USING ECONOMIC FACTORS IN MANAGING APPALACHIAN HARDWOODS FOR HIGH QUALITY

by

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(Abstract)

Because of the extremely wide range in product values from hardwood stands, harvest decisions must consider a multiplicity of factors, many of them economic. Among these are species, tree size, tree quality, logging costs, and market alternatives. This study demonstrates how to incorporate these, using a new microcomputer program with growth projection, YIELD-MS (Hepp, 1986), to find an economically favorable regime for a particular hardwood stand. The simulation approach presented allows for economic and silvicultural comparisons of many alternative treatments that need to be considered each time a stand is re-examined for prescription in the progress of a management plan. A decision tree was developed as a systematic way of reviewing the possibilities. In order to reduce the search time necessary to move through the decision tree, some parameters were found for describing value growth of hardwood stands. The percentage of stand basal area capable of grade change

(PBAGI) and the spread of percent price differentials between log grades (PPD) were tested by a series of simulation runs on data from a variety of actual stand conditions found in the Appalachian region. The results of these simulation and sensitivity tests indicate that as PBAGI and PPD increased the various economic criteria improved in value. It is concluded that recent developments in growth and yield modeling make it possible to economically evaluate various silvicultural treatments and harvest intensities at the stand level, and indications are that management for high quality can be economically desirable.

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CHAPTER I

Introduction

Eastern hardwood forests account for nearly 51 percent or 248 million acres of the Nation's total commercial timber land (USDA, 1982). Within this vast area, topography and site conditions vary dramatically resulting in a large number of timber types and many tree species, both commercial and noncommercial. Included in these associations is Appalachian mixed hardwood. The complexity and diversity of Appalachian mixed hardwoods (Smith et al., 1983) complicates efforts to understand and manage them.

Settlement in the Southern Appalachian mountains had an effect on quality and type of forests which currently exist. In general, much of Appalachia was settled in early 1800's, when small tracts were cleared for family farms and the remaining woodlands were open to grazing, burning, and recurrent high grading for building purposes.

In the early 1900's, many farms were abandoned, and gradually these areas reverted to new second growth forests. A major problem has been the practice of selective cutting which has continuously degraded quality and species composition of the residual stand. The consequence is thousands of acres of poor quality hardwood stands and a continual loss of forest capital. Generally, low quality stands tend to predominate in Appalachia (Cupp, 1984), although many high quality and potentially high quality trees do occur.

In today's economy, little value is placed on these low quality stands due to the lack of adequate markets, and investments in hardwood silviculture are often thought to be unprofitable. However, in many places where there is an oversupply of low quality hardwood timber, ready markets exist for high quality hardwood logs (Vachievich, 1984). Therefore, the dominant management effort, now and in the future, should concentrate on how to economically grow hardwoods for quality.

In the management of hardwoods, there are many alternative treatments that need consideration each time an area is examined for prescription in the formulation of a management plan. Each alternative involves economic factors of markets, associated harvest costs, and also silvicultural factors of growth rates, species composition and site adaptability. The combinations of these factors are so numerous that often all of them are never given full consideration, and each stand seems to require it's own analysis. With the infinite mixtures of species, tree sizes, tree qualities and site qualities, the formulation of a suitable silvicultural plan which includes full evaluation of regeneration potential is difficult from a simple cruise. The consequence has been that hardwood management decisions on both private and public lands have been reduced to a few simple alternatives, none of which may be completely satisfactory to the landowner.

The high growth capability and high value species occurring in mixed Appalachian hardwoods make it potentially more profitable for management and production of timber than any other in the Appalachian region (Trimble et al., 1974). The difficulty in economic evaluation is two-fold. First is consideration of individual tree quality and value in the overall value of the particular stand. Tree size, species differences, classification of tree quality (Hanks, 1971; Ernst and Marquis, 1979), and defect recognition and measurement must all be incorporated into individual tree valuations. A single tree could be valued at thousands of dollars thereby changing the overall value of what is otherwise a low quality stand. Second, the lack of individual tree growth and yield models for the Appalachian region has made it practically impossible to evaluate growth response and long term economic returns. However, with a recent series of growth and yield functions developed by Harrison _et al_. (1986) for Appalachian mixed hardwoods, economic evaluations are now possible for some of these stands.

1.1 Justification

In the Forest Survey of Virginia (Brown, 1986) the southwestern region, where the forest is 87 percent hardwood, is shown to have an 18 percent increase in hardwood growth in the past ten years. The growth rate was calculated to be five times the harvesting rate. It is true that there has been continuing high-grading in logging operations; however, the area of hardwood sawtimber stands has increased 27 percent in the last ten years. Currently, 58 percent of the total timber land in southwestern Virginia is considered medium to low quality hardwood (Brown, 1986). With such a large percentage of harvest-age timberland it's important that these stands be analyzed before harvesting, and that where high quality trees are present they be permitted to grow as long as economically feasible. While some of these stands contain little quality and should be clearcut for fiber production, fuelwood, and low quality sawtimber, earnings for others can be increased by partial cutting.

In the past, many area markets have existed only for higher quality hardwood products, but prospects are good for expanded market opportunities for species of lower grade and value. These new markets may provide opportunities of increased profitability and more economic incentives for more intense management of these lower quality hardwood stands (Bullard and Klemperer, 1985).

Less recognized is the high value placed on Appalachian hardwoods in the export market. This market is currently very active and is paying top dollar over domestic log purchases. We are overlooking the real potential for long range economic development in these regions if we continue to export the remaining high quality, while trying to build our industry only on a much lower grade of bulk fiber.

Because of the lack of reliable growth and yield equations for mixed Appalachian hardwoods, little research emphasis has been placed in predicting future quality and value for preferred species. Research efforts in development of economic analysis methods for hardwood stands have been minimal, and many questions remain. What changes should be made in silvicultural systems and associated harvest methods to bring about the most practical rate of return? If presented with some preliminary answers to such questions, landowners and managers would have a much stronger data base to use as a guide in effective hardwood stand management.

Timber prices vary greatly from one location to another depending on site, stand location, road access, local timber markets, tree species, quality and number of harvestable trees. Many of these factors can be manipulated through management techniques, and the corresponding effects on tree growth, volume, and profitability of investments can be measured. However, little research has been conducted to measure the economic relationship of changes in tree quality over time. Research has made progress in modeling volume response associated with different thinning regimes, but much work is needed in modeling changes in quality (Dale and Hilt, 1986). Because changes in quality, such as grade 2 logs moving into grade 1 class, can have such a dramatic effect on stand value, effective management of this variable resource requires additional quantitative information of individual trees of preferred species beyond the usual relationships gathered in forest cruises.

1.2 Objectives

The objective of this study was to develop a method to provide landowners and managers with information on the economic feasibility of growing and managing quality hardwood stands. More specific objectives include:

1. Develop a system to compute the current value on a mixed hardwood stands, based on quality, as indicated on species, size, grade, and defects in the trees of the stand. The system should permit modification of value to recognize location as it affects logging costs and local markets for various products.

2. Project changes in volume and other factors of value through time, using an appropriate forest growth model.

3. Determine the rate of return from the cash flow generated by the treatment and final harvest of such a stand.

4. Test the sensitivity of rate of return to several treatment schedules applied to a few typical hard-

wood stands to determine a near optimum schedule, and construct one or more sample guidelines for the management of such stands.

CHAPTER II

Literature Review

Most hardwood silvicultural management and research is conducted with the intention of controlling species composition and stand density, stimulating tree growth and maintaining or improving upon the quality of crop trees (Gingrich, 1970; Debald and Mendel, 1972; Sonderman and Brisbin 1978; Williston *et al*., 1982; Della-Bianca, 1983). According to Marquis *et al*. (1984), the basic rationale of hardwood silviculture is the establishment of new stands at high density, and maintenance of that high density throughout the juvenile years.

2.1 Management Approaches

Generally, stand management approaches fall into two categories, even- and uneven-age management. Individual stand treatment decisions are often the result of an evaluation made between two likely silvicultural treatments used in even- or uneven-age management. In stands where even-age silviculture is practiced, one reproduction cut is done at the end of each rotation. As the stand develops, intermediate cuts (crop tree release or thinnings as improvement cuts) are made at intervals until the next reproduction cut. In stands where uneven-age management practices are used, regeneration cuts and intermediate operations occur concurrently at each cutting period (Smith et al., 1983). Intermediate cuttings may increase the yield of wood products and increase the proportion of potential quality trees in a stand. Obviously, there are many variations possible in each category; therefore a simple comparison between the two is not possible, leading to much debate among foresters on silvicultural management objectives.

An even-age approach was presented by Debald et al. (1972) where the main stand is carried through a number of commercial thinnings until it was ready for harvest. It is generally recommended for maintaining Appalachian mixed hardwoods because intolerant and tolerant species can be retained together and more valuable intolerant species are favored in regeneration. The first commercial intermediate cut would remove large culls, biologically mature trees, and small culls in that order (Roach et al., 1968). Marquis (1981) recommends that trees removed should be primarily the smallest and the largest size classes, leaving those in the small sawlog class. These trees are at the stage where they increase in value most rapidly as they grow into new size classes qualifying them for possibly grade 1 sawtimber or veneer.

Clearcut, shelterwood and seed tree are three regeneration methods used in even-age management. Clearcutting is most often recommended to regenerate Appalachian mixed hardwood stands and has the greatest immediate impact on the total forest environment. The shelterwood method has a more gradual impact on the environment and is used to encourage desirable advanced regeneration. Regeneration cuts using the seed tree method are seldom prescribed in mixed hardwood stands because regeneration to comprise the new stand is already established or will be established the first growing season after cutting, regardless of the presence or absence of seed trees (Smith et al.,1983).

An uneven-age approach is implemented by the selection system where individually selected trees are removed periodically through the distribution of age classes. It is best adapted to shade tolerant tree species. Trimble et al. (1974) reported that the first commercial cutting should concentrate on cull and undesirable trees that are financially mature. This approach, however, fails to adequately maintain the less shade-tolerant desirable species and even flow of timber from the woodland (Della-Bianca et al., 1985).

Single tree selection and group selection are regeneration practices used in uneven-age management. Single tree selection results in the least disturbance to the forest canopy and is used where nearly continuous forest canopy is preferred or when stand and site disturbance must be minimized (Smith _et al._, 1983). Stands where single tree methods are recommended have been reduced to a few commercial species, such as American Beech, red maple, and sugar maple (Marquis 1979). Group selection results in both desirable tolerant and intolerant species depending on the size of the openings (Smith, 1975) and has not been widely adopted in most forestry management plans.

This study concentrated on the intermediate cuts used in even-age management, although the methods developed are thought to be adaptable to uneven-aged management also.

2.2 Effect of Stand Density

Stand density is one major factor in the production of high quality sawlog hardwoods. Ward (1964) presented evidence for maintaining higher densities to allow for natural pruning of even-aged red oak. In his study, he reports that a high initial stand density is probably the single most important requirement in producing trees with a desirable clear volume index along with providing a continuation of ample crown competition as trees are lost from the stand.

Godman and Books (1971) studied the influence of stand density on stem quality of pole-sized northern hardwoods and also concluded that the most improvement in stem quality occurs at higher stand densities. They suggested that the time to begin silvicultural treatments such as thinning is soon after limbs on the lower bole portion have died. The rate of tree growth and also the rate of healing after self pruning can be stimulated by heavier thinnings, however, this is species specific. Other studies have also concluded that high stand density throughout juvenile years will stimulate pruning of lower branches allowing for clear bole development, and also minimizes the tendency for forking (Gingrich, 1970; Marquis et al., 1984).

2.3 Thinning

As stands increase in age and density, individual tree diameter growth declines. Precommercial thinning is one alternative for increasing the rate of diameter growth. Precommercial thinning operations in young Appalachian hardwood sapling stands (stands less than 10 years old) does not result in significant increases in individual tree diameter growth (Trimble, 1973; Beck, 1977; Smith, 1979; Hilt and Dale, 1982). However, stands 10 years and older respond well to thinnings with increased diameter growth (Della-Bianca, 1983; Smith and Lamson, 1982). Thinning in these young stands contradicts silvicultural recommendations of high stand densities at young ages. Therefore as growth increases, it is also possible that a corresponding decline in quality may occur. The trade-off is between increased diameter growth and possibly lower quality trees, and it is here where the question of economics is important (Gingrich, 1970; Marquis et al., 1984). There is little evidence that precommercial thinning is an economical practice unless species composition can be significantly modified.

According to Miller (1986), precommercial thinning in young Appalachian hardwood stands can be a worthwhile investment for some landowners and the potential for economical precommercial cultural treatments is greatest in stands containing high value species. Related to Miller's findings, Risbrudt and Pitcher (1986) have demonstrated through repeated economic analysis that precommercial thinning is worthwhile only if no commercial thinnings will be made and if it results in a higher log quality. Otherwise, they suggest waiting until the stand is old enough for a commercial thinning. Of the information published on precommercial hardwood thinning, little is based on long term results and even less on the economics of such thinnings. There is a need for more studies of treated growth plots in this area. Again, a consideration of the value change in growth vs quality trade off and the land owner objective must be carefully studied before the most practical decision can be made.

Commercial thinning practices are currently viewed as economically important and often a silviculturally necessary practice in the development of quality hardwood stands (Utz and Balmer, 1970; Debald and Mendel, 1972; Anderson, 1975; Carvell, 1983). However, commercial thinnings have not been widely practiced in the past, chiefly due to inadequate markets for the material removed (Baumgrass, 1981) and an unwillingness to invest capital. As reported by Carvell (1983), correct timing of intermediate commercial cuttings and thinnings is important in determining clear bole length, thus total value of the crop. Thinnings should be directed to continuing even growth rates and maintaining quality of the best trees of the preferred species that will make up the final harvest cut.

How does the residual thinning level of a commercial thinning affect quality? Earlier studies have indicated that low residual volumes may provide too much growing space and result in epicormic branching, thus lower quality and value (Gingrich, 1970; Evans et al., 1975). However, a recent study by Dale and Sonderman (1984) concludes that for a white oak stand 33 years old, residual stand density does not markedly affect stem quality except for extremely heavy thinnings. Stocking should not be reduced by more than 50 percent. They also found that loss in tree quality is more than compensated by faster growth and shorter rotations lengths.

In general, thinning of hardwoods is the balance between financial gain due to high sawtimber volume production compared to gain from stand quality increase, and it's important to know how thinnings and harvesting can improve future stand value.

2.4 Quality

An important aspect in conducting an economic analysis is having a system to accurately measure quality. Tree grade is the mechanism that is used for quality evaluation.

Tree grades developed by Hanks (1971) are widely accepted and are used by the USDA Forest Service. The purpose of log grades is to separate logs into several different product classes based on the relative quality of products obtained from logs with common surface characteristics (Rast *et al*., 1973). In general, the Forest Service grading rules separates logs into 3 quality groups determined by the lumber-grade yield and gross value they can produce when sawed into lumber. Based on decreasing value, the 3 quality groups are grade 1 (the highest), grade 2, and grade 3.

The analytic basis for these log grades are lumber yield studies, which predict the volume of lumber by grade, species, and diameter class developed by the National Hardwood Association[1]. Hardwood lumber grades were developed so that buyers and sellers would have uniform standards for evaluating lumber products. These grades are based on minimum size of the board, minimum size cutting permitted, the number of cuttings permitted, and the area of clear cuttings. Cassens and Fisher (1984) clearly illustrate the direct relationship between the Forest Service log grades and the National Hardwood Lumber Association lumber grades

1) National Hardwood Lumber Assn.,
Box 34518, Memphis, Tennessee 38134

based on the percentage of clear cutting lengths. The advantage of such a relationship is in predicting lumber recovery by grade and thus the value of products; all of these factors should help determine log prices.

Other systems have also been developed to evaluate tree quality. Sonderman and Brisbin (1978) developed a system to quantify the quality of hardwood growing stock using external tree measurements as a basis for predicting the potential product value of immature hardwood stands. A very similar system for assessing individual bole quality was used by Zahner et al. (1984). Again, external tree measurements were used to derive general quality estimates, and, when combined with tree size and position in the stand, provided a method of determining crop tree potential. Ernst and Marquis (1979) presented a study entitled Tree Grade Distribution in Allegheny Hardwoods which provided estimates of tree grade distribution by diameter class for several species. Such estimates allow for the calculation of current or projected stand values when actual tree grade values are not available. Research efforts dealing with hardwood tree quality projection and distribution have been limited due to the many external factors which must be considered before such a projection can be made.

2.5 Economics

Information regarding economic evaluation of hardwood stands is limited. This is due partly to the great variation between hardwood stands and the long time interval required to evaluate treatment effects. Each hardwood management option is different based on site and stand conditions along with the changing market conditions for hardwood timber. By illustrating how value changes between grade 1,2, and 3 logs and how this may pay off, more emphasis may be placed on growing higher quality trees. An appropriate value ratio of 10 : 5 : 1 exists between lumber in grades 1, 2, and 3 logs respectively. If we manage or refrain from overcutting small second growth stands we can reap the monetary benefits of that restraint in the future (Paxton, 1981). Paxton also reported that owners of timberland of average or higher quality can more than keep pace with inflation if they are willing to forego income for extended periods.

The results of a study on the economics of thinning from a forest management standpoint by Theide (1984) shows that hardwood management can pay. Both precommercial and commercial thinning alternatives were evaluated and it was discovered that careful selection of stands considered for thinning can improve the rates of return if attention is focused on the quality-quanity relationships. If timber alone is not required to cover land purchase costs, returns from hardwood timber management can be quite high. However, because of the wide range of conditions in many hardwood stands, variations in the range of rates of return can be extreme.

Risbrudt and Pitcher (1986) evaluated the financial success from several different timber stand investments. With the assumption that thinning resulted in higher log quality, precommercial thinnings pay in northeastern hardwoods with or without commercial thinnings. The best returns resulted from earlier, heavier basal area removed on higher site quality tracts. It was also found that internal rates of return were sensitive to small changes in stumpage price and treatment costs but were insensitive to rotation volume yield total.

Vasievich (1984) presented a 7-step outline to figure financial returns from hardwood management. These included:

1. Identification of all feasible treatments.

2. Quantifying yield response.

3. Estimation of costs and benefits.

4. Computation of financial returns.

5. Testing the effects of assumptions.

6. Comparison of results.

7. Selection of the best option.

According to Vasievich, economic analysis for management of hardwood stands is difficult because prices vary greatly among quality classes, and also, changes in tree grade should be reflected in yield estimates.

One reason for the lack of economic analysis for quality Appalachian hardwoods has been the lack of growth and yield models for this timber region. However, within the past 3 years growth studies have produced 4 new sets of growth functions adaptable to hardwoods in the Appalachian region. Because this research project used a computer simulation approach in the economic analysis, growth and yield models were essential. A complete description and comparison of the models adaptable to the Appalachian hardwood timber region is given in the next chapter.

CHAPTER III

GROWTH AND YIELD MODEL DESCRIPTION AND COMPARISON

3.1 Background: Stand Level and Individual Tree Models

Economic analysis of hardwood forest management alternatives in the Appalachian region has been limited because of the lack of suitable growth and yield models. Growth and yield models can be classified into two primary groups with two subgroups in each:

1) stand level models
    - a) aggregate values only
    - b) size class information
2) individual tree models
    - a) distance independent
    - b) distance dependent

Stand level projection models use individual stands as the basis for prediction using variables such as age, density, and site index that result from stand level statistics. Models for aggregate values only predict the total volume or some defined merchantable portion from stand age, site index and stand density using multiple regression techniques. Whole stand models are becoming less poplar because the detail on diameter class frequencies is essential for economic analysis of thinning and various merchandising options (Hepp, 1987a).

Stand level models that provide size class information are quite often dervied through a "diameter distribution" method. Diameter distribution models use a probability density function such as Weibull or beta to estimate by diameter class or tree frequency. Site index, age, and density are used to predict parameters of the distribution which determines the stand table. Average heights for each diameter class are estimated by a separate equation. Tree volume equations are used to convert the stand into a stock table (Avery and Burkhart, 1983; Clutter et al., 1983). These models are most often used for monocultures because of homogeneity in the data used in model development.

The most recent approach to growth and yield modeling has been the development of individual tree simulation where individual tree characteristics are the basic predictor unit. The models simulate the growth of each individual tree after incorporating diameter, height, and crown measurements for a particular species and range of growing conditions. When compared to stand models, individual tree models can simulate competition factors between each tree (Davis and Johnson, 1987). Individual tree models are subdivided into distance dependent and distance independent simulators. These groups hinge on whether the spatial arrangement of the growth unit is incorporated into the model (Munro, 1974; Daniels and Burkhart, 1975).

Distance dependent models incorporate competition effects between trees. Coordinate locations of each tree in the stand are included. A competition index that is a function of the distance to, and size of all adjacent trees which compete for the same sources of light, moisture, and nutrients is used as a predictor variable. These models are extremely flexible, to accommodate a high variety of stand treatments (Daniels and Burkhart, 1975). One basic assumption of distance dependent models is that incorporation of the competitive distance relationship allows more flexibility in incorporating a wide range of stand conditions and treatments.

Distance independent models include competition factors by comparing individual tree statistics, such diameter at breast height, to average stand characteristics such as average diameter and basal area. These models assume that all species and tree sizes are distributed uniformly throughout the stand (Davis and Johnson, 1987). These models are conceptually attractive because they are highly flexible.

Some of the cited advantages of individual tree models are the potential for biological and economic evaluation of management alternatives (Dale, 1982; Clutter _et al_., 1983). Clutter _et al_. (1983) state that individual tree models are more biologically based and incorporate ecological interactions at a more fundamental level than do stand models. For any individual tree simulation, Ek and Monserud (1981) claim that the competition index and the situation in which tree growth is reduced by the index is of extreme basic importance. Because individual tree models are assumed to have a more sound biological base, it seems possible that they can adequately simulate the stand dynamics of tree growth, mortality, competitive effects and regeneration (Dale, 1982).

Primary disadvantages of individual tree models relative to stand models are the additional computation time and costs necessary to gather more specific data (Clutter _et al_., 1983). Other questions have been raised as to the improvement of an individual tree model's ability, over current stand models, to predict the basic components of stand dynamics. A studies by Beck (1974) showed that substituting various competition indexes for basal area made no significant improvement in growth prediction.

3.2 Individual Tree Model Description

The purpose of this chapter is to examine a series of popular individual tree growth and yield models used for mixed hardwood stands in the eastern region of the United States. The particular models selected for review are those incorporated into a microcomputer software package entitled YIELD-MS (Hepp, 1987b). YIELD-MS is a series of integrated growth, harvest simulation and economic analysis programs which can help in stand management planning. It is the only growth program used in this study, and a description of YIELD-MS is presented in Methods and Procedures. G-HAT (Harrison et al., 1986), TWIGS (USDA, 1979), OAKSIM (Hilt, 1985) and SILVAH (Marquis, 1986) equations are examined as to how they address tree growth, competition and mortality. Because of the lack of documentation describing SILVAH, only a general description is given.

3.2.1 Tree Growth

TWIGS (USDA, 1979)

This is the microcomputer version of STEMS (Stand and Tree Evaluation and Modeling System), developed by the North Central Forest Experiment Station (USDA, 1979 and 1984). TWIGS is a biologically based, individual tree, distance independent growth model developed for the Central States region. The application of TWIGS is limited as compared to STEMS because it can only analyize one stand at a time. However, when a management subsystem is incorporated, TWIGS is more flexible and designed to intensively examine one forest stand at a time. Initially, Hahn and Leary (1979) reported the general growth equations for STEMS which incorporated 26 tree species. These same growth equations were then incorporated into TWIGS (USDA 1984). The general form of the growth equation is:

$$dD = f(D, SI, CR)$$

where: dD = annual change in tree diameter

D = initial tree diameter at breast height

SI = plot site index

CR = crown ratio

The sample trees in the data set were stratified by one-inch diameter classes, 10-foot site index classes, and 10% crown ratio classes. Two important assumptions apply:

1) Potential growth is the annual increase in diameter of a tree in a stand that is free of competition (open grown).
2) Diameter growth distribution is normal.

<u>OAKSIM</u> : Individual-Tree Diameter Growth Model for Managed, Even-aged Upland Oak Stands (Hilt, 1985)

OAKSIM is another biologically based distance independent individual tree growth and yield model which can be used for a wide range of stocking, age and site conditions for even-aged upland oak stands. It was developed from data plots scattered in southern Ohio and southeastern Kentucky. The general form of the equation is:

BAG5YR = f(Dbh, SI, D, PS)

Where: BAG5YR = 5 year basal area growth (ft) for the jth tree

Dbh = diameter breast height of jth tree in the stand

SI = stand site index

D = quadratic mean stand diameter from trees > 2.5in

PS = stand percent stocking summed over trees > 2.5in dbh using Gingrich's 1967 stocking equation

Basal area growth is used as the dependent variable. According to West (1980) correlation between basal area increment and initial diameter at breast height was greater than diameter growth increment and initial diameter. In terms of prediction however, he found no advantage to using basal area over diameter as the dependent variable. Hilt (1983) also suggests that precision estimates of future diameters using either diameter increment or basal area are the same. The independent variables used in the model were previously determined significant for upland oaks by Dale (1975).

G-HAT: Growth of Hardwoods After Thinning (Harrison *et al.*, 1986)

G-HAT is a microcomputer program consisting of a series of programs used to predict growth and yield of Appalachian mixed hardwoods after thinning. This individual tree, distance independent model was developed for even-aged stands where no single species constitutes more than 60 percent of the stocking. Equations were constructed from thinned stand data collected in Virginia, North Carolina, Tennessee, and Georgia. The general form of the equation is:

$$G = b0 + b1B4/A + b2B5 + b3B6$$

Where: G = periodic annual tree basal area increment over 5 years

B4 = original tree basal area (in**2)/yr

B5 = stand basal area after thinning (ft**2)/acre

B6 = stand basal area before thinning (ft**2)/acre

A = breast height age at thinning year

b0, b1, b2, b3 = species specific coefficients

The dependent variable in this equation is periodic annual tree basal area. This equation, according to Harrison *et al*. (1985), proved to be superior in predictive ability for all data species except for the oaks. Harrison *et al*. (1985) suggested that the response of oaks to thinning is the direct result of the residual competition level, whereas stand density prior to thinning is important in non-oak species, with more growth occurring at higher initial densities.

3.2.2 Competition

TWIGS:

TWIGS is a distance independent model which incorporates crown ratio measurements to enable the model to respond to changes in stand density. Actual growth of an individual tree is obtained by multiplying potential growth and a modifier of the potential tree due to competition. The format for predicting growth increment is:

Y/T = (potential growth) * (# of trees) * (modifier function)

Where: Y/T = actual growth (inches/yr)

The modifier function reduces potential growth because of the tree's competition with other trees. It is given a value between 0 and 1 depending upon specific species basal area, average diameter of the stand, the tree's relative diameter and maximum expected basal area for the species. The current form of the modifier is (USDA, 1984):

M = 1 - e(**-B) *((BA Max**-BA)/BA)**.5

Where: BA Max = maximum basal area per acre that can be expected for the species

BA = current basal area per acre

B = f(R) * g(AD)

f(R) = relative dbh of the tree (ratio of tree's dbh to average stand diameter)

g(AD) = average stand diameter effect; g(AD) = C1(AD + 1) **C2

The modifier allows trees on less dense stands to keep a greater percentage of their potential growth as compared to trees in more dense stands.

OAKSIM:

Because this is a distance independent model, a indirect measure of inter-tree competition is included. Diameter at breast height was the only variable recorded for each tree. Therefore, individual tree growth was modeled as a function of tree diameter and stand attributes.

G-HAT:

This model is also distance independent, and therefore a indirect measure of inter-tree competition is included in basal area increment equations although stand basal area is used in the general equation.

3.2.3 Mortality

TWIGS:

The mortality function was developed by Buchman (1979). It predicts the probability of a individual tree dying during a single period as a function of the tree's current diameter and annual growth rate. The general form of the equation is:

$$P = (1 + e^{(B1 + B2DGR^{(B3)}) + B4D})^{(-1)} + B5$$

Where: P = estimated probability of a tree dying

DGR = annual diameter growth rate (in)

B1 = adjustment for diameter effect when DGR = 0

B2,B3 = adjustment probability of dying based on DGR

B4 = adjustment based on tree size

D = diameter at breast height

B5 = background annual death rate

B1,B2,B3,B4,B5 = coefficients for each species and species group

The number of trees per acre represented by each sample tree is reduced by the proportion predicted from the mortality function. Therefore, fractions of trees are used as the basis for number of surviving trees in each diameter class. Diameter growth and mortality are applied on a annual basis and are multiplied by the number of years in the projection period to derive the actual growth for that period.

OAKSIM:

Mortality is determined on a individual tree basis and is a direct function of periodic annual growth and diameter at breast height. More specifically,

$$PMORT = 1 / (1 + \exp(b0 + b1DBH + b2Dgrow))$$

Where: PMORT = mortality probability

DBH = diameter at breast height

Dgrow = periodic annual diameter growth of the tree for the past 5 years.

b0, b1, b2 = parameter coefficients

Mortality probability is calculated for an individual tree at the beginning of each 5-year projection period. A number of equations were developed for the following species groups: white oak, black oak, hickory, and understory species. This is because different species characteristically have significantly different probabilities of mortality.

G-HAT:

Harrison *et al*. (1986) used what they called "survival equations" to represent the five-year probability of individual tree survival. The probability of survival is a function of 5-year predicted annual basal area increment. The specific equation is:

$$S = .90477 + .09523(1 - \exp(-.7247G))$$

Where: S = 5-year survival probability

G = 5-year predicted basal area increment

This equation was constructed by ranking and grouping individual tree data in terms of 5-year predicted basal area growth. Survival probablilites and average basal area increments for each group were determined. Predicted survival probability is treated as a proportion which is multiplied by the number of trees resulting in the actual number surviving.

3.2.4 A Note on SILVAH

The growth and yield functions of SILVAH were released in February 1987 to Tennessee Valley Authority to be included in YIELD-MS. As a result, documentation describing the development of the equations has yet to be released. However, in a phone conversation with developer Dave Marquis, basic characteristics of the model were gathered (Interview, 1987).

DATA: Hundreds of permanent plots located in southern New York, Pennsylvania, Ohio, and W. Virginia were used as a basis for growth projection development. Growth data for two-thirds of these were collected for the last ten to fifteen years. The remaining one-third were from plots put in the 1920's from which successive five-year measurements were taken.

MODEL: The model is an individual tree, distance dependent, stand table projection method using one-inch diameter classes. The general outline of the model is:

Predict Growth

Predicting Mortality

Net Growth of Survivors

Stand Projection

EQUATION DEVELOPMENT: The equations are distance dependent which depends on species competition vigor or the relative position of the tree in the stand to the size and distance of it´s nearest competitors. This set of equations uses quadratic mean diameters and a measure of relative density to a fully stocked stand of a specific species. Considerations are also made for site classifications.

RANGE OF SPECIES: Equations strongly represent the growth characteristics of black cherry, red and sugar maple, yellow and black birch, beech, and hemlock. It is not applicable to stands greater than 20 percent oak. See Appendix I for a list of all models and their applications.

3.3 Comparisons and Conclusions

The general approach to predicting actual tree growth was similar for all models examined (Harrison *et al.*, 1986; Hilt, 1985; Marquis, 1986; USDA, 1979). In each case, estimations of potential growth under optimal conditions were made which were then modified by one or more factors. Of the models described, only G-HAT was developed exclusively for predicting growth increments after thinning. TWIGS, OAKSIM, and SILVAH can be used over a broader range of conditions. Even though the general modeling approach was similar, techniques used in equation development and evaluation varied. Harrison *et al.* (1986) for example, evaluated their species specific equations by a double cross evaluation technique. OAKSIM and TWIGS were evaluated with projections made from independent data using growth equations of GROAK and STEMS respectively (Dale, 1975; USDA, 1979).

3.3.1 Tree Growth

The method in which growth potential was estimated varied among the growth simulators. In TWIGS, the potential was a function of Dbh, site index, and crown ratio. Potential was then assumed to be the average growth per cell plus 1.65 standard deviations. In OAKSIM, the potential was calculated on the basis of diameter, site index and stocking;

G-HAT based growth on age and basal area before and after thinning.

Looking at the four models, four factors were repeatedly used in predicting tree growth: site quality, initial tree diameter, stand density, and crown ratio. Hahn and Leary (1979) presented a list of variables which theoretically affect tree stem growth and the four factors observed in the models evaluated are listed. Therefore, one would assume that these factors are highly significant in predicting future stem growth.

3.3.2 Competition

Most competition indexes used in various individual tree growth and yield models take into account the size of the tree and the distance between trees. Clutter et al. (1983) however, suggests that use of competition indexes in the place of stand level density variables does not significantly increase the explanatory value of the model.

Of the four models, G-HAT, OAKSIM, and TWIGS are distance independent and therefore lack direct measures of inter-tree competition. However, direct competition factors is important in SILVAH. The general approach in using competition factors is to compare each individual tree with the "mean" size of trees with which it might compete. Growth is adjusted accordingly. The basis of comparison for both TWIGS and SILVAH is basal area and diameter at breast height.

3.3.3 Mortality

Mortality prediction fell into two groups for the four models; mechanistic and empirical. G-HAT, OAKSIM, and SILVAH mortality functions include a mechanistic approach with assumptions of how a forest behaves; the mortality model developed agreed with this theory. TWIGS, however, used a more empirical approach, where models are based on equations fitted to experimental data using various statistical techniques, as described by Buchman (1979). Mortality was calculated by growth rate class, by a .02 inch/year increment. The annual mortality rate was then calculated as a function of the survival rate where survival rate = 1 -mortality rate. Buchman found mortality rates to be difficult to "correctly" simulate. The results of his mortality validation tests showed the best proportion of agreement between actual and simulated mortality was .47.

In all of the models, however, mortality/survival rates were a function of growth rates. Diameter at breast height was incorporated in the mortality equations for TWIGS, OAK-

SIM, and SILVAH as well as individual tree growth rates. Mortality rates for both OAKSIM and G-HAT are calculated for an individual tree at the beginning of each five-year projection period.

3.4 Trial: Variations in Growth and Survival

Based on the description of four individual tree growth, competition, and mortality functions, a comparison was made of methods used to predict and simulate final growth. With the known information, there is still great uncertainty as to the best method to employ for projection equations. The question remains as to the accuracy and precision of these individual tree growth and yield models as compared to stand level models.

For models to be used beneficially, their limitations should be known; otherwise illogical results or extremely large variations can occur. To observe the variations in the four models discussed, a comparison test was run with stand data (Wise 1) which was used extensively throughout the entire research project. The stand was projected for 15 years using each of the models. Initial stand conditions included:

1) basal area was 167.4 sq. ft. per acre

2) 275 trees per acre ranging from 4 to 18 inches in diameter

3) average stand age was 45 years

4) site index was 85 for yellow-poplar

Tables 2 and 3 in the next chapter contain a more compete description of initial stand characteristics.

In order to use OAKSIM, the site index for black oak was entered into the program. Because site index was collected solely for yellow-poplar a conversion was made to black oak using Doolittle´s site index comparison equations (Doolittle, 1958). Therfore, black oak site index 75 was used with OAKSIM for the 15-year projection.

Also included is a short economic analysis of the stand with the intent to observe how variation in the models affects various economic parameters. Stumpage prices are given in Table 4. The results are given in Table 1.

Basal area growth for G-HAT, OAKSIM, and TWIGS was very similar over the 15-year projection. SILVAH, however, predicted a final basal area considerably less than the other predictions. The greatest variation was in the survival models. The range was from 242 to 206 stems for SILVAH and

Table 1.

Results of Growth Model Comparison Trials

Wisel 15 Year Projection

Model	Final Basal[1] Area (sqft.)	# Stems	Final Ave. Dbh (inch)	IRR[2] after tax (%)	Total Cash Flow ($/acre)
G-HAT	199.5	232	13.89	2.4	892.43
OAKSIM	197.1	248	12.08	1.9	664.55
TWIGS	197.1	206	13.26	2.3	849.48
SILVAH	180.4	242	11.70	1.7	586.03

1 Initial Basal Area: 167.4 sq.ft. per acre

2 Marginal Tax 28% ; Capital Gains Portion 28%

TWIGS, respectively.

Evaluation of economic factors showed some variation between the models. The greatest returns for this particular stand resulted with use of G-HAT and TWIGS. The other two models, OAKSIM and SILVAH, are less financially favorable.

Growth and mortality rates between the models will vary depending on species, age, site index, stocking, and size of the trees being projected. Therefore, the results and rankings this example has shown may not be true for other stands of different initial conditions.

Of the models compared, G-HAT is the only one which attempts to model the effects of intermediate thinning treatments on residual stand growth. As a result, it may predict growth or the final distribution more accurately and precisely for thinning operations than other models. It seems possible that the development of future models based on other often-used silvicultural practices, can help produce more reliable growth estimates needed for economic analysis.

What this review has illustrated is that variation in equation development procedures is not a major factor in developing a model that does a good job in growth predictions. The strength of a model is not only determined by how well it predicts the growth of the stand from which the equations were developed but how well it predicts growth for other stands with similar species. For models to be used beneficially, their limitations should be known; otherwise illogical results or extremely large variations in growth prediction are possible. Finally, there is a need to further check all equations against actual growth on remeasured plots and revise the models if needed in view of these checks.

CHAPTER IV

METHODS AND PROCEDURES

4.1 Data

The field plot data for this work were collected from two seperate regions in the Appalachian mountain region. The USDA Southeastern Forest Experiment Station in Asheville, North Carolina, provided information on 10 separate research plots that were previously used by Harrison (1986) in the development of G-Hat. Data were also collected near Blacksburg and Wise, Virginia on the Jefferson National Forest.

A total of fifteen 1/5-acre plots was measured for specific elements. The 10 Asheville plots were thinned 15 years prior to data collection to concentrate growth on high value and high quality species, and larger stems and to improve species composition. Only one of the two plots in Wise was thinned 7 years prior to measurement. Site index (base age 50 years) for yellow-poplar varied from a high of 100+ at the Asheville sites to 80 in the Blacksburg region. Plot information collected included tree species, diameter at breast height, total height, merchantable height to a 5-inch top, current tree grade, potential tree grade, stand age, site index (base age 50 years, yellow-poplar), basal area, and aspect/%slope. The growth and yield functions used in Yield-MS use some or all the data collected depending on which model is selected.

At each location economic data were also collected in order to gain information concerning local markets. Information was gathered at the local USDA Forest Service office in each of the districts where field plot data were collected. Several saw mills, pulp mills, log buyers, and fuelwood sellers were visited in each location. They provided species specific delivered price information on the different log grades and/or the type of raw material they consumed. Mill timber supply radius information was also gathered along with each manager's personal view of the hardwood market and feeling for the future. This will help to provide logging cost and market information, a perspective for the timber situation in the future and types of silvicultural practices that may become more important in the future.

4.2 Economic Evaluation

The usual way to select the most economically advantageous logging or stand treatment method for a particular stand is to select successively two of the most likely alternative methods and then to generate the future cash flows that will come from each. (Methods of systematizing this search among alternatives is discussed more fully in the next section.) These two cash flow streams are then discounted, and the one showing the highest internal rate of return, or the highest net present value, is considered the preferable of the two treatments, possibly then to be compared to another likely alternative.

Internal rate of return (IRR) was used in this analysis because it requires no assumption of an alternative rate of return, a widely varying factor when interest rates are as unstable as they are today. IRR is directly interpretable in a context of many alternatives of various magnitudes, and the program is designed to check for abnormal cash flows that might give erroneous rates.

Hepp (1986) is currently developing a computer software package entitled Yield-MS: Timber Yield Planning Tool for Mixed Stands. Although it still contains some problems that make its use cumbersome, in concept it is suited exactly for the type of prescription problem being approached here. He has worked closely with us remedying operational difficulties, and a very useful piece of software should evolve.

YIELD-MS is an integrated collection of programs from several sources. The four growth and yield models described earlier are available to the user. Some other program segments are:

1) Estimation of stand value at any stage in stand projection, according to tree species, size, product, and grade.
2) Harvest simulation, for any kind of partial cut or complete harvest.
3) Projection of growth and yield, using the stand table projection method, in yearly increments.
4) Estimation of future cash flows, including incomes from any harvests simulated.
5) Calculations of different financial criteria for investment analysis.
6) Options to input local growth factors, individual stand data and volume tables.

YIELD-MS has the ability to incorporate changes in tree grade as part of its growth projection, an essential feature in management for high quality. A major part of the increase in stand value may be the increase in tree grade that comes with increasing tree diameter. Numerous sawmill grade recovery studies, such as Hanks (1976), have shown that larger diameter is the main factor that leads to higher percentage yields of higher grade lumber. Therefore, an important feature in Hepp's program is the probability factors, taken from Ernst and Marquis (1979), for an increase in tree grade with the increase in tree dbh into the lowest sizes of each grade.

These probabilities give a highly conservative estimate of value change from tree grade increment and are questionable as to how they were determined and incorporated into YIELD-MS. Using Ernst's results for the commercial species found in Pennsylvania Allegheny Mountain region (Ernst and Marquis, 1979), Hepp determined average grade change probabilities for those species and conditions also found in the Appalachian region and incorporated these averages into YIELD-MS. These averages, however, were generally lower than the grade change probabilities originally reported by Ernst and Marquis. For species not included in the original study, estimations were made as to the probability of a tree increasing in grade as it grew in diameter. These estimations were developed by grouping those species which lacked grade increase probability figures with those species which were originally reported by Ernst, according to similar physiological characteristics. Therefore, it is the average and estimated grade change probabilities that were incorporated into YIELD-MS. An important modification we are making in the program allows these probabilities to be set during the stand prescription tally, determined by present observable tree condition.

During the entire span of this research project, Hepp's program (YIELD-MS), was not completely formulated, so that detailed data entry and manipulation was laborious and therefore simulation runs of several different stands and conditions was cumbersome. This resulted in a limited number of sensitivity runs of only a select group of stand conditions due to the amount of time necessary for data input.

4.2.1 The Stand Treatment Decision

In section 4.2 above, it was mentioned that an evaluation must be made between two likely stand treatments. Obviously there are more than two possible treatments, so the question arises of how to select the first two to compare. Here is proposed a systematic way of reviewing possibilities, two at a time until the best decision is reached, beginning with the most desirable from both a silvicultural and financial viewpoint. In this way most possibilities will be considered, and, in the process of gathering market and cost data for each, the forester or owner will be lead through a thorough analysis of all economic factors surrounding the logging decision. The "decision tree" chart (Figure 1.) for comparing treatments can lead to one of six intermediate cuts, leaving to grow, or to a regeneration cut if estimated future growth does not indicate a suitable rate of return from any of the other treatments. Three methods of regeneration are possible, but that decision involves a number of silvicultural factors considered beyond the scope of this project.

One major question in the use of such an approach is the period of future time to consider in the analysis. This will depend upon several factors, including the age of the stand and the period for which the growth projection model is deemed suitable. In the work below we used a period of 20 years.

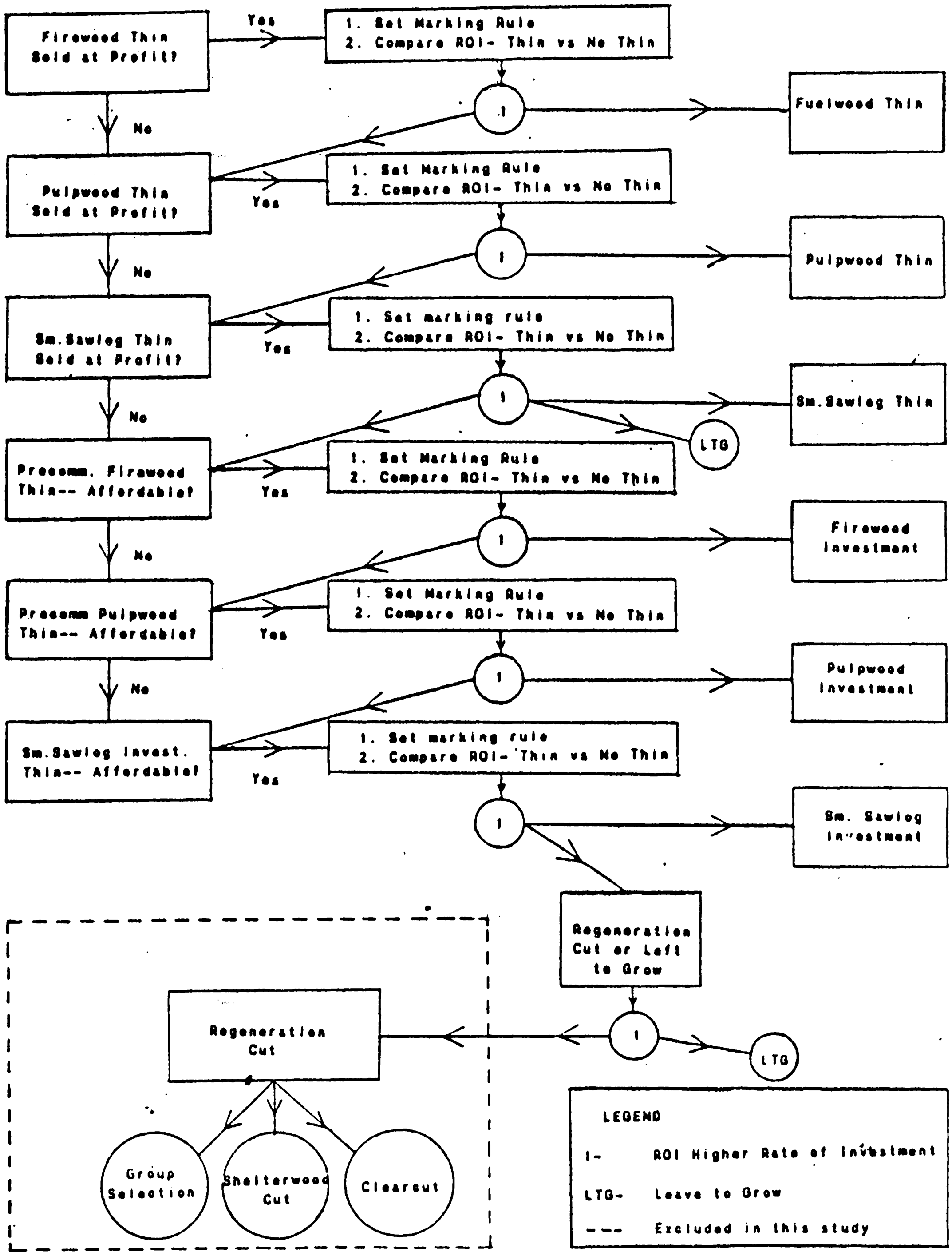

Figure 1.
Appalachian Mixed Hardwoods
Intermediate Thinning Prescription
Decision Tree

4.2.2 Demonstration Trial

To demonstrate the process involved, we have taken actual data from a plot in southwestern Virginia (Wise 1), with a wide range of species and sizes, with a few sawlog trees that show potential for growing into higher grades in the next 20 years, and with pulpwood-size trees that will grow into small sawlogs. This stand was recently thinned and therefore the G-HAT growth projection model was used. Initial stand conditions included basal area of 167 sq.ft./acre, site index 85 (yellow-poplar), and an average stand age of 45 years.

In order to incorporate the data into YIELD-MS the species were grouped into 3 classes based on similar stumpage values (Hardwood Market Report, 1986). Tables 2 and 3 show the species groups that were found on the particular plot and stand composition delineated by individual tree diameter class and tree grade, respectively. It represents the 1/5th acre plot expanded to one acre.

Besides tree species, other information collected for each tree included diameter at breast height, total and merchantable height, age, and tree grade. All trees were graded according to US. Forest Service guidelines (Rast

Table 2.

Hardwood Species Groups From Wise Data Sets Used in Both the Demonstration and Sensitivity Analysis

Group #	Name	Species
1	Oak	red oak, white ash
2	Bass/Pop/Maple	yellow-poplar, basswood, red maple, sugar maple, yellow birch
3	Hic/Cuc/Mag	hickory, cucumber, magnolia

Table 3.

Wisel

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	Grade	Two Inch Diameter Class 2	4	6	8	10	12	14	16	18	20	22
Oak[1]	1											
	2						10					
	3					5						
	2/stop.											
	3/stop.							5	5			
	pulp											
Bass/Pop/Maple[2]	1								5	10		5
	2							15				
	3					5						
	2/stop.							10	5			
	3/stop.							10				
	pulp		60	30	30	10	5					
Hic/Cuc/Mag[3]	1											
	2											
	3					5						
	2/stop.											
	3/stop.					15	15					
	pulp			5	10							
Totals = 275			60	35	40	40	30	40	15	10	0	5

== 275/ac

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

et al., 1973). In addition to the 3 sawlog grade classes used by the Forest Service, we made note of trees with defects or stoppers which would prohibit them from increasing in grade even though tree diameter satisfies minimum grade class standards. For example, there could be two 12-inch grade 3 red oak trees, one free of defect and the other with some crook and several live limbs on the butt log. Based on external qualities the tree without defect will improve to grade 2 as it grows into the 13 inch diameter class, whereas the second tree will remain grade 3 even though it grows larger than the minimum diameter for grade 2. Therefore, trees in the classes Grade 2 Stoppers and Grade 3 Stoppers can not improve in grade; thus the only value increase results from increases in tree volume. By incorporating the Grade 2 and 3 stopper classes, a better estimate of potential stand value can be made.

To demonstrate the methodology of our proposed system, the program was used to compare 2 possible stand treatments. One treatment is an immediate profit-yielding firewood thinning and salvage cut of the stand, after which the stand grows for 20 years. The alternative will be to let it grow, uncut in any way for the same period. Using the decision tree (Fig. 1), we asked if a thinning for firewood could be made at a profit - without an initial net investment. Since we are in an area where firewood cutters are active, we assume that a firewood thinning removing 2.5 cords per acre can be made, along with 5.2 mbf/acre from sawtimber trees with little prospect to increase in value. To generate the cash flows from the two stand treatments over 20 years the following assumptions were entered into the program:

1) Location is in a fairly good firewood market, to which stumpage may be sold for $17.00 per ton.
2) Stumpage prices will remain constant over the projection period, as do other prices. (The program permits specification of an estimated price inflation rate but that feature was not used.)
3) Tree quality classes have dollar values that represent a wide value spread based on the value of the lumber that could be cut from them. Tree grade 1 has the highest value, grade 3 much lower, but above pulpwood. See Table 4.
4) Thinning reduces stand basal area to 110 square feet per acre.
5) Both stands will be clearcut at the end of the 20-year projection period.
6) The G-HAT growth projection model was used.
7) Probability for "stopper" trees to improve in tree

Table 4.

Demonstration Trial: Summary of Stand Stumpage Price by Species Group and Tree Grade

Species Group	Grade	Price $/mbf
Oak[1]	1	196.79
	2	186.50
	3	84.51
	2/stopper	186.50
	3/stopper	84.51
	pulpwood	17.00/ton
Bass/Pop/Maple[2]	1	135.41
	2	96.40
	3	71.79
	2/stopper	96.40
	3/stopper	71.79
	pulpwood	17.00/ton
Hic/Cuc/Mag[3]	1	77.53
	2	64.09
	3	44.51
	2/stopper	64.09
	3/stopper	44.51
	pulpwood	17.00/ton

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow- poplar, basswood, red maple sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

grade was 0%, while it was 100% for all other trees.

Timber prices vary greatly from one location to another, depending upon site, stand location, access, local timber markets, species, quality and number of harvestable trees. Stumpage prices used here are given in Table 4. Lumber grade yields from Hanks (1976) were used, in conjunction with the Hardwood Market Report (1986), to determine the value by grade for each tree, by species, tree grade, diameter and merchantable height. Region specific average logging and milling costs were subtracted, resulting in stumpage prices shown in the table.

Appendix 2 shows an example of how stumpage prices were calculated.

4.2.3 Decision Tree Methodology Simulation

Inspection of the decision tree indicates a great many ROI comparisons, with each involving a careful trial marking and a run thru the growth projection. This might appear to be a tedious procedure if all the comparisons must be made, even with a powerful computer. In actual practice, however, many alternatives will not be locally feasible.

Using the same initial stand as in the previous procedure, including financial parameter data, a sequence of alternative cutting prescriptions was prepared with the overall management objective to leave a stand in which growth could be concentrated on higher quality and potentially more valuable trees. The guideline followed to determine which trees to remove in the various thinning operations were:

1) trees of species with low economic value and those with 0 percent probability of grade increase.
2) trees with the slowest growth rates.
3) residual basal area would not be taken below 105 sq.ft. per acre.

Following these guidelines, each successive simulation removed additional trees to make the thinning more profitable and approach a desirable range of basal area. The results of this trial are shown in the next chapter, in Tables 12 and 13.

4.3 Sensitivity Analysis

In order to find a way to reduce the search time necessary to move thru the decision tree, an effort was made to find some parameters for describing value growth potential of hardwood stands. Several were examined and then tested by simulation runs to determine which were most sensitive in portraying a wide range of value growth potential. Those chosen to test were:

a. percentage of stand basal area capable of grade change.
b. spread of price value differentials between tree grades.

These were then tested by simulation runs on data from a variety of actual stand conditions found on plots taken in the region. The spread in economic variables found by the simulation would presumably give a measure of the best parameter to use in typifying value growth potential.

One important measure of the economic value of mixed hardwoods is the percent of stand basal area in the higher grade classes. Potential for value increase is determined in part by the percentage of basal area capable of increasing to a higher grade. In even-aged stands, basal area is strongly correlated with age and to a lesser extent, site index. However, basal area per acre can be constant over time as the number of trees per acre decline, by compensation through increases in average tree size. Therefore, this measure, which can easily be obtained in a field cruise, can describe both actual and potential value of the stand.

The second parameter used to describe value growth potential of hardwood stands is the spread of price value differentials between tree grades. Such a measure provides a understanding of the importance of prices as related to species and grade. The percent price differential between grades can have a great effect on economic results of a particular management option. Large differences between grades along with other factors may provide economic incentives for landowners to manage for higher quality.

Because tree grade and the percent price differential between grade is important to economic analysis of hardwoods, several sets of simulations were run varying these two measures over their expected ranges. With such a comparison, it is possible that an economic trend may occur as the percent of stand basal area capable of improvement increased. In this way, comparisons could be made of the influence on each economic criteria. This comparison also demonstrated how important grade increase is in economic analysis of these stands. Presenting these sets of comparisons in two-way tables was just an efficient way of testing each measure over it is range while holding all other factors constant. Table 5 is a directory of the various sets of simulation runs which are discussed in more detail in the following sections.

4.3.1 Percentage of Stand Basal Area Capable of Grade Increase (PBAGI)

The purpose of this section is to illustrate the approach that might be used used for the series of simulation tests by giving one an actual simulation trial.

As described in the earlier section, Table 3 shows the initial stand composition and distribution by number of trees in each grade and diameter class for Wise 1 and is the set of data that is used as the basis for the simulation comparisons. All trees 10 inches in diameter and greater were graded not only on their current size but their potential to increase as they grew in diameter. Because stumpage prices used in section 4.2.3 were not representative of current prices between grades, new estimates were calculated. Again, using Hanks′ (1976) Hardwood Tree

Table 5.

Directory Of Simulation Trials Using Wise And Ashville Data

Simulation Set	Data Set	Variations in PBAGI[1]	Variations in PPD[2]	Variations in Base Price	Time Projections	Variable Timber Basis
1	Wise 1	X	X			
2	Wise 1a	X	X			X
3	Wise 1b	X	X			X
4	Wise 1c	X	X	X		X
5	Ashville 1				X	X
6	Ashville 2				X	X

1 PBAGI = Percent of Stand Basal Area Capable of Grade Change

2 PPD = Percent Price Differential Between Tree Grades

Grades for Factory Lumber and averaging the lumber grade volume and price for each species group, new stumpage prices were determined. Appendix 3 shows the set of stumpage prices for the oak group based on January 1986 Hardwood Market Report Prices (Hardwood Market Report, 1986). All lumber volumes were based on the initial stand (Table 3).

Initially, 40 percent of the stand in Table 3 was capable of increasing in grade. This initial stand basal area capable of grade change was then modified to 25, 55, and 70 PBAGI, respectively. For 55 and 70 percent stand grade change, the stand was modified by moving trees from grade 2/stopper and 3/stopper classes to grades 2 and 3. For the 25 percent class, trees were removed from grades 2 and 3 and placed in the same diameter class in grades 2/stopper and 3/stopper, respectively. In all cases, the initial basal area remained constant. Appendix 4-6 shows initial stand distribution by grade for each class.

Percent price differentials were determined using grade 2 stumpage price for each group as the basis from which grade 1 and 3 prices were calculated. For example, to determine a 10 percent price difference between grades for group 1 (Table 4), the stumpage value of grade 2 ($173/mbf) was the basis from which a +10 percent price difference for grade 1 stumpage price value, and a -10 percent difference for grade 3 stumpage price was determined. Table 6 shows stumpage prices at various percent differentials for each species group.

The actual initial value of the stand was $2200 per acre using the initial set of stumpage prices given in Appendix 3. This was used as the base value at which timber was carried in the accounts. Initial financial conditions and a set of sample transactions used throughout the analyses are given in Tables 7-8 respectively.

To generate cash flows from the various price differentials and percentages of stand basal area capable of increasing in grade over 20 years the following assumptions were entered into the program for the first Wise simulations:

1) the timber base value of $2200 per acre is used in all simulations. (Adjustments made in other simulation runs)
2) stumpage prices remain constant over the projection period as do other prices.

Table 6.

Stumpage Prices (Wise 1):
Percent Price Differential Between Grades Using Tree Grade 2
as a Basis for Each Species Group

% Price Differential	GROUP1[1]				GROUP2[2]				GROUP3[3]			
Tree Grade	10	30	50	80	10	30	50	80	10	30	50	80
Grade 1	192	233	259	311	105	124	143	171	86	102	117	141
Grade 2	173	173	173	173	95	95	95	95	78	78	78	78
Grade 3	155	120	86	35	85	66	47	19	70	54	39	15

(Species Group)

Pulpwood $6.00 per cord.

1 GROUP1 = red oak, white ash

2 GROUP2 = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 GROUP3 = hickory, cucumber, magnolia

Table 7.

Initial Financial Data Parameters for Percentage of Stand Basal Area Capable of Grade Increase Trials Wise 1 and Wise 1a

Planning Horizon is from 1986 to 2006			
Marginal Federal Tax Bracket	28.0%	Capital Gains	28.0%
Discount Rate Before Tax	7.0%	After Tax	5.0%
Capital Gains Treatment for Harvest Revenues			

Table 8.

Financial Transaction Assumptions
for Wise 1, Wise 1a, Wise 1b, Wise 1c, and
Ashville Stand Simulation Analyses

Transactions	First Year	Last Year	Amount (per acre)
Ad Valorem Tax	1986	2006	-1.75
Adjusted Basis	1986	1986	**
Annual Mgt. Fee	1986	2006	-1.50
Hunting Lease	1986	2006	2.00
Simulated Harvest	2006	2006	**

** Values vary depending on initial stand conditions.

3) initial stand basal area was 167.4 sq.ft. per acre and average stand age was 45 years.
4) stands clearcut at the end of the 20-year projection.
5) all stands evaluated on the basis of IRR, NPV, and total net cash flow.
6) G-Hat growth functions were used.
7) Probability for "stopper" trees to improve in tree grade was 0%, while it was 100% for all other trees.

4.3.2 Variations in Stumpage Price Differentials

From the previous series of simulations, a number of sensitivity tests were conducted using the same percentages of stand basal area capable of grade change but varying the percent stumpage price differentials. After evaluating a series of prices and the percent differentials occurring in the hardwood market, two new sets of percent price differentials were tested which were more representative of actual market conditions. Again, grade 2 stumpage prices for each species group was used as the basis from which grade 1 and 3 prices were determined. However, instead of using a constant percent difference between grades 2 and 1 and 2 and 3, variations in the percentages between grades were used. For example, 10:10 represents a 10 percent difference between grade 1 and 2 and a 10 percent difference between grades 2 and 3. Likewise, a 10:50 ratio represents a 10 percent difference between grades 1 and 2 and a 50 percent difference between grades 2 and 3. Tables 9 and 10 show stumpage prices calculated at various percent price differentials.

To get a more realistic analysis, the initial timber basis varied (Wise 1a) with each set of price conditions. For example, a 10:10 price differential for a stand with 25 percent of it's basal area capable of grade change had an initial basis of $2260 per acre as compared to a 10:50 price differential for the same stand whose basis was valued at $1915 per acre. Also the discount rate was changed to 5.5 percent before tax and 4.0 percent after tax to get a better understanding of net present values after the 20-year growth projection.

To generate cash flows from the various price differentials and the percentage of stand basal area capable of increasing in grade over 20-years two additional assumptions were added to the original set of assumptions in section 4.2.2 (Wise 1b):

Table 9.

Stumpage Prices (Wise 1a):
Various Percent Price Differentials Between
Grades Using Grade 2 Prices as a Basis for Each
Species Group

	Species Group								
	Group1[1]			Group 2[2]			Group 3[3]		
Tree Grade / % Price Diffference	1	2	3	1	2	3	1	2	3
10:10	192	173	155	105	95	85	86	78	70
10:30	192	173	120	105	95	66	86	78	54
10:50	192	173	86	105	95	47	86	78	39
10:80	192	173	35	105	95	19	86	78	15

Pulpwood $6.00 per cord

1 Group1 = red oak, white ash

2 Group2 = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 Group3 = hickory, cucumber, magnolia

Table 10.

Stumpage Prices (Wise 1b):
Various Percent Price Differentials Between
Grades Using Grade 2 Prices as a Basis for Each
Species Group

	Species Group								
	Group 1[1]			Group 2[2]			Group 3[3]		
Tree Grade / % Price Difference	1	2	3	1	2	3	1	2	3
30:10	233	173	155	124	95	85	102	78	70
30:30	233	173	120	124	95	66	102	78	54
30:50	233	173	86	124	95	47	102	78	39
30:80	233	173	35	124	95	19	102	78	15

Pulpwood $6.00 per cord

1 Group 1 = red oak, white ash

2 Group 2 = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 Group 3 = hickory, cucumber, magnolia

1) a new timber base value was determined for each separate price differential and percent of stand basal area capable of grade change.
2) the discount rate before and after tax was 5.5 and 4.0 percent, respectively.

4.3.3 Variations in the Grade 2 Stumpage Price Basis

The third aspect of this simulation (Wise 1c) sensitivity analysis was to use the 10:30 percent price differential throughout the analysis but to vary the base grade 2 stumpage prices used in the previous analyses, by -40, -20, +20, and +40 percent from which all other stumpage prices changed proportionately. This allows for a more complete analysis over a wide range of prices. Table 11 contains the various prices for each species group. The methods and assumptions are identical to those mentioned in section 4.2.2.

The remaining sensitivity analyses used stand data collected in Ashville, North Carolina which had completely different stand conditions than the Wise data. The analyses was focused on various economic criteria and their sensitivity to future projection lengths.

Table 11.

Stumpage Prices (Wise 1c):
10:30 Percent Price Differential Between
Grades With Variations of -40, -20, +20, and +40 Percent
in Grade 2 Base Price for Each Species Group

Tree Grade / % Change in Grade 2 Prices	GROUP 1[1]			GROUP 2[2]			GROUP 3[3]		
	1	2	3	1	2	3	1	2	3
-40	113	102	69	63	57	40	53	48	35
-20	151	137	96	84	76	53	69	62	43
+20	230	208	144	126	114	79	103	94	65
+40	275	250	175	147	133	92	120	109	76

Pulpwood $6.00 per cord

1 GROUP 1 = red oak, white ash

2 GROUP 2 = yellow-poplar, basswood, red maple, sugar maple yellow birch

3 GROUP 3 = hickory, cucumber, magnolia

4.3.4 Ashville Analysis

Two stands, which were part of Harrision's data set for G-Hat (Harrison et al., 1986), were evaluated over a series of time projections. The intent was to obtain an understanding of the importance of time in relation to the various cash flow analysis factors such as net present value, internal rate of return, benefit cost, and total net cash flow. Each stand was projected 20, 15, 10, and 5 years, respectively. Stumpage prices used were identical to those in Table 4.

Stand 1 (Ashville 1) carried an initial basal area of 89 sq.ft. per acre with only 65 trees per acre. The majority of the trees were in the 10-16 inch diameter class. The initial base value carried in the accounts was $1300/acre. This base value, the cost or actual value of the stand at the outset of the simulation process, was determined for the stand by summing the total value in each of the various species and grade classes. Only timber values were considered, land values and nontimber values were assumed not to be a part of the initial basis value. Appendix 7 shows the initial stand by species, grade and diameter class.

Stand 2 (Ashville 2) was very similar to stand 1, with an initial basal area of 84 sq.ft. per acre and 95 trees per acre. Again, the majority of the trees were in the saw-timber size classes of 10-16 inches in diameter. Appendix 8 shows the initial stand by species, diameter class and grade. However, the initial basis was lower, $950/acre, as compared to stand 1. The average stand age was 50 years for both stands.

The assumptions, financial data, and financial transactions used in cash flow generation for each projection period were identical to those used in the previous section.

CHAPTER V

RESULTS AND DISCUSSION

5.1 Decision Tree Demonstration Results

The financial analysis results of the two situations (Wise 1) presented to demonstrate the decision tree (see pg. 53-59), fuelwood thinning vs leave-to-grow, are given in Table 12. The analysis uses the current 1987 income tax law and allows capital gains treatment of timber income at the new individual rate of 28 percent, with a basis value of $529.00/acre at which timber was carried in the accounts. This value is the income that the standing timber would generate if all were sold as pulpwood. Therefore, the rate of return approximates that which would be earned by holding a stand of large pulpwood as it grew into sizes that would attract a sawlog buyer.

The absolute values of the internal rates of return are of less significance than the comparative rates between the 2 treatments, which indicate that the fuelwood and small sawlog thinning can result in a significant increase in the return on invested capital. The results show that an after-tax internal rate of return was 5.5 percent greater with

Table 12. Decision Tree Demonstration Comparative Results: Fuelwood Thinning VS Leave-To-Grow

<u>Financial Parameter Data</u>

Planning Horizon is From 1986 to 2006

Marginal Federal Tax Bracket= 28% Capital Gains Proportion= 28%

Discount Rate: Before Tax= 7.0% After tax= 5.0%

Capital Gain Treatment for Harvest Revenues

<u>Fuelwood Thin Alternative--- Financial Transactions</u>

Type	First Year	Last Year	Rep	$Amount	Inf%	Description
Ordinary Deduct Expense	1986	2006	1	-1.75	0	AD Valorem Tax
Capital Expense Timb DPLN ACC[1]	1986	1986	1	-529.26	0	Adjusted for Timber Base
Ordinary Deductible Expense	1986	2006	1	-1.50	0	Annual Mgt. Fee
Ordinary Taxable Income	1986	2006	1	2.00	0	Hunting Lease Income
Capital Gains Thinning Revenues	1986	1986	1	351.90	*	From Simulated Removals
Capital Gains Harvest Revenue	2006	2006	1	3042.59	*	From Simulated Removals

* Inflation rate is computed as composite of specified sawtimber and pulpwood inflation rates.

Total Net Cash Flow= $2838.98 per acre Internal Rate of Return: Before Tax 15.0% After Tax 14.3%

<u>Leave to Grow Option--- Financial Transactions</u>

Type	First Year	Last Year	Rep	$Amount	Inf%	Description
Ordinary Deductible Expense	1986	2006	1	-1.75	0	AD Valorem Tax
Capital Expense Timb DPLC ACC	1986	1986	1	-529.26	0	Adjusted for Timber Base
Ordinary Deductible Expense	1986	2006	1	-1.50	0	Annual Mgt. Fee
Ordinary Taxable Income	1986	2006	1	2.00	0	Hunting Lease Income
Capital Gains Harvest Revenues	2006	2006	1	3132.44	*	From Simulated Removals

* Inflation rate is computed as composite of specified sawtimber and pulpwood rates

Total Net Cash Flow= $2576.93 per acre Internal Rate of Return: Before Tax 9.2% After Tax 8.8%

---

1 Capital Expense Timber Depletion Account

the fuelwood alternative than with the leave-to-grow option. The fuelwood alternative also showed a $262/acre increase in net cash flow.

Figure 2 illustrates the value growth of the thinned stand over the entire 20-year projection period. The vertical scale is both basal area per acre and total stumpage value per acre. It is important to note that the thinning in the first year removed a proportionately greater basal area (and volume) than of value, but that subsequent value growth was at a greater rate than basal area growth. Stand value ended much higher than before thinning, although basal area (and volume) were lower. The rise in value is not only due to the earlier income from the thinning, but also to the growth of higher valued timber, as shown by the greater cash flow (undiscounted) generated by the thinning program.

Correct evaluation of this potential for value growth and benefit from improvement cuttings is very important in prescribing treatments. After a low thinning that removes defective, cull and low value species, one could expect a sharp increase in earning rate. However, it is possible that an excessively heavy thinning can reduce stocking so much that growth will be reduced, and stand quality might

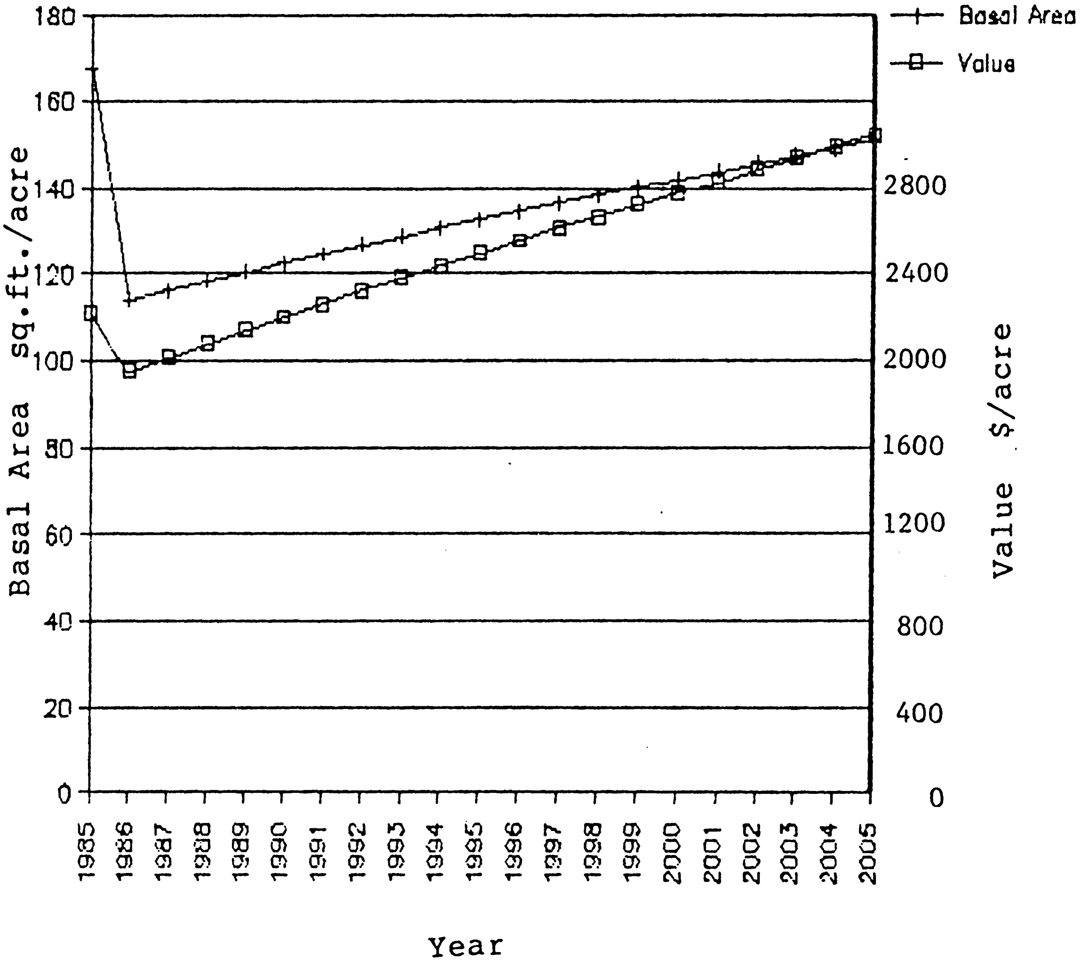

Figure 2.
Demonstration Trial: Value Growth of Thinned Hardwoods

suffer through an increase in epicormic branching.

5.1.1 Alternative Cutting Prescriptions

Following the guidelines described in section 4.2.3, a sequence of alternative cutting prescriptions removed additional trees to make the thinning more profitable and at the same time approach a desirable range of basal area. As shown in Table 13, application of these guidelines produced successively better results.

It is important to state that the intent of analyses 5.1 (Demonstration Trial) and 5.1.1 (Alternative Cutting Prescriptions) was to illustrate the procedures that would be used when following the decision tree. When evaluating the economic factors, absolute values are of little significance, but the comparative rate between trials is a true measure of the economic benefit of one trial as compared to a second trial under similar conditions. Management objectives, number and type of silvicultural practices, and other financial assumptions vary greatly among individual landowners. The decision tree approach, can help the landowner review from a financial viewpoint many silvicultural alternatives available.

Table 13.

Successive Mixed Hardwood Thinning Trials — Thinned at age 45, clearcut at age 65

Trial #	Basal Area Removed	Value Removed	NPV$ (after tax)	IRR%	Total Net Cash Flow	Description
1	0	0	553.95	8.8	2576.93	Stand projected with grade change.
2	0	0	530.33	8.7	2508.42	Stand projected without grade change.
3	28.3	91.94	693.84	10.1	2766.99	All pulpwood thinned except poplar & basswood
4	31.6	164.57	735.92	10.9	2766.07	Thinned same as #3, + low value grade 3 stoppers
5	38.4	231.31	778.31	11.8	2774.34	Thinned same as #4, + low value grade 3
6	56.55	351.90	872.89	14.3	2838.98	Thinned same as #5, low value grade 2 stoppers
7	56.55	403.84	904.01	15.9	2842.35	Thinned same as #6, removal of low value and slow growth species
8	60.32	464.41	931.77	18.6	2842.74	Thinned same as #7, removing more grade 3 & 2 with stoppers.
9	65.56	485.91	960.44	20.2	2864.78	Thinned same as #8, removing more 8" pulpwood from all species

It is important to understand that when using a computer simulation system many different management scenarios may be tested; however, in the field all scenarios may not be practiced. In the case of thinning, trees removed with the harvest simulator may not always be saleable or silviculturally removable in the actual stand, even though actual stand data is used. For example, it may not be silviculturally acceptable to remove all trees in the grade 2/stopper and 3/stopper class because of the actual spatial distribution in the stand. There are many factors and assumptions which affect financial analysis, and when used in proper context such computer analysis can be extremely beneficial. However, financial analysis that goes beyond the realistic limitations of the data, growth models and financial market conditions, can produce extremely unsatisfactory and illogical results. Assumptions should be checked with accepted theory and actual practice to assure that such deviations are avoided.

5.2 Percentage of Stand Basal Area Capable of Grade Increase (PBAGI)

The objective of this next research stage was to find measures of value growth potential for hardwood stands so that prescription decisions can be made without resorting (everytime a decision must be made) to such full projection runs as were illustrated here. In an effort to find such measures, several measures were formulated and tried in various simulation runs to test the sensitivity of value growth to variation over the possible range in the measures. The first stand used was the Wise 1 plot from the Jefferson National Forest, previously used in section 5.1.

One important aspect commonly associated with hardwood management is individual tree quality. Because of the extreme variation in prices between species and lumber grades, high financial returns can be expected from stands managed for higher valued species and improved tree quality. One measure to evaluate the potential of both economic and biologic stand conditions is the percentage of stand basal area capable of grade increase (PBAGI). Sensitivity tests were run with this measure using several sets of stumpage prices that vary in percent price differentials (PPD). A complete description of PPD calculations is given in Chapter 4.3.1 and 4.3.2.

PBAGI trials, which used Wise 1 data projected over 20 years, are given in Table 14. Several interesting trends are evident. As the PBAGI increases (read horizontally),

Table 14.

Wise 1

Percent of Stand Basal Area Capable of Grade Increase Simulation Results

20 year projection (Constant Base Value $2200/ac)

% Price Difference Between Grade	% of Stand Basal Capable of Grade Increase							
	25		40		55		70	
10	IRR[1]	1.70	IRR	1.8	IRR	1.8	IRR	2.1
	NPV[2]	-1052	NPV	-1037	NPV	-1033	NPV	-967
	TCF[3]	950	TCF	993	TCF	1004	TCF	1196
30	IRR	1.7	IRR	1.9	IRR	1.9	IRR	2.7
	NPV	-1057	NPV	-1012	NPV	-1000	NPV	-803
	TCF	935	TCF	1067	TCF	1101	TCF	1673
50	IRR	1.7	IRR	2.0	IRR	2.0	IRR	3.2
	NPV	-1060	NPV	-991	NPV	-972	NPV	-658
	TCF	927	TCF	1128	TCF	1183	TCF	2092
80	IRR	1.6	IRR	2.1	IRR	2.2	IRR	3.9
	NPV	-1067	NPV	-956	NPV	-927	NPV	-427
	TCF	905	TCF	1227	TCF	1314	TCF	2762

1 Internal Rate of Return (IRR)
2 Net Present Value (NPV) after-tax discount rate 5.0%
3 Total Cash Flow (TCF) expressed in dollars per acre

the various economic criteria (IRR, NPV, and TCF) also increase, and this is true for all levels of PPD. Figure 3 illustrates the IRR results for the various set of simulations. It would appear from this simulation that this stand must have over 55 percent PBAGI for an improvement cut to yield a significant increase in IRR.

The range of TCF per acre was extremely large depending upon the PBAGI; the greater the percentage, the higher the TCF. Figure 4 clearly shows the wide range of cash flows between the percentage groups.

In summary, as would be expected, the highest economic rate was earned where PBAGI was the highest.

5.2.1 Variations in Stumpage Price Differentials

The second measure used to evaluate both the economic and biologic stand conditions was percent price differential between log grades. PPD can have an effect on economic projections as shown by the results of Wise 1 and 1a simulation trials.

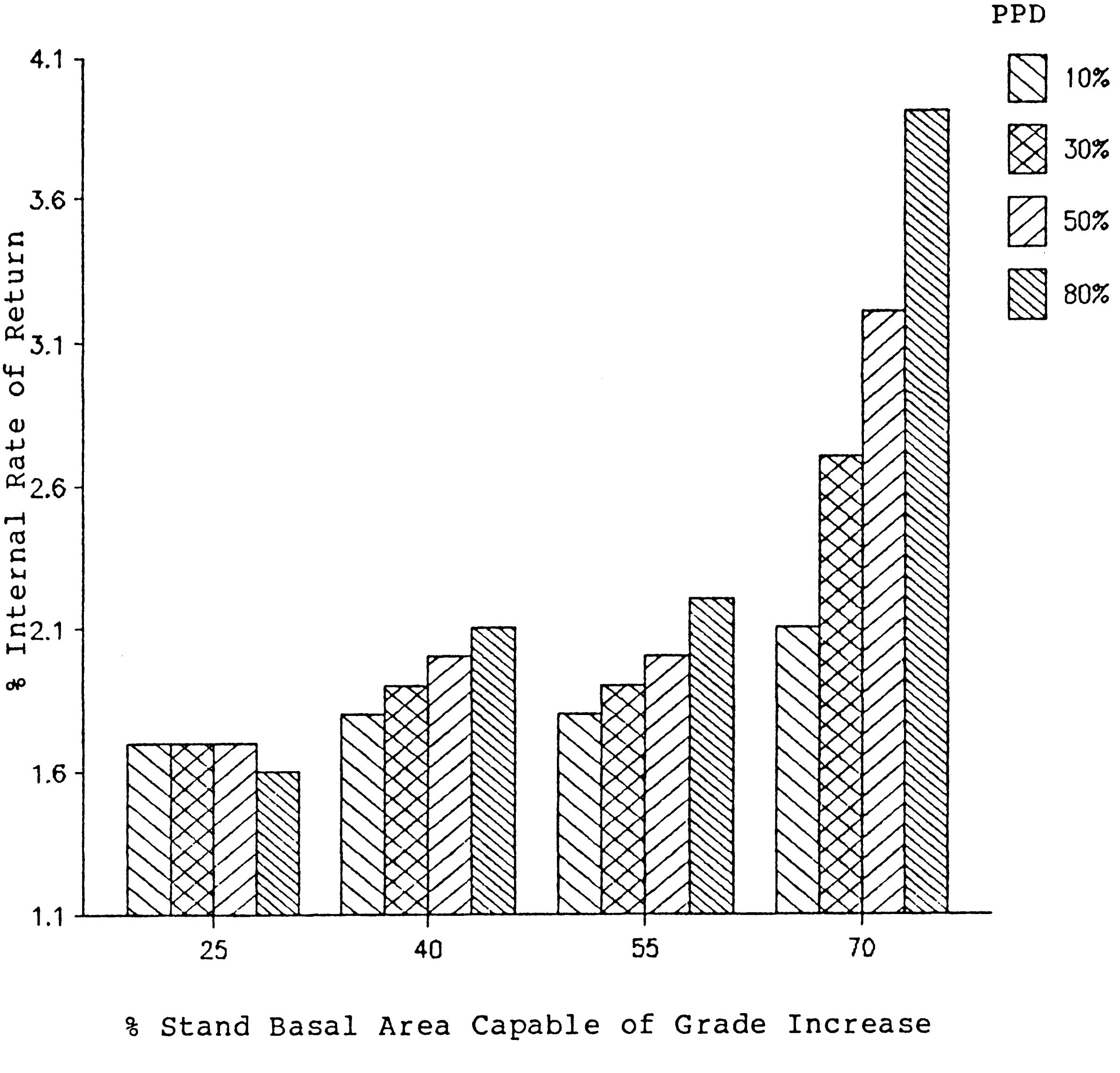

Figure 3.
Wise 1: Internal Rate of Return Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

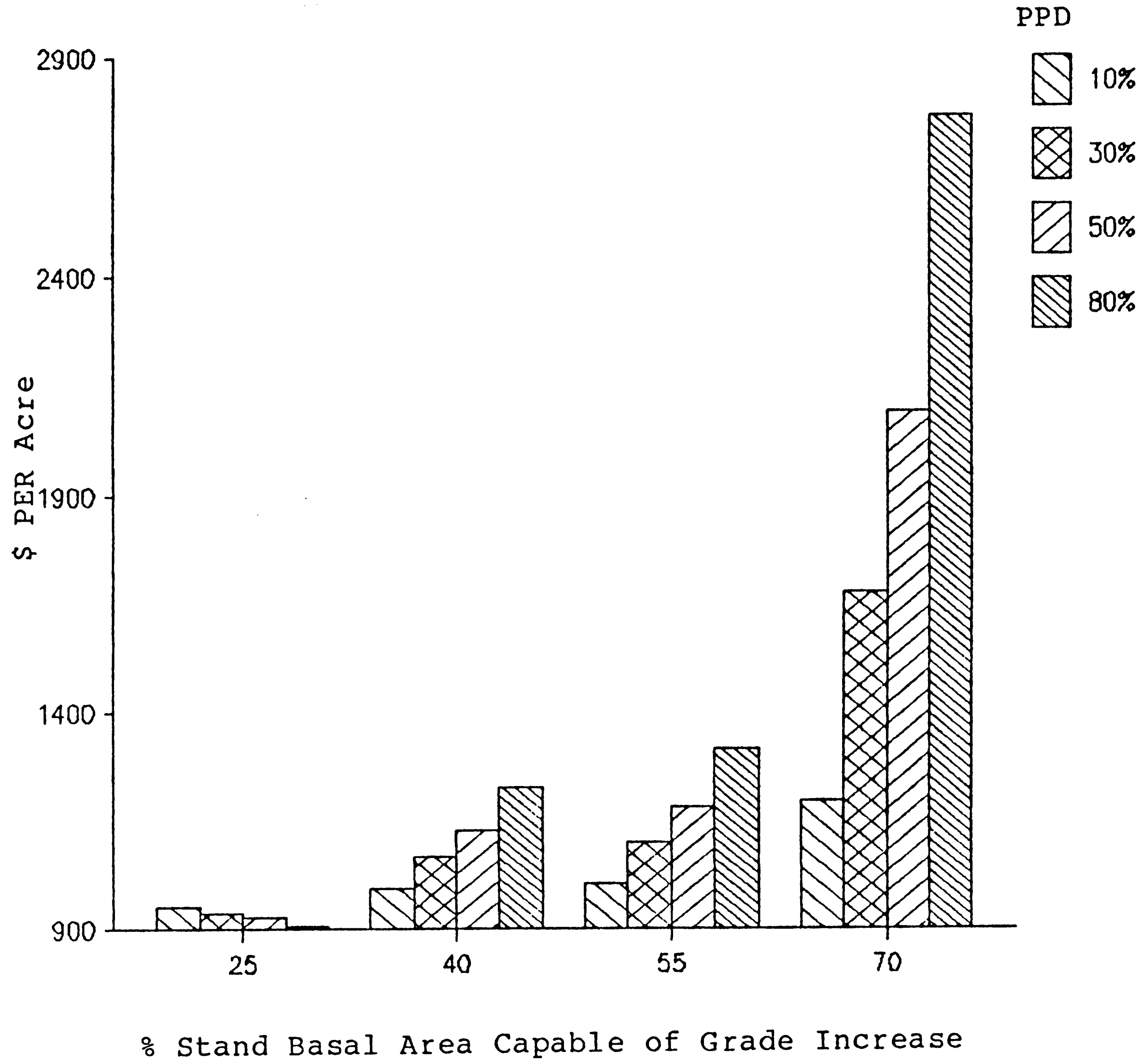

Figure 4.
Wise 1: Total Cash Flow Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

Wise 1:

The general results of the variations in stumpage price differentials between grade show that as PPD increases (read vertically) the various economic criteria improve in value (Table 14). This is true for all PBAGI trials tested except when 25 PBAGI, where no significant gain in IRR occurs, even with a very large price differential between grade.

The cause of a slight decline in the 25 percent case stems from the small number of trees capable of grade change. As compared to the other basal area situations (40, 55, and 70), this particular stand had the greatest number of trees, thus basal area, in the 2/stopper and 3/stopper grade classes. Therefore, even with the PPD increases between grades, few trees were valued at the higher prices listed for grades 1 and 2. The remaining trees in the lower grade classes did not have sufficient value growth to cause an increase in the various economic factors over the 20 year projection period. For the other stands, a greater number of trees were in those higher grade classes, therefore a higher economic and financial value resulted.

Wise 1a:

As described in the methods and procedures section, similar 20-year projections were run with the same 4 stands of various PBAGI; however, stumpage price ratios were changed and the initial basis in the accounts was adjusted for each run depending upon the new stumpage price values. These new stumpage ratios, between grades 1 and 2 as well as grades 2 and 3, were 10:10, 10:30, 10:50, and 10:80 using grade 2 as the basis from which other tree grade values were determined. The intent was to use more realistic price assumptions to better reflect actual market conditions.

As in the previous results, all economic factors increased as PBAGI increased (Table 15). Again, this seems a logical progression since a greater number of trees have a greater probability of high value obtained in grade classes 1 and 2 as PBAGI increased from 25 to 70 percent.

<u>IRR:</u> When PPD is considered, IRR increased for all situations except for the 25 percent PBAGI. Here, IRR remained constant until the 10:80 differential, and then only 1/10 of a percentage point was gained. Figure 5 illustrates the various IRR results.

<u>NPV:</u>

Table 15.

Wise 1a

Percent of Stand Basal Area Capable of Grade Increase Simulation Results
With Percent Price Differentials of 10:10, 10:30, 10:50, and 10:80
20 Year Projection

% Price Difference Between Grade	% of Stand Basal Capable of Grade Increase							
	25		40		55		70	
10:10	IRR[1]	1.6	IRR	1.7	IRR	1.7	IRR	1.8
	NPV[2]	-845	NPV	-817	NPV	-812	NPV	-813
	TCF[3]	890	TCF	943	TCF	954	TCF	1061
10:30	IRR	1.6	IRR	1.8	IRR	1.8	IRR	1.9
	NPV	-774	NPV	-714	NPV	-708	NPV	-738
	TCF	835	TCF	926	TCF	941	TCF	1109
10:50	IRR	1.6	IRR	1.9	IRR	1.9	IRR	2.0
	NPV	-704	NPV	-615	NPV	-607	NPV	-666
	TCF	783	TCF	909	TCF	927	TCF	1155
10:80	IRR	1.7	IRR	2.1	IRR	2.2	IRR	2.3
	NPV	-597	NPV	-464	NPV	-455	NPV	-558
	TCF	705	TCF	885	TCF	907	TCF	1223

1 Internal Rate of Return (IRR)
2 Net Present Value (NPV) after-tax discount rate 5.0%
3 Total Cash Flow (TCF) expressed in dollars per acre

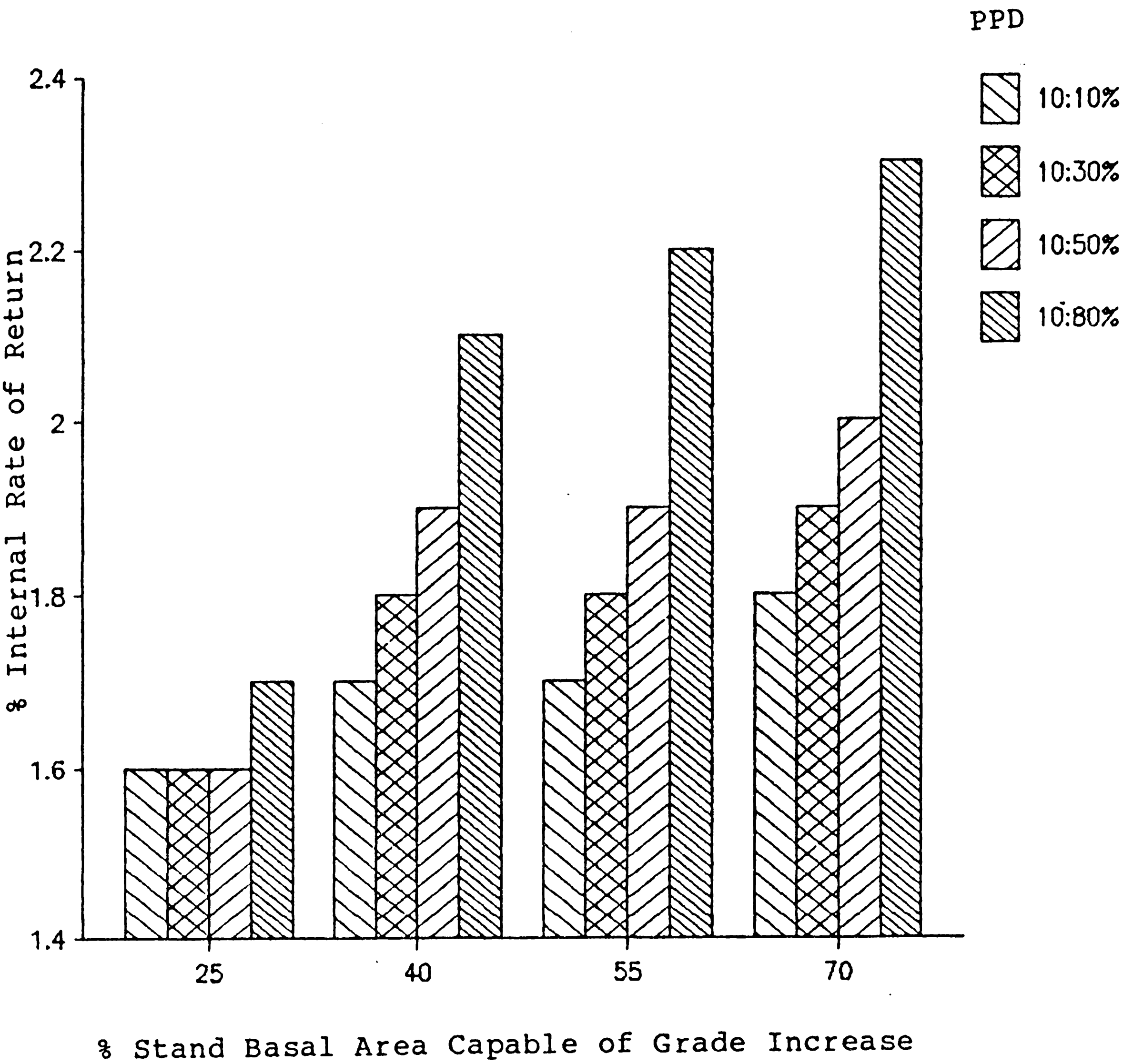

Figure 5.
Wise 1a: Internal Rate of Return Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

Looking at NPV for the entire group, NPV improves until 70 PBAGI. At 70 percent, NPV decreases in value. However, when PPD is considered as well as PBAGI NPV improves as the PPD gap widened between grades 2 and 3.

TCF (Total Cash Flow):

As compared to the previous TCF results where the cash flow increased for all PBAGI trials, here TCF (Figure 6) only showed increases with 70 PBAGI at the various prices used in simulation. This is expected as the value of grade 3 trees becomes successively lower.

In general, as the PPD between grades 2 and 3 increased as well as PBAGI, IRR and TCF increased. However, NPV decreased for all PPD at 70 PBAGI; otherwise NPV increased.

The greatest effect in using percent variations in stumpage values between grades 2 and 3 is evident in TCF results. The comprehensive totals are much lower as compared to the situation where constant price ratios are assumed. Changes in initial basis for each new set of prices also had some effect on the various economic factors. Both the change in stumpage prices and the basis influenced NPV calculations which is evident when 70 percent of the stand is capable of grade improvement. A new

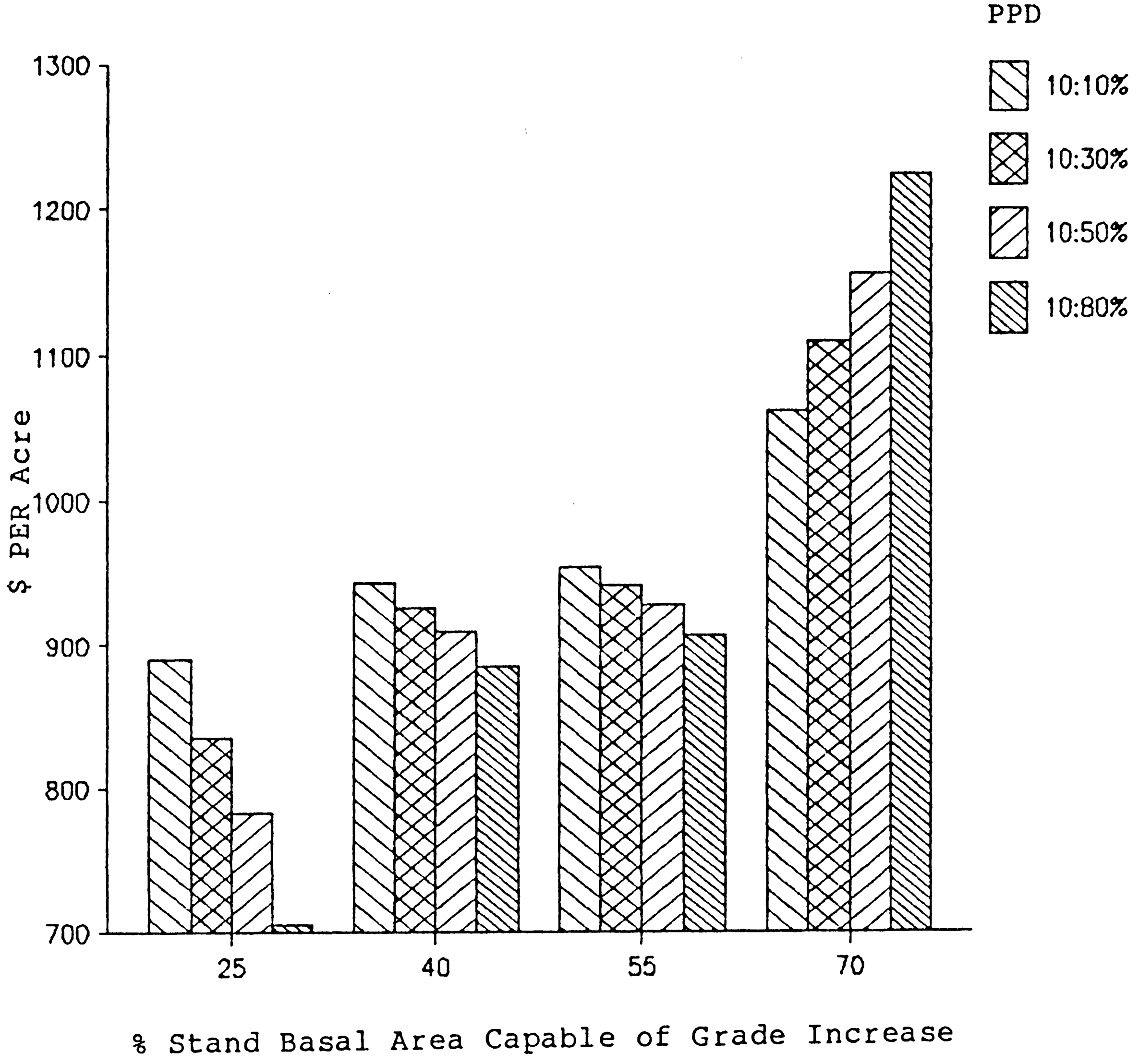

Figure 6.
Wise 1a: Total Cash Flow Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

set of stumpage price assumptions and base values are analyzed in the next section.

5.2.2 Results: 30 Percent Price Differential Between Grades 1 and 2 (Wise 1b)

Table 16 shows the economic criteria and results of the 20-year projection with separate sets of stumpage prices calculated from 30:10, 30:30, 30:50, and 30:80 percent price differentials between grades 1 & 2 and 2 & 3, respectively. The evaluation shows the trends for the various economic criteria to be identical to those of previous simulations. More specifically:

1) As PBAGI increase, values of economic criteria increase (Table 16)
2) As the PPD increases between grades 2 and 3, IRR increases for all cases (Figure 7).
3) As both PBAGI and PPD increase, NPV improves until the point where PBAGI is 70; there a decrease occurs.
4) TCF increased for all stand basal area percentages. However, as the PPD widens, TCF decreases until 70 PBAGI (Figure 8).

The major difference from the previous simulation was the

Table 16.

Wise 1b

Percent of Stand Basal Area Capable of Grade Increase Simulation Results
With Percent Price Differentials of 30:10, 30:30, 30:50, and 30:80
20 Year Projection

% Price Difference Between Grade	% of Stand Basal Capable of Grade Increase							
	25		40		55		70	
30:10	IRR[1]	1.6	IRR	1.8	IRR	1.8	IRR	2.1
	NPV[2]	-890	NPV	-824	NPV	-812	NPV	-788
	TCF[3]	963	TCF	1100	TCF	1130	TCF	1384
30:30	IRR	1.6	IRR	1.9	IRR	1.9	IRR	2.2
	NPV	-818	NPV	-724	NPV	-710	NPV	-714
	TCF	909	TCF	1081	TCF	1115	TCF	1431
30:50	IRR	1.6	IRR	2.0	IRR	2.1	IRR	2.3
	NPV	-748	NPV	-624	NPV	-609	NPV	-641
	TCF	857	TCF	1065	TCF	1101	TCF	1477
30:80	IRR	1.7	IRR	2.0	IRR	2.1	IRR	2.5
	NPV	-639	NPV	-474	NPV	-457	NPV	-531
	TCF	781	TCF	1039	TCF	1081	TCF	1548

1 Internal Rate of Return (IRR)
2 Net Present Value (NPV) after-tax discount rate 5.0%
3 Total Cash Flow expressed in dollars per acre.

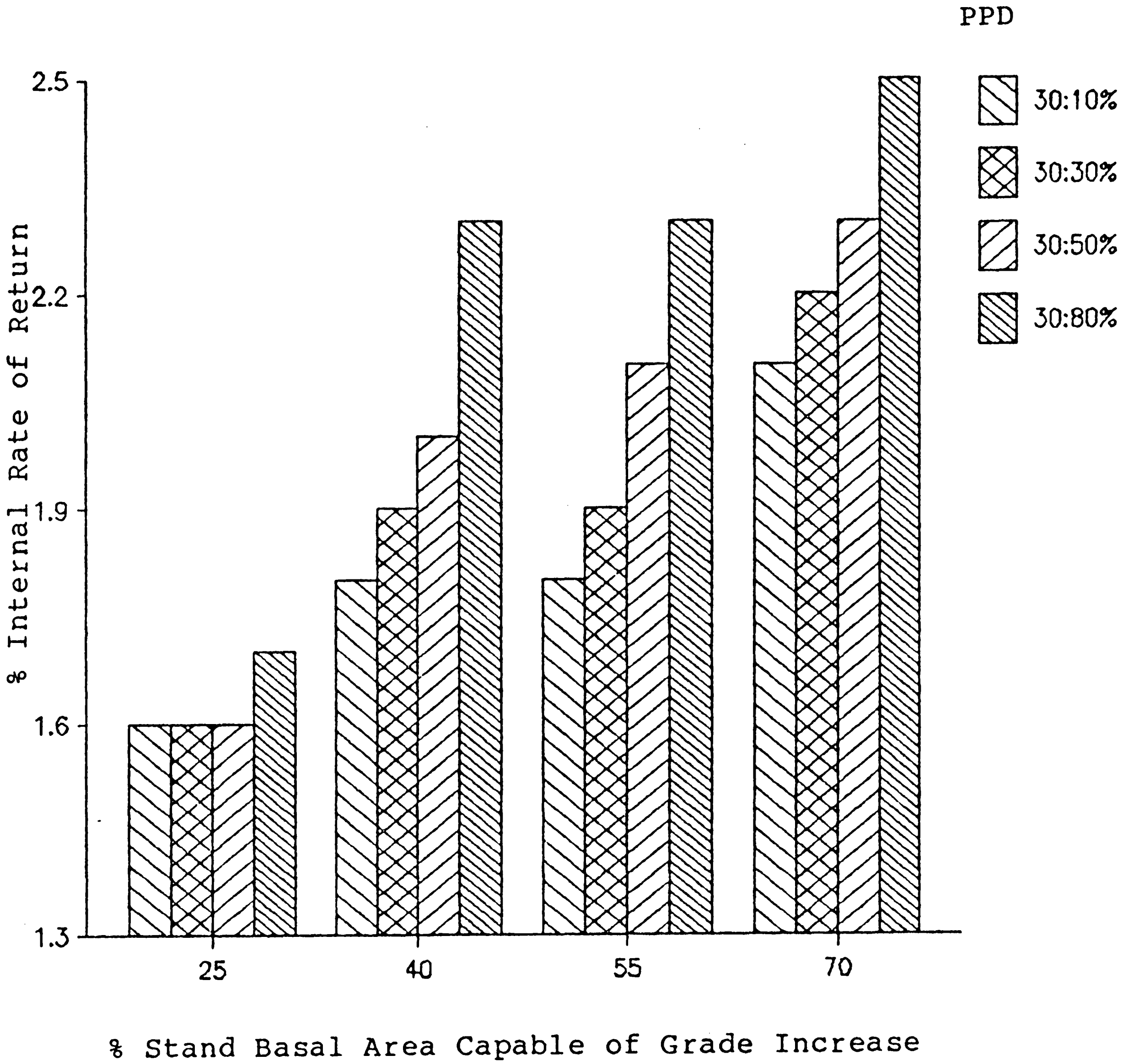

Figure 7.
Wise 1b: Internal Rate of Return Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

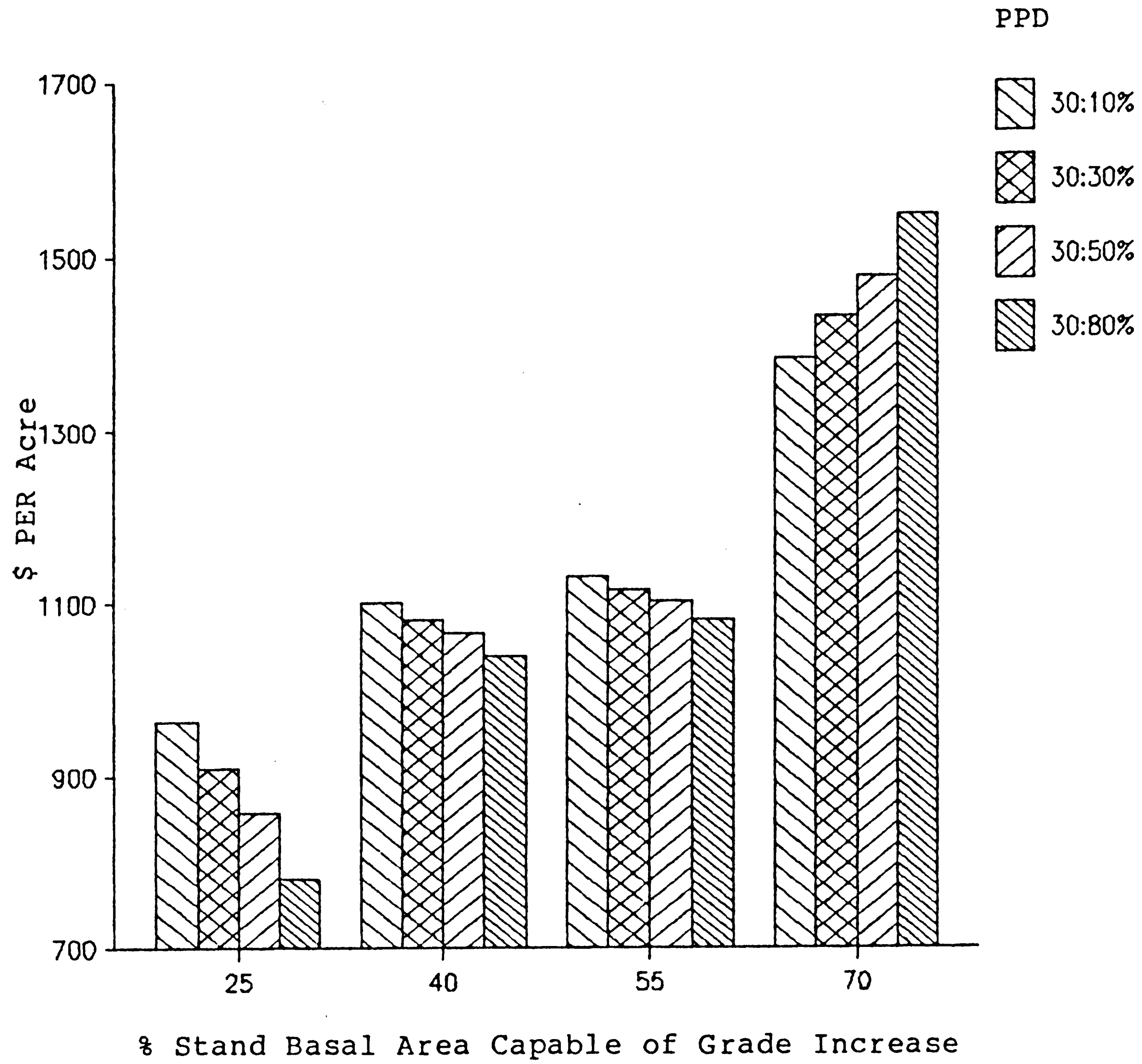

Figure 8.
Wise 1b: Total Cash Flow Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

actual values. The 30 percent PPD between grades 1 and 2 produced significantly higher values. This is logical, since it was the only factor modified in the second simulation. It operates through changing the timber basis. Here, the big increase in IRR comes between 25 and 40 percent PBAGI.

5.2.3 Variations in The Grade 2 Stumpage Price (Wise 1c)

The third test for sensitivity was to use the 10:30 PPD throughout the analysis but to vary the grade 2 base stumpage prices used in the previous analyses by -40, -20, +20, and +40 percent, from which all other grade stumpage prices change proportionately.

Table 17 shows the results after the various sets of 20 year projections.

IRR:

As PBAGI increased all economic factors increased, shown in Figure 9. Again, when both PBAGI and PPD are evaluated together, IRR tends to increase. However, no difference were found in IRR between the +40 and +20 percent change in each of the stands tested. Changes in IRR between

Table 17.

Wise 1c

Percent of Stand Basal Area Capable of Grade Increase Simulation Results Using the 10:30 Percent Price Differential With Variations in the Grade 2 Base Price 20 Year Projection

% Price Difference Between Grade	% of Stand Basal Capable of Grade Increase							
	25		40		55		70	
10:30 -40	IRR[1]	1.5	IRR	1.7	IRR	1.7	IRR	1.8
	NPV[2]	-486	NPV	-450	NPV	-446	NPV	-465
	TCF[3]	480	TCF	535	TCF	544	TCF	643
10:30 -20	IRR	1.6	IRR	1.7	IRR	1.8	IRR	1.9
	NPV	-629	NPV	-583	NPV	-577	NPV	-601
	TCF	658	TCF	728	TCF	742	TCF	872
10:30 +20	IRR	1.6	IRR	1.8	IRR	1.8	IRR	1.9
	NPV	-920	NPV	-847	NPV	-840	NPV	-886
	TCF	1010	TCF	1120	TCF	1138	TCF	1328
10:30 +40	IRR	1.6	IRR	1.8	IRR	1.8	IRR	1.9
	NPV	-1072	NPV	-987	NPV	-978	NPV	-1021
	TCF	1197	TCF	1326	TCF	1347	TCF	1579

1 Internal Rate of Return (IRR)
2 Net Present Value (NPV) after tax discount rate 5.0%
3 Total Cash Flow (TCF) expressed in dollars per acre

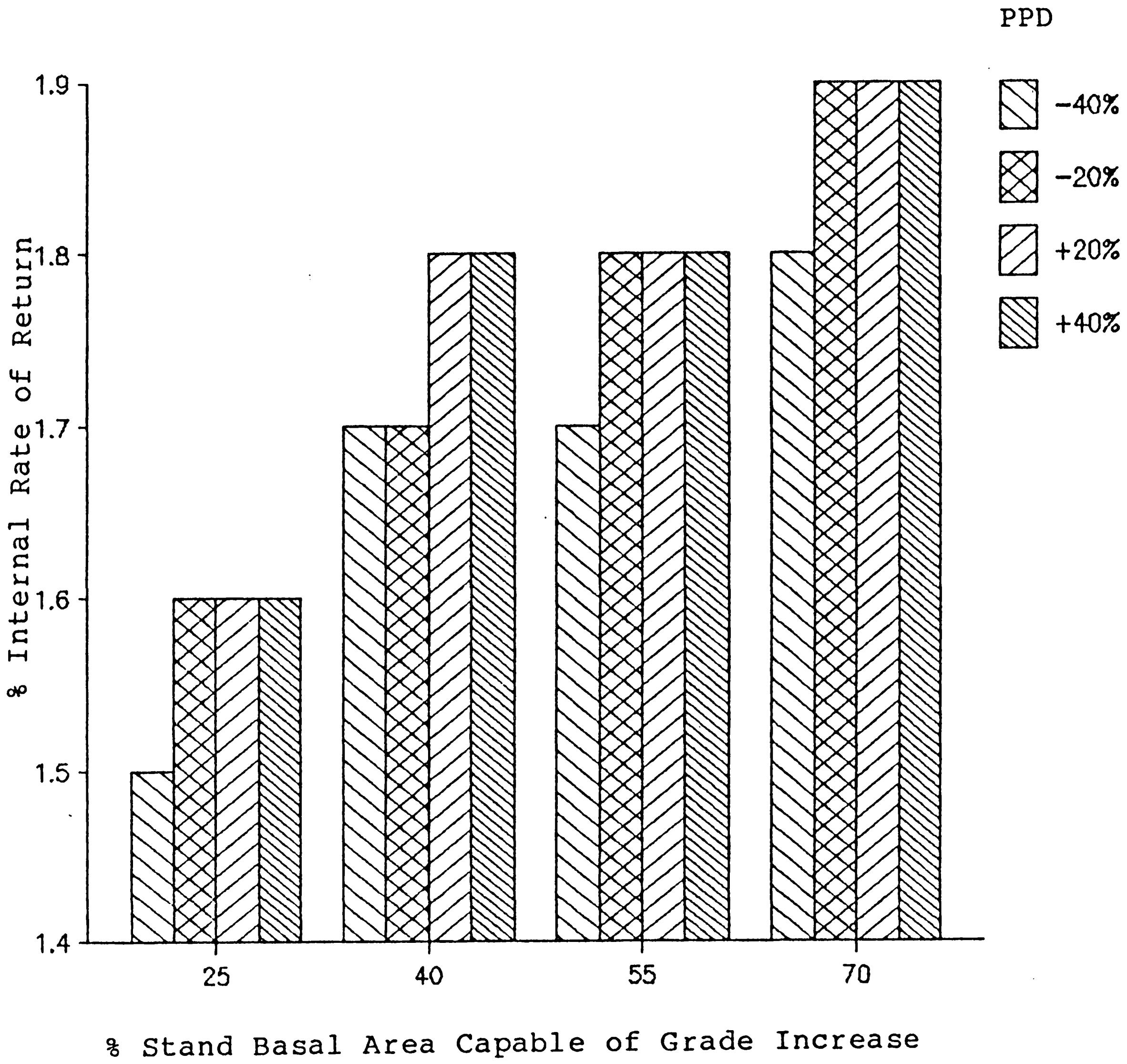

Figure 9.
Wise 1c: Internal Rate of Return Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

-40 and +40 percent difference over all PPD was generally insignificant.

NPV:

Similar to earlier simulations, NPV improves until the point where 70 PBAGI. As shown in Table 17, at 70 PBAGI, NPV drops. However, it is also interesting to note that as the grade 2 base price changed from -40 to +40 percent, NPV also decreased.

TCF (Total Cash Flow):

As shown in Figure 10, TCF increased not only as PBAGI increased but over the range of PPD as well. The lowest per acre dollar values were found on stands with small percentages of stand basal area capable of grade increase and where stumpage prices were cut by 40 percent. Likewise, the greatest cash flow per acre occurred on stands with large percentages of stand basal area capable of grade increase and where stumpage prices were increased by 40 percent.

The significance of the entire group of results (Wise 1, 1a, 1b, and 1c) is provided in Table 18. There is an indication that there may be a greater sensitivity to PBAGI, but that PPD may also be a useful measure. More extensive evaluation of the real range of each measure nor-

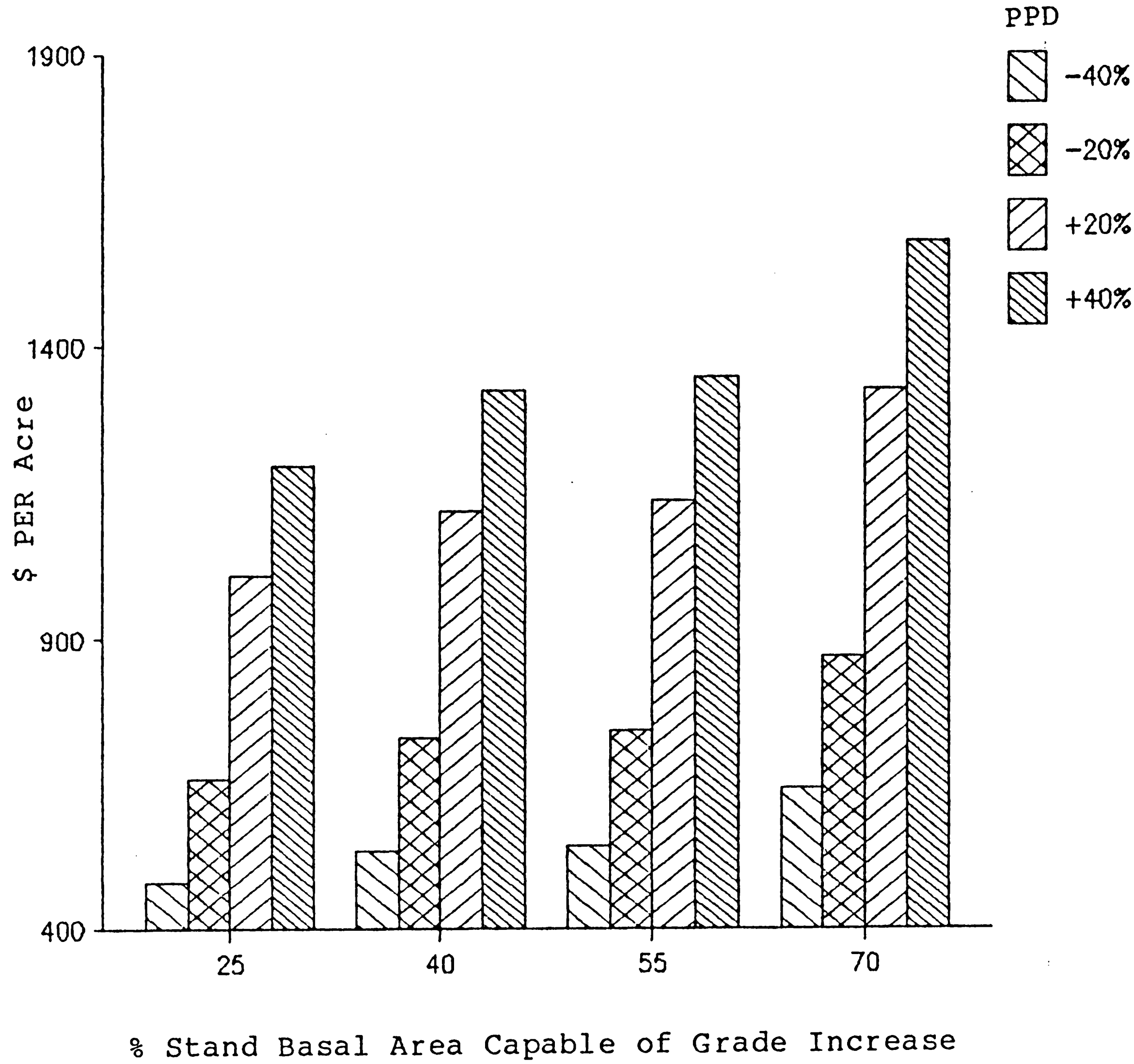

Figure 10.
Wise 1c: Total Cash Flow Simulation Results From 20-Year Cash Flows With Varying Grade Percentages and Percent Price Differentials Between Tree Grades (PPD)

Table 18.

Comprehensive Sensitivity Test Results of Both Percent of Stand Basal Area Capable of Grade Increase and Percent Price Differential Between Tree Grades

Trial	Maximum Increase in IRR w/ Change in PBAGI[1] (%)	Maximum Increase in IRR w/ Change in PPD[2] (%)
Wise 1	3.9 - 1.6 = 2.3	3.9 - 2.1 = 1.8
Wise 1a	2.3 - 1.7 = 0.6	2.3 - 1.8 = 0.5
Wise 1b	2.5 - 1.7 = 0.8	2.5 - 2.1 = 0.4
Wise 1c	1.9 - 1.8 = 0.1	1.9 - 1.6 = 0.3

1 Percent of Stand Basal Area Capable of Grade Increase (PBAGI)
2 Percent Price Differential Between Grades (PPD)

mally encountered in the Appalachian region may be needed to further verify these preliminary trends.

5.3 Ashville Analysis

Of the two Ashville stands (Ashville 1 and Ashville 2) reviewed, over 98 percent of the measured trees were in the sawtimber size class, 10 inches in diameter or greater. These stands had been previously thinned to remove smaller and poor quality trees. An intent in simulating value growth here was to understand of the importance of time in relation to various cash flow factors.

Table 19 shows the various financial results for Ashville 1. The results presented are on an after-tax condition. For the various economic evaluation criteria (IRR, NPV, and B/C), as the projection period increased the values decreased. Total net cash flow per acre, however, increased as the projection period lengthened. The negative sign associated with NPV results indicate that economic growth rate was less than the specified after-tax discount rate.

The results and trends of Ashville 2 given in Table 20

Table 19.

Ashville 1

A Comparison of Various Economic Criteria Over
A Range of Planning Periods

Years	Economic Factor			
	NPV[1]	IRR[2]	B/C[3]	TCF[4]
5	31	5.5	1.0	435
10	-94	4.2	0.9	727
15	-221	3.7	0.8	1040
20	-345	3.4	0.8	1368

1 Net Present Value (NPV) after-tax discount rate 5%
2 Internal Rate of Return (IRR)
3 Benefit-Cost Ratio (B/C)
4 Total Cash Flow (TCF) expressed as dollars per acre

Table 20.

Ashville 2

A Comparison of Various Economic Criteria Over a Range of Planning Periods

Years	Economic Factor			
	NPV[1]	IRR[2]	B/C[3]	TCF[4]
5	-73	3.4	0.9	184
10	-167	3.0	0.8	357
15	-270	2.7	0.7	514
20	-371	2.5	0.6	656

1 Net Present Value (NPV) after-tax discount rate 5%
2 Internal Rate of Return (IRR)
3 Benefit-Cost Ration (B/C)
4 Total Cash Flow (TCF) expressed in dollars per acre

are similar to those of Ashville 1. However, the actual value and change in the economic factor values are not as great, due to differences in tree species, diameter classes, and the number of trees in each grade class between Ashville 1 and Ashville 2. The actual growth rate of Ashville 2 was very similar to Ashville 1 even though it contained only two-thirds as many trees per acre. This was expected, since G-HAT is a distance independent model and there is no direct measure of inter-tree competition included.

The evident trend in both sawtimber size stands is that the sooner the stand is harvested the greater the financial gain. The indicated rate of return (IRR) would show that the stand should be held until it's rate drops below some indicated alternative. There it would be harvested, on purely economic grounds. However, other considerations (silvicultural etc...) may lead to holding it longer (or liquidating it sooner).

These two trials have illustrated that time is an extremely significant factor in determining economic gain. The sooner income is received, the greater the financial gain. Compared with the simulation results from 5.1, the time element in these is much more significant and important in obtaining high rates of return than potential grade change. Because thinning has removed most low grade and poorer trees in these stands, the rate of grade change and growth was not great enough to offset the influence of time. However, when comparing 2 or more projects for the purpose of implementation, the projects need to have the same project life and investment costs. It is the difference in cash flows which leads to differences in IRR. In the case with hardwood management, many silvicultural alternatives involve a different set of associated costs and project lengths. Therefore, to use the approach that is described here, attention between comparisons must be focused on project length, timing of cash flows and size of investment costs.

To make a unbiased comparison, alternatives that have a wide range of cash flows and project lengths need to be normalized to a common basis. The normalization process to allow for a fair analysis may involve adjusting all projects to the lifetime of the longest projection period, and making several assumptions as to how cash flow revenues are reinvested with considerations for various inflation rates. According to Davis et.al. (1987), reinvestment opportunities at the project earning rate is the implied assumption made whenever projects of different lengths are compared by the unnormalized project earning rates. As a result, comparisons on the basis of project earning rates tend to be misleading when differences in project lengths are substantial. The guiding rate is often the best assumption for reinvestment considerations. Therefore, it is important that when considering various long term hardwood management alternatives from a financial perspective and developing a comparative analysis, normalization of assumptions is necessary.

5.4 Discussion

The broad objective of this entire study was to provide landowners and managers a means of locating hardwood stands with the economic feasibility of management through intermediate cutting. The approach presented in this research project was intended to simulate possible methods and alternatives which individual landowners could easily apply to their own forest properties. At the sametime, we tried to go beyond the broad objective and set the basis for further more specific research in regards to evaluating economic feasibility of growing and managing hardwood stands. Because of the importance of individual tree quality as a basis for hardwood stand management, we approached the situation by considering individual tree value in each step of the corresponding economic analysis.

By introducing the decision tree, additions to tree grade interpretation and delineation of stands as to their percent capability of basal area to increase in grade, a computer growth and yield simulator like YIELD-MS can make possible an economic analysis of hardwood stand silvicultural alternatives. Because of the limited economic and financial analyses available, many individual landowners tend to refrain from intensive hardwood management. With guidelines or examples of how such analyses can be efficiently and effectively developed, many so called "non-intensive" landowners may take more interest in managing their hardwood lands.

As for the results presented, the importance is not in the actual figures but a comparison between the results of several sensitivity or simulation tests. Because there are many factors which affect final economic results, it is important to understand the effect of each factor involved. For example, based on our set of transactions used throughout the analysis, the most important factor affecting the economic results was the initial base value carried in the accounts representing starting investment. The value of this initial basis could determine whether or not the final economic results were either favorable or negligible; the lower the basis, the greater the economic return.

For our analysis, it was assumed that the basis included only the value of the timber and not the land. This is the viewpoint of the manager who does not consider the sale of the land an option. In other words, he has decided to continue timber growing, he only wishes to determine the most profitable method to do it. The uncertainty of how to determine basis valuation complicates financial analyses, and often logical assumptions must be made as to the method for basis calculation. It is also possible that more financial transactions generating positive cash flows from possible management practices throughout the projected time frame may offset the influence of the initial basis value.

The introduction of cash incomes throughout the projection may also cause possible problems depending upon which economic value is used as the base value for analysis. With several cash incomes injected into the analysis, multiple solutions are possible with IRR. However, no estimates of before and after tax discount rates are necessary for IRR calculations. When using NPV, difficulties arise as to the appropriate discount rate to use throughout the projection period. A 4 percent after-tax discount rate may be acceptable today, but how about in 20 years? The intent of such economic analysis is to project possible financial scenarios and results. This is the advantage of a computer simulation package such as YIELD-MS; it allows the operator to review financial results under different assumptions and market conditions. Over 20 years, the projection period used for our analysis, many important factors can change such as market prices and actual stand conditions. The procedures and methods used in this research project allow landowners to continually review the financial condition of their investment.

Introduction of the concept, percent of stand basal area capable of grade increase (PBAGI) allow landowners to gain a simple perspective on potential stand value and possible management alternatives. This idea, when used in conjunction with various stumpage price differentials (PPD), may be a practical way to categorize hardwood stand value potential. By gaining a better understanding or determining the actual financial and economic importance of individual tree grade change over a projection period as compared to other factors such as time, advances can be made as to the type of stand conditions suitable for quality management.

Based on the results of this analysis, the most important factor affecting economic analysis after a projection period is time before any significant income increase is received. The earlier income is obtained in a projection period, the better the economic condition. In some hardwood stands, the impact of tree grade does not seem to be a highly significant in economic analysis. Although, total net cash flows are greater, IRR and NPV are not significantly affected by potential grade increase. This seems to down play all the emphasis of the importance of grade change potential and time in relation to growth rate for greater economic gain. Again under different stand conditions, tax and discount rates, individual tree grade potentials may be a more significant element in financial calculations. Much more testing is needed over a wide range of conditions.

The type of economic approach used here is on the forefront of hardwood management financial feasibility research because it depends so heavily on the projections from individual tree growth and yield models. The lack of these models in the past has resulted in limited economic analysis of these hardwood resourses. Recent developments of such growth and yield models allows increased financial evaluation of many hardwood stands throughout the eastern U.S..

However, limitations of many of these models as to where and under what conditions they can be applied will remain a problem for economic analysis. For example, G-HAT (Harrison _et al_., 1986) is the only model developed specifically for the Appalachians. However, it is only applicable to those stands that have been thinned recently.

Other factors such as methods for determining stumpage price, probabilities of trees increasing in grade, and initial timber basis calculation are not well documented in the literature and are limitations of the economic analysis used in this study. However, such analysis is desperately needed and can be used as one of several elements in the decision making process. Research approaches like the one presented here identifies the current limitations in actual knowledge of many hardwood stand management practices and suggests opportunities for new research in areas which can strengthen economic evaluations.

In today's society, economic considerations are an extremely important factor in the decision making process. Often in forestry, silvicultural considerations are slighted when considered in financial evaluations. It may be possible that with better economic analysis of hardwood stands, wiser silvicultural decisions may be implemented.

The opportunities for further research identified through the development of this research project are many and varied. These include:

1) Better information and methodology for stumpage price determination to reflect local markets and logging and milling costs.
2) Probabilities of individual trees improving in grade as they grow into larger diameter classes, based on species, and site conditions.
3) Consistent methods for determining initial timber value basis.
4) Further development of growth and yield models for mixed hardwood stands for the Appalachian region especially in unthinned stands.
5) Economic analysis of many silvicultural practices including thinning operations, regeneration operations, and harvest methods.

Hopefully, this research project will stimulate further interest in economic analysis of hardwood stands.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Complete economic analysis of hardwood stands for high quality holds great promise in evaluation of many financial and silvicultural management alternatives. This study described an approach to economic analysis as well as explored several means of describing value growth potential of hardwood stands. What has evolved is a greater understanding of the complex set of factors which must be considered when evaluating hardwood stands for possible management. Many of these factors are highly inter-related, complicating efforts to develop specific guidelines for all hardwood stands.

The results of this study lead to some interesting conclusions relevant to the studies of Appalachian hardwoods and to hardwood management in general. The following is a summary of conclusions concerning the suitability of the approach and methods used in evaluating the economic feasibility of hardwood management alternatives.

1) It is now possible to economically evaluate various silvicultural treatments and harvest intensities at the stand level constrained by available growth and

yield models.

2) The decision tree can help landowners review possible stand treatments adapted to their local markets.

3) Tree quality information, including a record of trees not capable of grade improvement, can provide a more precise estimate of potential stand value.

4) The project has provided a better understanding of some of the factors which are sensitive to value growth potential and may provide needed parameters for economic analysis of hardwood stands. Percent stand basal area capable of grade change and percent price differential between grades are two such parameters which are sensitive in portraying a wide range of growth potentials.

5) Hardwood management for high quality can be economically desirable in certain locations, which can be selected by careful analysis.

The approach presented in this research project was intended to examine possible methods and alternatives to be used in further more specific research to evaluating economic feasibility and managing hardwood stands. Each of the economic factors evaluated deserves further study, especially in the context of Appalachian hardwood management. As this approach is further refined and applied to a larger range of conditions, these findings can be incorporated in the development of hardwood stand management guidelines for the individual landowner.

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Appendix 1.

INDIVIDUAL TREE GROWTH AND YIELD MODEL APPLICATIONS AND SPECIFIC USE CONDITIONS AS INCORPORATED INTO YIELD-MS

TWIGS:

* Developed primarily for the Central States region
* All major species occurring in the Central States
* Trees 2.0 dbh and greater
* 30-year projection

OAKSIM:

* Even-age upland oak stands with at least a 75 % oak component
* Stand age from 30 to 120 years
* Black oak site index 50 to 85
* Percent stocking 20 to 120 percent
* Trees 2.6 dbh and greater
* 50-year projection

G-HAT:

* Even-age Appalachian mixed hardwood stands
* No single species constitute more than 60% total basal area
* Stand age 19 to 63 years

* White oak site index 62 to 96
* Projections should occur immediately after thinning
* Not for stands thinned from above more than once or high graded.
* 10-year projection

<u>SILVAH:</u>

* Developed for cherry-maple, beech-birch-maple, and oak-hickory forests of the Allegheny Mountains
* Best suited for intermediate, even-age stands
* 30-year projection

Appendix 2. Decision Tree Methodology Simulation
Stumpage Price Determination

Group 1 Average Prices of Lumber by Grade per Thousand Board Feet

FAS	1F	1C	2C	3A&B
680	670	523	240	205

Tree Grade 1: 2.5 logs Northern Red Oak 16 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	13.6	.68	9.25
IF	16.5	.67	11.06
SEL	6.2	.67	4.15
1C	43.6	.52	22.67
2C	88.5	.24	21.24
3A&B	42.1	.21	8.85
TOTALS	210.5		77.22

Value per thousand = \$77.22 / 210.50 bdft * 1000
= \$366.79/mbf

Stumpage Price = \$366.79 - \$170.00
= \$196.79/mbf

where \$170.00 = region average logging and milling costs

Tree Grade 2: 2.0 logs Northern Red Oak 14 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	1.3	.68	.88
IF	17.0	.67	11.39
SEL	3.7	.67	2.48
1C	24.3	.52	12.64
2C	46.5	.24	11.10
3A&B	38.0	.21	7.83
TOTALS	130.8		46.32

Value per thousand = \$46.32 / 130.00 bdft * 1000
= \$356.50/mbf

Stumpage Price = \$356.50 - \$170.00

= $186.50/mbf

where $170.00 = region average logging and milling costs

Tree Grade 3: 2.0 logs Northern Red Oak 12 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	-	-	-
IF	1.5	.67	1.01
SEL	2.0	.67	1.34
1C	6.8	.52	3.54
2C	18.8	.24	4.51
3A&B	67.1	.21	14.09
TOTALS	96.2		24.49

Value per thousand = $24.49 / 96.20 bdft * 1000
= $254.51/mbf

Stumpage Price = $254.51 - $170.00
= $84.51/mbf

where $170.00 = region average logging and milling costs

GROUP 2 Stumpage Prices Based Stand Presented in Table 2.

Grade	Value per mbf
1	135.41
2	96.40
3	71.79
2/stop	96.40
3/stop	71.79

Pulpwood 6.00/cord

GROUP 3 Stumpage Prices Based Stand Presented in Table 2.

Grade	Value per mbf
1	77.53
2	64.09
3	44.51
2/stop	64.09
3/stop	44.51

Pulpwood 6.00/cord

Appendix 3.
Percentage of Stand Basal Area Capable of Grade Increase
Stumpage Price Determination
Set II

Group 1 Average Prices of Lumber by Grade per Thousand Board Feet

FAS	1F	1C	2C	3A&B
658	648	448	210	195

Tree Grade 1: 2.5 logs Northern Red Oak 18 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	36.8	.658	24.10
IF	26.1	.648	16.90
SEL	7.8	.648	5.06
1C	68.7	.548	30.74
2C	93.1	.218	20.24
3A&B	46.5	.195	9.07
TOTALS	279.0		106.21

Value per thousand = $106.211 / 279.00 bdft * 1000
= $380.68/mbf

Stumpage Price = $380.68 - $170.00
= $210.68/mbf

where $170.00 = region average logging and milling costs

Tree Grade 2: 2.0 logs Northern Red Oak 14 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	1.3	.658	.86
IF	17.0	.648	11.02
SEL	3.7	.648	2.40
1C	24.0	.448	10.89
2C	46.0	.210	9.75
3A&B	38.0	.195	7.41
TOTALS	130.0		42.33

Value per thousand = $42.33 / 130.00 bdft * 1000
= $323.62/mbf

Stumpage Price = $323.62 - $170.00
= $153.62/mbf

where $170.00 = region average logging and milling costs

Tree Grade 3: 2.0 logs Northern Red Oak 12 inch diameter

LUMBER GRADE	BDFT	PRICE	VALUE
FAS	-	-	-
IF	.5	.648	.32
SEL	2.0	.648	1.30
1C	1.8	.448	.80
2C	13.5	.210	2.84
3A&B	63.3	.195	12.34
TOTALS	81.1		17.60

Value per thousand = $17.60 / 81.10 bdft * 1000
= $217.07/mbf

Stumpage Price = $217.07 - $170.00
= $47.07/mbf

where $170.00 = region average logging and milling costs

GROUP 2 Stumpage Prices Based Stand Presented in Table 2.

Grade	Value per mbf
1	133.24
2	95.25
3	59.61
2/stop	95.25
3/stop	59.61

Pulpwood 6.00/cord

GROUP 3 Stumpage Prices Based Stand Presented in Table 2.

Grade	Value per mbf
1	98.12
2	78.32
3	41.84
2/stop	78.32
3/stop	41.84

Pulpwood 6.00/cord

Appendix 4.

Wise 70

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	Grade	Two Inch Diameter Class .2	4	6	8	10	12	14	16	18	20	22	24
Oak[1]	1								5				
	2							5					
	3					5	10						
	2/stop												
	3/stop												
	pulp												
Bass/Pop/Maple[2]	1								10	10		5	
	2							35					
	3					5							
	2/stop												
	3/stop												
	pulp		60	30	30	10	5						
Hic/Cuc/Mag[3]	1												
	2							5					
	3					20		10					
	2/stop												
	3/stop												
	pulp			5	10								
Totals			60	35	40	40	25	45	15	10	0	5	== 275

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

Appendix 5.

55 Percent of Stand Basal Area Capable of Grade Increase
(Wise 55)

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	.Grade	.2	4	6	8	10	12	14	16	18	20	22	24
		Two Inch Diameter Class											
Oak[1]	1												
	2												
	3					5	10	5					
	2/stop												
	3/stop								5				
	pulp												
Bass/Pop/Maple[2]	1								5	10		5	
	2							20					
	3					5		5					
	2/stop							5	5				
	3/stop							5					
	pulp		60	30	30	10	5						
Hic/Cuc/Mag[3]	1												
	2												
	3					15	5						
	2/stop												
	3/stop					5	5	5					
	pulp			5	10								
Totals			60	35	40	40	25	45	15	10	0	5	-- 275

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

Appendix 6.

25 Percent of Stand Basal Area Capable of Grade Increase
(Wise 25)

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	Grade	.2	4	6	8	10	12	14	16	18	20	22	24
					Two Inch Diameter Class								
Oak[1]	1												
	2												
	3					2							
	2/stop							5					
	3/stop					3	10		5				
	pulp												
Bass/Pop/Maple[2]	1								5	10		5	
	2							2					
	3					2							
	2/stop							23	5				
	3/stop					3		10					
	pulp		60	30	30	10	5						
Hic/Cuc/Mag[3]	1												
	2												
	3					2							
	2/stop												
	3/stop					18	10	5					
	pulp			5	10								
Totals			60	35	40	40	25	45	15	10	0	5	-- 275

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

Appendix 7.

Ashville 1

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	Grade	Two Inch Diameter Class .2	4	6	8	10	12	14	16	18	20	22	24
Oak[1]	1								5	5		5	
	2							5					
	3						5						
	2/stop								5	5			
	3/stop					5		5		5			
	pulp				5								
Bass/Pop/Maple[2]	1												
	2												
	3							5					
	2/stop								5				
	3/stop												
	pulp												
Hic/Cuc/Mag[3]	1												
	2												
	3												
	2/stop												
	3/stop												
	pulp												
Totals			0	0	5	5	5	15	15	15	0	5	== 65

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

Appendix 8.

Ashville 2

Stand Composition: Number of Trees in Individual Diameter Class and Tree Grade

Initial Basal Area: 167 sqft

Species Group	Grade	Two Inch Diameter Class											
		2	4	6	8	10	12	14	16	18	20	22	24
Oak[1]	1												
	2												
	3					15	25						
	2/stop							5		5			
	3/stop						5	15		5			
	pulp				5								
Bass/Pop/Maple[2]	1								5				
	2												
	3												
	2/stop												
	3/stop												
	pulp				5								
Hic/Cuc/Mag[3]	1												
	2												
	3												
	2/stop												
	3/stop						5						
	pulp												
Totals			0	0	10	15	35	20	5	10	0	0	-- 95

1 Oak = red oak, white ash

2 Bass/Pop/Maple = yellow-poplar, basswood, red maple, sugar maple, yellow birch

3 Hic/Cuc/Mag = hickory, cucumber, magnolia

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