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Crop Tree Management in West Tennessee: A Traditional Financial Analysis

Scott Lorenz Twillmann
University of Tennessee, Knoxville

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To the Graduate Council:

I am submitting herewith a thesis written by Scott Lorenz Twillmann entitled "Crop Tree Management in West Tennessee: A Traditional Financial Analysis." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Donald G. Hodges, Major Professor

We have read this thesis and recommend its acceptance:

Steve Knowe, Burt English, Allan Houston

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Crop Tree Management in West Tennessee: A Traditional Financial Analysis

A Thesis
Presented for the
Master of Science degree
The University of Tennessee, Knoxville

Scott Lorenz Twillmann
May 2004

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Abstract

Crop tree management was designed to fulfill a combination of goals such as wildlife, aesthetics, and timber management. This silviculture method was designed for small woodlots with high value species and can be easily understood by non-industrial private landowners. It focuses on selecting and releasing trees that will yield multiple benefits to the landowner.

The purpose of this study was to determine if crop tree management on an upland oak site in west Tennessee was a financially attractive option for individual landowners. The primary objective of this study was to determine the profitability of crop tree management by examining different treatments (untreated, fertilization, release, release and fertilization) at different rotation lengths (50-60-70-80). Net present value was the chosen the criterion.

Net present values were also examined with price increases of one and two percent to see exactly what level of price increase would be needed to cover the costs of a specific treatment. Stand level rates of value increase for the crop trees from the untreated stand were compared to rates of value increase for the crop trees in the treatments in order to determine differences in when financial maturity occurred due to the treatment application and increases in quality.

Results showed that the release treatment was the most financially attractive investment for each rotation length if prices remained constant or if a one percent price increase occurred. A two percent price increase made fertilization the most financially attractive investment.

The release and release fertilization treatments showed lower rates of value increase than the control for each rotation length. The increased growth due to the treatment application increased the amount of high grade sawtimber, faster, yielding higher present values, sooner, than the control treatment. Therefore, the crop trees in the release and release fertilization treatment reached financial maturity faster than the control and the fertilization treatments.

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CHAPTER 1

INTRODUCTION

Society has associated the agricultural economy of the South with traditional row crops such as cotton, soybeans and tobacco, not realizing that timber produces more income than all other agricultural commodities combined (Webb 1990). According to the recently published Southern Forest Resource Assessment the South produces approximately 60 percent of the nation's timber products; almost all of it from private forests. The South produces more timber than any single country in the world, and it is projected to remain the dominant producing region for many decades to come (Wear and Griese 2001). Non-industrial private forests (NIPF) comprise the bulk of this private ownership with most raw materials for production coming from NIPF land.

NIPF landowners own 70 percent of the South's commercial timberland and manage these forests for a variety of reasons including wildlife, aesthetics, recreation, and income (Kluender 2000). A lack of knowledge hinders sound forest management for many. Moreover, the average landowner does not take full advantage of the many timber and non-timber economic opportunities associated with sound hardwood management. Landowners may never consider managing their forests unless outside economic pressures force them to consider harvesting their timberland (Bommer 1982). Many people associate a "timber harvest" with a "clear-cut" and shy away from the many management and investment alternatives that can accomplish landowner goals and still provide an income. Consultants, industry, timber buyers, state foresters, and extension foresters all must learn how to work with NIPF owners in a manner that meets the personal needs of the landowner and optimizes the utilization of the resource.

The hardwood component of Tennessee's NIPF forests is a valuable commodity that in the past has fallen victim to high grading which allows for the healthiest, most vigorous trees in the stand to be cut while leaving the less desirable trees. Numerous studies on how NIPF landowners value their land suggest that income from timber production ranks below nontimber amenities such as wildlife, aesthetics, and recreation. For many NIPF ownerships in hardwood producing regions, profitable timber management has become increasingly difficult. Forestland has become increasingly fragmented, being divided up into smaller and smaller parcels as developmental pressures make selling the land more profitable than keeping it. Therefore, fewer NIPF ownerships are large enough to be self-sustaining timber production units effectively driving down the appeal for owning land based primarily on timber production (Kingsley 1987).

Other options exist for the sustainable management of southern hardwoods that may offer profitable investment opportunities while achieving the non-timber objectives of the landowner. Studies have shown that although southern NIPF landowners own forestland for a variety of reasons most have positive views on harvesting timber (Moulton 1995). Intermediate stand treatments such as thinning, improvement cutting, and crop tree release could increase yields on an estimated 20 million acres of NIPF land nationally (Alig et al 1990). Such treatments can be implemented in a manner that enhances non-timber values while providing landowners with higher quality timber of the more valuable species.

NIPF Timberland Investment

Investment decisions concerning hardwood management in the South are complex compared to pine. Significant factors that make decision making more uncertain include species composition, product definition and value, and importance placed on non-timber benefits (Gardner and Apt 1995). When a forester recommends management decisions for a private tract of land, the decision making process should reflect the ownership objectives of the landowner. Aesthetics, wildlife habitat, and recreational uses often are not subject to the same objective criteria as timber management for financial purposes.

Timberland owners who view their forestland as an investment should seek clear management choices that fit within a financial decision-making framework. By simplifying a timberland investment into a decision based on costs, returns, rotation length and a chosen interest rate, a landowner may be more willing to sacrifice the capital up front for an expected return in the future that meets given objectives. However, estimating future returns is not without uncertainty. Returns depend on volume and value growth per acre, expected trees per acre, tree size and species. Tree quality, products and markets, and harvesting costs will affect future returns as well (Gardner and Apt 1995).

Once a landowner has determined an acceptable level of return, the financial criteria used to measure success at a given point in time must be identified. Several studies recommend rate of value increase as a basis for deciding what, how, and when to cut certain trees or stands. It serves as a calculable measure of financial maturity for the objectives of the landowner (Debald and Mendel 1971). The rate of value increase over a time period is determined by initial stand value and the relationship between the costs at the beginning and end of the time period (Herrick 1984).

The value of a particular tree or stand is directly related to diameter, grade and species. As size increases over time, so does the proportion of higher grade lumber that may be removed from the stand in the future (Smith et. al. 1979). Smith (1979) demonstrated that leaving vigorous, high quality trees that exhibit the potential to produce larger butt logs or possibly veneer material will increase tree/stand value. One means of accomplishing this involves concentrating management efforts on individual (crop) trees with the greatest potential for producing high value forest products through crop tree management. This thesis reports on an evaluation of the economic returns associated with crop tree management options utilized on hardwood forests in west Tennessee. The primary objective of the study was to determine the returns from four crop tree management alternatives: no treatment, crop tree release by removing competitors, fertilization, and a combination of fertilization and competitor tree release.

Thesis Organization

This paper focuses on crop tree management by examining the effect of different treatment applications on net present values and rates of return. Costs and revenues associated with no management, fertilization, release, and a combination of fertilization and release were evaluated. The purpose of the study was to identify the management regime that will yield the greatest financial return and provide insights into the most financially acceptable treatment at different ages throughout the life of the stand.

Rates of value increase for the crop trees were also examined at the stand level in order to calculate value increases due to biological growth compared to value increases due to treatment applications and grade increases. Rates of value increase were assessed

at 10-year growth intervals beginning with stand age 50 to determine when the rate of value increase approached the alternative rate of return of 4 percent.

CHAPTER 2

PREVIOUS RESEARCH

Crop Tree Management

Crop Tree Management (CTM) is not a new concept, although foresters have been encouraging NIPF owners to adopt the technique more intensively during the last 20 years. Its applicability to NIPF owners lies in the fact that CTM can fulfill multiple landowner goals simultaneously including habitat improvement, aesthetic enhancement, and timber production. Much of the crop tree literature suggests that a clear understanding of landowner objectives (e.g., recreation, income, wildlife), stand-specific objectives, and criteria for selecting crop trees should be developed before the actual crown release is implemented (Perkey 1993, Bardon and Gardner 2002???).

Crop tree management is an intermediate treatment that can be considered both a thinning and a timber stand improvement operation. Crop tree literature has been focused primarily on the release of sapling (Della-Bianca 1975, Lamson and Smith 1978, Ward 1995) and pole sized hardwood stems (Dale and Sonderman 1984, Mitchell et. al. 1988, Miller 2000). Little effort has been expended on assessing the potential of releasing older hardwood crop tree stands because earlier studies suggested that mature trees in unthinned stands respond little to thinning (Sander 1977, Hibbs and Bently 1983, Dale and Hilt 1989). Ward (2002) challenged this notion by examining the response of 74 to 94 year old red oaks to crop tree release over a 6-year time interval. The study revealed that the upper age limit to which red oaks respond to release is 90 years. Ward reported a 53 percent increase in diameter growth for sawtimber red oak over the 6-year period. Annual increase in volume growth averaged 95 percent for 11-inch trees (beginning

DBH) and 25 percent for 20-inch trees. Releasing the crowns of selected crop trees by felling competing trees allows the crown to expand, increasing leaf area. As a result, diameter growth is increased and value is added to the tree at an increasing rate. Houston (1995) extended the model by demonstrating that fertilization applications in addition to crown touching release will generate higher rates of growth than either one of the single treatments by themselves.

Problems with NIPF Timberland Investment

A high quality hardwood forest growing on a private tract is a prime commodity. Long-term management has become increasingly difficult as demand for wood products and services from NIPF land has increased from both domestic and international entities. Some analysts suggest that consumption of higher grades of hardwood timber is greater than most supply and demand forecasts indicate (Bommer 1982).

. Bommer (1982) lists several inherent problems and risks with private forestland investment that landowners must consider.

1. Conflicts between timber production and surrounding environmental pressures.
2. Tax and land policy decisions by federal, state, and local government agencies.
3. Lack of proper equipment and manpower needed for small ownership tracts.
4. Lack of experienced personnel to advise on small landowner investments.
5. Questionable credibility of the forest-timber community.
6. Unavailability of markets in certain areas.
7. Constantly changing ownership patterns.

Private forest landowners may also be reluctant to invest in their hardwood timber stands because the return on such investments is realized only after decades of growth. Landowners may be able to offset some or all of the original cost of the investment in CTM by receiving periodic income from the release that is necessary to implement the practice. Several specific obstacles to crop tree management exist, however, that landowners must consider. According to Perkey (1993), the problems that a landowner may encounter with CTM include:

1. There may be relatively few high value crop trees per acre in the stand.
2. The value of the land does not reflect the future value of high quality crop trees. The non-liquidity of the investment is a disincentive, especially if land is sold before maturity of crop trees.
3. High-value timber crop tree investments are moderately risky. Weather events, insect and disease and market fluctuations can affect the rate of return on the investment by degrading log quality and therefore stumpage value.

Crop Tree Management Investment Criteria

Crop tree management may be a viable management alternative for private landowners that view their property as an investment. Management should be concentrated on liquidating the money invested in individual trees with low earnings potential and reinvested on those that have high earnings potential. However, there are factors that determine whether CTM is feasible for a particular tract of land or a particular landowner. Limiting financial factors include establishing crop trees at a reasonable cost, increasing the growth rate, and maintaining or improving the characteristics that make them valuable (Perkey 1993).

Several researchers have assessed the economic benefit of hardwood timber management to private landowners using different variables and criteria to determine the profitability of hardwood timber investments. Bullard et al. (No Date) compared a *simple financial maturity* model that only considers timber value, to an *adjusted financial maturity* model, in which both land and timber values are considered. Their study defined financial maturity with regards to timber harvest age as "when the rate of value increase falls below what the landowner can earn in alternative investments that are comparable in investment period, risk, liquidity and other factors." The results reveal that with the adjusted model, timber will be financially mature at a younger age because the opportunity cost of the land is taken considered.

Perkey (1992) reported real rates of return of 6 to 16 percent on pre-commercial to medium-sized red oak sawtimber crop trees without considering land and administrative costs. In another study, Perkey (2000) considered rate of return and annual income to be critical financial parameters in evaluating the conversion of physical growth to financial growth of red oak and yellow-poplar. The results revealed increases of 8.5 percent and 11.5 percent, respectively, in red oak and yellow poplar stumpage value for the 10 year growth period. This study considered criteria such as stumpage prices, inflation, size and quality of trees (grade), and cost-sharing programs in order to describe the attractiveness of the investment. However, these studies did not incorporate the aggregate costs commonly associated with implementing CTM effectively, namely periodic costs, annual costs, capitalization costs.

Hamilton (2002) used a hypothetical situation to illustrate the potential profitability with CTM. His example assumed a site index of 75 for white and red oak,

50 crop trees per acre between 10 and 13 inches in diameter at 4.5 ft. (DBH), and an average DBH growth rate of 2.2 inches per decade with CTM. The main goal of this example was to grow the smallest current DBH class to 18 inches by rotation age. Like Perkey (2000), Hamilton's example also considered cost-share programs but actual landowner costs of $24 per acre after cost sharing were also considered. Hamilton concluded that at 36 years, stand value was 51 percent higher in the treated area ($3,017/acre) than in the untreated area ($1,540/acre).

Treatment Costs Associated with Crop Tree Management

Intermediate stand treatments can be expensive and labor intensive. Money expended on treatments such as release, fertilization, weed control, or burning must be considered as part of the investment. When determining whether to apply a specific treatment to a stand, the present value of the cost of the investment must be equal to or less than the present value of the benefit gained. To determine the benefit of a TSI operation, Mills et. al (No Date) suggested an investment analysis that focused on future stand conditions and capitalization costs (e.g.; cost of holding an investment over time). The length of the investment affects the rate of return because as the investment period increases the cost of capital increases as well.

Miller (1986) examined the economic feasibility of pre-commercial treatments by using crop tree release to increase a stand's future value. In addition to considering rate of return, growth, and investment period, periodic treatment costs were considered in a 15 to 20 year old hardwood stand. Miller concluded that future revenues from pre-commercial thinnings would be higher only in young stands with high value species. Miller (1984)

also compared costs associated with chainsaw felling, stem injection and basal spraying and concluded felling with a chainsaw to be the cheapest at $0.42 per tree.

To determine whether fertilization is profitable, Lamson and McCay (1978) tested four different financial methods and concluded that calculating "timber value needed" is a better gauge than ROR, volume increase needed, or fertilization costs needed. Dwyer et. al. (1988) examined four different treatment scenarios; 1) Pruning 2) Release 3) Release and Prune 4) Control. Net Present Value was used to determine the most financially attractive management scenario at a given rotation length.

Discount Rates

Choosing an appropriate interest rate is important for accurately estimating a stand's future value when considering investments in forest management activities. Slight changes in the interest rate (i.e., discount rate) may significantly affect the profitability of long-term forestry investments. Gardner and Apt (1995) suggested that an appropriate interest rate be high enough to cover "risk, uncertainty and a reasonable return." A study in southeastern Michigan (Smith and McClain, 1980) that was focused on managing small woodlots revealed that the cost of owning woodland at a time of high interest rates prohibits earning a profit on timber if all costs are considered unless periodic timber stand improvement investments are made.

Clatterbuck and Orr (1988) compared the financial attractiveness of open grown cherrybark oak versus cherrybark oak that was restricted by competing trees using real rates of return between 2 and 5 percent. The study found no significant difference in Net Present Value (NPV) at an interest rate of 2 to 5 percent. However, differences in NPV

increased when the discount rate was 6 percent and higher. From this, the authors were able to conclude that the shorter rotation of the open grown cherry bark would be a more financially attractive investment.

CHAPTER 3

METHODS

Study Objectives

The primary goal of this study was to assess the financial profitability of Crop Tree Management on an upland oak site and determine the effect of physical and economic variables on profitability. Specific objectives include:

1. Determine the profitability of CTM within a range of values for:
    a. Different Treatments at different rotation lengths
    b. Timber Prices
2. Identify stand level rates of value increase due to:
    a. Biological Growth
    b. CTM Treatments
    c. Increase in Quality

Study Site

This study utilized data collected as part of a study in 1995 by O'Neil, a former graduate student in Forestry at the University of Tennessee. In addition new growth and volume data were collected on the same site as part of the current study. The following descriptions of location, climate, and topography and brief historical record were taken from O'Neil (1995).

Study Location, Climate, Topography

Both the original and current studies were conducted on a 20-acre upland oak site at Ames Plantation located 60 miles east of Memphis. The plantation is 18,548 acres and

arguably one of the largest private landholdings in the state of Tennessee. The study site is located on a 370-acre demonstration farm that was established in 1955 as a model for converting "run down" land used for cotton into a working farm with commodities such as cotton, hog, beef, and timber.

Climate for the area can be described as mild. The western part of Tennessee is characterized as having mild winters and hot summers with an average growing season of 210 days and 61 total inches of precipitation (O'Neil 1995).

The study site is located on rolling hills with slopes of up to 20 percent. Soils on the site include silt loams of the Lexington series and sandy clay loams of the Smithdale series. The average site index for oaks, base age 50, is 75 to 85 feet.

Brief Site History

Timber harvests were nonexistent on Ames Plantation between 1903 and 1945. Partial harvests were conducted in the study area in 1945-1946 and 1955-1956. These partial harvests established regeneration that now comprises the present stand. In 1967, a commercial harvest was conducted that removed all merchantable timber larger than 11 inches in diameter at breast height (dbh) and releasing the advanced regeneration. The current age of the stand is estimated to be 50 years old.

Design of Original 1993 Study

O'Neil's (1995) study examined the 2-year growth rate of various hardwood species and their response to treatment. The stand was subdivided into twenty 1.01-acre plots (Figure 1). Within each plot, 36 - 35 x 35 ft. square cells were established.

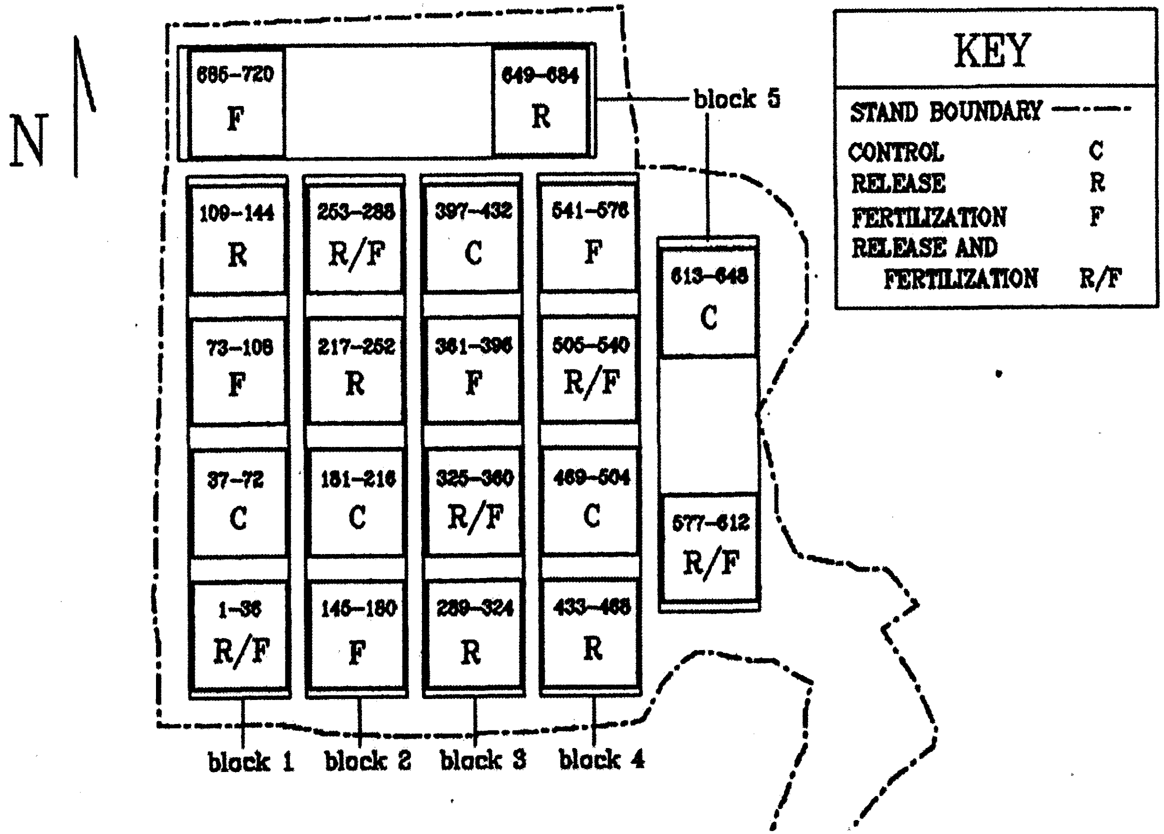

Figure 1. Original Layout of White Oak Crop Tree Management Study in West Tennessee, 1993

The study consisted of five complete-block replications of four different treatments: 1) Control (no treatment), 2) Release, 3) Fertilization, 4) Release and Fertilization. The primary species for consideration were white oak and southern red oak. If a suitable primary species was not available, secondary species (black cherry and black oak) were considered. Crop trees were evaluated for each cell where at least one tree met the predetermined criteria. The predetermined crop tree criteria included:

1. A score of 10 or better in Point System for Hardwood Crown Classes. Values ranging from 1 to 28 were given to each tree based on amount of sunlight from above and from the side, crown balance, and crown size.

2. Based on the existing stem, the crop tree must have the potential to produce a 16 ft merchantable log.

3. The crop tree could not be a super dominant/wolf tree or in an older age class.

4. Crop tree species preference was based on what was most valuable in the stand. In this stand the species of concern in order of importance are white oak and black or southern red oak. When a high value species was absent then other species like black cherry were selected.

5. Additional considerations include avoiding stems with excessive sweep, crook, lack of crown vigor, and extreme epicormic branching.

Prior to treatment, tree quality was assessed using a USDA Forest Service Tree Classification System (modified from Putnam 1960). Tree quality was recorded as either 1) Preferred, 2) Reserve, 3) Cutting. The number of epicormic branches was also recorded for each 16-foot log.

The release treatments consisted of removing neighboring trees to expose the crown to sunlight on at least three sides. Competing trees were felled using a chainsaw and sold for firewood. Nitrogen was applied as urea at 148.5 pounds per acre and

Phosphorus was applied as triple super-phosphate at 29.7 pounds per acre. Each treatment was applied to ten treatment plots.

2002 Data Collection-Crop Trees and Competing Trees

The following crop tree data were collected in the fall of 2002 and used to develop local volume equations in order to project volumes for the remainder of the rotation.

Crop Tree Data Collected-Fall 2002

1. DBH was measured to the nearest 0.1 inch using a diameter tape.
2. Merchantable height was measured with a Vertex III and Transponder T3. For sawtimber size trees, with DBH greater than 11 inches, merchantable height was determined by the first major branch, crook or sweep. For pulpwood size trees, height was measured to a 4 inch top unless defects (fork, crook, sweep, general condition of tree) prevented this.
3. Diameter outside bark at merchantable height (top DOB) was measured with a Wheeler Pentaprism.
4. Tree Grade was assessed according to the parameters set forth by Hanks (1976).
5. Species
6. Basal area of each crop tree

"IN" Tree Data Collected Fall-2002

For each 1.01-acre treatment plot a subset of 6 white oak crop trees were randomly selected. All trees determined to be "IN" a 10 BAF prism sweep were recorded as competitors. These "IN" trees served as the basis for determining volume for a future

release and final harvest at rotation age. The same measurements gathered on the crop trees (DBH, merchantable height, top DOB) were collected for the competitor trees, with the exception of tree grade. In each crop tree cell basal area (not including the crop tree) was measured with the crop tree as point center. Basal area per crop tree cell was needed to develop a volume-basal ratio (VBAR) which was used to determine the volume of the competitor trees per acre to be harvested in a future release and the final harvest at rotation age.

Volume Estimates

Crop Trees-2002

Volumes were calculated using Microsoft Access with the Southern Tree Species Stem Taper and Volume Prediction Equations (Souder et. al., unpublished. Each 8-ft bolt was merchandized as pulpwood or sawtimber based on scaling diameter, position and length. Volumes were calculated for four sets of data: 1) 2002 crop trees, 2) 1993 crop trees, 3) trees cut for the 1993 firewood sale, 4) 2002 competitor trees. For the 2002 crop tree data, pulpwood was defined as stems to a 4-inch top less than 11 inches DBH and sawtimber was defined as stems to a 9-inch top and DBH greater than or equal to 11 inches.

Red and white oak sawtimber volume was divided into grades 1, 2, and 3. Other species were classified as miscellaneous hardwoods. The butt log (first 16 ft) of each crop tree merchandized as sawtimber was assigned the grade given to the tree in the field during the 2002 data collection. Each 16-ft log above the butt log was assumed to decline one grade from the previous log (Campbell 1955). The percentage of total volume

in each 16-ft sawtimber bolt merchandized as sawtimber was estimated by dividing the board feet in that log by the total board foot volume of the tree. The resulting volume was categorized as either grade 1, 2, or 3 board foot volume depending on the grade of the butt log. Volume in any second or third 16-foot section was assumed to be a grade below the previous log and percentages were figured in the same manner.

Competitor Trees-2002

Competitor tree volume was calculated on a per acre basis using a volume basal area ratio (VBAR). Trees were categorized as miscellaneous hardwood, red oak, and white oak. A VBAR for sawtimber and pulpwood was calculated for each category and applied the estimates of basal area per acre of competitors around each crop tree to determine the volume of competitor trees.

Future Volume Projections

Crop Trees

Local prediction equations were developed for each treatment. Equations were based on the 10-year DBH growth between 1993 and 2003. The following equations were used to project diameters for stand ages 60, 70, and 80.

Control $\text{Future DBH} = 1.5703 * \text{Current DBH}^{.8842}$

Fertilize $\text{Future DBH} = 1.5703 * \text{Current DBH}^{.8947}$

Release $\text{Future DBH} = 1.5703 * \text{Current DBH}^{.9012} * e^{(.0964 * \%\text{ BA cut})}$

Rel Fert $\text{Future DBH} = 1.5703 * \text{Current DBH}^{.9117} * e^{(.0964 * \%\text{ BA cut})}$

The following equations were used to project pulpwood and sawtimber volume by tree using volume as a function of diameter.

For DBH less than 11 inches, pulpwood volume (ft^3) = $0.0567*DBH^{2.3589}$

For DBH greater than 11 inches, pulpwood volume ((ft^3) = $(0.0567*11^{2.3589})$ – $(8.6025*(DBH-11)^{0.2034}$

On the control plot and release plots Doyle (bd. ft) volume = $0.0082*DBH^{3.3619}$

On the fertilization plots, Doyle (bd. ft) volume = $0.0082*DBH^{3.4279}$

If a treatment was not applied during the decade of growth the equation for the control plot was used to estimate future DBH and volume.

Board foot volumes were assumed to move up in grade according to diameter limits set forth in Hanks (1976). Trees with a butt log diameter of 16 or greater were grade 1. Trees with a butt log diameter of 13 or greater were considered grade 2, and trees with a butt log diameter of 10 or greater were considered grade 3. Some trees were assigned a lesser grade than the diameter limit suggests because of the overall condition of the tree. These trees are assumed to retain that grade through all future volume projections. Future volumes by log were estimated in the same manner as described above using the same percentages figured from the original 2002 data.

Volume of Competitors

The same methods used in projecting growth for the crop trees were used for the competitors. For each rotation new VBARs and per-acre estimates were calculated for each product category. Growth and mortality were assumed to effectively offset each

other. Therefore, basal area was assumed to remain the same throughout future projections.

Each stand age represented the end of the rotation when the stand was assumed to be clearcut. Crop tree volumes were added to per-acre estimates of competitors to obtain the amount of current and future pulpwood and sawtimber volume to be removed from the stand during the final harvest.

Financial Considerations

The financial analyses were conducted with data from O'Neil (1995) and the data collected in the fall of 2002. Net present value was the selected criteria for ranking the best treatment at each 10-year growth interval. A positive net present value indicates that the present value of the treatment revenues exceeded the present value of all expenses at the landowners chosen discount rate. A negative net present value occurs when revenues from the investment do not cover all management costs associated with the treatment. The rate of return was calculated where the present value of costs equals the present value of revenues. Rates of value increase for each treatment were calculated and compared to the control for each 10-year growth interval in order to determine financial maturity (when rates of value increase approaches the 4 percent discount rate).

Crop Trees Prices

No price reporting system provides stumpage prices for hardwood sawtimber by species and tree grade in Tennessee. The Tennessee Department of Agriculture, Forestry Division (TDF) (2002), publishes a quarterly report of delivered prices for six species by

three grades. TimberMart South (TMS) publishes a quarterly report for stumpage and delivered prices for mixed sawtimber and oak sawtimber. The difference between TMS stumpage and TMS delivered prices has averaged 61.36 percent between the years of 1982 and 2002. This difference represents the average logging and hauling costs for Region 3 (west Tennessee). By using the TMS percentage, the following equation was used to determine stumpage prices.

Stumpage Price =Average TDF Delivered Price by grade-(Average TDF Delivered Price by grade *0.6136)

Sawtimber was reported by the Doyle log rule. Pulpwood volume was converted to cords by dividing total cubic feet by 90.

Stumpage prices applied to competitor tree volumes were estimated using the same equation as the 2002 crop trees. Sawtimber was categorized as white oak, red oak, or miscellaneous hardwood. Since competitor trees were not graded, the average of the grades 3 and 2 for white and red oak were used as the base price. Table 1 lists sawtimber and pulpwood prices applied to the 2002 crop trees and the 2002 competitors.

Prices applied to trees cut and sold during the first release for firewood were estimated using the same equation used for previous price calculations. All wood cut for the 1993 release and sold for firewood was considered pulpwood. The average price for pulpwood in west Tennessee in 1993 was $14.73/cord.

Management Costs

The average fertilization costs per acre for 1994 and 1992 were obtained from Dubois et al. (2003) and totaled $42.09 per acre including the cost of fertilizer.

Table 1. 2002 Stumpage Prices ($/MBF) Applied to Crop Trees and Competitors

Species	Grade 1	Grade 2	Grade 3	Competitor Trees
White Oak	$ 202.03	$ 121.04	$ 72.41	$ 96.73
Red Oak	$ 300.25	$ 190.73	$ 119.16	$ 154.94
Miscellaneous Hardwoods				$ 54.10/MBF $ 20.78/cd pulp

The average cost for marking the trees for management was estimated as $13.46 per acre. This represents the cost associated with marking timber in preparation for various types of thinning as reported by Dubois et al. (2003). Property tax was estimated as $3 per acre based on average costs for Tennessee (Tankersley 2003).

Timber Sale Income and Crop Tree Value

Income was received for firewood in 1993 for trees cut in the release and release/fertilization plots prior to April 15, 1993 (O'Neil 1995). Additional final harvest incomes were based on price increases and timber growth projections.

Crop tree value was calculated for each 10-year growth interval beginning with 2002 (stand age 50). Dollar values applied to crop trees were considered the amount of revenue a landowner would receive if the crop trees were harvested at that particular stand age. Competitor tree and crop tree values were applied on a per acre basis.

Financial Analysis

Pulpwood and sawtimber volumes were multiplied by the crop tree and competitor tree prices in order to determine the total value per acre for each treatment. Each treatment represents 5 acres of the stand. The present value of all costs and revenues for each 10-year growth interval were calculated with various interest rates for each treatment. Net present values were then calculated and reported on a per acre basis. The best financial investment was determined by examining the net present value of each treatment at stand ages 50, 60, 70 and 80. A 4 percent real discount rate was used as a landowner's alternative rate of return.

In the U.S., real market value increases for hardwood sawtimber have averaged 2 to 3 percent per year over the last 200 years (Davies 1999). For this study, net present values were recalculated assuming real price increases of 1 and 2 percent. Price increases were estimated to see if the increase in actual value changed which treatment option was financially acceptable.

A rate of value increase (RIV) was calculated for the crop trees in each treatment to examine the rate of 10-year value growth increment. This was used to estimate the stand level financial maturity of the crop trees. Financial maturity for this study is defined as when the value growth of a tree or stand drops below the landowner's alternative rate of return (4 percent for this study). The untreated control (biological growth) plots were compared to the treatments to assess the increase in value that could be attributed to the treatment application (i.e., fertilization, release, release and fertilization).

A rate of value increase was estimated for grades 1, 2, and 3 sawtimber volume for each 10-year growth period as well. Both rates of value increase and actual monetary increases in the control were compared to the treatments in order to determine value increases due to an increase in quality (grade).

CHAPTER 4

RESULTS

Crop Tree Sample Size by Treatment

Local volume equations were based on the 10-year growth period from 1993 to 2002. Data from 1993 were taken prior to treatment application. Table 2 contains the initial (year 40) and ending (year 50) average DBH and 10-year average DBH growth by treatment. The release-fertilization treatment exhibited the greatest average 10-year growth at (3.6 inches), followed by the release (3.1 inches), fertilization (2.3 inches) and the control (2 inches).

A total of 598 of a possible 720 crop trees (180 cells per treatment and 4 treatments) were sampled (Table 3). The design of the original study resulted in some cells containing no suitable crop tree. An ice storm in 1994 and natural mortality decreased sample size as well. Volumes could not be computed for 14 crop trees because of inconsistent measurements (measurements did not fit the species specific stem and taper function used by the access program).

The largest 10-year increase in total board foot volume per acre was in the release-fertilization treatment (1,384.7 bd. ft). Following in order of volume increase were the release (857.5 bd. ft), fertilization (745.9 bd. ft) and the control (487.3 bd. ft) treatments (Figure 2).

As expected, pulpwood volume per acre (cords) decreased over the 10-year period because smaller diameter trees moved into the sawtimber size class. The most significant decrease was in the release-fertilization treatment (1.0 cords) followed by the release (0.5 cords), fertilization (0.4 cords) and the control (0.2 cords) treatments (Figure 3).

Table 2. Average 10-year DBH Growth (Inches) for Crop Trees by Treatment

Treatment	***DBH (in.) at Stand Age 40 DBH***	***DBH (in.) at Stand Age 50 DBH***	***Average 10 Year DBH Growth***
Control	9.5	11.5	2.0
Fertilization	9.8	12.1	2.3
Release	9.9	13.0	3.1
Release Fertilization	10.3	13.9	3.6

Table 3. 2002 Crop Tree Sample Size by Treatment and Species.

	Control	***Fertilization***	***Release***	***Release-Fertilization***
Misc. Hardwoods	9	6	4	7
Red Oak	37	31	37	43
White Oak	98	118	112	96
Crop Trees 2002	**144**	**155**	**153**	**146**
Unfilled Cells	23	10	16	14
Dead Trees	6	12	11	16
Inconsistent Data	7	3	0	4
Total Possible Crop Trees	**180**	**180**	**180**	**180**

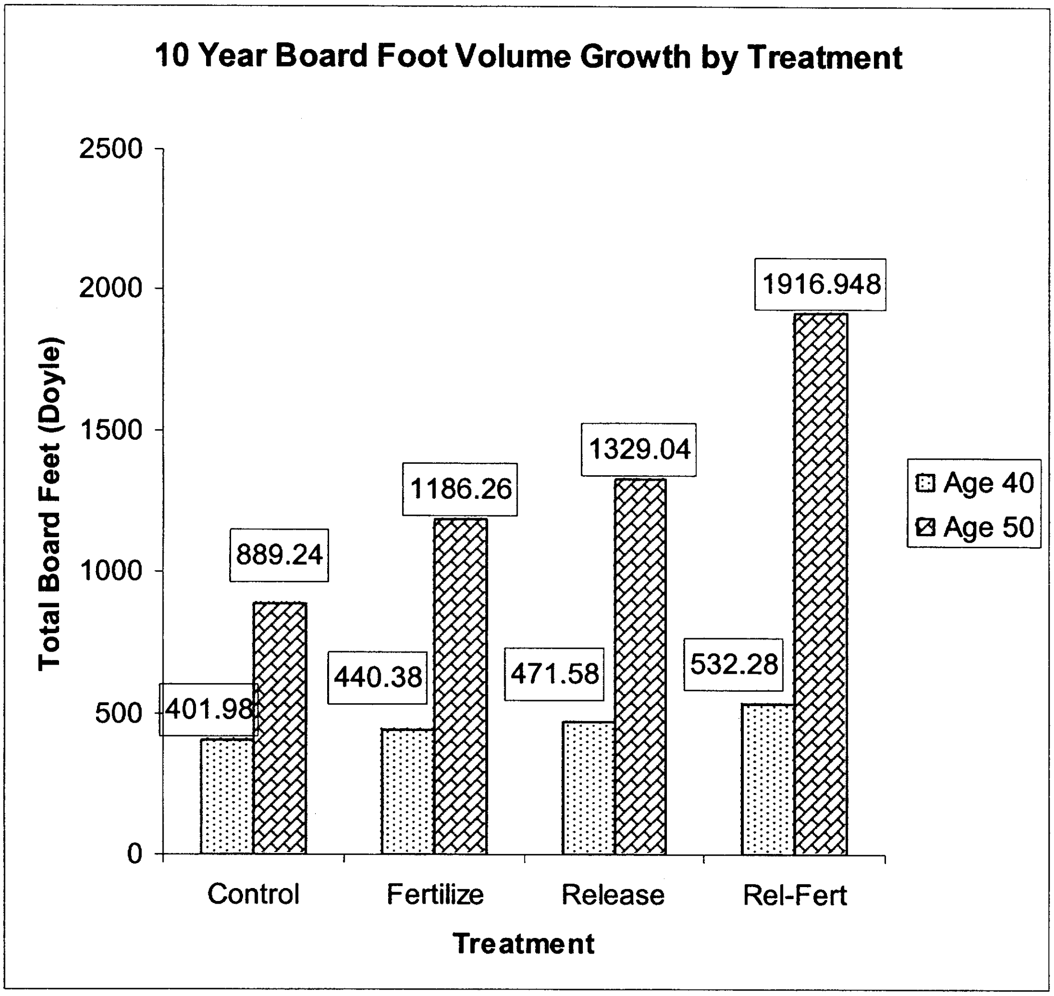

Figure 2. Sawtimber 10-Year Volume Growth (bd.ft./acre) Between Stand Ages 40-50 Years

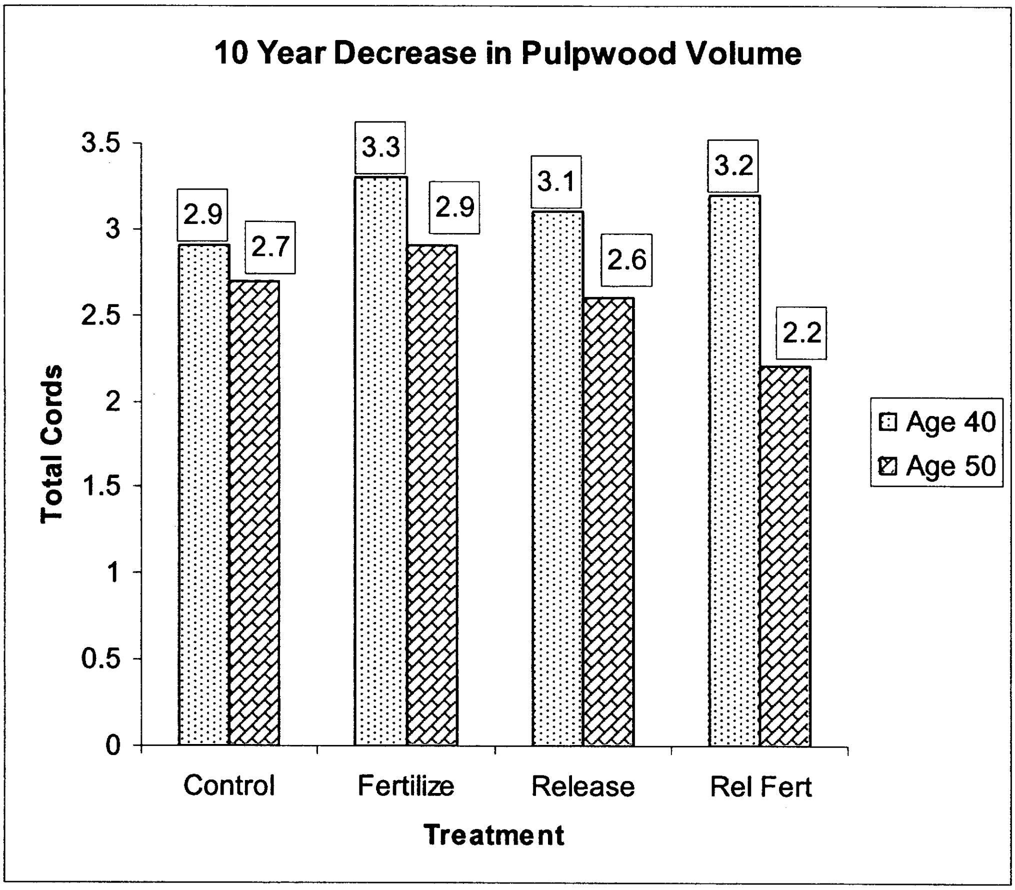

Figure 3. Ten Year Change in Pulpwood Volume (cords/acre) Between Stand Ages 40-50 Years

Volume Growth by Tree Grade

Grade 1 red oak and white oak board foot volume increased as smaller diameter crop trees grew into larger diameter classes. The pretreatment data at stand age 40 years shows 77 percent more grade 1 volume in the fertilization treatment than in the control, 60 percent more grade 1 volume in the release treatment and 18 percent less grade 1 volume in the release-fertilization treatment. The largest increase in grade 1 sawtimber volume occurred in the decade immediately following treatment applications between stand ages 40 and 50. The greatest increase over the control was in the release-fertilization treatment (55%) followed by the release (47 %) and fertilization (34%) treatments (Figure 4). After stand age 50, the rate of volume increase for grade 1 sawtimber began to decrease.

Pretreatment data at stand age 40 for grade 2 sawtimber exhibited 23 percent less board foot volume in the fertilization treatment than in the control. The release and release-fertilize treatments included 12 and 3 percent more grade 2 volume, respectively than the control. The greatest increase in grade 2 sawtimber volume was in the release-fertilization treatment (55 %), followed by the release (41 %) and the fertilization (26 %) treatments at stand age 50. After stand age 50 the rate of grade 2 sawtimber volume increase over the control began to decrease (Figure 5).

Pre-Treatment board foot volumes at stand age 40 for grade 3 sawtimber were 26 percent more in the release-fertilization treatment than in the control. The release (16 %) and fertilization (8 %) treatment had grade 3 volumes that were larger than the control as well (Figure 6). The greatest increase in grade 3 sawtimber volume over the control

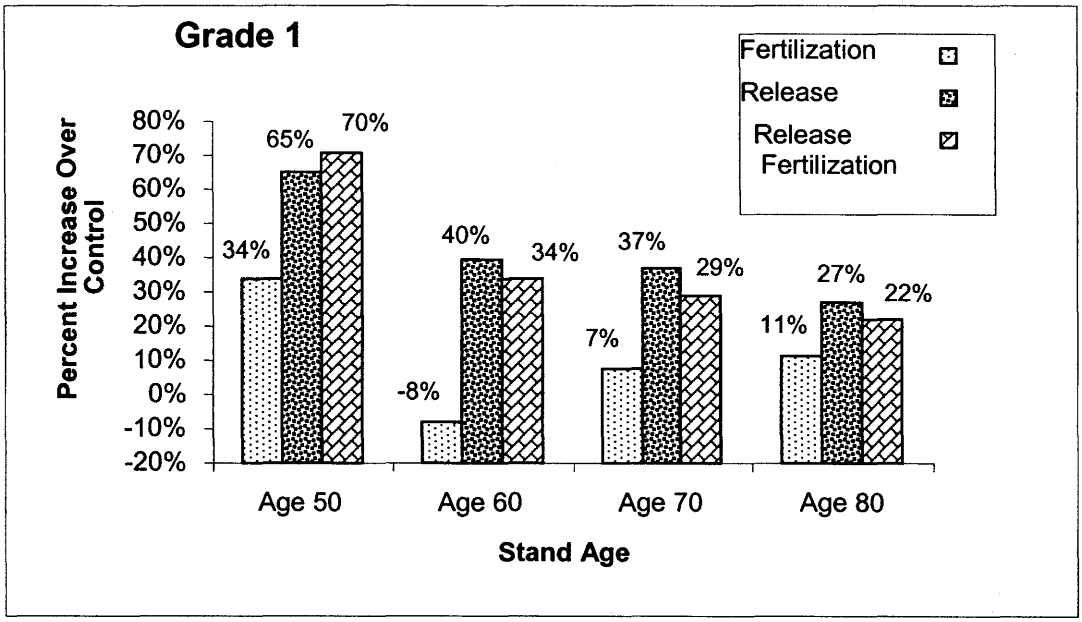

Figure 4. Percent Increase in Grade 1 Sawtimber Over the Untreated Stand for each 10-Year Growth Interval

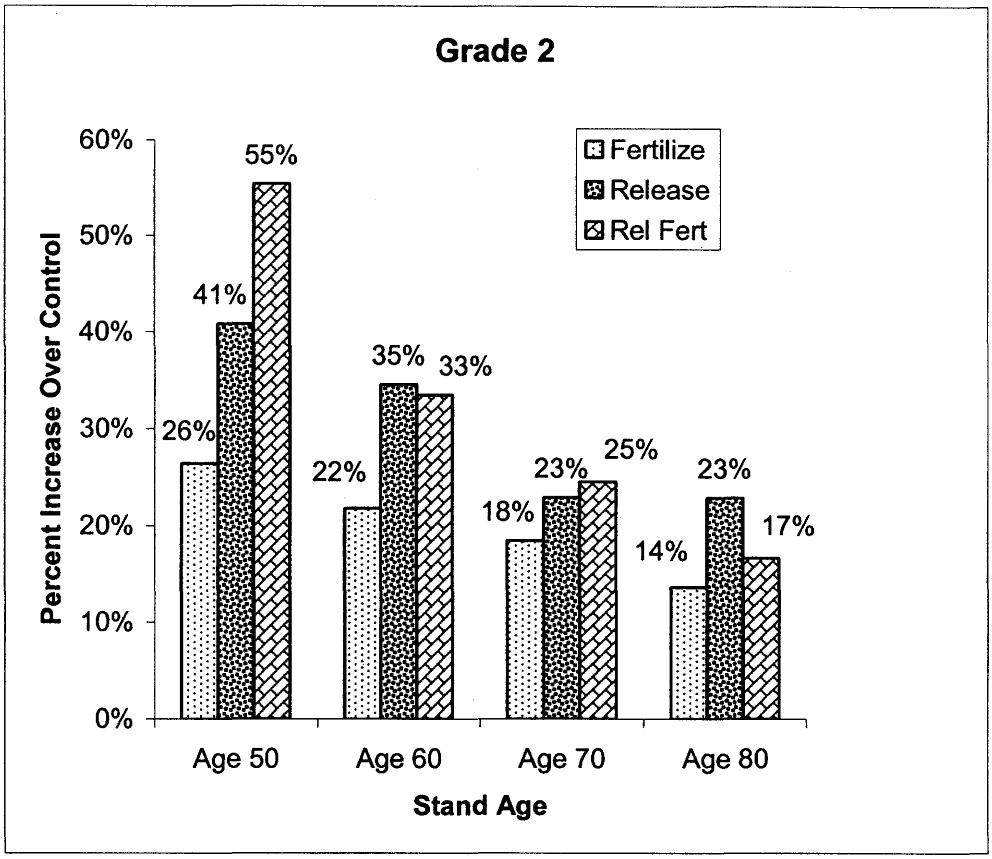

Figure 5. Percent Increase in Grade 2 Sawtimber Over the Untreated Stand for each 10-Year Growth Interval

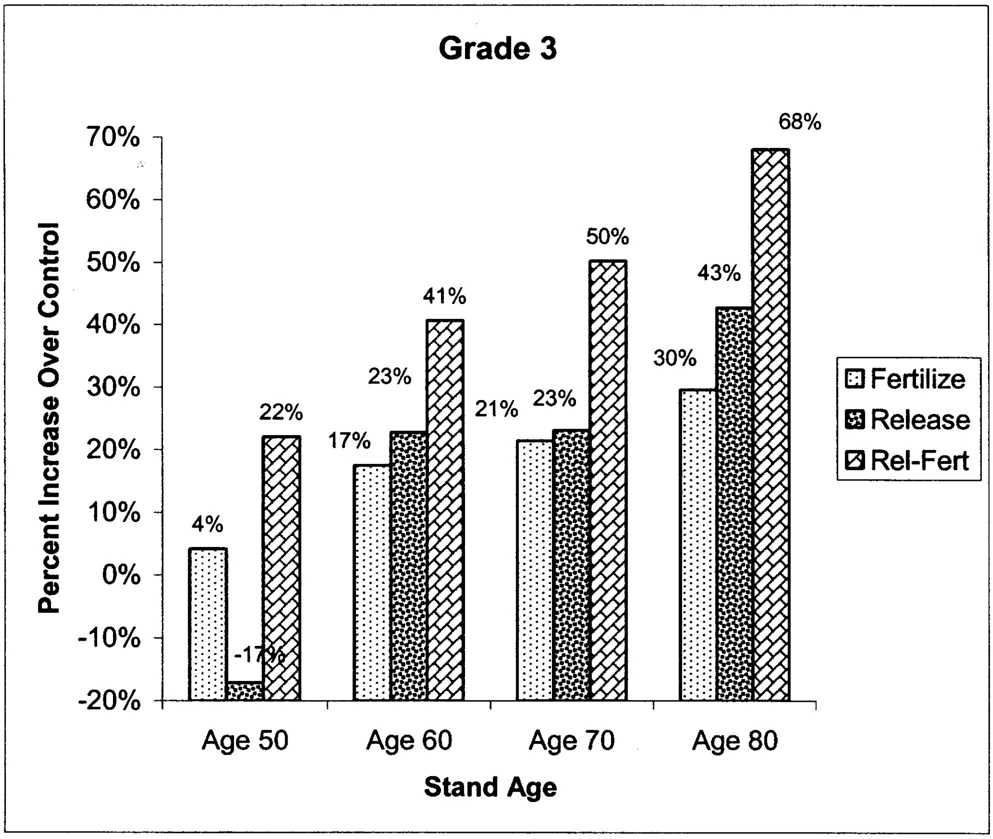

Figure 6. Percent Increase in Grade 3 Sawtimber Over the Untreated Stand for each 10-Year Growth Interval

between stand ages 40-50 was in the release-fertilization treatment (68 %) followed by the release (43 %) and the fertilization (30 %) at stand age 80.

Financial Criterion

Treatments were compared between each 10 year growth period. The most financially acceptable management scenario for each growth period was chosen where NPV was maximized. For purposes of this study, the discount rate where NPV equals zero is the rate of return (ROR) the landowner is earning during that particular 10 years. The same periodic expenses and incomes were factored in to all three price scenarios.

Determining the Most Financially Acceptable Treatment Option

The optimal management scenario was defined as the treatment that yields the highest NPV during a particular 10 years. Table 4 summarizes the maximum per acre net present values and rates of return for each treatment in each 10-year growth interval. Because real price increases can have a dramatic affect on financial criterion, results associated with 2 different price increases were calculated.

No Price Increase

At stand age 50 the maximum NPV ($40.23) occurred in the fertilization and release treatments with the rate of return being slightly higher in the release at 5.62%. At stand ages 60, 70, and 80 NPV was highest in the release treatments. Rates of return were highest in the release treatments as well at ages 60 and 70. At age 80 the rate of return was higher in the release-fertilization treatment by 0.03 percent over the release.

Net present value was negative for the fertilization treatment at 70 and 80 years and negative for the control at 80 years.

Price Increase of 1 %

Price increases can affect NPV estimates and the rate of return from a timberland investment significantly. At rotation age 50, the fertilization treatment had the largest NPV ($120.90) and ROR (7.11%). At ages 60, 70 and 80 the release treatment had larger net present values and rates of return. There was no significant change in net present value in the release treatments between stand ages compared to changes in net present values in the other treatments (see Table 4).

Price Increase of 2 %

Assuming a 2 percent price increase, net present values in the fertilization treatment were greatest for all rotation ages. The rate of return was also optimized in the fertilization treatment at age 50. The rate of return was highest in the release treatments for ages 60, 70, and 80 (see Table 4).

Value Increase Due to Biological Growth

The focus of crop tree management is the individual crop trees. By examining the rate of value increase for a stand or individual crop trees a landowner can determine financial maturity and determine when the stand or tree should be cut. A tree reaches financial maturity when its rate of value increase falls below a landowners chosen alternative rate of return.

Table 4. Maximum Net Present Value and Rates of Return for each Treatment at each Stand Age with 1 and 2 percent Price Increase Scenarios.

	N/A Age 50		**1% Price Increase Age 50**		**2% Price Increase Age 50**	
Treatment	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**
Control	$ 32.96	5.30%	$ 95.75	6.79%	$ 197.74	8.22%
Fertilize	$ 40.23	5.44%	$ 120.90	7.11%	$ 250.58	8.66%
Release	$ 40.23	5.62%	$ 93.57	6.88%	$ 180.20	8.14%
Release-Fertilization	$ 38.99	5.52%	$ 101.57	6.94%	$ 203.22	8.33%
	Age 60		**Age 60**		**Age 60**	
Treatment	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**
Control	$ 14.59	4.49%	$ 81.93	5.96%	$ 202.67	7.35%
Fertilize	$ 12.86	4.39%	$ 94.86	6.02%	$ 241.89	7.53%
Release	$ 31.65	5.09%	$ 95.02	6.33%	$ 208.64	7.57%
Release-Fertilization	$ 19.33	4.66%	$ 85.36	6.07%	$ 203.76	7.42%
	Age 70		**Age 70**		**Age 70**	
Treatment	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**
Control	$ 0.72	4.02%	$ 72.11	5.46%	$ 213.41	6.82%
Fertilize	$ (5.13)	3.86%	$ 80.17	5.43%	$ 249.01	6.89%
Release	$ 23.35	4.71%	$ 95.45	5.95%	$ 238.17	7.17%
Release-Fertilization	$ 10.76	4.31%	$ 85.87	5.70%	$ 234.53	7.02%
	Age 80		**Age 80**		**Age 80**	
Treatment	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**	**NPV ($/acre)**	**ROR (%)**
Control	$ (10.38)	3.71%	$ 64.28	5.12%	$ 227.43	6.45%
Fertilize	$ (17.39)	3.58%	$ 72.69	5.10%	$ 269.53	6.52%
Release	$ 15.22	4.02%	$ 94.36	5.65%	$ 267.28	6.86%
Release-Fertilization	$ 2.23	4.05%	$ 84.53	5.41%	$ 264.37	6.71%

Table 5 depicts the stand level rates of value increase and actual monetary value increases for the control and the treatments for each 10 year growth period.

The rate of value increase for the control group between stand ages 50-60 was 9.1 percent or $154.15/acre. Between stand ages 60 and 70 the value increased at 6.3 percent ($223.08/acre) and between ages 70 and 80 the rate of increase dropped to 5.1 percent ($313.97/acre). This serves as a gauge as to what sort of value increase can be expected if no management is performed on the stand.

Value Increase Due to Treatment

After the initial 10-year period (ages 40-50) the rates of value increase for the treatments were less than the control. The crop trees in the release treatment had the largest rate of value increase among the treatments at 7.7 percent ($204.23/acre). The rate of value increase was actually 1.4 percent less than the control during the same time period but actual monetary increase was significantly higher. The release-fertilization treatment had the lowest RVI at 4.8 percent ($154.51/acre) which was substantially less than the control (4.3 percent less) but the actual monetary value was almost equal. The fertilization treatment increased in value at a rate of 6.6 percent ($133.42/acre) which was less than the control.

Between ages 60 and 70 the RVI for the release treatment (5.9% or $302.13/acre) and the release-fertilization treatment (5.5% or $295.21/acre) decreased from the previous 10-year growth period. However, actual monetary values for the treatments were significantly larger than the control. The value increase in the fertilization treatment was 0.4 percent larger than the control at 6.7 percent ($259.61or acre).

Table 5. Rate of Value Increase Comparison Between the Untreated and Treated Stands

		Rate of Value Increase due to Biological Growth			
Treatment	**Stand Age**	**Crop Tree Volume (bd.ft./acre)**	**Crop Tree Value ($/acre)**	**Value Increase ($/acre)**	**Rate Value Increase (%)**
Control	50	889.24	$ 110.55	$ -	
	60	1773.24	$ 264.70	$ 154.15	9.12%
	70	2913.66	$ 487.78	$ 223.08	6.30%
	80	4423.44	$ 801.75	$ 313.97	5.09%
		Rate of Value Increase due to Treatment			
Treatment	**Stand Age**	**Crop Tree Board Foot Volume/Acre**	**Per Acre Crop Tree Value**	**Per Acre Value Increase**	**Rate Value Increase**
Fertilization	50	1186.26	$ 148.60		
	60	1998.62	$ 282.02	$ 133.42	6.62%
	70	3329.74	$ 541.63	$ 259.61	6.74%
	80	5026.54	$ 891.75	$ 350.12	5.11%
Release	50	1329.04	$ 185.06		
	60	2561.94	$ 389.30	$ 204.23	7.72%
	70	4003.34	$ 691.43	$ 302.13	5.91%
	80	5869.38	$ 1,059.69	$ 368.26	4.36%
Release-Fertilization	50	1916.94	$ 259.67		
	60	2816.8	$ 414.19	$ 154.51	4.78%
	70	4329.14	$ 709.40	$ 295.21	5.53%
	80	6238.46	$ 1,081.90	$ 372.51	4.31%

Between stand age 70 and 80 the crop tree value in the fertilization treatment increased at the same rate as the control at 5.1 percent ($350.12/acre). The value in both the release (4.4% / $368.26/acre) and release-fertilization (4.3% or $372.51/acre) treatments increased at a slower rate than the control (0.7% and 0.8% slower, respectively) during the same time period. Again, actual monetary value in all 3 treatments was greater than the control.

<u>Value Increase Due to Quality</u>

The value increases due to an increase in tree grade were calculated for each 10-year growth interval between stand ages 50 and 80 (Tables 6, 7 and 8). Grade 1 sawtimber in the control increased $526.19 per acre with an average rate of value increase of 10.4 percent between stand ages 50 and 80. The largest increase was 15.7 percent between stand ages 50 and 60. Grade 2 value in the control increased $163.73 per acre with an average rate of value increase of 5.4 percent for the same time period. As expected, the rate of value increase for grade 3 sawtimber was negative as crop trees increased volume and moved into higher diameter classes. Between stand ages 60 and 70 increases in grade 3 sawtimber became negative in the control.

For grade 1 sawtimber, the average rate of value increase for the fertilization (9%), release (8%), and release-fertilization (6.9%) were all less than the control during the same time period. The actual increase in monetary value for fertilization ($568.16/acre), release ($662.21/acre), and release-fertilization ($622.23/acre) treatment were all larger than the control.

Table 6. Rate of Value Increase Due to an Increase in Grade 1 Sawtimber.

Treatment	Stand Age	Red Oak Value ($/acre)	White Oak Value ($/acre)	Total Value ($/acre)	Grade 1 Value Increase ($/acre)	RVI (%)
Control	50	$ 13.99	$ 15.24	$ 29.23	$ -	
	60	$ 65.07	$ 60.62	$ 125.70	$ 96.47	15.70%
	70	$ 121.08	$ 170.12	$ 291.20	$ 165.51	8.76%
	80	$ 221.16	$ 334.26	$ 555.42	$ 264.22	6.67%
Fertilization	50	$ 25.49	$ 20.18	$ 45.67	$ -	
	60	$ 47.75	$ 64.49	$ 112.24	$ 66.57	9.41%
	70	$ 107.05	$ 199.66	$ 306.71	$ 194.47	10.58%
	80	$ 211.05	$ 402.79	$ 613.83	$ 307.13	7.18%
Release	50	$ 10.00	$ 64.02	$ 74.01	$ -	
	60	$ 40.41	$ 145.61	$ 186.02	$ 112.00	9.65%
	70	$ 133.02	$ 307.20	$ 440.21	$ 254.20	9.00%
	80	$ 222.66	$ 513.56	$ 736.22	$ 296.01	5.28%
Release-Fertilization	50	$ 44.67	$ 52.98	$ 97.65	$ -	
	60	$ 93.65	$ 94.35	$ 188.00	$ 90.35	6.77%
	70	$ 184.68	$ 229.14	$ 413.82	$ 225.82	8.21%
	80	$ 310.75	$ 409.13	$ 719.88	$ 306.06	5.69%

Table 7. Rate of Value Increase Due to an Increase in Grade 2 Sawtimber

Treatment	Stand Age	Red Oak Value ($/acre)	White Oak Value ($/acre)	Total Value ($/acre)	Grade 2 Value Increase ($/acre)	RVI (%)
Control	50	$ 20.27	$ 23.06	$ 43.33	$ -	
	60	$ 31.25	$ 61.54	$ 92.79	$ 49.46	7.91%
	70	$ 52.37	$ 100.85	$ 153.22	$ 60.44	5.14%
	80	$ 75.72	$ 131.34	$ 207.06	$ 53.83	3.06%
Fertilization	50	$ 15.28	$ 39.12	$ 54.40		
	60	$ 33.77	$ 82.63	$ 116.39	$ 61.99	7.90%
	70	$ 60.11	$ 126.27	$ 186.37	$ 69.98	4.82%
	80	$ 68.59	$ 164.18	$ 232.77	$ 46.40	2.25%
Release	50	$ 24.86	$ 44.95	$ 69.81		
	60	$ 62.84	$ 84.54	$ 147.38	$ 77.57	7.76%
	70	$ 78.79	$ 123.98	$ 202.78	$ 55.39	3.24%
	80	$ 101.70	$ 168.13	$ 269.83	$ 67.05	2.90%
Release-Fertilization	50	$ 39.87	$ 55.26	$ 95.13		
	60	$ 62.68	$ 82.54	$ 145.22	$ 50.09	4.32%
	70	$ 87.96	$ 121.91	$ 209.87	$ 64.65	3.75%
	80	$ 108.86	$ 146.20	$ 255.06	$ 45.19	1.97%

Table 8. Rate of Value Increase/Decrease Due to an Increase/Decrease in Grade 3 Sawtimber

Treatment	Stand Age	Red Oak Value ($/acre)	White Oak Value ($/acre)	Total Value ($/acre)	Grade 3 Value Increase ($/acre)	RVI (%)
Control	50	$ 12.41	$ 22.81	$ 35.22		
	60	$ 14.15	$ 27.24	$ 41.39	$ 6.17	1.63%
	70	$ 13.88	$ 21.56	$ 35.44	$ (5.95)	-1.54%
	80	$ 9.13	$ 17.86	$ 26.99	$ (8.45)	-2.69%
Fertilization	50	$ 15.20	$ 31.10	$ 46.30		
	60	$ 16.97	$ 33.11	$ 50.08	$ 3.78	0.79%
	70	$ 12.74	$ 30.40	$ 43.15	$ (6.93)	-1.48%
	80	$ 8.99	$ 27.77	$ 36.76	$ (6.38)	-1.59%
Release	50	$ 18.06	$ 22.01	$ 40.07		
	60	$ 19.00	$ 34.83	$ 53.83	$ 13.76	3.00%
	70	$ 15.27	$ 29.73	$ 45.00	$ (8.83)	-1.78%
	80	$ 18.91	$ 29.33	$ 48.24	$ 3.24	0.70%
Release-Fertilization	50	$ 22.66	$ 35.81	$ 58.47		
	60	$ 25.53	$ 44.79	$ 70.32	$ 11.85	1.86%
	70	$ 26.42	$ 44.09	$ 70.51	$ 0.18	0.03%
	80	$ 32.51	$ 53.33	$ 85.84	$ 15.33	1.99%

A somewhat similar result occurred for the rate of value increase in grade 2 sawtimber. In the treatments, value increased at a slower rate than the control. The smallest rate of increase for grade 2 sawtimber was exhibited by the release-fertilization treatment (3.3%), followed by the release (4.6%) and the fertilization (5%). Actual monetary increases were larger than the control in the release ($200.18/acre) and the fertilization ($178.39/acre) treatments. In the release-fertilization treatment, the actual value increase ($159.91/acre) was less than the control.

Value increases for grade 3 sawtimber were small in all treatments. Both the rate of value increase and the actual monetary value increase became negative in the control, fertilization, and release treatment between stand ages 60 and 70. The largest grade 3 increase was in the release-fertilization treatment ($27.36/acre) followed the release treatment ($8.17/acre). Rates of value increase were 0.6 percent for the release and 1.3 percent for the release-fertilization treatment.

The average rate of value increase for the treatments between stand ages 50 and 80 varied. As trees increased in diameter so did the amount of higher grade material. Actual monetary value increases were greater in the treatments while RVI for grades one and 2 were somewhat less than the control. Grade 3 decreases were expected as the stand aged for the reasons mentioned above.

CHAPTER 5

DISCUSSION

Best Treatment at a Given Rotation Age

When determining when to cut or leave individual trees, or stands of trees, financial considerations must be taken into account. Species, tree size, biological growth, log quality, chosen discount rates, stand treatments, price increases and management costs may have a dramatic affect on the financial maturity of the crop trees. By taking these factors into account a landowner should be able to determine which biological forest management option available to them will provide the greatest financial return.

Given the long investment period for timber, a landowner must rely on financial criteria that relate costs and returns from different years. The financial analysis done on the white oak crop tree management study at Ames Plantation suggests that releasing crop trees is the best management regime for each 10-year growth period, assuming prices remain constant. Internal rates of return and net present values were greater than or equal to the other treatments for each 10-year growth period.

Applying the release treatments to individual crop trees focuses maximum value growth on the individual tree and provides for several economic advantages. First, rotation lengths may be shortened as trees increase in size at a faster pace producing larger log sizes in less time. Second, growth can be focused on the higher value species in the stand as well as trees that have the potential to produce higher quality logs. Third, intermediate revenues may be realized from trees that are cut during periodic release treatments, thereby increasing a landowner's rate of return and offsetting some of the original costs that are associated with the treatment. Other studies (Miller 1986 and

Baumgras 1992) suggest investing in precommercial thinnings in sapling-size hardwood stands. By accelerating growth of the crop trees earlier, the rest of the stand is simultaneously being thinned adding growth and value to the residual trees. This improves the possibility of a future commercial thinning earlier in the rotation which generates increased revenues.

Adding fertilization to the release treatment provided the greatest volume increase among the treatments. Adding fertilization to the release treatment significantly increased DBH by 55 percent over the control and sawtimber volume by 46 percent over the control during the 10 years immediately following treatment application. Studies (Auchmoody 1986 and Schlesinger 1978) indicate the growth response from fertilization may persist up to 5 years while the growth response from release may last up to 20 years. Repeated fertilization and release treatments were not considered in this study although repeated treatment applications would add significant volume and value increases, and do so sooner, than just a single treatment in the middle of the rotation.

The costs of adding fertilization treatments to a thinning regime make it the second most attractive financial investment. The net present value for each 10-year growth interval remained positive at a 4 percent discount rate. The required rate of return stayed positive through stand age 80. After stand age 80 the response from the release and fertilizer applications and the added revenue from the trees cut during the release cease to carry the cost of fertilization. The growth response from the added fertilization applications was not enough to financially justify letting the stand grow past an 80 year rotation.

The growth response from fertilization becomes unprofitable at rotation age 70. In year 70 the net present value is negative as it dips below the chosen discount rate of 4 percent. This is a decade earlier than in the control. The net present value and rate of return for the control is less than the chosen discount rate at age 80. This is due to the minimal cost associated with not investing in any management. Therefore, when considering which silvicultural treatment in which to invest, dollars associated with release treatments should take first priority.

Price Increases

Prices for raw material will change over time depending on supply and demand of local markets. Determining the correct species and the management regime in which to invest dollars in is of no consequence if price trends for the specific target product are not favorable. Price increases significantly affect rates of return and net present values as well. Although the price increases of 1 and 2 percent used in this study were conservative net present values, rates of return and actual dollar values increased dramatically. Comparable studies (Buongiorno and Hseu 1993, Utz and Sims 1981) have used real price increases of anywhere from 10 percent to 14 percent.

A price increase of 1 percent resulted in fertilization being the best investment if harvest was planned at stand age 50 and releasing the best option for stand ages 60, 70, and 80 based on the largest net present values and rates of return. This may be partly due to a large amount of crop tree volume in grades 1 and 2. However, a price increase of 2 percent made fertilization the most profitable investment for each 10-year growth period based on maximum net present values. A 2 percent price increase covered all

fertilization and capitalization costs through stand age 80. Determining whether or not to harvest beyond eighty years will be a decision based on the personal long and short term financial goals of the landowner.

The age of financial maturity will increase or decrease depending on whether prices increase or decrease. The price increase assumptions used in this study lengthened the rotation for all treatments beyond 80 years assuming the 4 percent real discount rate. Price increases add monetary value increasing the rates of value increase. Therefore it will take longer for rates of return to approach a landowner's alternative rate.

When considering which treatment to apply, an investigation of price trends is important if the investment is to meet the time constraints set forth by the landowner. Increasing the discount rate may help shorten the length of the investment when higher returns are expected due to price increases.

Crop Tree Rate of Value Increase Due to Treatment and Grade

The financial maturity of a tree (Mills 1979) is "when a trees rate of value increase is equal to the landowners cost associated with the capital investment of the tree." In other words, a tree reaches financial maturity when its rate of value increase falls below the interest rate that a landowner could earn on alternative investments of comparable duration and risk. This is reflected in the calculations as the chosen discount rate used to determine the present value of costs associated with a specific treatment. This concept also assumes that when a stand reaches financial maturity it should be cut and the money invested elsewhere at an interest rate equal to or greater than the rate of value increase of the tree.

The highest RVI was observed in the control between stand ages 50 and 60 and the lowest RVI was observed in the release and fertilization treatment for all 10-year growth periods. This was unexpected since the greatest increase in diameter was in the release and fertilization treatment and the smallest was in the control. The variability in the RVI is probably less due to treatment application than low-grade trees that have low present values. Out of 144 trees in the control, 63 percent changed grade between stand ages 50 and 60 resulting in a RVI of 9.1 percent. A high percentage of that change (46%) was from small diameter trees moving up to grade 3 and grade 3 trees moving up to grade 2. The actual per acre dollar value in the control increased from $110.55 to $264.70 for a per acre increase of $154.15 between stand ages 50-60. Consequently, this produced a high RVI when the FV/PV ratio was calculated as part of the RVI equation. This has been shown (Debald and Mendel 1971 and Herrick 1984) to be the case when discussing RVI due to quality increases for small diameter trees. These trees affect the stand level RVI by showing high rates of value increase but do not add much in actual dollar value.

Conversely, stand level RVI decreases in stands with larger diameters trees because of the FV/PV ratio (Trimble et al 1974). Larger diameter trees will usually have a large dollar value increase. Since their initial value is large as well, a low RVI will be calculated. Stand level RVI between ages 50 and 60 for the release and fertilization treatment was 4.8 percent. The treatment application resulted in an average diameter increase of 3.6 inches during the 10-year growth period (40-50) following the treatment application compared to 2.0 inches in the control. The actual dollar value was $259.67 in year 50 and $414.19 in year 60 for a per acre value increase of $154.51 which was just slightly larger than the control. As a result of the initial growth from the treatment, most

of the crop trees from the release and fertilization treatment had already moved up in grade by age 50 (average DBH at age 50 was 13.6 inches). Consequently their actual dollar value was higher but RVI was lower between ages 50 and 60.

The difference in per acre dollar value among the treatments and the control increased significantly between ages 60 and 70 and 70 and 80. As the stand ages the crop trees in the treatment add value due to quality faster than the untreated stand (control). By stand age 80 the per acre dollar value of the crop trees in the release fertilization treatment was 26 percent higher than the control and the RVI was close (4.3%) to the chosen alternative rate of 4 percent. This was also the case in the release treatment (25% higher/RVI=4.4) as well.

By examining the lower RVI at stand age 80 in the release and release and fertilization treatment it is apparent that releasing or releasing and fertilizing the stand moved the crop trees closer to financial maturity, quicker, than the control and the fertilization treatments. The RVI is approaching the 4 percent alternative rate of return that signals when the crop trees should be cut. These treatments also have the largest per acre dollar values of the treatments. (Note that no costs were considered for RVI calculations). The treatment speeds up volume growth and consequently value growth due to quality enabling the released and release and fertilized stands to reach financial maturity sooner.

Risk Factors and Limitations for Crop Tree Management

Certain stand conditions will determine whether or not crop tree release will be a cost-effective option for the landowner. Some risks, like damage due to insect and

disease, will not be treatment specific. The probability of an insect infestation or disease outbreak would be the same in all treatments. However, the overall impact of such an event may differ between treatments due to the density and spacing of the stand.

Part of the challenge of crop tree management is working within the natural limitations of the stand. The stand must be well stocked with a desirable species and the site must be an above average site for that particular species. Also, the stand must be young enough in order to insure that the crop trees possess enough vigor to respond to the release treatment. In addition, the stand should be far enough along in its development that the four crown classes are easily discernable. Meeting these criteria will help justify the expense of a pre-commercial release at a young age or a commercial release later on.

Another limitation is that the stand must possess a significant number of trees to justify management expenses and regeneration costs to manage the stand through rotation. The number of trees per acre of the chosen species should have good form and meet specific criteria with regard to quality. Trees with the longest, straightest stems, free from defects such as forking, frost cracks or lighting damage, and show signs of good natural pruning should occupy the stand in large numbers. This will insure higher quality wood at rotation, therefore higher returns on the investment.

Trees falling due to natural mortality may damage residual crop trees. The risk of damage to the residual stand would be higher in the untreated and fertilization treatments than in the release because of the higher residual basal area of a stand that has not been released. Furthermore, damage to the residual crop trees from the actual release should also be considered a risk. Trees falling during the release can cause severe damage to the boles or tops of the residual crop tree decreasing the value of the tree and hindering

growth. The importance of maintaining the quality of the crop trees should be communicated to the sawyers when the actual release is carried out.

Risk increases in the release treatments for a variety of reasons. Trees are more susceptible to wind-throw in stands that have been released. Trees growing in dense forest stands become very prone to wind-throw when surrounding trees are removed, exposing the residual stand to the full force of the wind. Wind-throw can topple individual trees or groups of trees. Over time wind-throw can disrupt the root-soil relationship, water absorption and leaf area. These things combined over time can affect growth, consequently adding an additional measure of uncertainty to the overall productivity of the crop trees.

Damage incurred from the ice storm of 1994 illustrated that trees in the release treatments were more susceptible to ice damage than trees in the control or the fertilization treatments. Since the ice storm occurred right after the release severe damage occurred due to the loss of mutual support of neighboring trees. Ice damage to trees occurs when ice adds excessive weight to leaves and branches of trees. Trees may be uprooted or suffer crown loss as large branches are broken off. Loss of large portions of the crown usually results in reduction of growth. Trees may also be bent over by the ice load. Some may eventually recover, but many will be deformed lowering the quality and value of tree. A tree's susceptibility to ice damage also depends on species. The O'Neil study was able to conclude that black cherry was not a good candidate for crop tree release since it suffered the most damage from the ice storm of 1994. The red oak and white oak suffered the least damage.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Crop tree management is a financially attractive option for private small woodlot owners. It can provide multiple benefits and depending on the management regime can provide attractive financial results. The choice of which treatment application to apply is important since the treatment is the mechanism which drives both volume and value growth of the tree. This decision should be made depending on the financial objectives of the landowner and the time sequence that fits personal financial goals.

The financial analysis of the white oak crop tree study at Ames Plantation draws these conclusions:

1. Based on net present values, releasing crop trees is the best management regime assuming prices remain constant. Internal rates of return and net present values were greater than or equal to the other treatments for each 10-year growth period. Assuming a 2 percent price increase, fertilizing becomes the best management option.
2. The highest rates of value increase among the crop trees were found in the unmanaged control group among smaller diameter trees. As smaller diameter trees increase in quality due to increase diameter the rate of value change will increase dramatically due to an increase in price between grades. The improvement in quality results in a higher rate of value increase than increases due to growth alone. The increase in quality is reflected in the actual monetary gain between each 10-year growth period.

3. Price increases will lengthen financial maturity. Assuming 1 and 2 percent price increases pushes financial maturity passed stand age 80. This can be offset by increasing a landowner's discount rate enabling a landowner to adjust his financial goals to stay within personal time constraints.

Recommendations for Further Research

Determining rates of value increase on a stand level may not have been the best possible way to explore value increases for a crop tree management study. The focus of crop tree management is on the individual tree. Since all trees in a stand do not reach financial maturity at the same time, figuring rates of value increase for individual trees may have been more appropriate.

Examining a crop tree management study in a stand that was precommerically thinned at a young age (20 years) may yield better financial results. One or two commercial thinnings may be incorporated into the management plan increasing intermediate returns a landowner may expect if investing in just releasing his trees. Incorporating incremental fertilization treatments may yield more financially acceptable results as well.

A more in depth study on the affect that discount rates and price increases have on the costs and revenues associated with crop tree management would be appropriate. Since private landowners differ with regards to time preference, financial wealth, age etc., the chosen alternative rate of return that would make an investment acceptable to one landowner may be too high or low with regards to another.

In addition, projecting future growth using individual tree equations may give a more realistic picture with regards to the potential future volume and value growth one may expect by applying crop tree management. Again, since the focus of crop tree management is on the individual tree, individual growth projections would seem appropriate.

An analysis of the potential for crop tree management to grow veneer grade trees would provide information on the maximum benefit of this silviculture method. An examination of both domestic and export markets should be incorporated along with realistic expectations with regard to quality, prices, and costs and revenues associated with managing for veneer grade trees.

An examination of the silviculture involved in regenerating the stand after the crop trees or tree are cut should be evaluated assuming a landowner will keep the land for further timber production. Post harvest treatments that control unwanted species and herbaceous vegetation may be considered along with costs involved with site prepping the stand for natural regeneration or plantings.

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Vita

During the process of achieving his academic goals Scott gained state forestry experience with the Tennessee Department of Forestry working with area foresters and meeting with private landowners addressing different natural resource management problems and concerns. He was also a member of an east Tennessee firefighting crew with wildland fire suppression responsibilities in 12 East Tennessee counties.

Scott's federal experience includes working with the Forest Inventory and Analysis Unit of the Rocky Mountain Research Station taking and recording inventory data in Montana and Idaho.

Scott is currently employed with Plum Creek Timber Company doing presale work with the Flathead Unit in Kalispell Montana.

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