison Basal Area Raw Data Graphs

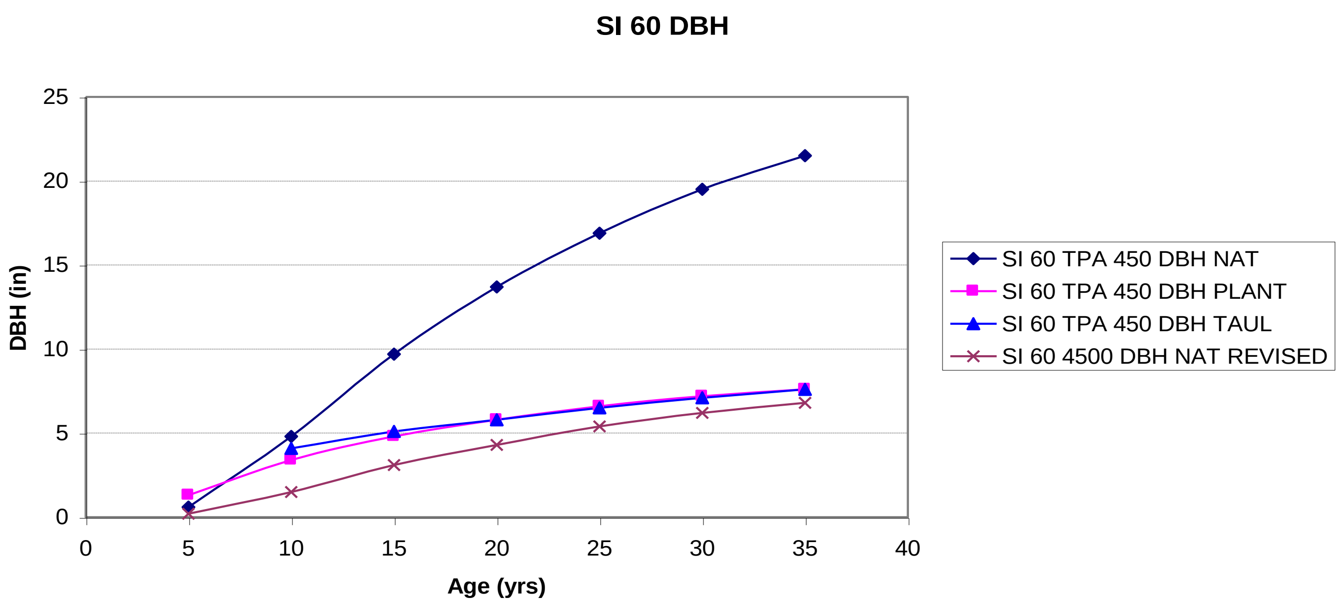


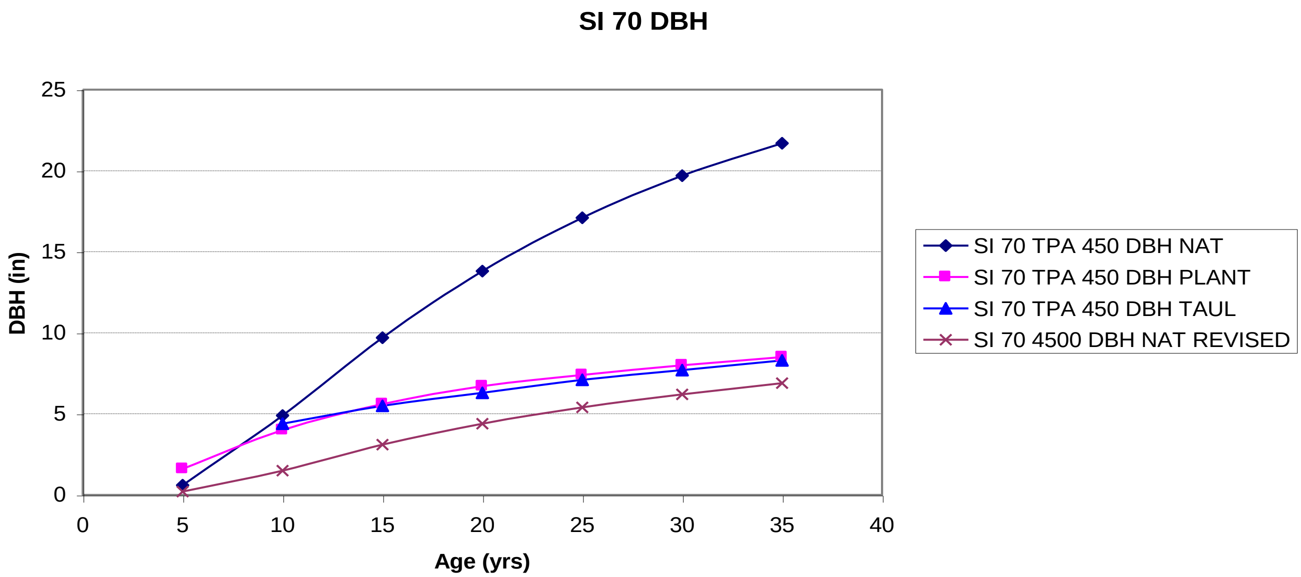


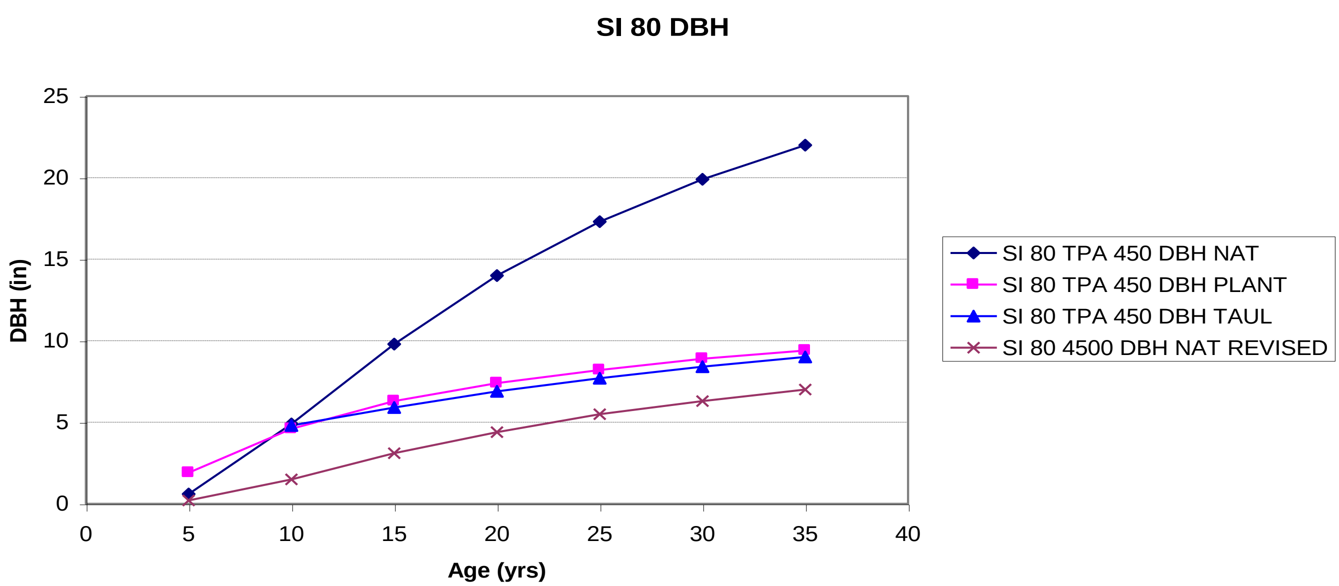

SI 80 BA
BA (FT^2)
Age (yrs)
0
20
40
60
80
100
120
140
160
180
200
0
5
10
15
20
25
30
35
40
SI 80 TPA 450 BA NAT
SI 80 TPA 450 BA PLANT
SI 80 TPA 450 BA TAUL

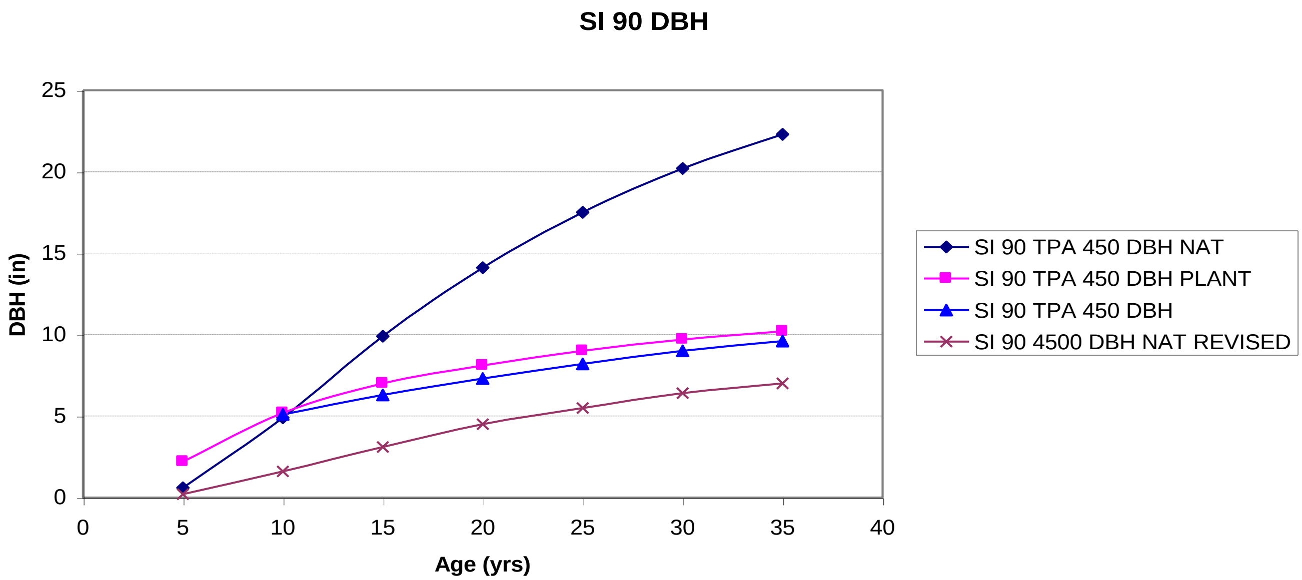

SI 90 BA
BA (FT^2)
Age (yrs)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40
SI 90 TPA 450 BA NAT
SI 90 TPA 450 BA PLANT
SI 90 TPA 450 BA TAUL

Growth and Yield Model Comparison DBH Raw Data Graphs

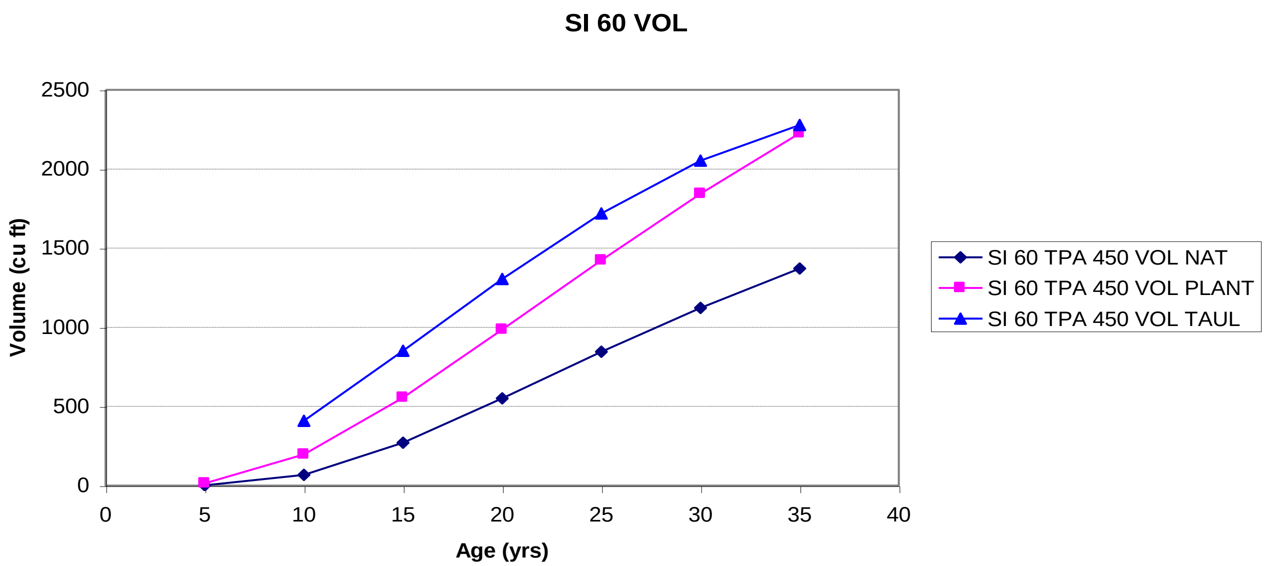


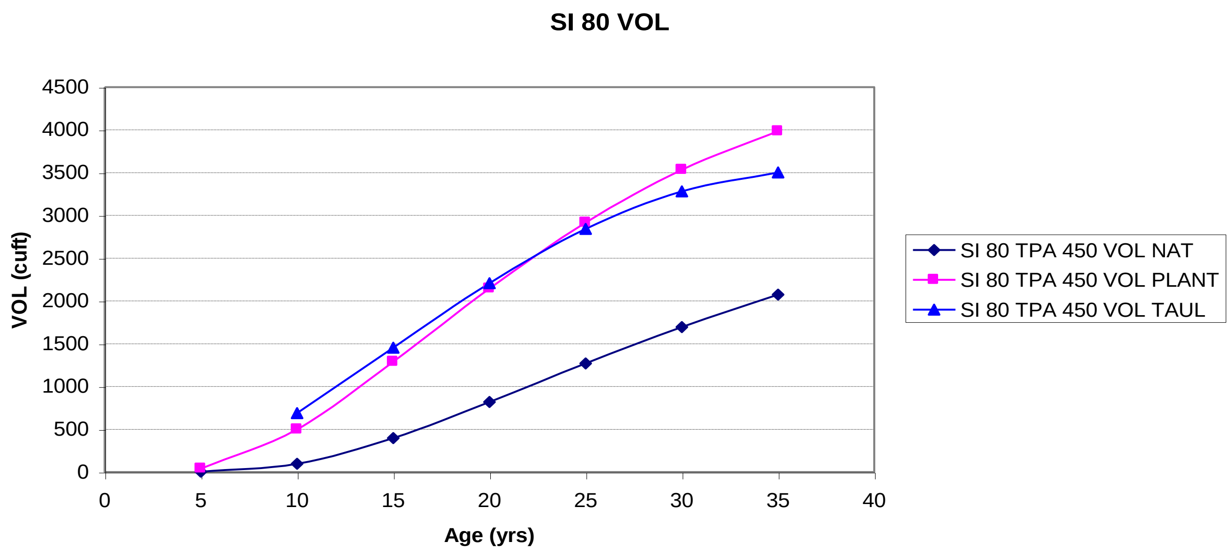

SI 70 DBH
25
20
15
10
5
0
DBH (in)
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 70 TPA 450 DBH NAT
SI 70 TPA 450 DBH PLANT
SI 70 TPA 450 DBH TAUL
SI 70 4500 DBH NAT REVISED

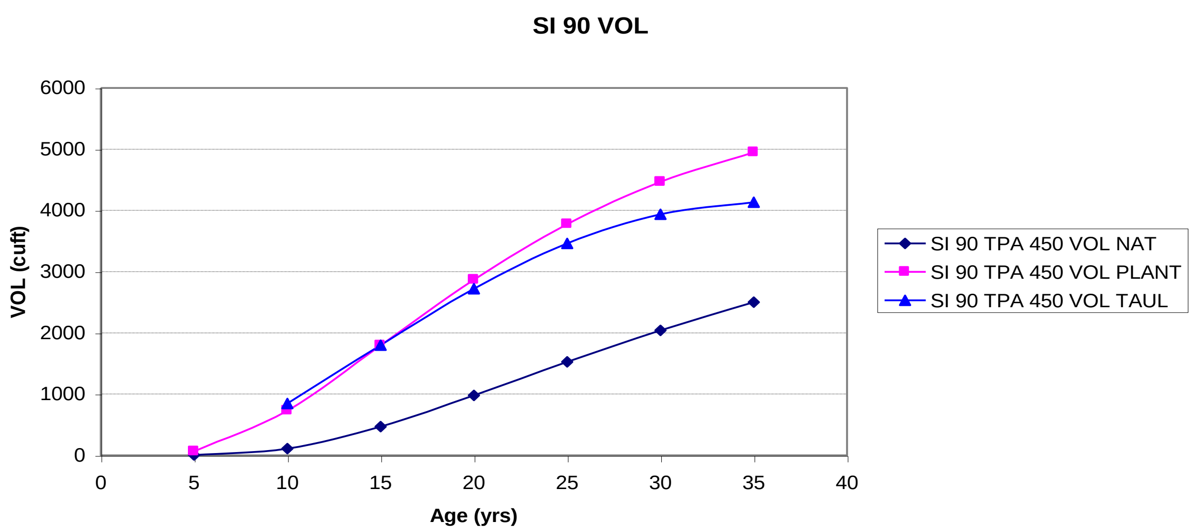

SI 80 DBH
25
20
15
10
5
0
DBH (in)
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 80 TPA 450 DBH NAT
SI 80 TPA 450 DBH PLANT
SI 80 TPA 450 DBH TAUL
SI 80 4500 DBH NAT REVISED


SI 90 DBH
DBH (in)
Age (yrs)
0
5
10
15
20
25
30
35
40
SI 90 TPA 450 DBH NAT
SI 90 TPA 450 DBH PLANT
SI 90 TPA 450 DBH
SI 90 4500 DBH NAT REVISED

Growth and Yield Model Comparison Volume Raw Data Graphs

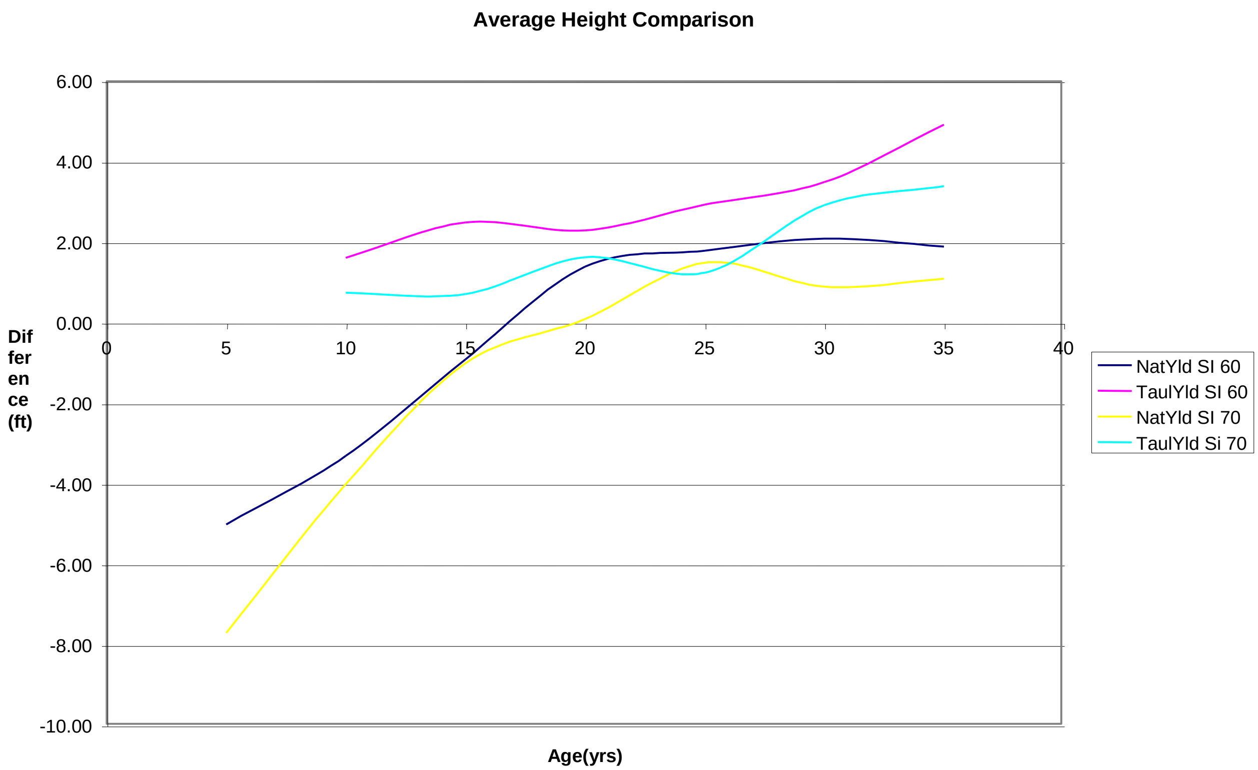


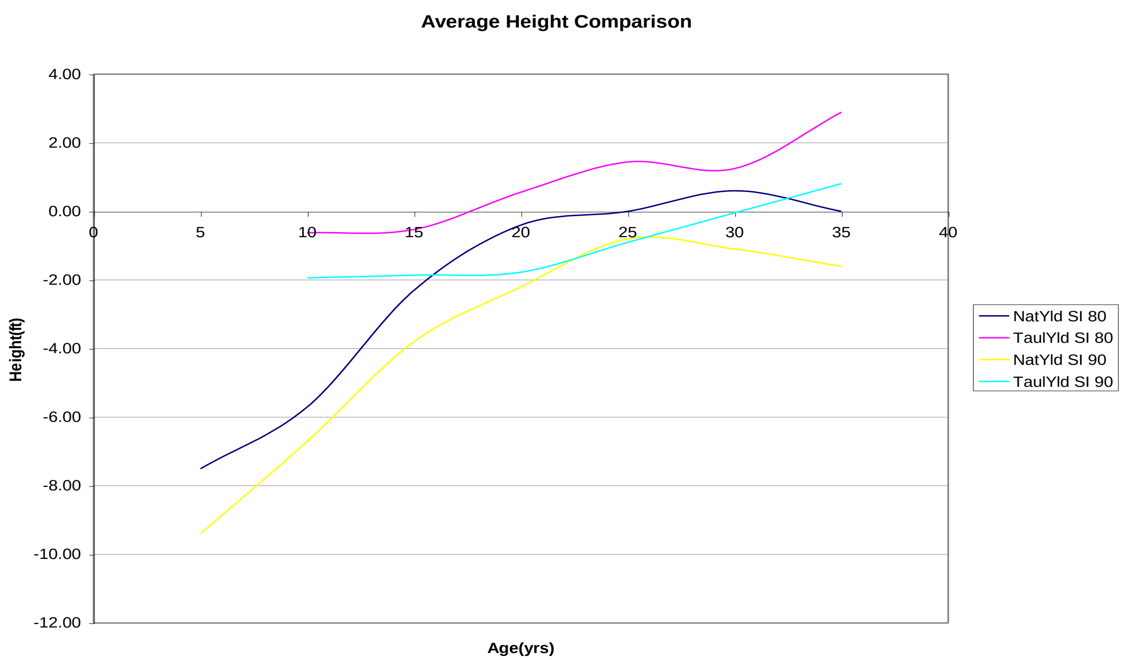

SI 80 VOL
VOL (cuft)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 80 TPA 450 VOL NAT
SI 80 TPA 450 VOL PLANT
SI 80 TPA 450 VOL TAUL


SI 90 VOL
VOL (cuft)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
Age (yrs)
SI 90 TPA 450 VOL NAT
SI 90 TPA 450 VOL PLANT
SI 90 TPA 450 VOL TAUL

Appendix C: Growth and Yield Model Graphs of Model Comparisons for Output Variables Average Height, TPA, Basal Area, DBH, and Volume

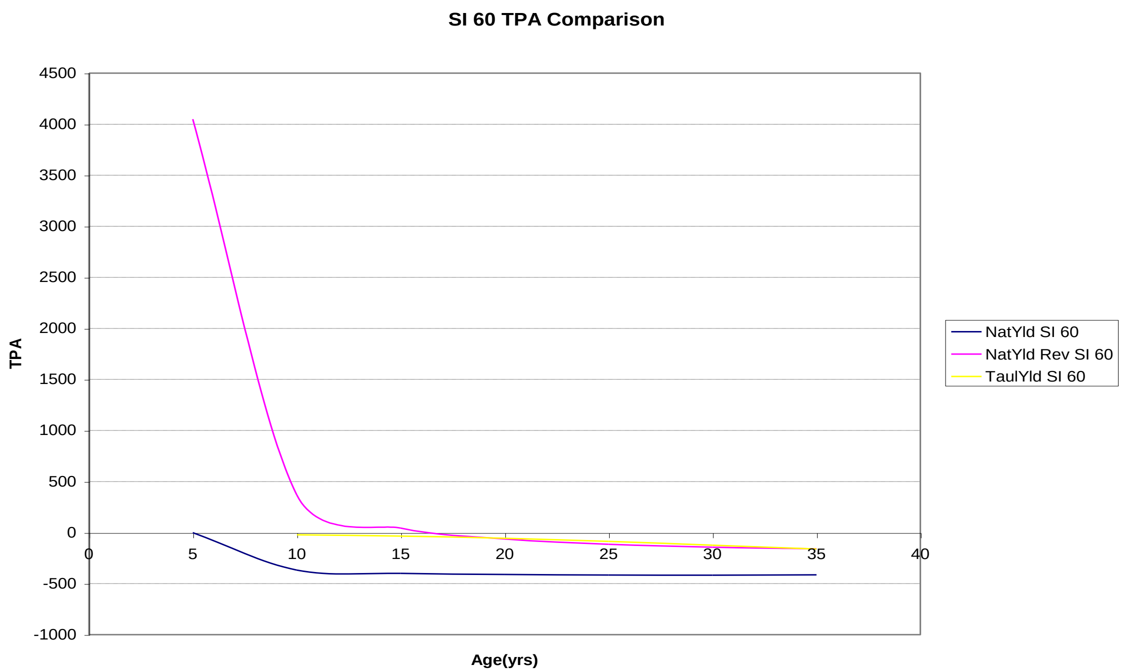
Growth and Yield Average Height Model Comparisons

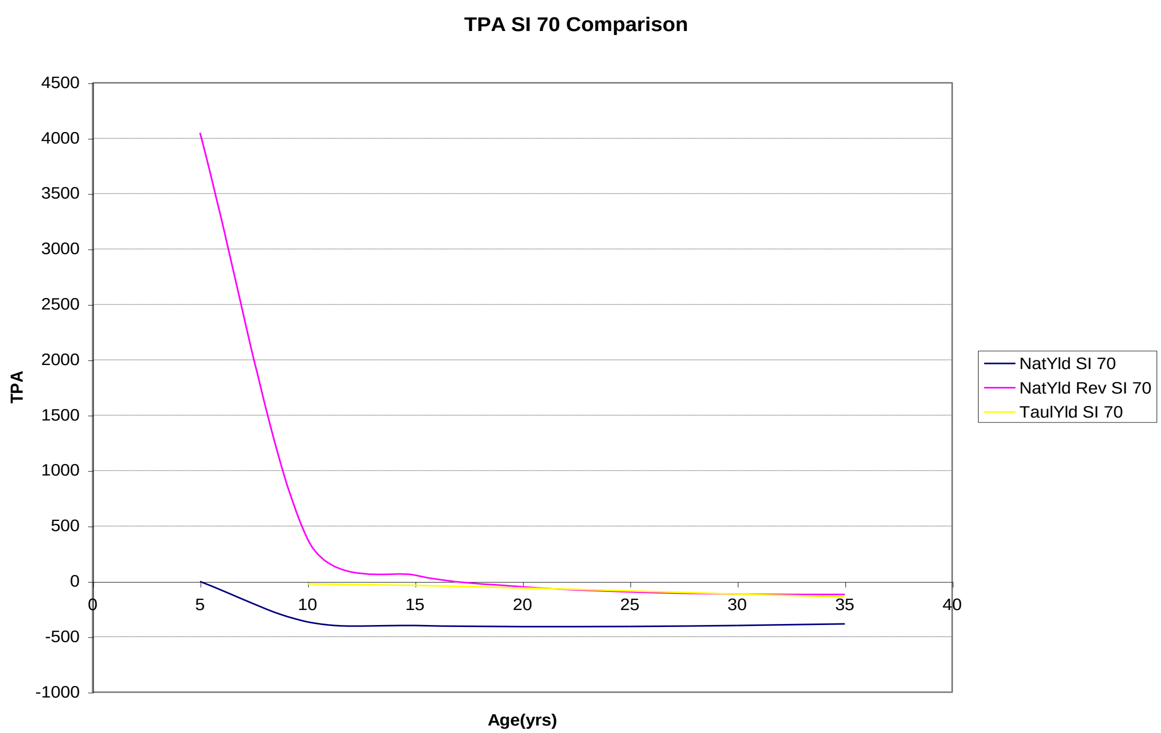


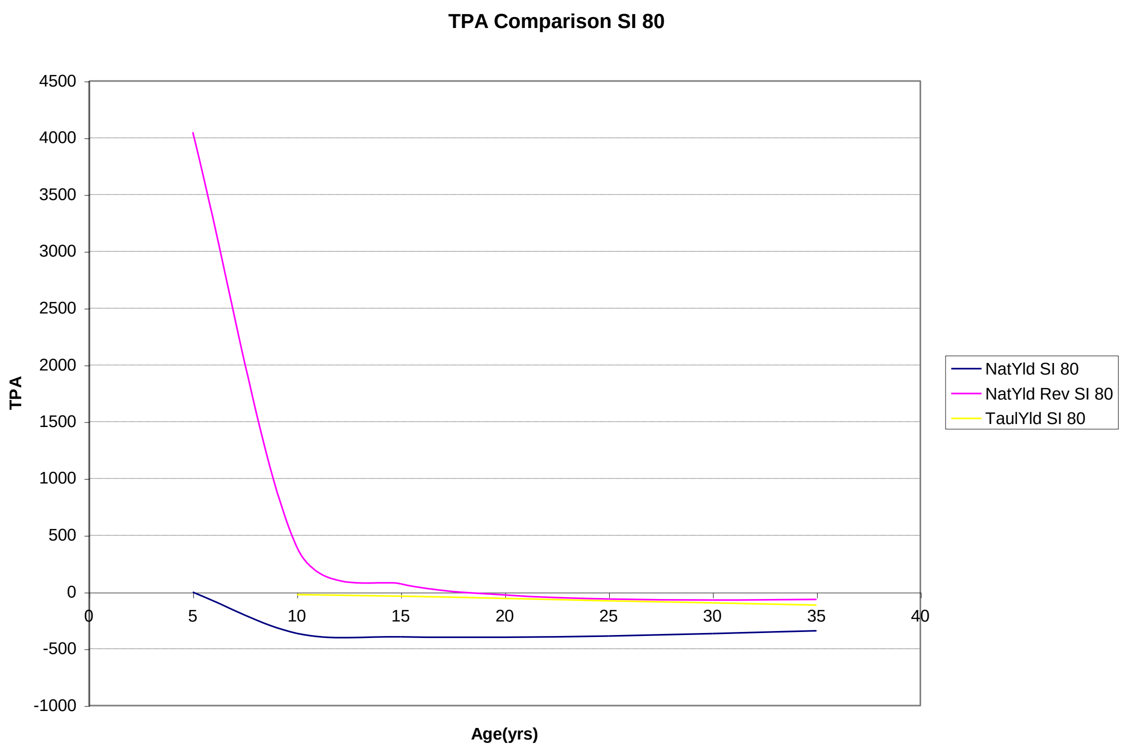


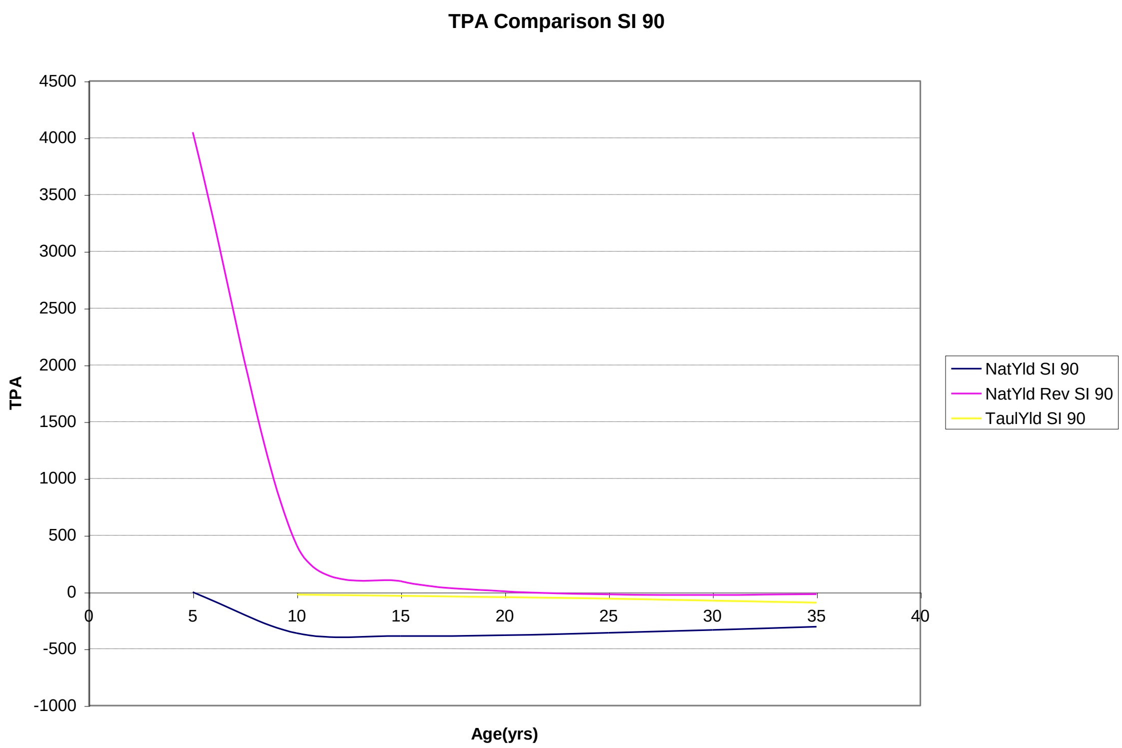
Average Height Comparison
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-12.00
Height(ft)
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 80
TaulYld SI 80
NatYld SI 90
TaulYld SI 90

Growth and Yield TPA Model Comparisons

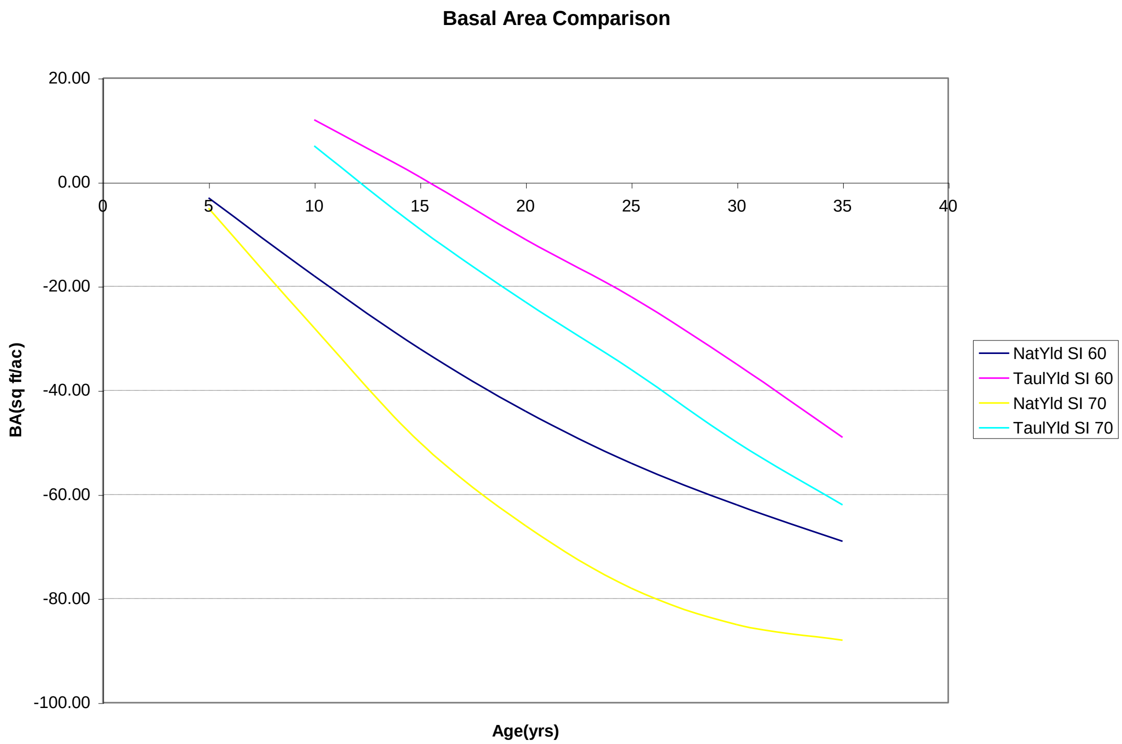


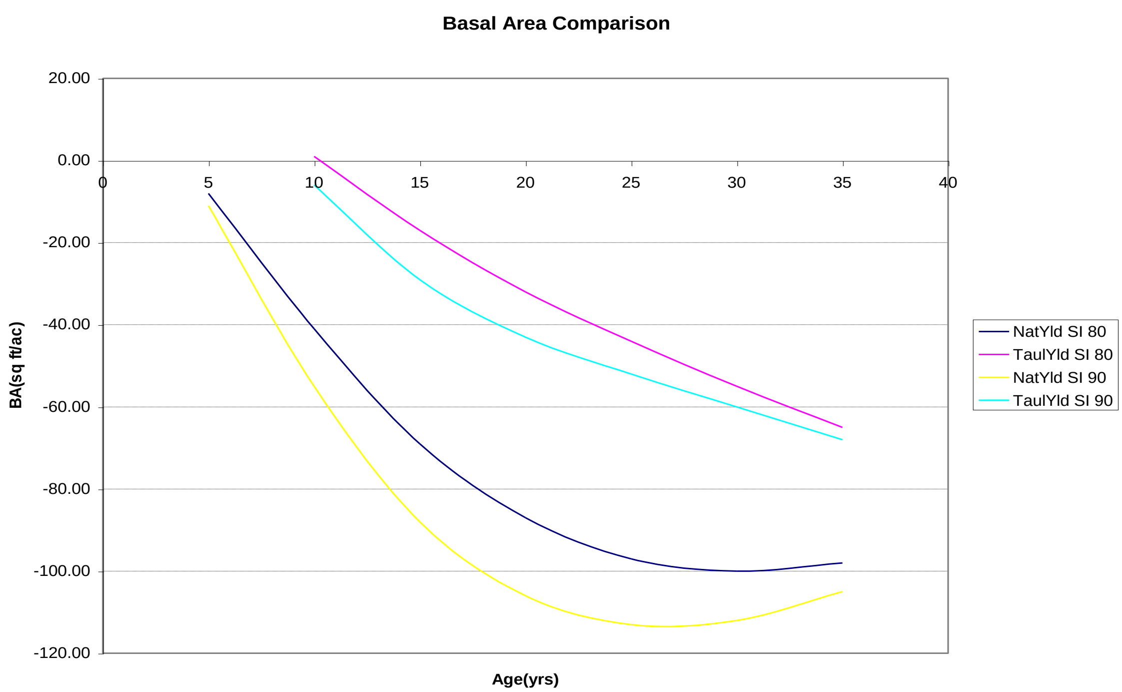



TPA Comparison SI 80
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
TPA
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 80
NatYld Rev SI 80
TaulYld SI 80

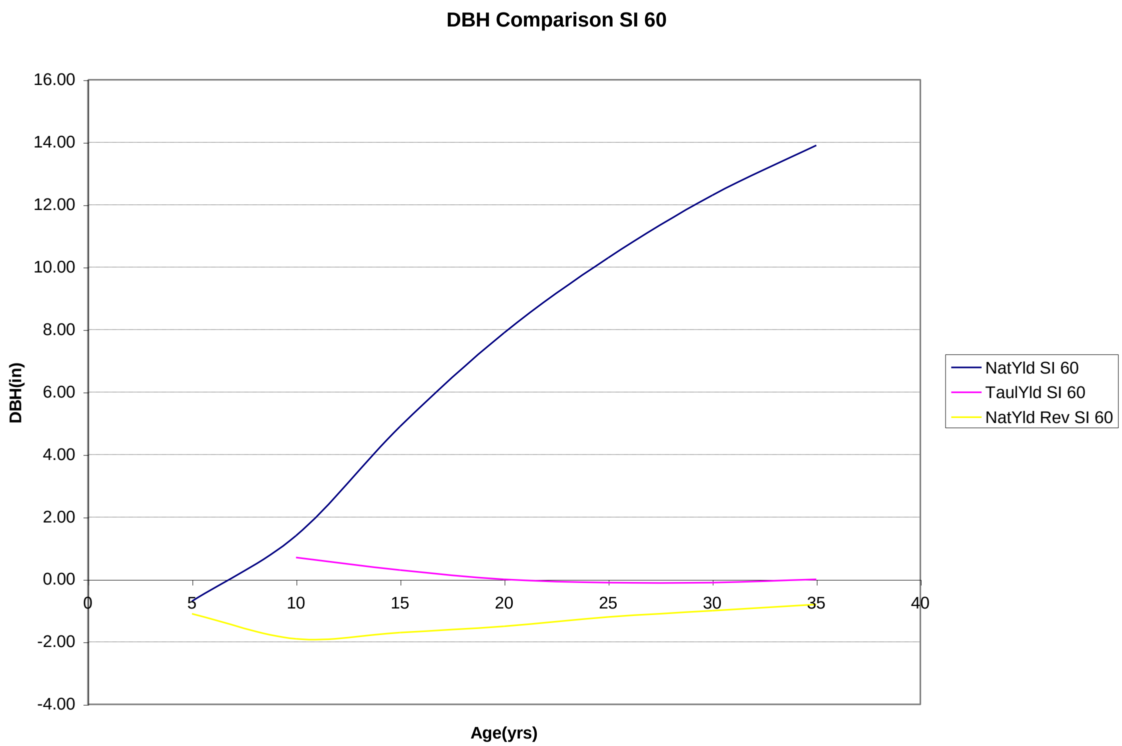

TPA Comparison SI 90
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
TPA
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 90
NatYld Rev SI 90
TaulYld SI 90

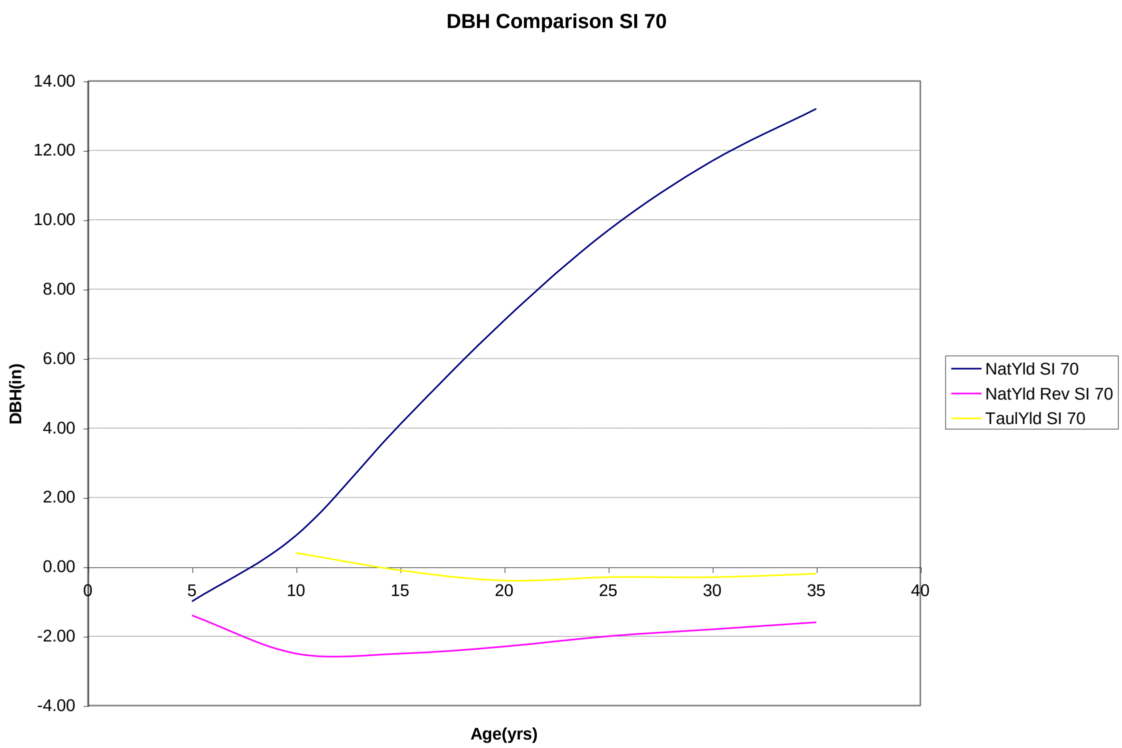
Growth and Yield Basal Area Model Comparisons

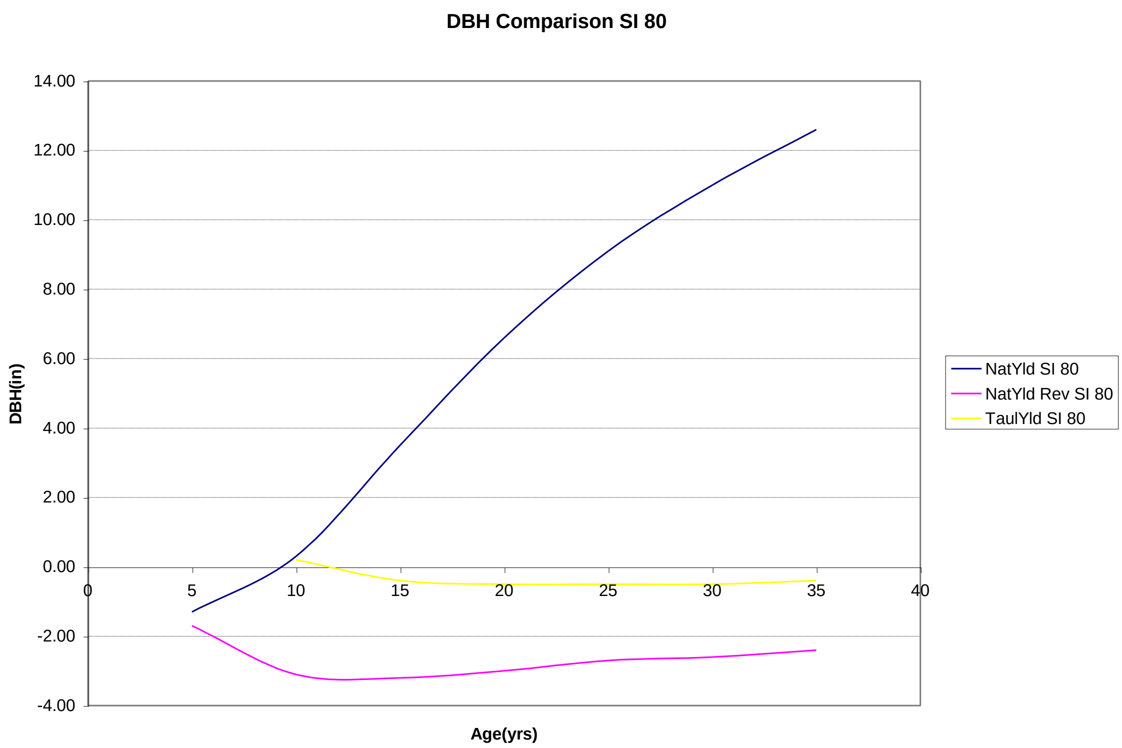


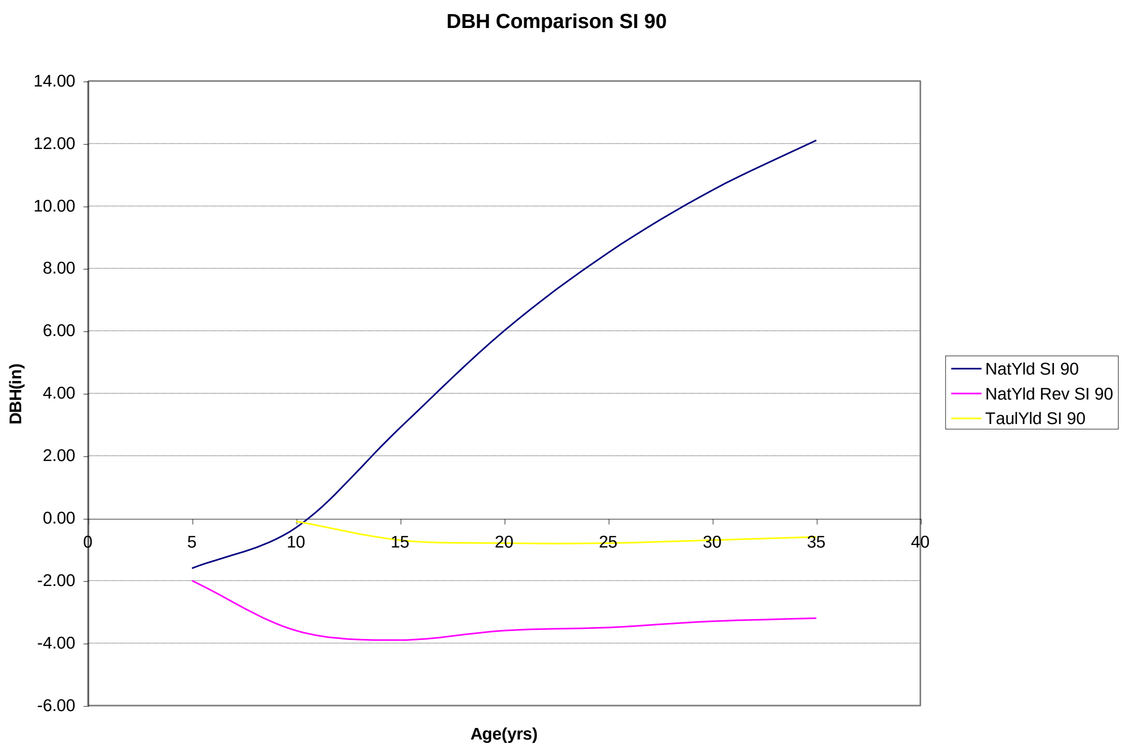


Growth and Yield DBH Model Comparisons




DBH Comparison SI 70
DBH(in)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 70
NatYld Rev SI 70
TaulYld SI 70


DBH Comparison SI 80
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
DBH(in)
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 80
NatYld Rev SI 80
TaulYld SI 80


DBH Comparison SI 90
DBH(in)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
0
5
10
15
20
25
30
35
40
Age(yrs)
NatYld SI 90
NatYld Rev SI 90
TaulYld SI 90

Growth and Yield Volume Model Comparisons