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ECONOMIC ANALYSIS OF TREE IMPROVEMENT RESEARCH IN MICHIGAN

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ECONOMIC ANALYSIS OF
TREE IMPROVEMENT RESEARCH
IN MICHIGAN

By

Burton E. Levenson

A DISSERTATION

Submitted to
Michigan State University
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ABSTRACT

ECONOMIC ANALYSIS OF
TREE IMPROVEMENT RESEARCH
IN MICHIGAN

By

Burton E. Levenson

This dissertation describes and estimates the economic value of tree improvement research in Michigan. A classification of research products is constructed and applied to the forest products industry. Research activities are divided into three classes, primary, intermediate, and final research products. Only final research products are considered for economic valuation in this dissertation.

The approach most appropriate to determine the economic worth of tree improvement research is calculation of net present value. Key factors which influence the value of tree improvement research are: the interest rate used in discounting; the degree to which the industry adopts use of genetically improved trees or how many trees are planted; the price of the forest product when sold at harvest; and, the genetic gain or percent improvement over the "wild population" resulting from tree improvement research. The use of two valuation methods are employed to calculate net present value, discounting time, and discounting quantity or price.

The results of the analysis indicate that primary benefits of research realized by the forest products industry may range from \$52 million to \$25 billion. A realistic estimate for the value of tree improvement research in Michigan is \$262 million. Economic value of research using case studies representative of three forest product industry sectors were estimated. A typical pulp and paper company may derive a benefit of

$1 million per mill from tree improvement research in Michigan. The State of Michigan public forestry program through the Department of Natural Resources may receive direct benefits from tree improvement research in excess of $5.5 million. A large Christmas tree farm in Michigan may derive a benefit of $895 thousand from tree improvement research.

Surrounding states may receive direct benefits at least equal to those in Michigan due to the large number of seedlings exported by the Michigan nursery industry. Indirect and secondary benefits are not empirically calculated in the analysis, but appear to be large. Total costs of the research program when compared to the benefits are relatively insignificant.

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Lee James provided valuable insights about the broader implications of my work. Paul Rubin challenged me to be exact and helped in the mathematical aspects. He also painstakingly read the drafts of this dissertation and provided detailed comments and criticisms which resulted in significant improvement, both in the style and substance of the final version. John Gunter provided valuable advise and insights on the forest products industry. Mel Koelling and Jonathan Wright were particularly helpful and a source of valuable information.

My research could not have been completed without the cooperation and assistance of many people in the forest products industry. I thank all those who helped. I am primarily indebted to the United States Forest Service which provided partial funding to sponser the research.

My fellow graduate researchers, Mike Morris, Art Gold, and the MICHCOTIP Lab were generous with their time and offered continual encouragement. I am especially thankful to Mike and Julie Gold for all their assistance and support.

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INTRODUCTION

The General Economic Problem

Calculating the economic return attributable to research is a problem in many scientific fields. In the field of forestry, this problem is particularly acute. Tree improvement research and development activities provide a potentially interesting case study. these activities are conducted under the assumption that the forest products industry and, ultimately, society will benefit. Research on tree improvement contributes to productivity in several ways: it increases the amount of raw material available, reduces the cost of obtaining the raw material, and improves the quality of the raw material. All three lead to increases in the total productivity of the forest products industry.

If unlimited resources existed to conduct tree improvement research, all possible areas of potential productivity increase could be investigated at once. This is not the case. Resources available to conduct research programs are limited and decisions must be made as to which programs to fund. In the world of applied research, funding sources demand documentation of the expected returns from a research program. To justify the research, we must calculate the worth of the research investment and show the contributions the research makes to science.

The Problem: Michigan Tree Improvement Research

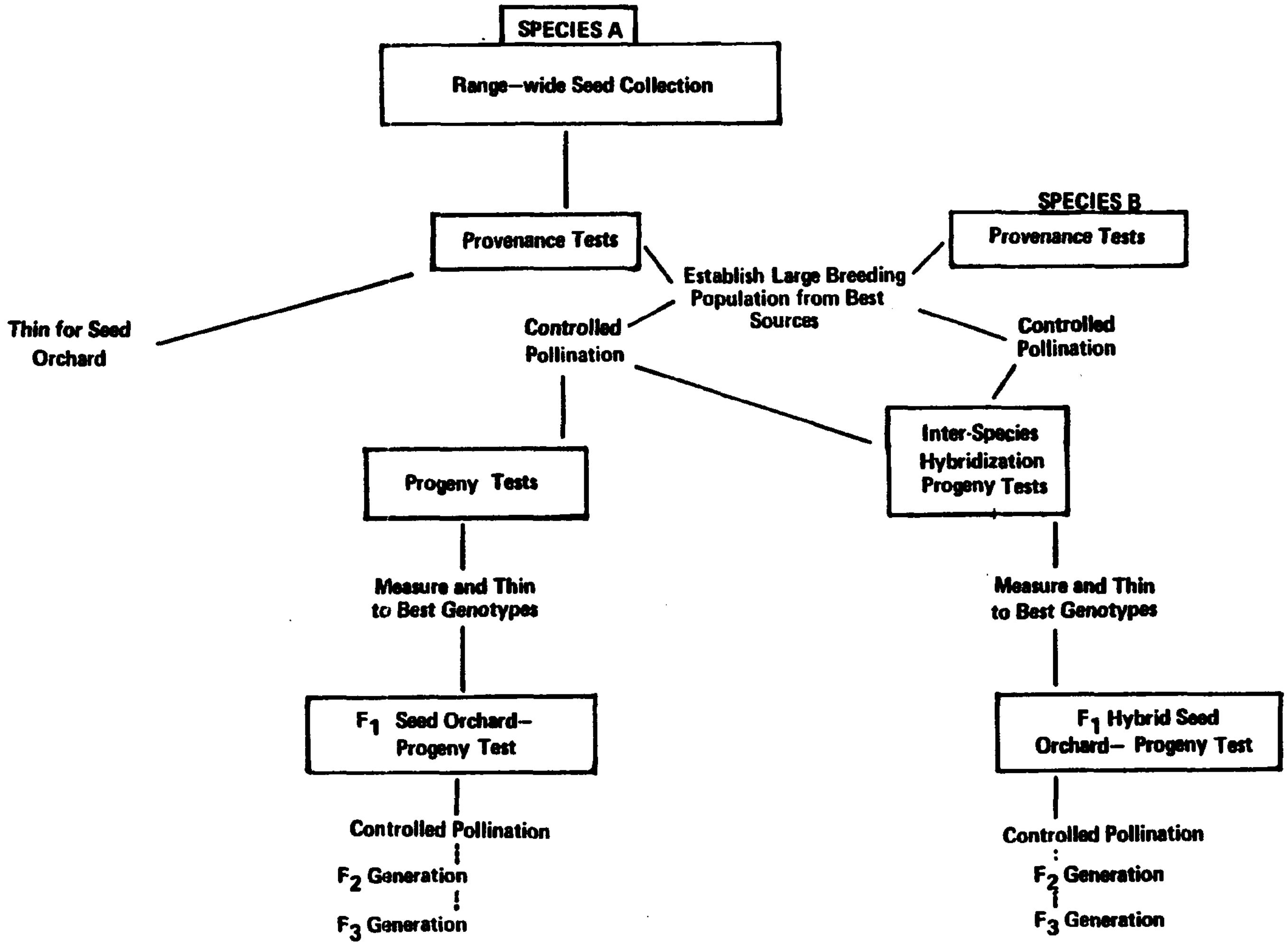
Michigan State University has been a focal point for tree improvement research conducted in Michigan since 1960. Almost 400 forest genetic plantations have been established on 550 acres throughout Michigan, 96% having been planted since 1960. The primary purpose of these plantations are: (1) to determine the type and degree of genetic variation for the commercially important species planted in Michigan; and (2) to serve as breeding arboretums for successive research and commercial establishment of seed orchards or vegetative propagation production centers.

The tree improvement program implemented in Michigan is designed first to identify and quantify variation in a species through rangewide seed collection, and subsequent provenance planting or progeny testing. The next step is to identify the commercially valuable traits, and determine the extent of inheritance through progeny tests. The third step is to convert the progeny test into a genetically improved seed orchard by thinning the genetically inferior genotypes. A fourth step would be to do controlled crossing and breed a species to capture further improvement. Figure 1.0 shows the research pathways for production of genetically superior trees.

The outline of the tree improvement program is basically the same as for highly successful agricultural crop plant breeding programs. Although similar in design to crop breeding programs, the time span for a breeding cycle in a tree species is measured in decades rather than the few years for most crop breeding. The long time span

Figure 1.0

RESEARCH PATHWAYS OF TREE BREEDING FOR THE MICHIGAN TREE IMPROVEMENT PROGRAM



(Repeat breeding cycle again for subsequent generations) involved in tree breeding programs presents special problems to the research scientist and the economist documenting benefits to the tree improvement program. It should be pointed out that other breeding pathway options exist. Other tree improvement programs have used the breeding option of selecting in native stands using a "plus tree" phenotypic selection criterion. The validity of this breeding pathway for producing proven genetically superior trees has not yet been established. There are strong indications that the option used in the Lake States breeding program is the desired research pathway to obtain the maximum genetic gain per breeding cycle. (The program in Michigan has evolved to where this is the primary research pathway.) Special circumstances and individual needs of commercialization for some species do not rule out alternative research options.

Relative to agriculture, tree breeding programs in the United States are a recent phenomenon. Only in the past three decades has a serious attempt been made at systematically establishing a commercial source of genetically superior trees for artifical regeneration.

<u>Timber Supply.</u> One can see that eventually such a program to increase the supply of raw forest products might be attempted. Given an increasing population, growing economy and greater per capita consumption of wood-based products, the pressures on the forest as a raw materials supplier will increase. At the same time, pressures which demand a greater supply of wood fiber and forest products, also compound the demand made on the total forest resources through additional recreation, wildlife and wilderness demands. These

combined factors result in a decreasing forest land base from which to produce the raw forest products which are increasingly in demand. It is estimated that in Michigan alone, 44,000 acres per year of commercial forest will be converted to agriculture, or developed for recreation each year until at least the year 2000.[1] The United States Forest Service projects the demand for round wood from United States forest land will more than double by the year 2030 over the 13.7 billion cubic feet consumed in 1977. Much of the increase in demand is for pulp products. Timber product exports are also projected to substantially increase over the next 60 years.

The Lake States region appears to be a major factor in future expansion of the nation's timber supply. From a national perspective the United States Forest Service anticipates a net wood supply deficit of approximately three billion cubic feet for the period 1990 to 2030. From a state perspective, Michigan's supply of timber products is seriously under utilized. Michigan is endowed with a land resource of 17.5 million acres of commercial forest land. A recently completed study shows positive ratios of net annual growth to removals for virtually all commercial forest species, ranging from 2.9 to 4.8.[2] In terms of 1980 timber volume, Michigan had a net increase of over 600 million cubic feet. Abundance of the timber resource, close proximity to eastern markets and inexpensive international water transportation routes, present an opportunity for expansion of production.

In Michigan, the economic value of the 17.5 million acres is not entirely based on tree fiber products. A large but unquantifiable portion of the value is attributed to recreation, wildlife, and reserve values. Of the 6.4 million acres in public ownership (2.5 million acres in three national forests, 3.6 million acres in the nations largest state owned forest system, and the remainder in special public catagories) almost 1 million acres are either in reserve (no commercial access to raw wood products) or are managed for a primary product other than raw wood products (wilderness, grouse management, wild and scenic river land etc.).

The time frame for planning in the forest products industry is unique in agricultural and natural resource production activities. Production cycles in excess of fifty years are common, with some exceeding 100 years. Even the relatively fast production of Christmas trees approaches 15 years to complete one crop rotation. This is one reason why so much attention is given to long-range projections of timber supply and demand. The number of years required for one cycle of a comprehensive breeding program is in excess of 50 years. A projection for the completion date of the first breeding cycle for all species in the Michigan tree improvement program is into the 21st century (approximately year 2008). To demonstrate how far into the future the effects of this program extend, the first harvest of genetically superior jack pine trees planted for a pulpwood harvest will begin 40 years from 1985 or in the year 2025.

The imposition of such long time spans, and future projections of dubious accuracy, create special problems in determining the economic value that can be assigned to the Michigan tree improvement program.

<u>Outline of the Dissertation</u>

This dissertation approaches the problem of measuring returns from research by looking at the actual situation of the Michigan tree improvement research program. (This situation has unique features in the returns from research class of problems). Although on the surface it is similar to agriculture and extension research programs, it possesses special characteristics which set returns from forest tree improvement research apart in a class of problems by itself. The long time periods involved, and very large potential supply needs mandate a model where the discount rate and projections of future use play an unusually important role.

CHAPTER I describes the Michigan Tree Improvement Program as a comprehensive breeding research program. The research program is presented as a discrete program with both a beginning and ending date. The scope of total costs of the program are defined. The economic level of costs and benefits are confined to the same level of research product activity. The primary economic level of benefits and costs are associated with final product research activities.

CHAPTER II presents the economic environment in which the research program is conducted. Gross benefits to the research program are a direct function of at least four important variables. These are: the quantity of research product used (improved trees planted and harvested); the price of the trees when sold; the amount of genetic gain produced through the breeding program; and the discount rate used. The determination of values used in the model are given.

CHAPTER III presents the various models which have been used in the past to estimate returns from research in biological situations. There are two common basic approaches. The first basic approach uses ex-post studies. These studies look at completed research programs and subsequent changes in output and prices. The ex-post studies can be further classified into consumer and producer surplus analyses (estimating average rates of return), or production function analyses (calculating the marginal rates of return). Neither is particularly suited for the tree improvement research situation. The second basic approach uses ex-ante studies. These look at future potential returns from completed or on-going research programs. Ex-ante studies are grouped into four classes: those using scoring models to rank research activities; analyses using benefit - cost methodology to establish ratios or rates of return; simulation models; and analysis using mathematical programming to select an optimal combination of research activities. A mathematical ex-ante benefit - cost is one suitable methodology for the tree improvement research situation.

CHAPTER IV presents the model used. Major assumptions inherent to the model are listed and explained. The three computer programs used and necessary to analyze a case study are outlined.

CHAPTER V presents the results of a case study based on the model described in Chapter IV. The model shows large benefits from tree improvement research in Michigan. The range of estimates varies greatly according to future demand projections, relative scarcity of timber, and discount rate. Costs appear to be relatively insignificant when compared to even the most conservative estimates of benefits.

CHAPTER VI shows how three different users of the forest resource individually benefit under the tree improvement program. The benefits to a large integrated pulp and paper company with a substantial artificial regeneration program are shown. The benefits to the Forestry division of the Department of Natural Resources for Michigan are presented. And, benefits to a large integrated nursery and Christmas tree operation are shown.

CHAPTER VII evaluates the research program in light of the model results. Discussion of secondary benefits and costs is presented. Policy alternatives are presented for completion of the research program.

NOTES - INTRODUCTION

1) Statistics are derived from many sources. Key studies used in this dissertation include; "Michigan Forest Resources 1979 - An Assessment", Michigan Department of Natural Resources; "An Assessment of the Forest and Range Land Situation in the United States", United States Forest Service; "Trends in Natural Resources Commodities", Potter and Christy; and the Forest Resources Inventory Survey currently being completed by the North Central Region of the United States Forest Service.

2) From, Lee James, Suzanne Heinen, David Olson, and Daniel Chappelle. 1982. Timber Products Economy of Michigan. Agricultural Experiment Station Research Report No. 446, Michigan State University; 23 p.

CHAPTER I

A RESEARCH CLASSIFICATION AS APPLIED TO TREE IMPROVEMENT

The Research Process

When applying economic theory to the field of science, it is useful to view science as "the information industry." Research is then the production process of new information. As with more traditional industries, there is an ordered sequence of markets forming a market chain in which there is movement from "raw" to "partially fabricated" to "finished goods." At each level in the market chain, the number of potential uses or access to higher links in the market chain is reduced.

Research production processes have problems or questions as inputs; information or answers as outputs. The process itself is "innovative discovery."[1] Research production processes can be classified by two similar schemes of classification; innovative process, or research output. Industrial organizations find it convenient to identify three stages of technological innovation. An example of such a classification would be the steps involved in bringing a new product to the commercial market. The first step would be the exploratory and discovery stage. Second is the applied research stage, developing techniques and methods of refinement. And third, is the development stage, including such activities as market research and pilot scale production.[2]

To apply economic theory in the analysis of research, it is more useful to classify the research production process in terms of output. Three classes of output or research products are defined: primary, intermediate, and final. The decision rule for classification is based on the diversity of the products' application to scientific disciplines and industrial processes. The logic behind this rule is to classify research products as to their relative effect on the economy. Research products which are the broadest in application, are primary research products.

The biological research process can be viewed as a production activity resulting in three classes of research outputs; primary research products; intermediate reseach products; and final research products. In a two stage classification scheme, primary research is termed "basic research" or "pure research" and final research is called "applied research". Intermediate research products are blended into either primary or final research product classes. Primary biological research in forestry investigates the basic biological processes. Primary research topics tend to be discipline oriented or at least at the sub-discipline level. This research may be completely theoretical in nature. The research products further the frontier of knowledge at the most fundamental level of understanding. The impetus for conducting primary research may be anticipatory to a final research product. Public institutions such as the National Science Foundation are a primary funding source for this research class.

Primary research is valuable in expanding the frontier of knowledge and certainly is the foundation of most applied or final research. Determining a specific value of this class of research is virtually impossible without conducting a comprehensive global consumer and producer surplus analysis. In practice this type of analysis cannot be done.

Intermediate research activities are those which enhance further investigation of primary and final research activities. These research products are more narrow in the scope of application than primary research products. This class of research includes discovery and testing of new scientific methods and analysis techniques. Examples of intermediate research are the invention and validation of new research methodology such as testing plant breeding experimental design, and discovery and refinement of analytical procedures such as high performance liquid chromatography. Intermediate research is also disciplinary in nature but tends to be limited to the discipline of the research process itself.

Final product research or applied research is problem oriented and is highly specific in application. In the industrial world, this is the development class in a two-stage R&D classification scheme. Final research is the activity which combines knowledge and inventiveness to produce a commercial product. There are many examples of this class of research. Virtually the entire field of silviculture can be defined as producing final research products. The applied research which produces genetically superior tree populations is another example. The final research product in this case is the identifed, evaluated, and genetically isolated population of trees which by some genetically controlled trait, on the average are "better" than the wild population.

Tree Improvement Research in Michigan

The scope of this dissertation is confined to investigating the potential returns to the final stage of research in the tree improvement programs at Michgan State University. The final product of this research is information; information to produce genetically superior seed orchards, (commercial seed orchards).

The tree improvement research program designed to produce a commercial genetically superior tree began in 1960, 1961, and 1962 with Dr Jonathon Wright's work on Scotch pine, eastern white pine, Austrian pine, red pine, Japanese larch and Hybrid larch (European/Japanese larch mixture). Of the 302 genetic plantations listed in "A Directory of Forest Genetic Planting in Michigan: June 1980", only 15 were planted prior to 1960. Most of these very early plantings were jack pine and Scotch pine and are not considered as efforts included in the final product research stage. These 15 early plantations were established more for the purpose of evaluating experimental design methods, and reforestation than as part of a comprehensive genetic breeding program.[3]

This dissertation will consider 1961 as the effective beginning date for the final product stage of the tree improvement research activities in Michigan. By 1961, a comprehensive plan for evaluating genetic variation and breeding selected populations of individual species for commercial use was established. The first species to receive major attention was Scotch pine. The primary need and potential beneficiary of the Scotch pine program was the Christmas tree industry. Many thousands of acres were being planted for Christmas trees in the early 1960's. Wright estimates that in 1960 there were 100 million Scotch pine seedlings growing in Michigan nurseries, most of these intended for Christmas tree plantations.

The research program expanded in the late 1960's with the addition of a second full-time researcher, Dr. James W. Hanover. Currently, final research is in some stage of completion for 21 different tree species representing 29 commodities/species.[4] Many additional species are being examined under intermediate and basic research programs. Twenty-one species are in some stage of investigation. Because of the long time periods required between various research activities (such as the time between planting a provenance test and measurement) the investigation of a specific species may go "dormant" for several years at a time. The research program at its current size has the capacity to intensively investigate six species at a time. To intensively investigate a species in the context of the Michigan tree improvement research program means to allocate resources and active research effort to the following activities: collect seed, grow seedlings, plant seedlings in genetic plantations, make controlled crosses (for progeny tests) and make grafted trees for vegetative propagation and seed orchard establishment. The research program is capacitated or constrained by greenhouse size, labor supply, and operating budget. Assuming a future commitment to funding at the present level, the research program is expected to be completed for all 21 species by the year 2008. Of the 21 candidate species for genetic improvement, five are close to commercial utilization in the next two years. Figure 1.1 graphically depicts the expected time of commercial seed orchard availability.

Tree Improvement Research Products

The 21 species investigated for final research products can be classified into three commercial uses: twelve species are in use or have potential for use in reforestation (pulp, fuelwood, and timber which includes both lumber and veneer); ten species are either used as Christmas trees or interest has been expressed for potential use as Christmas trees; and seven species are currently used as ornamental planting in the landscape industry. The species and commodities analyzed are listed in Table 1.1.

Different lengths of market chains are observed in the three commercial uses of species the research program is investigating. The sale of raw forest products is only one stage in a progressive chain of markets between trees and final consumer products. Products at

Figure 1.1

YEARS REMAINING UNTIL PRODUCTION OF PROVEN
GENETICALLY IMPROVED COMMERCIAL SEED ORCHARDS **

YEARS TO PRESENT (1983)

1983 1 2 3 4 5 6 7 8 9,.....,14 15 16 17 18 19 20,.....,25

* HYBRID PINE (proven better than either parent)

* JACK PINE
* SCOTCH PINE
* BLUE SPRUCE
* HYBRID POPLAR

* EASTERN WHITE PINE

* WHITE SPRUCE
* HYBRID SPRUCE (blue x white)

* RED PINE
* ASPEN
* BLACK SPRUCE

* WESTERN WHITE PINE
* NORWAY SPRUCE
* HONEYLOCUST

* AUSTRIAN PINE
* ENGLEMANN SPRUCE
* DOUGLAS-FIR
* EUROPEAN LARCH
* HYBRID LARCH
* BLACK WALNUT

* WHITE FIR

** *These estimates are based on the stage of research each species is at in the program, and biological parameters such as years-to-flowering. Initial commercial seed orchards are assumed to be constructed either from thinning progeny tests, or graphed from progeny test stock.*

Table 1.1

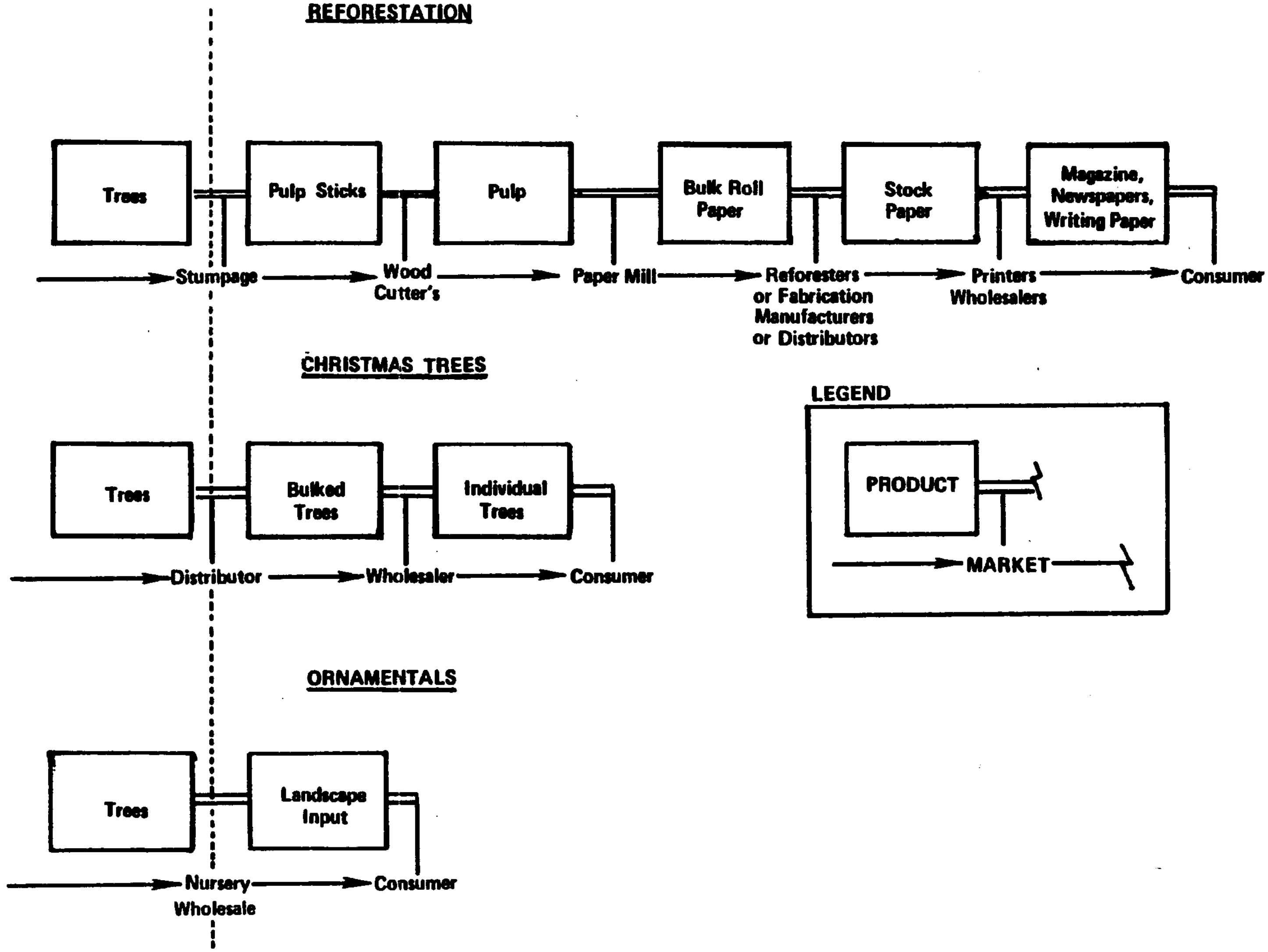
COMMODITY/USE AT PRIMARY VALUATION LEVEL

SPECIES	COMMODITY
USE CLASS - REFORESTATION	
HYBRID PINE	Pulp (stumpage)
JACK PINE	Pulp (stumpage)
HYBRID POPLAR	Pulp (stumpage)
E. WHITE PINE	Pulp (stumpage)
WHITE SPRUCE	Pulp (stumpage)
RED PINE	Pulp (stumpage)
HYBRID ASPEN	Pulp (stumpage)
BLACK SPRUCE	Pulp (stumpage)
HONEYLOCUST	Pulp (stumpage)
EUROPEAN LARCH	Pulp (stumpage)
HYBRID LARCH	Pulp (stumpage)
BLACK WALNUT	Veneer (stumpage)
USE CLASS - CHRISTMAS TREES	
SCOTCH PINE	Cut wholesale trees (F.O.B. farm)
BLUE SPRUCE	Cut wholesale trees (F.O.B. farm)
E. WHITE PINE	Cut wholesale trees (F.O.B. farm)
WHITE SPRUCE	Cut wholesale trees (F.O.B. farm)
HYBRID SPRUCE	Cut wholesale trees (F.O.B. farm)
W. WHITE PINE	Cut wholesale trees (F.O.B. farm)
AUSTRIAN PINE	Cut wholesale trees (F.O.B. farm)
ENGLEMANN SPRUCE	Cut wholesale trees (F.O.B. farm)
DOUGLAS-FIR	Cut wholesale trees (F.O.B. farm)
WHITE FIR	Cut wholesale trees (F.O.B. farm)
USE CLASS - ORNAMENTAL	
BLUE SPRUCE	Wholesale landscape stock (F.O.B. nursery)
E. WHITE PINE	Wholesale landscape stock (F.O.B. nursery)
WHITE SPRUCE	Wholesale landscape stock (F.O.B. nursery)
NORWAY SPRUCE	Wholesale landscape stock (F.O.B. nursery)
HONEYLOCUST	Wholesale landscape stock (F.O.B. nursery)
AUSTRIAN PINE	Wholesale landscape stock (F.O.B. nursery)
DOUGLAS-FIR	Wholesale landscape stock (F.O.B. nursery)

lower markets are inputs to higher markets. The effects of lower markets are transmitted upward through the supply functions of higher markets. The dynamics of an individual link in a market chain are directly effected by supply and demand factors of the other links in the chain. The factor demand of the higher markets are determined in part by the marginal revenue product and marginal factor cost of the factor input of the lower markets.[5] This statement implies the profit of raw forest products effects the supply of many other higher market products.

The reforestation species are at the bottom of a very long market chain. Trees are sold for pulp or timber in the forest to a woodcutter or wholesaler. This is the most basic or lowest level in the market chain at which a market exchange situation exists. In the example of trees sold to a pulp mill, six to ten subsequent market chain links or production processes are added until the consumer gets a final product and the ultimate direct value of the tree (now paper) is realized. The Christmas tree is linked to the consumer through a much shorter chain, composed of only two to four links. The first link is when the Christmas tree is cut and sold to a wholesaler. The Christmas tree is then sold to a distributor or directly to a consumer. The ornamental tree shows the shortest market chain, with only one or two links. The nursery sells a tree to a landscaper who uses the tree as an input into a consumer oriented production process (landscaping). Figure 1.2 is an example of the various possible market chains for the three commercial uses described.

Figure 1.2


REFORESTATION
Trees
Pulp Sticks
Pulp
Bulk Roll Paper
Stock Paper
Magazine, Newspapers, Writing Paper
Stumpage
Wood Cutter's
Paper Mill
Reforesters or Fabrication Manufacturers or Distributors
Printers Wholesalers
Consumer
CHRISTMAS TREES
Trees
Bulked Trees
Individual Trees
Distributor
Wholesaler
Consumer
ORNAMENTALS
Trees
Landscape Input
Nursery Wholesale
Consumer
LEGEND
PRODUCT
MARKET

The economic analysis recognizes that various levels of value are attained in each market. On a ton equivalent, a ton of stumpage is worth $3.20; a ton of wood chips at the pulp mill is $25.00; a ton of pulp ready for paper manufacture or sale is worth $350.00; and a ton of finished glossy magazine paper is sold for $2,000.00. At the consumer level, one ton of TIME magazines retails for $12,400.00. At each market exchange level, additional inputs are added to the basic raw resource (wood) to increase the value. The market exchange levels may be thought of as analogous to the three research levels (primary, intermediate, and final) in their effect. As this analysis restricts research to final product development, it also restricts the valuation of the resource to the first link in the market chain. At this level in the market chain, there is a minimum of outside, value-laden inputs. The first level of valuation (assuming competitive markets) is where the most clearly defined (with respect to market imperfections) effects of tree improvement research are felt. To conduct the analysis at a higher level in the market chain, say at the paper mill level where the price of pulp is used as the index of value, would not only be counting gains to genetic improvement research but also gains to technological innovations in transportation, chemical refining processes and machinery control fields. It would be difficult to analytically separate the individual technical and research effects on production and the economy.

The costs of the research are calculated over the life of the program, from year 1961 to 2008. During this time period, all 21 species are expected to have genetically superior populations segregated providing the opportunity for commercial seed orchard establishment. The benefits or value attributed to the research is carried to the same level for which costs of research are calculated.

NOTES - CHAPTER I

1) Schumpeter in "The Theory of Economic Development" discusses the classical theory of innovation, making the point that innovation itself is instantaneous but requires development, the process of creating a set of technical instructions to utilize the innovative discovery. The combination of the two processes will be called research in this dissertation.

2) This classification is given by Americo Albala in "Stage Approach for the Evaluation and Selection of R&D Projects". Joel Goldbar, Louis Dragaw and Jules Schwartz in "Information Flows, Management Style, and Technological Innovation" also present a similar classification system: Stage 1, idea generation and design concepts; Stage 2, problem solving and engineering; Stage 3, commercialization and marketing. These are two examples of many similar classifications dealing with industrial product development.

3) Personal communication concerning the history of tree breeding in Michigan with Dr. J. Wright.

4) Some species are used for more than one purpose. As an example, white pine is used for reforestation, Christmas trees, and as an ornamental. The term "commodities" will be designated to mean a species being used for a distinct commercial purpose.

5) Mills discusses this interaction in detail using the softwood lumber market as an example in "An Econometric Analysis of Market Factors Determining Supply and Demand for Softwood Lumber", PhD thesis MSU, 1972. p. 14-24.

CHAPTER II

THE ECONOMIC ENVIRONMENT AS IT AFFECTS TREE IMPROVEMENT RESEARCH

Introduction

The economic environment in which the research process takes place is an important factor to consider in the tree improvement program. The economic environment often dictates the direction and scope of research. In conducting an economic analysis, one of the first steps is to identify and measure the economic parameters which have an affect on the research process.

Setting up and defining the economic enviromnment is critical to the analysis of returns to research. Environmental and industrial constraints put limits on the potential use and application of the final research product. In Michigan, potential gross benefits to tree improvement programs are a function of numerous variables. Four broadly aggregated variables interact to determine the gross level of benefits. These are: the number of genetically superior seedlings produced and planted; the price of the tree when sold (at the first level of valuation); the percent genetic gain of a trait (over the mean of the wild population) which can be expected to occur as a result of the breeding program; and the discount or interest rate used. These variables are broadly aggregated and incorporate several assumptions and "hidden" functions. As an example, price, as defined here, assumes a certain grade or quality of product and is represented as an average price incorporating differences in regional demand, location differences, and seasonal factors.

Artificial Regeneration Levels

Quantity is an important variable in the analysis. Three different estimates reflecting three separate possible economic levels of activity were used. The first is the number of seedlings commercially planted in Michigan in 1981. The second estimate is the number of seedlings which are currently planned for commercial planting in 1986. The third estimate is the projected number of seedlings planted, assuming logistic growth functions in the commercial planting industry.

These three estimates of commercial planting represent conservative, middle-of-the-road, and optimistic outlooks respectively, on the future of the commercial tree planting industry in Michigan. To develop a minimum baseline economic level of activity in the tree planting industry, a comprehensive state-wide survey of the tree seedling industry was conducted.[1] The purpose of the survey was to determine an accurate estimate for the number of tree seedlings planted in Michigan.

Michigan Tree Seedling Industry Survey In early 1982, over 500 potential members of the tree seedling industry were sent a four page questionnaire. The survey was designed to obtain information on the commercial tree seedling nursery, and commercial tree seedling planting activities in Michigan. Information was requested about current production levels (1981), and future production levels (1986). The response from the industry to the survey was excellent with over 70% returning completed questionnaires. A random sample of nineteen members of the potential industry not responding (the 30% of the industry which did not return a questionnaire) was contacted by phone. By selecting a random sample of the non-respondents, an accurate estimate could be made for the entire industry.[2]

The format of the survey allowed information to be tabulated by firm and by species of tree seedlings both grown and planted. This was accomplished by aggregating the survey across species and across firms respectively. Two tree seedling sub-industries were identified by the survey: the nursery sub-industry which produces seedlings for sale, and the planting sub-industry, planting seedlings as part of a production process. In Michigan there are four important economic production activities which rely on trees as raw inputs in the production process. The raw inputs are classified according to the production processes as follows: reforestation (planting thirteen different species in 1981 primarily for pulpwood production); Christmas trees (twelve species planted in 1981); ornamentals (five species produced from seedlings in 1981 and hundreds produced from whips or cuttings); and fruit trees (primarily produced from whips or cuttings). This analysis will not be concerned with vegetatively propagated ornamentals or fruit trees. The scope is limited to reforestation, Christmas tree, and ornamental production processes that use planted seedling derived trees.

The survey polled only those companies, institutions and individuals considered commercial members of the tree seedling industry. Not included are the numerous "hobby" planters and small landscape nurseries each producing less than one thousand seedlings per year. The rationale behind excluding this non-commerical group from the survey is that commercial members need less convincing to implement use of genetically superior tree seedling stock (i.e., adoption costs of new products are close to zero).

The results of the survey provided accurate information on the number of commercial tree seedlings produced by nurseries and planted in Michigan both in 1981 and projected in 1986. In the commercial tree planting industry, a planning lead time of four to five years is necessary. The planting site must be cleared and prepared and seedlings contracted for (if quantities are large) several years in advance to assure adequate supply. Therefore, figures projected for 1986 also represent a realistic assessment of planting levels for 1986.

There are approximately 300 commercial or industrial organizations which are extensively involved with growing and planting tree seedlings in the state. These include the state and federal agencies which engage in reforestation for all purposes. The majority of these firms are in planting as a sub-production activity, usually for a future end-product such as Christmas trees, woody fiber (pulp), or timber. There are very few strictly professional planting companies in Michigan. Seventy percent of the tree seedling industry engages strictly in planting, buying all their seedling planting stock from nurseries. Ten percent of the tree seedling industry specializes in growing tree seedlings and does not engage in significant planting activities. The remaining twenty percent are combinations of nurseries and planters who grow their own seedlings for their own planting operations.

In 1981 over 37 million tree seedlings were planted in Michigan. Virtually all the seedlings planted were produced by Michigan nurseries. At the present time, either by convenience or quality needs, the Michigan planting sub-industry is quite dependent upon Michigan nurseries. There is very little seedling stock brought in from nurseries in surrounding states. Plans for 1986 show even less willingness by commercial planters to rely on out-of-state nurseries for supplies of planting stock.

Nine conifer species accounted for over 90% of the commercial planting in 1981. These species are, European larch, white spruce, blue spruce, jack pine, Austrian pine, red pine, white pine, Scotch pine, and Douglas-fir. This includes the "pine and spruce species-undifferentiated." Almost 40% of all the seedlings planted were for Christmas trees and 50% were for reforestation purposes. The Soil Conservation District (SCD) supplied only a small number of seedlings to commercial planters (less than 600 thousand) with most of the SCD stock going to the "non-commercial" planter or "hobby-farmer."

Over 86 million tree seedlings were grown in 1981. The nursery industry is a strong export industry supplying many planters outside of Michigan. In 1981, 25 million Michigan-grown tree seedlings were planted in other states. The same nine conifer species account for over 80% of the total seedling production in number of seedlings grown. The species which are exported out of the state are primarily for Christmas trees and high value ornamentals.

In both the nursery sub-industry and planting sub-industry, a few firms or organizations account for the bulk of the commercial production. The planting sub-industry has 7.5% of the firms controlling 77.5% of the total production. The nursery sub-industry has 8.9% of the firms, controlling 54.5% of the total production. In this sense, the planting sub-industry is subject to less competitive pressures than is the nursery industry. Additionally, more of the nurseries rely on selling seedlings as their primary economic activity, than do the majority of the commercial planters. Most of the commercial planters are planting tree seedlings as one input into a larger production activity. The practical implication of this observation is that the nursery industry will most likely bend to the increased demand from the planting sub-industry and expand production.

The Christmas tree and reforestation industrial sectors account for most of the volume in tree seedling production and planting. The ornamental industry sector may account for a higher dollar percentage than the volume in ornamental seedling production indicates, (ornamental seedlings typically are much higher priced than Christmas tree or reforestation stock.) Fruit tree production is controlled by two or three companies with one nursery exerting virtual monopolistic control on fruit tree seedling production in Michigan.

Within the Christmas tree industrial sector, the importance of various species to the commercial grower may change in the coming years. The basic four: Scotch pine, blue spruce, white spruce, and Douglas-fir will still account for the bulk of the industry in volume, but Fraser fir, Balsam fir, and white pine will become increasingly important. There has also been a large increase in the amount of Christmas tree planting over the past decade. Data from this survey indicate an increase of more than 20% per year in the total number of seedlings planted. This trend is calculated by combining results from a survey conducted by the Cooperative Extension Service several years ago with the results from this survey.[3] This survey anticipates that industry growth will be sustained if there is not a serious shortage of seedlings for the grower. The source of seedlings for the planting sub-industry is expected to be Michigan nurseries. There are no indications from commercial planters of a willingness to go out of state to purchase seedlings. Shortages of seedlings for Christmas trees may occur in blue spruce, white spruce, and White fir if nurseries are unresponsive and planters implement projected plans.

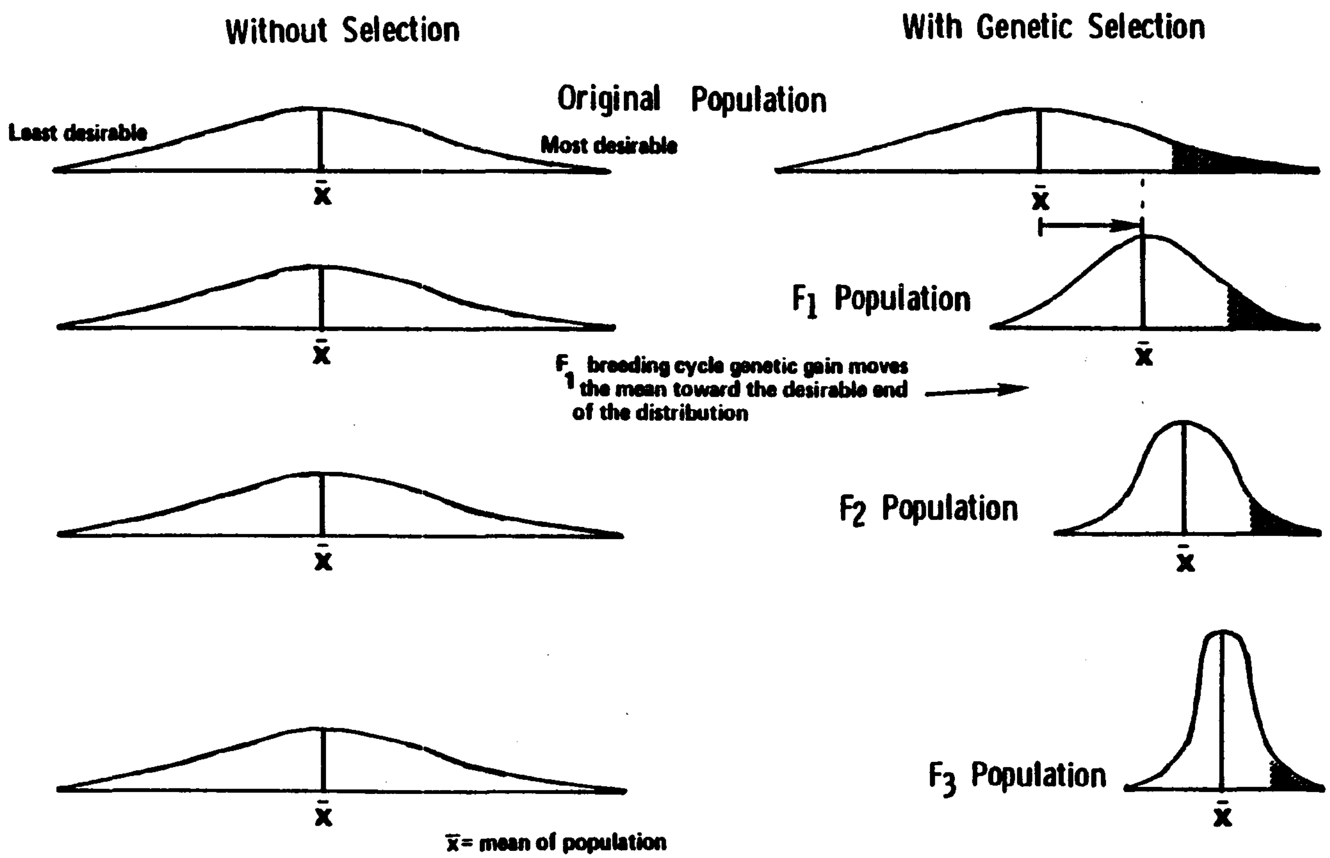
The reforestation industrial sector has also experienced a rapid growth over the past decade. Results from our survey predict this industry sector will continue its expansion, planting almost 27 million seedlings in 1986 for reforestation purposes. The primary expansion is projected to occur in red pine. European larch, and jack pine are also expected to increase in number of seedlings planted for reforestation purposes. The major future source of the seedlings is anticipated to be provided by "own production" facilities and, by private Michigan nurseries. There appears to be a strong market for high quality, genetically improved seedlings of red pine, white spruce, and European larch. The availability of commercial quantities of genetically improved seed for these species will further fuel seedling demand in the next decade. The implication of the tree seedling industry analysis is that the demand and potential use of tree improvement research products will continue to grow.

Genetic Gain

The amount of genetic gain is also an important variable. Genetic gain is defined as the percent improvement of the mean of the selected population (F_1 generation) over the mean of the wild population for the trait being considered. Figure 2.1 shows the results of genetic breeding on the variation of economic traits found in tree populations. Gain can be applied to any genetically determined trait and population. Within the context of this analysis,

Figure 2.1

POPULATION DISTRIBUTION OF ECONOMIC TRAITS



genetic gain is only relevant insofar as it effects the price of the product sold.

As an example, it may be possible to select for and capture a 50% gain in fall leaf color in aspen (used almost exclusively for pulp and structural timber). This would not effect the price of aspen as a wood fiber material. Thus, in this model, that trait is not considered.

For species used as timber (pulp), the primary characteristic or trait selected is volume or growth rate. Other traits such as specific gravity are also considered. In the current market structure for pulp stumpage, volume and species are the only factors considered in determining price (regional, economic, and geographic factors ceterus paribus). For Christmas tree species a multitude of genetically controlled characteristics contribute to the price formulation. Species, tree color, needle sharpness, needle stiffness, needle length, needle retention, natural form (which itself includes many traits), growth rate, and uniformity, among others, are all part of the price function. As in the case of Christmas trees, for species commercially grown from seedlings and used as ornamentals, price is calculated based on a "bouquet" of characteristics. Many of these characteristics are the same as those found in the Christmas tree price function and are genetically controlled. Growth rate is certainly highly weighed but tree form, color and hardiness (tolerance to cold, pollution etc.) are also important.

Specific determination of genetic gain is difficult to calculate before progeny tests are evaluated. F-1 seedlings must be produced, allowed to mature, and harvested, to compare yields with similar environments of "wild" populations. The actual genetic gain can then be determined. None of the species being investigated in the research program are currently at this stage. Fairly accurate estimates of genetic gain can be made at the progeny test evaluation stage of development. Based on statistical estimation of heritability and roguing rates, numerous estimates of genetic gain have been made for a number of species commercially propagated in the Lake States. The most complete and accurate estimates are available for the genetic gain of jack pine when used as a timber (pulp) species and blue spruce when used as a Christmas tree or ornamental. A recent unpublished evaluation of jack pine 1/2-sib progeny tests designed for conversion to seed orchards show a genetic gain in volume ranging from 8% at a 62% roguing rate, to 13% at a 87% roguing rate. A genetic gain of 3.1% in specific gravity is estimated at a 75% roguing rate.[4] A slightly positive correlation is observed between volume and specific gravity. The actual roguing plan may be determined by a linear programming model or other appropriate optimization technique to maximize overall genetic gain. Detailed information concerning the genetic variation in important Christmas tree traits has recently become available for blue spruce. Schaffer determined the variation in needle length to be 18% genetically determined, needle sharpness 28%, and variation in needle stiffness to be 19% genetically determined. Color or "blueness" is also observed to be under strong genetic control.[5] Wright has found substantial genetic differences in Scotch pine for several economically important Christmas tree traits. A 58% difference in resistance to Pine Root Collar Weevil was observed in a Scotch pine provenance plantation consisting of trees from 108 different natural stands, collected from twenty-one different geographic regions. Similar differences in Scotch pine are observed for height (growth), fall foliage color, needle length, and form.[6]

Work in Black pine (<u>Pinus nigra</u>) indicates a range of 11% to 19% of the growth rate may be attributable to genetic factors.[7] Guries has reported that red pine progeny plantations after roguing and conversion to seed orchards will yield a 9-12% genetic gain in volume.[8] Work with several species of larch point to genetic gains of 10-15% in volume during the first breeding cycle (F_1) using the best geographic seed source.[9]

The range of values used in this analysis represent low, medium, and high estimates of genetic gain for respective species. The genetic gain estimates, as defined here, are the differences in total net revenue which can be expected from using genetically improved stock. For instance, a 10% genetic gain for a reforestation species means that the genetically improved stock, when harvested, will yield 10% more net revenue. This is because there is a direct price-volume relationship for stumpage. For the reforestation species this is brought about primarily through an average increased growth rate raising total gross revenue, (with costs held constant). Other genetically controlled traits may contribute to lowering the cost thereby increasing net revenue. Genetic gain is represented in Christmas trees as an increase in net revenue brought about through improvement in a multitude of traits. Christmas trees and ornamentals propagated from seedlings exhibit a tremendous price differential at the wholesale level. An unpublished 1982 survey of the Michigan Christmas Tree Growers Association (accounting for 60% of Michigan Christmas tree production) showed price differences as wide as 450% from low price to high price.[10] The differences in the price of Christmas trees are shown in Table 2.1.

After extensive and detailed discussions with key figures in the reforestation, Christmas tree, and ornamental industries, (and with the primary researchers conducting the tree improvement program) the following estimates of genetic gain were determined for all twenty-nine species/commodities which are in the economic model. These estimates are presented in Table 2.2.

Price of Forest Products

Prices of the commodity at the designated market link are taken from the competitive market place. Reforestation commodity prices are shown as dollars per tree for stumpage. This price is derived using the following method. The base price used is the average price per cord stumpage in the appropriate region as reported by Timbermart North Price Reporting Service 1st Quarter 1983. A cord is assumed to have 100 cubic feet (since harvest methods assume whole tree

Table 2.1

WHOLESALE PRICE RANGE OF CHRISTMAS TREES - 1982 SEASON

SPECIES	SIZE CLASS (FEET)	LOW PRICE ($/TREE)	HIGH PRICE ($/TREE)
SCOTCH PINE	5 - 6 1/2	2.50	10.50
SCOTCH PINE	6 1/2 - 8	3.00	13.50
BLUE SPRUCE	5 - 6 1/2	6.00	17.00
BLUE SPRUCE	6 1/2 - 8	7.35	20.00
DOUGLAS-FIR	5 - 6 1/2	6.00	20.00
DOUGLAS-FIR	6 1/2 - 8	7.35	25.00
WHITE SPRUCE	5 - 6 1/2	6.32	12.50
WHITE SPRUCE	6 1/2 - 8	6.00	17.50
AUSTRIAN PINE	5 - 6 1/2	2.00	7.50
AUSTRIAN PINE	6 1/2 - 8	12.50	17.50
WHITE PINE	5 - 6 1/2	5.50	9.00
WHITE PINE	6 1/2 - 8	8.00	11.33

From the annual Michigan Christmas Tree Association Marketing Survey Department of Forestry, Michigan State University, 1983.

Table 2.2

PARAMETER VALUES FOR GENETIC GAIN ESTIMATES

COMMODITY/SPECIES	GENETIC GAIN ESTIMATE		
	LOW	MEDIUM (PERCENT)	HIGH
REFORESTATION/			
HYBRID PINE	5	10	30
JACK PINE	5	10	15
HYBRID POPLAR	5	10	30
E. WHITE PINE	5	10	30
WHITE SPRUCE	5	10	30
RED PINE	5	10	15
HYBRID ASPEN	5	10	30
BLACK SPRUCE	5	10	15
HONEYLOCUST	5	10	15
EUROPEAN LARCH	5	10	30
HYBRID LARCH	5	10	30
BLACK WALNUT	5	10	15
CHRISTMAS TREES/			
SCOTCH PINE	5	10	30
BLUE SPRUCE	5	10	30
E. WHITE PINE	5	10	30
WHITE SPRUCE	5	10	30
HYBRID SPRUCE	5	10	30
W. WHITE PINE	5	10	30
AUSTRIAN PINE	5	10	30
ENGLEMANN SPRUCE	5	10	30
DOUGLAS-FIR	5	10	30
WHITE FIR	5	10	30
ORNAMENTAL/			
BLUE SPRUCE	5	10	30
E. WHITE PINE	5	10	30
WHITE SPRUCE	5	10	30
NORWAY SPRUCE	5	10	30
HONEYLOCUST	5	10	30
AUSTRIAN PINE	5	10	30
DOUGLAS-FIR	5	10	30

chipping). One individual tree at harvest is assumed to yield fifteen cubic feet of chips.

Lake states industry trends show a progression of harvest methods from the chainsaw skidder method to whole tree chipping. By the time most of the new timber will be harvested (a minimum of 35 years from 1983) it is expected that virtually all the commercial harvest of pulp plantations will be by whole tree chipping.

Using Miller's Hybrid pine biomass equations, a tree with a volume of 15 cubic feet would be 32 feet high, have a specific gravity of 0.4, and a 7.5 inch DBH. Using Smalians formula it would be a log 37 feet long with a butt diameter of 10.575 inches and a top diameter of 6 inches.[11] In a plantation setting, a tree yielding 15 cubic feet of usable chips would have dimensions between the above two extremes. The price per cord is converted to price per tree using 100 cubic feet per cord and a 15 cubic foot tree as parameter values. Prices of Christmas trees are derived using weighted averages of wholesale prices received by Christmas tree producers in the 1982-1983 season. These are reported in the Michigan Christmas Tree Growers Association market survey.[12] The price of ornamental species is derived from a telephone survey of four large area wholesale ornamental nurseries. According to these nurseries the most common size of ornamental tree sold is the six foot size stock with price averaging $10 per foot. A wide variation exists depending upon the quality, form, and general condition of the tree.[13] The prices used for all commodities in each use class is shown in Table 2.3.

Table 2.3

PARAMETER VALUES FOR 1983 PRICES OF COMMODITIES

COMMODITIY/SPECIES	UNIT/TREE	PRICE/UNIT	PRICE/TREE
REFORESTATION	cu ft/tree	stumpage $/cord	stumpage $/tree
HYBRID PINE	15	7.00	1.05
JACK PINE	15	10.00	1.50
HYBRID POPLAR	15	8.00	1.20
E. WHITE PINE	15	8.00	1.20
WHITE SPRUCE	15	6.50	0.975
RED PINE	15	7.00	1.05
HYBRID ASPEN	15	5.00	0.75
BLACK SPRUCE	15	6.50	0.975
HONEYLOCUST	15	8.00	1.20
EUROPEAN LARCH	15	5.00	0.75
HYBRID LARCH	15	5.00	0.75
		$ M/bd ft	
BLACK WALNUT	40	1,000.00	480.00
CHRISTMAS TREES	individual tree cut at the farm		$/tree wholesale F.O.B. farm
SCOTCH PINE			8.75
BLUE SPRUCE			12.00
E. WHITE PINE			11.00
WHITE SPRUCE			10.00
HYBRID SPRUCE			12.00
W. WHITE PINE			11.00
AUSTRIAN PINE			12.00
ENGLEMANN SPRUCE			12.00
DOUGLAS-FIR			12.50
WHITE FIR			7.00
ORNAMENTAL	height (feet)	$/foot	$/6 foot tree
BLUE SPRUCE	6	10.00	60.00
E. WHITE PINE	6	10.00	60.00
WHITE SPRUCE	6	10.00	60.00
NORWAY SPRUCE	6	10.00	60.00
HONEYLOCUST	6	10.00	60.00
AUSTRIAN PINE	6	10.00	60.00
DOUGLAS-FIR	6	10.00	60.00

Rotation Period

Inherent in the total net revenue function is the number of years each rotation requires for a given forest product. All revenues are counted at time of harvest (end of a rotation) and discounted back to 1983. The longer the rotation, the greater the effect the discount rate will have on total revenues. In present value dollars, longer rotations are worth less than shorter rotations, ceteris parabus. In this way the length of the rotation is important in determining the magnitude of the total revenue. For a given environmental site, price and demand structure, an optimal rotation period can be determined. For timber species, this range where the optimal rotation period occurs begins when the average revenue starts to decrease (diminishing average returns).[14]

The values for rotation length were taken as average production rotation periods expressed in years. The rotation period for reforestation species is standardized for 15 cubic foot tree yields. (The number of years it takes to produce a tree with 15 cubic feet of chips.) The number of years required to grow a tree with 15 cubic feet of chips is dependent upon many factors such as site index, stem density, and numerous silvicultural inputs. The rotation values used are within the range of feasible optimal rotation periods for pulp production.[15]

The value for rotation period of the Christmas tree species is an approximate value derived from two marketing surveys and discussions with both Christmas tree producers and the Cooperative Extension Service. As with reforestation species actual rotation lengths may vary according to local climatic conditions, soil fertility, and a host of management practices. Rotation periods for ornamental species are set according to the number of years required to produce a saleable six foot tree in the wholesale ornamental nursery environment. The parameter values for the rotation period of each commodity is presented in Table 2.4.

Interest Rates

Economic analysis of production processes which necessitate long time requirements are sensitive to interest rates when present value determinations of benefits and costs are made. A wide range of interest rates was used in the analysis to discount benefits and costs. The range spans the "typical" interest rates used by the range of producers in the forest products industry. There are two institutional groups of forest products producers (potential direct beneficiaries of genetic tree breeding programs): private companies and public institutions. Each uses a different discount factor. Public institutions use a relatively low discount factor, an interest rate of 4-8%, while private companies use 10-14% and higher as typical interest rates. Interest rates throughout the analysis are presented as real interest rates, net of inflation. This implies prices of goods and labor are constant; further, the assumption is made that prices are constant with respect to each other.[16]

Table 2.4

PARAMETER VALUES FOR INITIAL SEED ORCHARD PRODUCTION AND ROTATION PERIOD

COMMODITY/SPECIES	INITIAL PRODUCTION SEED ORCHARD (YEAR)	ROTATION (YEARS)
REFORESTATION		
HYBRID PINE	1984	20
JACK PINE	1985	45
HYBRID POPLAR	1985	15
E. WHITE PINE	1986	35
WHITE SPRUCE	1987	40
RED PINE	1988	40
HYBRID ASPEN	1988	15
BLACK SPRUCE	1988	45
HONEYLOCUST	1998	20
EUROPEAN LARCH	2003	30
HYBRID LARCH	2003	25
BLACK WALNUT	2003	50
CHRISTMAS TREES		
SCOTCH PINE	1985	10
BLUE SPRUCE	1985	12
E. WHITE PINE	1986	10
WHITE SPRUCE	1987	12
HYBRID SPRUCE	1987	10
W. WHITE PINE	1998	10
AUSTRIAN PINE	2003	10
ENGLEMANN SPRUCE	2003	12
DOUGLAS-FIR	2003	12
WHITE FIR	2008	12
ORNAMENTAL		
BLUE SPRUCE	1985	8
E. WHITE PINE	1986	8
WHITE SPRUCE	1987	8
NORWAY SPRUCE	1998	8
HONEYLOCUST	1998	5
AUSTRIAN PINE	2003	8
DOUGLAS-FIR	2003	8

Costs of the Research Program

Costs of the research are not allocated to specific activities such as seed collection, and seedling production. This kind of detailed accounting is not possible with the wide spectrum of concurrent primary, intermediate and final product research investigations taking place at Michigan State University. A fairly accurate "lump sum" cost of the final product research program may be estimated. Two methods of cost estimation were used: past budgetary allocations to tree improvement research, and a detailed cost budget constructed from expenditures made during the 1982 planting season. Costs were calculated for the duration of the research program, 1961 to 2008. The two major research cost inputs are primary investigator's labor and operating expenses. Tree improvement research is highly labor intensive. Much of the research activity is performed by advanced degree research personnel. The salary of the professional researchers (portion allocated to research if teaching duties are also part of the scientist's responsibilities) comprises approximately 50% of the total program cost. Operating expenses were calculated over a long time period (22 years) and includes the capital cost of major equipment, along with seasonal operating funds. The operating expense costs are determined by averaging the grant funds and other budgetary items not including salary of researchers from 1961 to 1982. These costs are determined before the University extracts "indirect" costs. In this way, overhead (capital costs and other maintenance costs) were included in the cost of the research program. Two trends of grant funding were observed. From 1961 to 1971 approximately $25,000 per year was allocated to the operating expense category for tree improvement. For the period of 1972 to 1982, $50,000 was allocated to tree improvement operations.[17] All salaries and other operating expenses were deflated using the Gross Domestic Product Consumer Price Index to reflect 1983 constant dollars.[18]

Actual salary expenditures for tree improvement research were obtained for the period 1971 to 1982. Estimated costs based on the 1971 to 1982 period are extrapolated for the period 1961 to 1970. Salary costs from 1983 to 2008 are assumed to be held constant (in real dollars) at the 1983 level. This assumption reflects the conservative flavor of the analysis, going against the observed downward trend of real expenditures for salary.

A second method of cost estimation is possible by constructing an operating budget for the most expensive research activity. Based on the 1983 spring planting season, the cost of a progeny test for one species is determined to be $13,000. The detailed budget for this research activity is given in Tables 2.5, 2.6, and 2.7. This cost represents the expenditure for the operating expense. For the 21 species considered in the analysis, there would be 42 such activities, one provenance test and one progeny test for each species. The total expenditure would then be $546,000 for this research activity. Added to this amount is $25,000 per species for rangewide collection, and the sum total operating expense is $1,071,000 in constant dollars.

Table 2.5

COSTS FOR ONE PROGENY TEST
(CONIFER SPECIES)
(Based on a 6000 Tree Progeny Test)

PLANTING COST FIGURES

	TIME (hrs)	MATERIALS
Seedlings bundled in the cooler ready for planting:		
-Mix soil, band and fill cases	11	6,000 bands, 122 cases $ 250.00 , $ 74.00
-Sow seeds	15	-
-Thin and transplant	34	-
-Maintain in greenhouse	16	fertilizer $ 100.00
-Move to shade	2	-
-Bring in and replicate	42	banding and moss $ 200.00
-Greenhouse fuel and light expense		$ 800.00
SUB-TOTAL (hrs)	120	$ 1424.00
PLANTING AT THREE MICHIGAN SITES: (4 PLANTING DAYS @ 1500 TREES/DAY)		
-Load up	8	-
-Pre-week maintenance	8	repair material $ 400.00
-Extra vehicle	1	$ 60.00
-Travel mileage		$ 160.00 (.40/mile)
-Tractor run-time for 30 hours		$ 60.00 ($2/hr)
-Planting labor (five worker crew)	200	per diem for 5 days $ 500.00 ($20/day)
-Hotel (4 nights)		$ 320.00
-Unload	8	
-Mapping and record keeping	20	
SUB-TOTAL (hrs)	245	$ 1500.00

Table 2.6

SITE PREPARATION AND MAINTENANCE FOR TWO YEARS:
(COSTS FOR ONE TRIP)

-Load up	8	
-Pre-week maintenance	8	repair material $ 400.00
-Travel mileage		$ 160.00 (.40/mile)
-Tractor run-time for 18 hours		$ 32.00 ($2/hr)
-Labor (2 worker crew)	64	per diem for 4 days $ 160.00 ($20/day)
-Hotel (3 nights)		$ 90.00
-Chemicals		herbicides $ 600.00
-Record keeping	8	
-Unloading	8	
SUB-TOTAL (hrs)	96	$ 1442.00
FOR THREE TRIPS (X 3)		
(hrs)	256	$ 4326.00

Table 2.7

TOTAL COST FOR ONE PROGENY TEST *

		LABOR COST $7/hr	LABOR COST $9/hr	LABOR COST $11/hr
SEEDLING COST:				
labor hours	120	$ 840	$ 1080	$ 1320
material	$ 1424.00			
PLANTING COST:				
labor hours	245	$ 1715	$ 2205	$ 2695
material	$ 1500.00			
MAINTENANCE:				
labor hours	256	$ 1792	$ 2304	$ 2816
material	$ 4326.00			
TOTAL $		11,592.00	12,839.00	14,081.00

PER SEEDLING COST FOR ONE PROGENY TEST
(6000 SEEDLINGS)

	LABOR COST $7/hr	LABOR COST $9/hr	LABOR COST $11/hr
SEEDLING IN COOLER:	.38	.42	.46
PLANTING:	.54	.62	.70
MAINTENANCE:	1.02	1.10	1.19
TOTAL $/SEEDLING	1.94	2.14	2.35

* Calculated by MICHCOTIP personnel, summer of 1983. All costs are based on the actual level of planting and material used for the 1982-83 MICHCOTIP planting season.

The total operating expense calculated under the lump sum method is $2,050,000. The more economically conservative method and larger figure of $2,050,000 is used in the analysis. Salary and total nominal costs for 1961 to 2008 are shown in Figure 2.2.

Time Table for Commercial Production

The tree improvement research program moves through 5 steps from research initiation to final research product. Initially, a rangewide seed collection is made. The seeds are grown to seedlings and planted in a provenance test. The provenance test is evaluated and controlled crosses are made. Seeds from the crosses are grown and planted out in a progeny test. The progeny test is measured and evaluated for a number of years. Finally, the progeny test is rogued and genetically improved seed and vegetative cuttings are available for commercial seed orchard production. The nearest commercial production date for the species considered in the analysis is 1984, when F_1 hybrid pine stands will produce commercial quantities of seed to be used in reforestation. The anticipated initial production of commercial seed orchards for each species is the projected year F_1 progeny tests can be converted to seed orchards. Table 2.8 lists the current research stage for each species considered in the analysis.

The actual value for initial production year is based in part on the observed research interest and priority, and in part on the biological constraints in the breeding stages (year to flowering, possibility of early evaluation etc.). Those species being considered

Figure 2.2

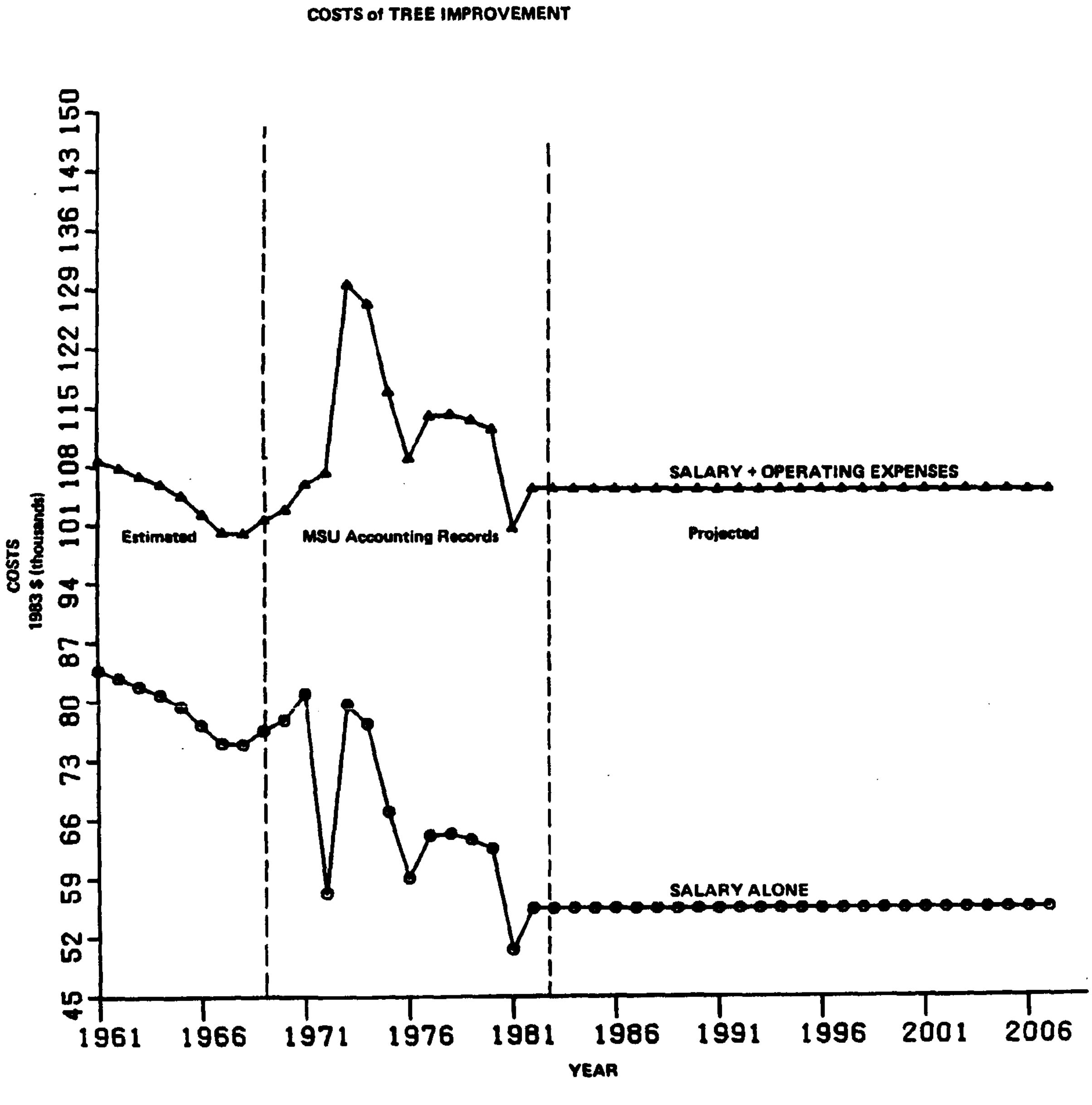

COSTS of TREE IMPROVEMENT
COSTS
1983 $ (thousands)
45
52
59
66
73
80
87
94
101
108
115
122
129
136
143
150
Estimated
MSU Accounting Records
Projected
SALARY + OPERATING EXPENSES
SALARY ALONE
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
YEAR

Table 2.8

RESEARCH DEVELOPMENT PROGRESS FOR VARIOUS SPECIES

SPECIES	CURRENT RESEARCH STAGE	YEARS UNTIL COMMERCIAL SEED ORCHARD PRODUCTION
AUSTRIAN PINE	F-02	20
JACK PINE	F-05	2
RED PINE	F-03	5
SCOTCH PINE	F-05	2
E. WHITE PINE	F-04	3
W. WHITE PINE	F-02	15
HYBRID PINE (jap x nigra)	F-05	1
BLACK SPRUCE	F-04	5
BLUE SPRUCE	F-05	2
ENGLEMANN SPRUCE	F-03	20
NORWAY SPRUCE	F-03	15
WHITE SPRUCE	F-04	4
HYBRID SPRUCE (blue x white)	F-04	4
DOUGLAS-FIR	F-02	20
WHITE FIR	F-02	25
LARCH (all species)	F-02	20
ASPEN	F-04	5
HYBRID POPLAR	F-04	2
BLACK WALNUT	F-02	20
HONEY LOCUST	F-02	15

F-ij: i = breeding generation;
0 = breeding from wild populations
1 = is a genetically improved population

j = research development stage;
1 = Rangewide seed collection
2 = Provenance test
3 = Progeny test from controlled crosses
4 = Measuring, evaluation and testing
5 = F(i) seed orchard construction

for only Christmas tree and ornamental uses will be able to take advantage of early evaluation methods and procedures. Since the production age of the Christmas tree is only 10 to 12 years, evaluation of progeny tests could be carried out in 8 to 10 years, rather than in 20 to 25 as is required for reforestation species.

NOTES - CHAPTER II

1) Levenson, Burton E., and J. W. Hanover. 1983. Michigan Tree Seedling Industry Survey. Michigan State Agricultural Experiment Station Research Report, In Press.

2) Cochran, William G. 1977. Sampling Techniques. Wiley Press; 428 p.

3) James, Lee M., Victor J. Rudolph and Melvin R. Koelling. Production and Marketing of Christmas Trees in Michigan. Michigan State University Agr. Exp. Station Research Report 412; 8p.

4) MICHCOTIP research results compiled by Glenn Howe and Steve Ernst, summer, 1983, Michigan State University.

5) Unpublished statistical results by Schaffer from research conducted at Michigan State University, 1981-1983.

6) Jonathan W. Wright, and Louis Wilson. 1972. Genetic Differences in Scotch Pine Resistance to Pine Root Collar Weevil. Michigan State University Agricultural Experiment Station Research Report 159.

7) N. C. Wheeler, H. B. Kriebel, C. H. Lee, R. A. Read, and J. W. Wright. 1976. 15-Year Performance of European Black Pine in Provenance Tests in North Central United States. Silvae genetica, 25: 1; p. 1-5

8) R. Guries, and A. Ager. 1980. Red Pine Seedling Seed Orchard: 10 Year Results. University of Wisconsin-Madison Department of Forestry Research Notes No. 242, Dec. 1980. 4 p.

9) R. F. Calvert and R. M. Rauter. 1979. Status of Larch Improvement. LSTIC Proc. 1979. p. 145-152.

10) Annual Michigan Christmas Tree Growers Marketing Survey, Department of Forestry, Michigan State University, January, 1982.

11) Miller's formula is found in; James W. Hanover. 1983. Short Rotation Woody Crops Program, Annual Technical Report, 1983. Report Submitted to Union Carbide, March 15, 1983. Smalian's formula is from; Reginald D. Forbes, 1955. Forestry Handbook. Ronald Press Co., p. 1-51.

12) This survey classified Christmas trees by species; 2 size classes; wholesale, retail, and cut-your-own. The price used here is the average wholesale price of both size classes weighed by the number of trees sold.

13) Telephone inquiries were made to either the owners or managers of the following Michigan nurseries: Cottage Gardens, Bosmon's Evergreen Garden Nursery and Landscape, Summit Nursery, and Lincoln Nursery.

14) The theory of forest production economics will not be expounded on here. The reader is directed to three texts for a more complete understanding: "Forest Resource Economics", by G. Robinson Gregory, 1972; "Price Theory and Applications", by Jack Hirshleifer, 1980; and "Managerial Economics", by Pappas and Brigham, 1979.

15) There are few well managed plantations for pulp production. A review of L. Zsuffa's two 1979 working papers titled, "A Breeding Program for Short Rotation Poplar Biomass Production in Ontario" point to the recent efforts in this field. A review of the literature and consultations with the faculty of the Forestry Department at Michigan State University, along with discussions with R. Woessner of Mead Corporation and Richard Sirken from Champion Timberlands, have resulted in fairly accurate estimates of rotation lengths.

16) The one exception is for the sensitivity analysis on price, when the real price is allowed to rise at 1.2% per year.

17) The University accounting system is not set up for cost accounting purposes. Exact expenditures are not available on a single research activity basis. These estimates represent the high cost figures for tree improvement expenditures.

18) Consumer Price Index series is from the 1982 "Economic Report to the President".

CHAPTER III

MODELS FOR ECONOMIC ANALYSIS OF BIOLOGICAL RESEARCH

Economic Analysis of Tree Improvement Programs

There are two fields of plant breeding research where major analysis of productivity and research efficiency have been attempted: forestry and agricultural field crops.

In forestry a great deal of research has been devoted to improving silvicultural management technology, yet little research has been directed toward improving the biological resource base through genetic breeding. It is not surprising, then, to find only a few economic and financial analyses of tree breeding (tree improvement) research programs. Perry and Wang authored a short note in the November 1958 issue of Journal of Forestry describing the value of genetically superior seed.[1] Their intention was to show the potential value due to selection from the "best" geographic source. The extent of detail in this analysis is sparse, and the assumptions inherent in their calculations are broad and largely unspecified. The application is limited to loblolly pine in the southern forestry region. The article does not mention breeding programs, but implies "genetic gain" derived through proper geographic seed source selection. Perry and Wang did initiate the investigation of the value of tree improvement programs. In 1965 Allen Lundgren was one of the first economists to recognize the potential returns to be realized even from slight genetic improvement.[2] Lundgren used an entirely hypothetical situation of tree improvement through limited provenance progeny and plus-tree selection as applied to jack pine and red pine in the Lake States. The criterion for improvement was expressed as an increase in the site index (a proxy for volume or growth rate increase). The evaluation criterion was net present value. Lundgrens model included detailed costs of grafted seed orchard establishment and maintenance. Seed orchard establishment and maintenance are not part of the tree improvement research program. The Lundgren model also was analyzed under the static assumption of only 16,500 acres of planted forest. There was no distinction between returns to research activities and returns to seed orchard production activities.

Davis (1967) performed a similar analysis on cost-return relationships of tree improvement programs in southern pines.[3] Davis also included seed orchard establishment and management costs in his analysis, stressing these activities. It is unclear what, if any, research activities were included in the Davis analysis. Davis uses a net present value methodology but neglects both quantity effects and interest rate sensitivity. The study implies a break-even approach was used to calculate the genetic improvement needed to cover investment costs in seed orchards, but this is never formally presented.

Several studies have noted the potential for tree improvement or opportunities for tree improvement in species commercially utilized for timber. Dawson and Pitcher (1970), Silen and Doig (1976), Zobel (1974), Callahan and Smith (1974), and Marquis (1973), are a few of the early proponents documenting opportunities and potential rewards from tree improvement.[4]

Carlisle and Teich (1970) recognized the difference between the research component and the seed production component, but found no way to separate these costs in the hypothetical case they analyzed.[5] In 1971, Carlisle and Teich presented the results of the first computerized model (implemented on a DEC PDP-8 computer) to analyze costs and benefits of tree improvement programs.[6] This model did not segregate the research and production components nor did it perform a sensitivity analysis on a key variable, the number of trees planted. The model assumed 100,000 acres of commercial forest land would be planted yearly in white spruce. The model provided sensitivity analysis on other important variables, namely interest rate, genetic gain and price.

After a series of introductory papers on opportunities in tree improvement from 1958 to 1971, Schreuder presented a marginal analysis of the economics of tree improvement in a short course at the Center for Quantitative Sciences.[7] This analysis was one of the first to look at the efficiency of tree improvement programs, attempting to optimize the program. The situation is hypothetical and the analysis is simplified, but it represents the beginning of the next phase in the investigation of economic returns to tree improvement. Van Buijtenen and Saitta (1972) subsequently used a linear programming model applied to the economic analysis of tree improvement.[8] Their definition of tree improvement consisted primarily of seed orchard development and propagation. Using plus-tree selection as a "research method" for tree improvement, Van Buijtenen and Saitta used the linear programming model to optimize southern pine seed orchard size and roguing intensity.

In 1975, Porterfield performed the most detailed economic analysis of tree improvement programs to date.[9] Porterfield used the southern pine (loblolly pine) tree improvement program as a case study to perform a goal programming analysis of tree improvement efficiency. Although Porterfield's model separated the research costs from seed orchard management, the goal programming model optimized seed orchard management. Porterfield also ignored limits on quantity of seedlings assuming instead that an unlimited number of seedlings would be planted. In subsequent studies Porterfield and Ledig (1981) used a break-even, benefit-cost analysis to determine the minimum gain needed for tree improvement research.[10] Both these studies, one dealing with white and black spruce in an eastern United States setting, and the other looking at ponderosa pine and Douglas-fir on the west coast, segregate costs associated with selection (provenance and progeny test programs) and with seed orchard development and management. These studies also recognized the quantity question, but performed no sensitivity analysis. They simply assumed a fixed number of acres planted annually for the life of one seed orchard.

The progression in economic analysis of tree improvement programs has gone from broad speculative analysis to rather detailed optimization studies of seed orchard management. Most of the analyses have centered around the financial returns to seed orchard development and management. Few studies delineate the research component as a separate input in tree improvement programs. Only a handful of analyses address the question of quantity. No study goes beyond tree improvement research for products other than timber and pulp. In addition, no study has modeled tree improvement programs with more than two species.

The works completed in this field so far cannot be classified as economic analysis of research programs. Studies have investigated tree improvement programs, making little distinction between seed orchard management and the research necessary to lay the foundation for commercial production. Rarely are quantity and market effects mentioned. The definitions of market and benefit levels are vague. There is virtually no mention of secondary effects from tree improvement programs (non-market cost and benefits and multiplier effects). Most of the studies in the literature fall into the category of financial analysis of seed orchards. These studies calculate the return to seed orchards, not to research.

None of the papers address the returns to research question as a separate component in tree improvement programs. To investigate the models and methods used for this type of economic analysis the work in agricultural economics is reviewed.

Economic Analysis of Agricultural Research

Ex-Post Studies. There are two broad classes of methodologies relating to analysis of returns to research in agriculture. One class is ex-post studies. These studies analyze completed research programs and review the resulting changes in output or price. The ex-post studies can be further classified into consumer and producer surplus analyses, estimating average rates of return, and production function analyses which determine marginal rates of return. Shultz (1953) was among the first to attempt a major quantitative evaluation of agricultural research investments by calculating the value of inputs saved through more efficient production technologies compared to the costs of research programs.[11] He estimated what the output of the agricultural community would have been in 1950 using 1910 technology and material inputs, in effect calculating the increase in consumer surplus resulting from the savings in inputs. To do this, it was necessary to calculate a marginal per unit cost of production using 1910 and 1950 technologies. Shultz further made some rather sweeping assumptions concerning demand. No attempt was made to segregate individual research components (new machinery development versus crop breeding research etc.).

Since Shultz's initial work, two landmark studies have calculated net consumer surplus for discrete research programs. Griliches (1958) calculated the loss in net consumer surplus if hybrid corn were to disappear.[12] The basic assumptions inherent to Griliches' study are that use of hybrid corn has shifted the supply curve for corn downward (greater output for a given price) and that the net consumer surplus is the value of the hybrid corn research program. This study is extremely thorough in its sensitivity analysis, estimating net consumer surplus for all intermediate and all polar cases of supply and demand (perfectly elastic versus perfectly inelastic) and for a variety of interest rates. Schmitz and Seckler (1970), in their study on social welfare (consumer surplus) as affected by the mechanized tomato harvester, used Griliches' approach but went into more detail on non-marginal effects of the increased mechanization and production. Specifically, they attempted to "appraise both the heightened production efficiency and its effect on the welfare of the workers."[13] Not only did Schmitz and Seckler compute the gross social benefits and research costs, but also calculated a net social rate of return by including the cost of wage loss of the displaced labor force. This was one of the first major studies to recognize and quantify the full economic implication of research programs resulting in wide spread use of more efficient production technologies. Griliches, and subsequently Schmitz and Seckler, of necessity made broad and simplistic assumptions concerning the dynamics of the supply and demand curves for corn and tomatoes respectively. Even today, with more accurate data series and powerful computers, estimation of these curves is complex. At a national commodity level, the construction of a dynamic supply and demand curve is difficult. When Griliches, and Schmitz and Seckler did their work, construction of accurate and meaningful national level supply and demand curves was clearly infeasible. In the last decade, many papers have been presented dealing with the effects more complex and dynamic supply and demand curves have on the conclusions of Griliches and Schmitz and Seckler. Nonetheless, the basic conclusions of Griliches and Schmitz and Seckler have stood up to the past decade of scrutiny.

Lindner and Jarrett (1978) recognized that total benefits are inflated by the nature of the research generating the supply shift.[14] They hypothesized that some innovations are more likely to generate divergent and others convergent supply shifts. Their reasoning focused on the effects different types of innovations (biological, chemical, mechanical, and organizational), on the average costs of marginal and lower cost firms (less than marginal) and the location of those firms on the industry supply curve.

The production function approach is the other ex-post methodology used to estimate returns to agricultural research. Research is included as an input in the production function for a commodity. The basic model which is log-linear in its inputs, is:

Equation 3.1 $$Q=A\prod_{i=1}^{m} X_i^{B_i}\prod_{j=0}^{n} R_{t-j}^{a_{t-j}}u$$

Where Q is value of agricultural output, A is a shift factor, X_i is the ith conventional production input, R_{t-j} is the expenditure on research in the t-jth year, B_i is the production coefficient of the ith conventional input, a_{t-j} is the partial production coefficient of research in the t-jth year and u is the random error term.

This methodology has been applied using primarily cross-sectional data. A major difference in the various studies using this approach has been the length of the time lag reflecting the impact of research expenditures on output. The production function approach is attractive to economists because it yields the value of the marginal return to research. The production function approach has been primarily used at the national level of output. Griliches (1964) and Davis (1979) used it to calculate aggregate output for the United States.[15] This model has been particularly popular in Third-World countries, where production functions are simpler to construct. Evenson (1967) first applied this approach in the United States to calculate the marginal product of research in the United States.[16] The production function methodology is useful for separating the production effects of research from those of education and conventional inputs (materials and labor) among geographic areas. A major difficulty is obtaining detailed data on production inputs such as labor, machinery, and management. The production function methodology is best applied at the individual firm or farm level. In theory, large aggregate national production functions for a commodity can be constructed by summing individuals' functions. In practice, these large aggregate production functions are at best, fiction. Aggregation of individual functions does not yield manageable national functions. Assumptions dealing with non-marginal effects by the individual do not translate to the national level. Since research as an input affects the total production, there is some doubt as to the validity of this approach.

Neither methodology is particularly well suited for analyzing tree improvement programs. There are no completed tree improvement programs for which a sufficient number of years of economic data exists to perform the analysis. Consumer surplus methodology centers around the ability to construct a demand curve for the consumer commodity research effects. If sufficient data on the demand of seedlings existed in the Lake States (which it does not), 29 separate demand curves would be required to investigate returns of the Michigan tree improvement program as each species/commodity has its own unique market structure and characteristics.

The production function approach relies on accurate cross-sectional data on individual firms' production functions. This data does not exist for the forest products industry in the Lake States.[17]

Ex-Ante Studies. Ex-ante methodologies can be classified into four groups: those using scoring models to rank research activities; those using mathematical programming to select an optimal mix of research activities; those studies using stochastic simulation models; and those employing benefit cost analysis to establish returns to research.

Scoring models have been used to evaluate research alternatives primarily by public institutions (USDA, land grant colleges etc.) which have a sizable and diverse research component. Shumway and

McCracken (1975) use the results of a scoring model analysis in ranking research activities.[18] Mahlstede (1971), in another study, states "the validity of the study rests heavily on the premise that scientists, through a systematic group effort, can predict, to some degree, the outcome of scientific inquiry and thus improve the basis of selecting research activities that will offer the highest return."[19]

This type of analysis does not return a cardinal value for research benefits. An ordinal value is returned, useful for comparison to other research alternatives under the same management umbrella. Evaluation of just one isolated research activity or program is not possible with scoring models.

Mathematical programming models (linear programming, dynamic programming, and goal programming) have been used to optimize a given research program.[20] These models, although theoretically useful, require assumptions which limit their practical use.[21] Detailed data on the research process and returns to separate research activities are also necessary to fully utilize this methodology.

Several studies have used stochastic simulation models to investigate the returns to research.[22] These models are generally large, complex and costly to run. Simulation models are more widely used for research evaluation in the private sector than for public research evaluation. This is because private sector research is often more narrow and select than public sector research. Private research generally involves only processes and reward schedules which are well known. A simulation model for tree improvement programs would theoretically be possible and the methodology conclusive to the research environment. These models require extensive data series to estimate the parameters; not enough data exists to create probability functions necessary in simulation models for various tree breeding activities.

Benefit cost studies, the last category of ex-ante methodologies, are similar to consumer and producer surplus methodology. One major difference is that ex-ante benefit-cost studies must project what the future yield or gain will be, whereas consumer surplus studies calculate the yield based on past production.

Fishel (1971) describes and reviews a comprehensive computerized model for collecting and processing information needed to evaluate research activites and to select an efficient allocation of resources among research activities.[23] The model, called the Minnesota Agricultural Research Resources Allocation Information System involved three major steps: specification, estimation, and analysis. Benefit-cost ratios, net present value, and internal rate of return are returned by the model for each research project. The Minnesota model relied on surveys sent to scientists in the field to estimate annual expenditures, time requirements, and technical feasibility of research. This model is extremely complex, but considering the accuracy of the estimation step, the complexity may be spurious.

Ramalhode, Castro, and Schuh (1977) created a model with a slightly different approach.[24] Their study focused on growth and distributional effects of technological change along with direct and indirect effects of research. This approach is quite similar to consumer surplus methodology in that it also assumes the supply curve shifts in different directions for various crops. The data for this model is derived through secondary sources, to project yield increases, adoption rates, and probability of success.

Two key studies, Easter and Norton (1977) and Araji, Sim and Gardner (1978), applied benefit-cost methodology to specific commodity research programs.[25] Easter and Norton used scientists' estimates for yield and cost effects of various research conducted at land grant universities. These estimates were then compared with the 1978 United States Department of Agriculture budget requests for soybean and corn production research. An important aspect of this study was the sensitivity analysis performed. The benefit-cost ratio sensitivity to variations in probabilities of success, yield increases, commodity prices, and research program completion time, were analyzed.

The Araji, Sim, and Gardner study evaluated returns to agricultural research and extension programs for sheep, fruit and vegetables, potatoes, cotton, and rice in the western United States. An important aspect of this study is the distinction between research programs and extension activities. Both research and the agent to facilitate widespread use (extension) are needed to garner benefits.

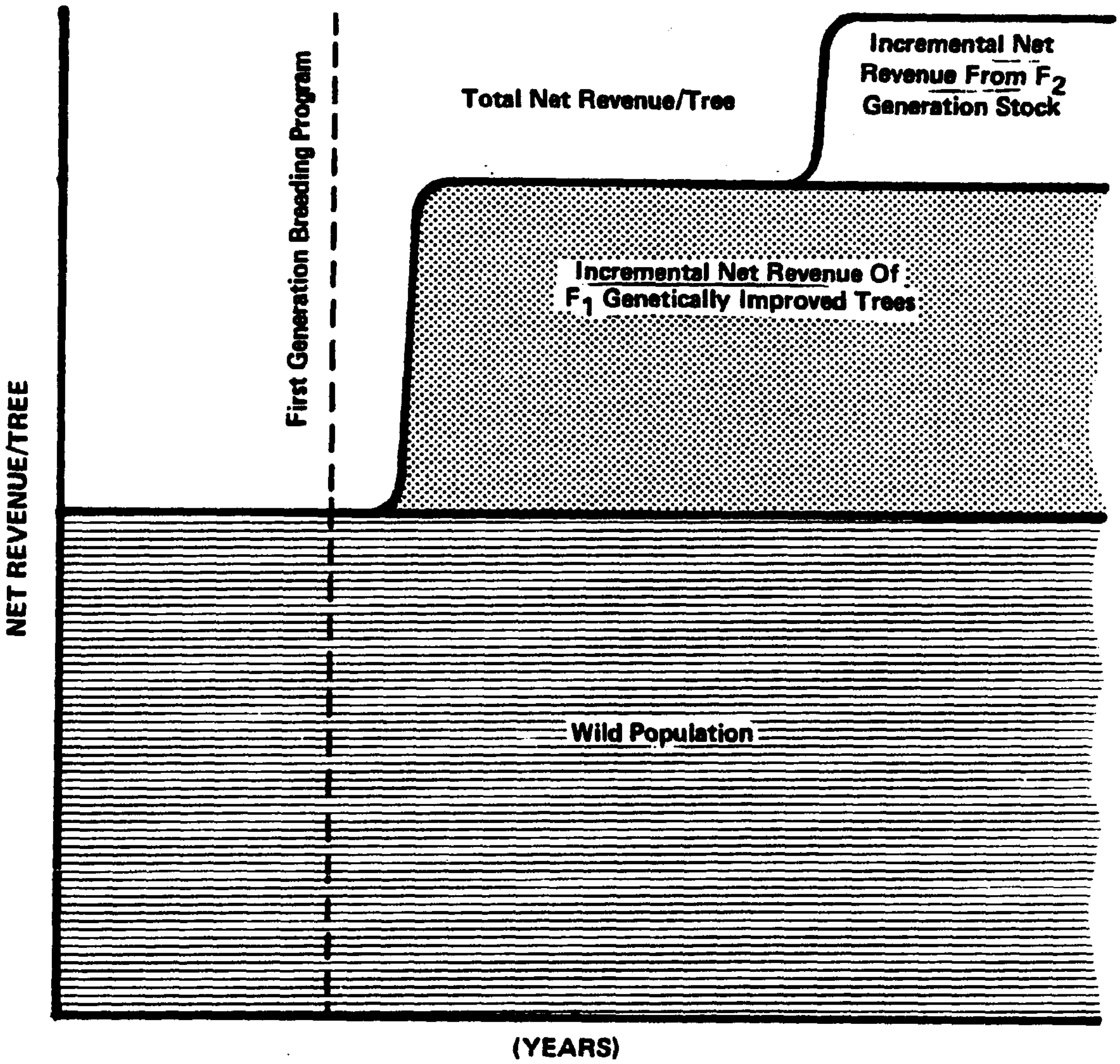
Their methodology was similar to that of Easter and Norton. Personal interviews of agricultural researchers and extension specialists were conducted to gather data for the study. The main parameters of the analysis were all determined through interviews. They include: the initiation and termination dates of research projects for each commodity; the probability of success; probability and rate of adoption of research results (with and without extension); and extension resources required to implement and maintain the new technology. The Araji, Sim, and Gardner study did not perform sensitivity analysis on the several key variables in the model.

Benefit Cost Analysis Applied to Tree Improvement Research

Considering the unique economic environment of forestry and limited data available, an ex-ante benefit cost methodology is best suited to analyze the returns to tree improvement research. A benefit-cost analysis applied to tree improvement research will compare the increase in net revenue resulting from using genetically superior trees to the costs of the final product research. The cost of the research is a one-time expenditure yielding a product (information and genetically improved stock) which produces an infinite stream of benefits. The realization of benefits relies on the ability of forest managers to maintain segregation of the genetically superior population from the wild population, and to maintain the regenerative capability of the superior population. A graphic depiction of tree improvement research benefits is shown in Figure 3.1. Both benefits and costs are converted to present value

Figure 3.1

BENEFITS OF TREE BREEDING RESEARCH



Net Revenue/Tree Increases With Each Generation Of Tree Breeding terms using 1983 as the base year. A generalized economic model is shown in Figure 3.2.

The benefit cost methodology is chosen for two primary reasons: to determine the magnitude of potential economic benefits or losses; and to conduct a sensitivity analysis to see how changes in key variables affect the outcome. Four key variables which affect the economic analysis show a high degree of uncertainty. These are the interest rate, the genetic gain expected (in terms of the effect on price), the future price of the commodity itself, and the future level of production.

Because of the extremely long time periods involved on both the cost and benefit side, the interest rate used to calculate present values is a highly sensitive variable. The interest rate is one variable on which sensitivity analysis is performed. The price of the commodity and level of production (quantity) are both variables with a degree of uncertainty attached to them. Price and quantity are critical variables to the benefit cost methodology since revenue (from which present value benefits are calculated) is determined by the product of price and quantity. These two variables are the subject of a sensitivity analysis. The genetic gain variable is used to calculate the difference in revenue between commodities not affected by the research and those which are. Sensitivity analysis is applied to this variable also.

Figure 3.2

GENERAL ECONOMIC MODEL

$$\text{Total Value of Genetic Research} = \sum_{i=h+F_1}^{\infty} \sum_{j=1}^{n} (PVB^{*}_{ij} - PVB_{ij}) - \sum_{i=r}^{p} PVC_i$$

PVB^{*} = Present Value Benefits of Genetically Superior Population

PVB = Present Value Benefits of Wild Population

PVC = Present Value Research Costs

h = Rotation Length

F_1 = Year F_1 Seed Orchard Begins Production

p = Year Research Program Ends

r = Year Research Program Begins

j = 1,...., n Species

i = Years

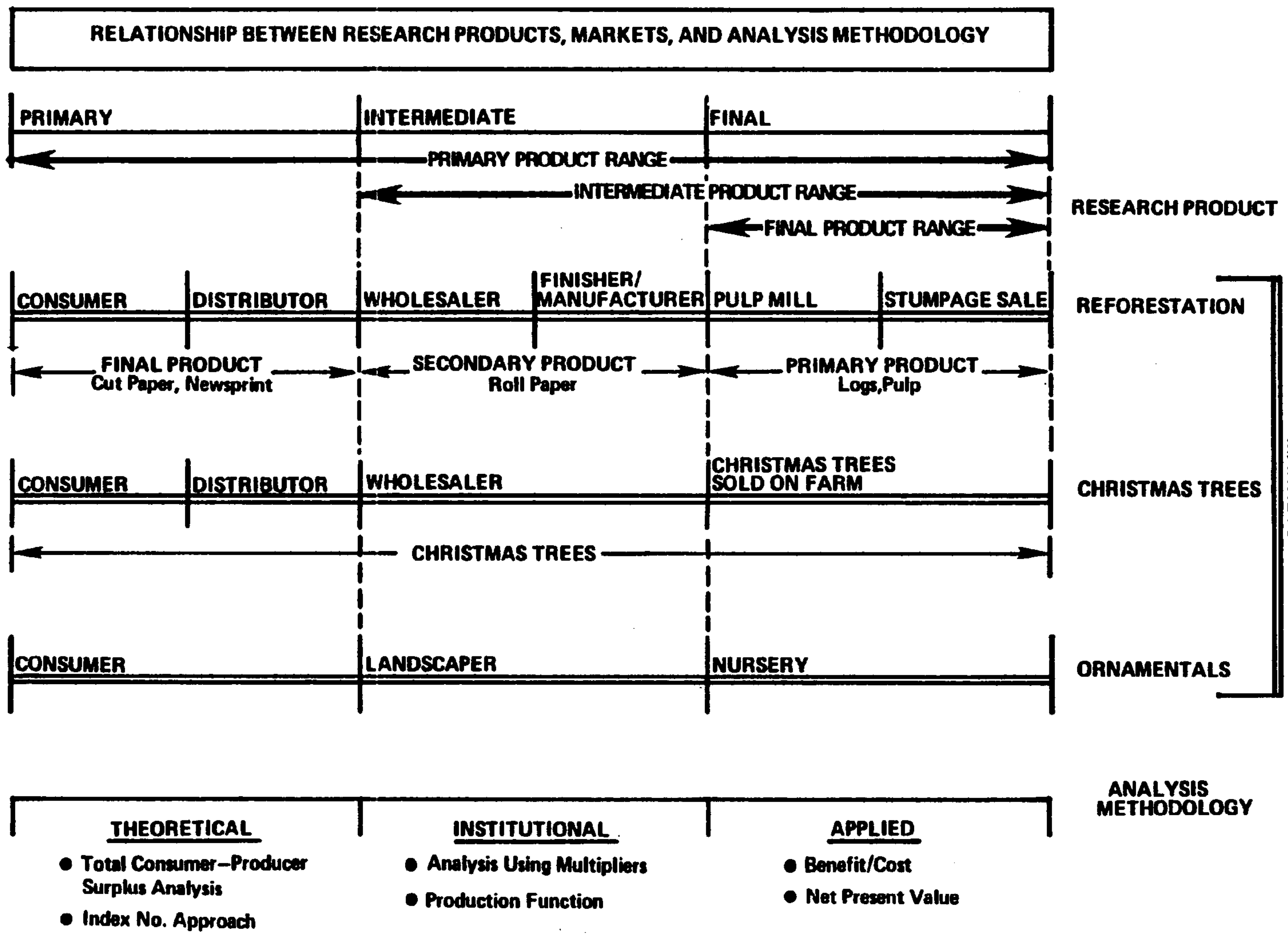
The major drawback with this methodology is the static nature of the model. For each estimate of net benefits, the values for the variables in the model are fixed. The sensitivity analysis is also static. Only one variable is changed at a time while all others are held constant, implying independence of all the variables. Obviously, variables such as price and quantity are not independent, but other models which may take this factor into account are equally unsuited for reasons already stated, or are infeasible with the available data.

Summary

There is a relationship between market levels, analysis methodology, and the scope of effect from research products. This is shown in Figure 3.3. The final research products are specific in application. Primary market levels are directly influenced by final research products. The methodologies most suited for this level of economic analysis are benefit-cost, and net present value. Both are methodologies which have few built-in assumptions, and both methodologies are highly flexible in the amount of detail allowed in analytical model construction.

Intermediate research products have a wider effect on market levels. This type of research product not only affects primary market levels but also directly affects higher market levels. To account for these effects, a more encompassing economic analysis methodology is needed. Studies at this level are usually industry-wide studies. Frequently used methodologies are those using multipliers (such as

Figure 3.3


RELATIONSHIP BETWEEN RESEARCH PRODUCTS, MARKETS, AND ANALYSIS METHODOLOGY
PRIMARY
INTERMEDIATE
FINAL
PRIMARY PRODUCT RANGE
INTERMEDIATE PRODUCT RANGE
FINAL PRODUCT RANGE
RESEARCH PRODUCT
CONSUMER
DISTRIBUTOR
WHOLESALER
FINISHER/ MANUFACTURER
PULP MILL
STUMPAGE SALE
REFORESTATION
FINAL PRODUCT
Cut Paper, Newsprint
SECONDARY PRODUCT
Roll Paper
PRIMARY PRODUCT
Logs,Pulp
CONSUMER
DISTRIBUTOR
WHOLESALER
CHRISTMAS TREES SOLD ON FARM
CHRISTMAS TREES
CHRISTMAS TREES
MARKETS
CONSUMER
LANDSCAPER
NURSERY
ORNAMENTALS
ANALYSIS METHODOLOGY
THEORETICAL
● Total Consumer–Producer Surplus Analysis
● Index No. Approach
INSTITUTIONAL
● Analysis Using Multipliers
● Production Function
APPLIED
● Benefit/Cost
● Net Present Value

input/output analyses), and production function approaches. Analytical studies at this level have more assumptions than studies of final research products. These assumptions are needed to account for the greater economic complexity at this level. The detail of the analysis at this level is constrained by the number and scope of economic assumptions.

Primary research products are most encompassing in their affect on the economy. The effects of primary research products envelop all levels of consumer markets. The analysis methodology at this level is theoretical at best. Studies at this level have a questionable quantitative accuracy. Those few analytical studies which are attempted at this level are highly constrained in detail. These studies incorporate the greatest number and broadest assumptions.

NOTES - CHAPTER III

1) Thomas Perry and Chi-Wu Wang. 1978. The Value of Genetically Superior Seed. J. For. 56: 11; p. 843-845

2) Allen Lundgren and James P. King. 1965. Estimating Financial Returns from Forest Tree Improvement Programs. Working paper from the Lake States Forest Experiment Station, St. Paul, Minnesota; 17 p.

3) Lawrence S. Davis. 1967. Cost-Return Relationships of Tree Improvement Programs. Working paper from Virginia PolyTechnic Institute, Blacksburg Virginia; 6 p. Problem Analysis. USDA Forest Service North Central Forest Experiment Station

4) David H. Dawson and John A. Pitcher. 1970. Tree Improvement Opportunities in the North Central States as Related to Economic Trends, A Problem Analysis. USDA Forest Service North Central Forest Experiment Station NC-40; 30 p., and David Marquis. 1973. Factors Affecting Financial Return From Hardwood Tree Improvement. J. For. 71: 2; p. 79-83, and John C. Callahan and Robert P. Smith. 1974. An Economic Analysis of Black Walnut Plantation Enterprises. Purdue University Research Bulletin No. 912, August, 1974; 20 p., and Bruce Zobel. 1974. Increasing Productivity of Forest Lands Through Better Trees. S. J. Hall Lectureship in Industrial Forestry, April 18, 1974; 19 p., and Roy Silen and Ivan Doig. 1976. The Care and Handling of the Forest Gene Pool. Pacific Search, 10: 8, June, 1976; p. 7-9

5) A. Carlisle and A. H. Teich. 1970. The Costs and Benefits of Tree Improvement Programs. Petawawa Forest Experiment Station Information Report PS-X-20, June, 1970; 28 p.

6) A. Carlisle and A. H. Teich. 1971. The Costs and Benefits of Tree Improvement Programs. Canadian Forestry Service Publication, No. 1302; 34 p.

7) Gerald Schreuder. 1971. The Economics of Tree Improvement. WFGA Short Course, Mimeo Handout; 11 p.

8) J. P. Van Buijtenen and W. W. Saitta. 1972. Linear Programming Applied to the Economic Analysis of Forest Tree Improvement. J. For. 70: 3; p. 164-167

9) Richard Porterfield. 1974. Predicted and Potential Gains from Tree Improvement Programs--A Goal Programming Analysis of Program Efficiency. North Carolina State University School of Forest Resources Technical Report No. 52; 112 p.

10) F. T. Ledig and Richard Porterfield. 1981. West Coast Tree Improvement Programs: A Break-Even, Cost-Benefit Analysis. Pacific Southwest Forest and Range Experiment Station Research Paper, PSW-156; 8 p.

11) Theodore Schultz. 1953. The Economic Organization of Agriculture. New York, McGraw-Hill Book Co.; 374 p.

12) Z. Griliches. 1958. Research Costs and Social Returns: Hybrid Corn and Related Innovations. J. Polit. Econ. 66: p. 419-431

13) Andrew Schmitz and David Seckler. 1970. Mechanized Agriculture and Social Welfare: The Case of the Tomatoe Harvester. Amer. J. Agr. Econ. 52: 10; p. 569-576

14) R. K. Linder and F. G. Jarrett. 1978. Supply Shifts and the Size of Research Benefits. Amer. J. Agr. Econ. 60: 1; p. 48-56

15) Z. Griliches. 1964. Research Expenditures, Education, and the Aggregate Agricultural Production Function. Amer. Econ. Rev. 54: p. 961-974, and J. Davis. 1979. Stability of the Research Production Coefficient for U.S. Agriculture. Ph.D. thesis, University of Minnesota.

16) Robert Evenson. 1967. The Contribution of Agricultural Research to Production. J. Farm Econ. 49: p. 1415-1425

17) A recent input-output study on the timber products industry is in the final stages of completion and should contribute to the cross-section data void which exists. One publication, "Timber Products Economy of Michigan" by James, Heinen, Olson, and Chappelle has resulted from this study.

18) C. R. Shumway and R. J. McCracken. 1975. Use of Scoring Models in Evaluating Research Programs. Amer. J. Agr. Econ. 57: 10; p. 714-718

19) J. P. Mahlstede. 1971. From, "Long-Range Planning at the Iowa Agricultural and Home Economics Experiment Station" in, "Resource Allocation in Agricultural Research" edited by W. L. Fishel, Minneapolis: University of Minnesota Press; p. 327

20) For examples of detailed studies, see: R. W. Cartwright. 1971. Research Management in a Department of Agricultural Economics. Ph.D. thesis, Purdue University; and Richard Porterfield. 1974. Predicted and Potential Gains from Tree Improvement Programs--A Goal Programming Analysis of Program Efficiency. North Carolina State University School of Forest Resources Technical Report No. 52; 112 p.; and D. G. Russell. 1977. Resource Allocation Agricultural Research Using Socio-Economic Evaluation and Mathematical Models. Can. J. Agr. Econ. 23: 2; p. 29-52, and Donald Keefer. 1978. Allocation Planning for R&D with Uncertainty and Multiple Objectives. IEEE Transactions on

Engineering Management, Vol EM-25, No. 1; p. 8-14; and Bernard Tailor, Laurence Moore and Edward Clayton. 1982. R&D Project Selection and Manpower Allocation with Integer Non-linear Programming. Mgt. Sci. 28: 10; p. 1149-1158; and Tom Lee. 1982. A Nonsequential R&D Search Model. Mgt. Sci. 28: 8; p. 900-909.

21) Ronald Heiner. 1983. The Origin of Predictable Behavior. Amer. Econ. Rev. 73: 4; p. 560-595

22) Robert Evenson and Yoav Kislev. 1976. A Stochastic Model of Applied Research. J. Pol. Econ. 82: 2; p. 265-281; and P. E. Winkofsky, N. R. Baker, and D. J. Sweeney. 1981. A Decision Process Model of R&D Resource Allocation in Hierarchical Organizations. Mgt. Sci. 27: 3; p. 268-283

23) Walter Fishel. 1971. The Minnesota Agricultural Research Resource Allocation Information System and Experiment. in "Resource Allocation in Agricultural Research", W. Fishel, ed. University of Minnesota Press, 1971.

24) J. P. Ramalhode de Castro and G. E. Schuh. 1977. An Empirical Test of an Economic Model for Establishing Research Priorities: A Brazil Case Study. in, "Resource Allocation and Productivity in National and International Agricultural Research", ed. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan, University of Minnesota Press, 1977.

25) K. W. Easter, and G. W. Norton. 1977. Potential Returns from Increased Research Budgets for the Land Grant Universities. Agr. Econ Res. 29: 1; 127-133; and A. A. Araji, R. J. Sim, and R. L. Gardner. 1978. Returns to Agricultural Research and Extension Programs: An Ex-Ante Approach. Amer. J. Agr. Econ. 60: 11; p. 964-968

CHAPTER IV

THE MODEL USED IN THE ANALYSIS

The Model

The model in this analysis uses a benefit cost methodology to return an estimate of net present value for the tree improvement research in Michigan. Equations 4.1 and 4.2 in Figure 4.1 show the basic structure of the model. Pij represents the price per unit (tree) of the ith year for the jth commodity. Qij is the number of the jth commodity in units entering the market or sold in the ith year. The rotation length (h), is the number of years necessary to produce one crop of the jth commodity. The genetic gain (g), is the F1 breeding cycle gain for the jth commodity. The interest rate (r), is real interest net of inflation. The year (i), is when the genetically improved crop is harvested for commodity j. Years are normalized so that the year 1983 corresponds to $i=0$.

These equations contain the parameters most sensitive and important in determining benefits. In developing a model for a benefit cost analysis, there is a trade-off between model detail (formulation), execution cost, and accuracy. The execution cost is somewhat dependent on technical model programming skills. The accuracy of the results, however, is a function of the raw data inputs and the ability of the model to utilize the degree of detail represented in the raw data. The complexity and detail of the model presented in this dissertation reflects the same level of detail and

Figure 4.1

EQUATIONS TO CALCULATE ECONOMIC GAIN FROM GENETIC BREEDING

$$\sum_{i=h+F_{1_j}}^{\infty} \sum_{j=1}^{n} \left\{ \left[P_j Q_j \left[\frac{1}{(1+r)^{i-(h_j g_j)}} \right] \right] - \left[P_j Q_j \left[\frac{1}{(1+r)^{i}} \right] \right] \right\} \qquad \text{Formula 4.1}$$

$$\sum_{i=h+F_{1_j}}^{\infty} \sum_{j=1}^{n} \left\{ \left[P_j Q_j \left(1+g_j\right) \left[\frac{1}{(1+r)^{i}} \right] \right] - \left[P_j Q_j \left[\frac{1}{(1+r)^{i}} \right] \right] \right\} \qquad \text{Formula 4.2}$$

P= Price/Unit

Q= Quantity (Units)

g = Genetic Gain (decimal) (%/100)

r = Interest Rate (decimal) (%/100)

F_1 = Year F_1 Seed Orchard Begins Production

j = 1,...., n Species

h = Rotation Length of Unimproved Stock

i = $h+F_1$,...., ∞ Years

accuracy found in the raw data.

Certain economic assumptions are inherent to the model. For the most part, the level of complexity determines the assumptions. This model was constructed realizing the limitations of the data availability, and knowledge of the production functions and operations of the three commodity qroups included in the analysis. Further detail incorporating dynamic interaction of the following assumptions would cloud the observations of the more important sensitivity analysis for the key parameters: genetic gain, price, quantity and interest rates.

Assumptions.

The level of complexity of the model requires the following major assumptions to be built into the analysis:

1. Real price of the commodity is constant with respect to time and with respect to all other commoditites. This assumption is dropped in the sensitivity analysis in which the real price of all products rise according to historical trends.

2. Prices of all resource commodities and costs of research represent the opportunity cost or shadow price of the resource. For the timber resource (pulp, timber etc.) and Christmas trees this implies the price of the resource includes economic rent of the land. Research costs, are also assumed to be the opportunity cost of the research activity. Prices and costs are therefore always assumed to

be what the price or cost would be under perfect competition with perfect knowledge by all producers and consumers. Firms are also assumed to be pure price takers.

3. The interest rate (net of inflation)) is assumed to be constant over time. Obviously, real interest rates fluctuate over time. Since interest rate is one of the more sensitive variables in the analysis and future interest rate changes difficult to predict, a constant rate is used in the model.

4. Rotation periods are assumed to be infinitely divisible. Forest management practices treat rotation period as an integral number of years. In this model, rotations can involve a fraction of a year.

5. The model assumes an infinite number of rotations for each commodity included in the analysis. The number of trees harvested in each rotation remains the same, with the exception of the analysis of sensitivity to industry growth assumptions. Trees in this model, are being treated as an infinitely renewable resource.

6. The model does not allow for extraordinary capitalization on onetime profits resulting from genetic improvement. It is assumed that all normal profits resulting from sales of the commodities in the analysis are reinvested in the production operation to sustain further rotations. Any windfall profits from using genetically superior stock are also assumed to be reinvested in the production operation or are assumed to be invested at the same interest rate specified for the

same time period as one rotation ad infinitum.

7. Availability of land in Michigan for planting trees is assumed not to be a constraint or limiting factor. This qualification is necessary to avoid negative joint impact effects a land constraint would have on the economic valuation of the commodities in the analysis. The maximum land use for artificial regeneration under the expanding industry assumption is set to one half the commercial forest land area in the state.

8. Several management assumptions are needed primarily for the timber industry sector commodities in the model. One assumption is that all plantations are on "good" growing sites. For all industrial sectors, it is an assumed that all labor and material inputs and the timing of these inputs into the production of "wild trees" are identical to inputs into genetically improved trees. This says that no extra inputs are required to produce trees with superior genes.[1]

Valuation of Benefits

Benefits are evaluated in the model in two different ways. Equation 4.1 "discounts time". The genetic gain is seen as a reduction in the rotation period of each crop. The value to the producer of trees is the difference in the timing of revenue realization (interest charge) between longer "normal" rotations and shorter rotations resulting from faster growing trees. Equation 4.2 "discounts quantity." The genetic gain is reflected by either a higher price for the commodity or a greater volume of the commodity.

The value is the difference between the quantity or price of the normal tree and the higher quantity or price of the genetically superior tree. A basic assumption is that no extra inputs are required to grow a genetically improved seedling to maturity. Net revenue per tree (value) can, therefore, be expressed three independent ways. The first is increased net revenue due to a decrease in interest charges resulting from shorter rotations (trees grow faster). The second is an increase in net revenue due to higher prices received in the market (trees have better qualities which command higher prices). The third expression of an increase in net revenue is due to a reduction in the cost of the production process (trees are more uniform and easier to manage and harvest).

The model assumes only one method of calculating net revenue for each commodity. Of course, if two or three valuation assumptions interact in a positive manner, the total benefits would be greater than under a single valuation assumption alone. As an example, there is little price variation within a species used for pulp stumpage based on quality (form of the tree, specific gravity, etc.). The price function for reforestation species within a commodity group is based on volume of fiber. Genetic improvement of these commodities results in a faster growing tree. The increase in net revenue is from decreased interest charges; the trees are harvested earlier. Some cost reduction may also occur if genetically controlled traits, which may decrease silvicultural management costs, are favorably correlated with growth rate. The total net revenue with the cost reduction is greater than when calculated based on decreased interest charges alone. For each commodity the model calculates the net revenue using both valuation methods (discount time and discount quantity). The method which returns the highest value is used to calculate the benefits.

<u>Computer Programs Used to Run the Model</u>

The model is available in the form of a series of Fortran V (ANSI 1977 standard) programs which reside on magnetic tape under the control of the Michigan State University Forestry Department. The face validity of the code was checked and confirmed by qualified programmers. Appendix I is a listing of the three programs used to calculate benefits and costs. The main program (ECON) calculates the present value benefits for each commodity and performs the sensitivity analysis. Program ANALYS sums the benefits and provides other information. Program ECOSTS determines the present value of the research costs for the same interest rates used in ECON and ANALYS.

In this dissertation, program ECON calculates the present value benefits gain for each of the 29 commodities in the analysis. The program internally determines which equation (4.1 or 4.2) to use for each commodity. The decision rule is to use the equation which yields the greater net revenue. Program ECON approximates an infinite number of rotations at 300 years plus the commercial life of the F1 seed orchard. A test for the accuracy of this approximation was conducted. The test consisted of comparing a present value sum calculated at each interest rate using the model (300 plus years) and calculating a present value using an infinite period formula. Program ECON returned the same answer as the infinite period formula, accurate to 32 decimal places, for the range of interest rates used in the analysis. The formula to calculate the present value for an infinite series could have been used, except in the sensitivity analysis in which both real price and quantity are expanding. To be consistent in the presentation of results between sensitivity runs, the approximation was used. Inclusive of all commodities and sensitivity analysis, program ECON in this dissertation calculated the net revenue of 1,049,220 rotations. Program ANALYS uses the output file from ECON to calculate the benefits from tree improvement research. A benefit estimate is returned for each sensitivity analysis, 108 in all. Program ANALYS also calculates the contribution of each use category (reforestation, Christmas tree, and ornamental) to the benefit estimate. The contribution of each commodity to the benefit estimate is also calculated for two representative sensitivity analyses. Finally, program ANALYS recalculates the benefits under the assumption that 50% of the reforestation commodities/species will not reach the market to be harvested due to thinning, fire, insect damage, etc. In this dissertation each benefit estimate is the sum of net revenues from 9,715 rotations of the 29 commodities included in the analysis. Program ECOST calculates the costs in present value terms for the six different interest rates used in the analysis.

Sensitivity Analysis

Sensititvity analysis is performed on four critical parameters: price, quantity, genetic gain, and interest rate. Two price assumptions are used, the first fixes price as a constant, as explained earlier in Chapter III, and the second assumes a 1.2% real increase per year in the price of forest products. Three quantity assumptions are used: first that the quantity planted is a constant value equal to the 1981 planting level for each commodity; second that the quantity planted is a constant value based on the projected 1986 planting level; third quantity involves an increase in the number of seedlings planted. The last assumption is based on the observed growth pattern in seedlings planting from 1971 through 1986 projected levels. Available production data for each commodity was used to determine the commodity growth rate. In most cases, production data from 1971, 1981, and 1986 (projected) were used. If 1971 data was not available for a commodity, 1981 and 1986 data alone were used. If 1986 data was not available, a minimum commercial threshold level of production was assumed. A logistic curve representing a theoretical economic growth pattern was then fitted to the data. For comparison these industry expansion curves for all commodities are shown in Figures 4.2 to 4.8. Under the expanding industry assumption, the 1981 value for production level is used until the year commercial seed orchard production begins. The industry expansion curves then determine the quantity. Figures 4.2 to 4.8 show all the curves beginning at the same year for comparison only.

Figure 4.2

REFORESTATION COMMODITIES

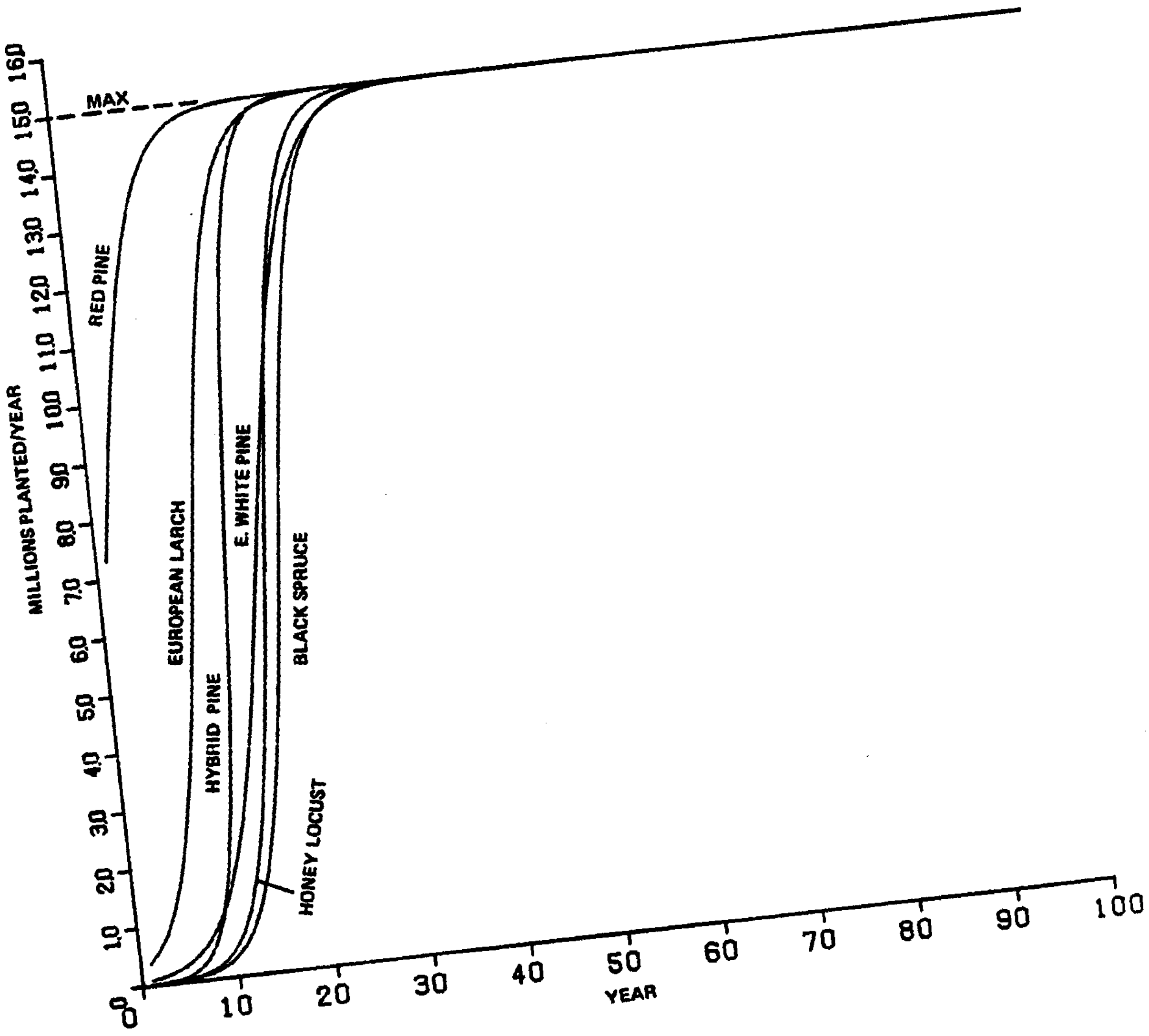


Figure 4.3

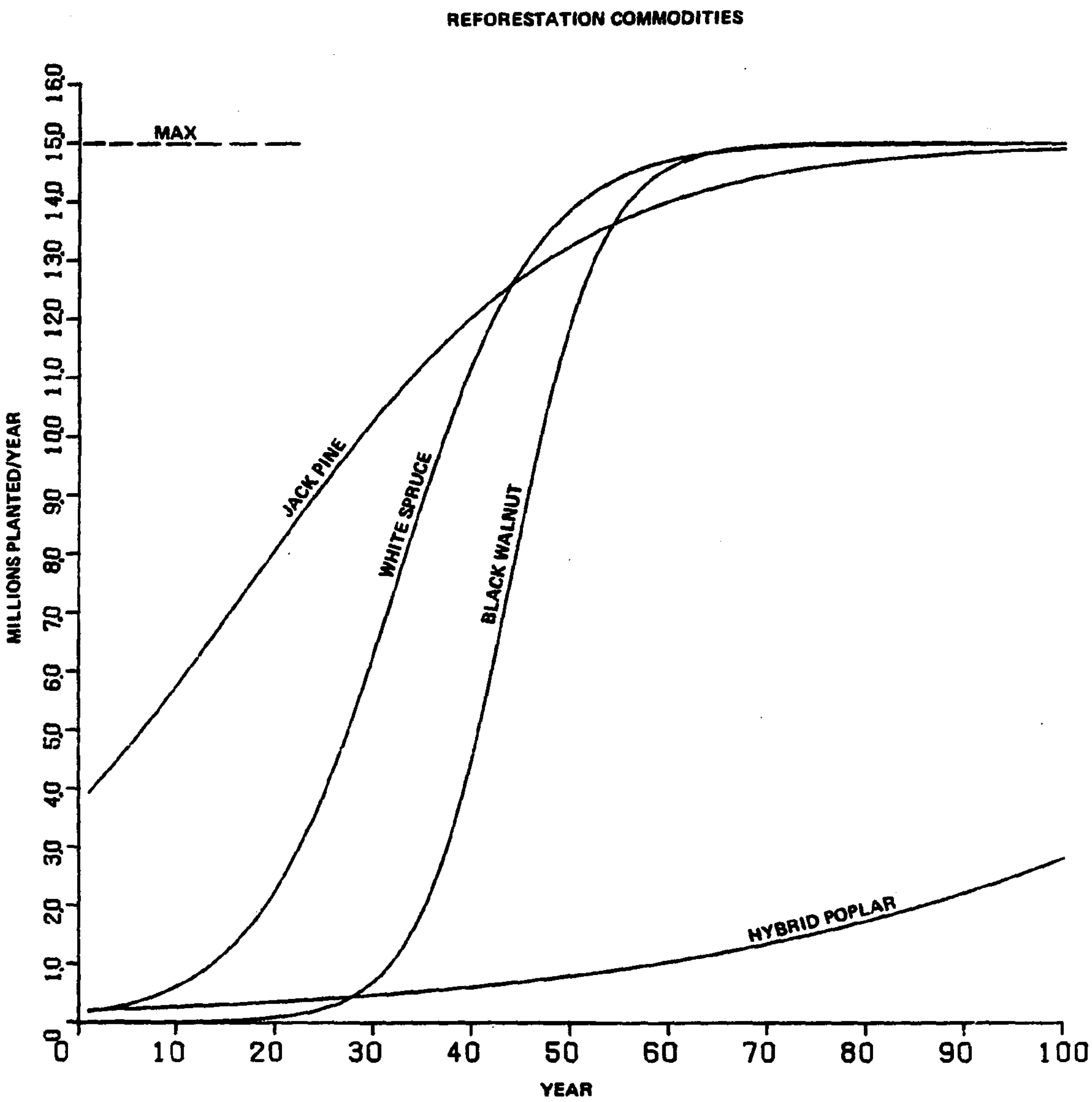
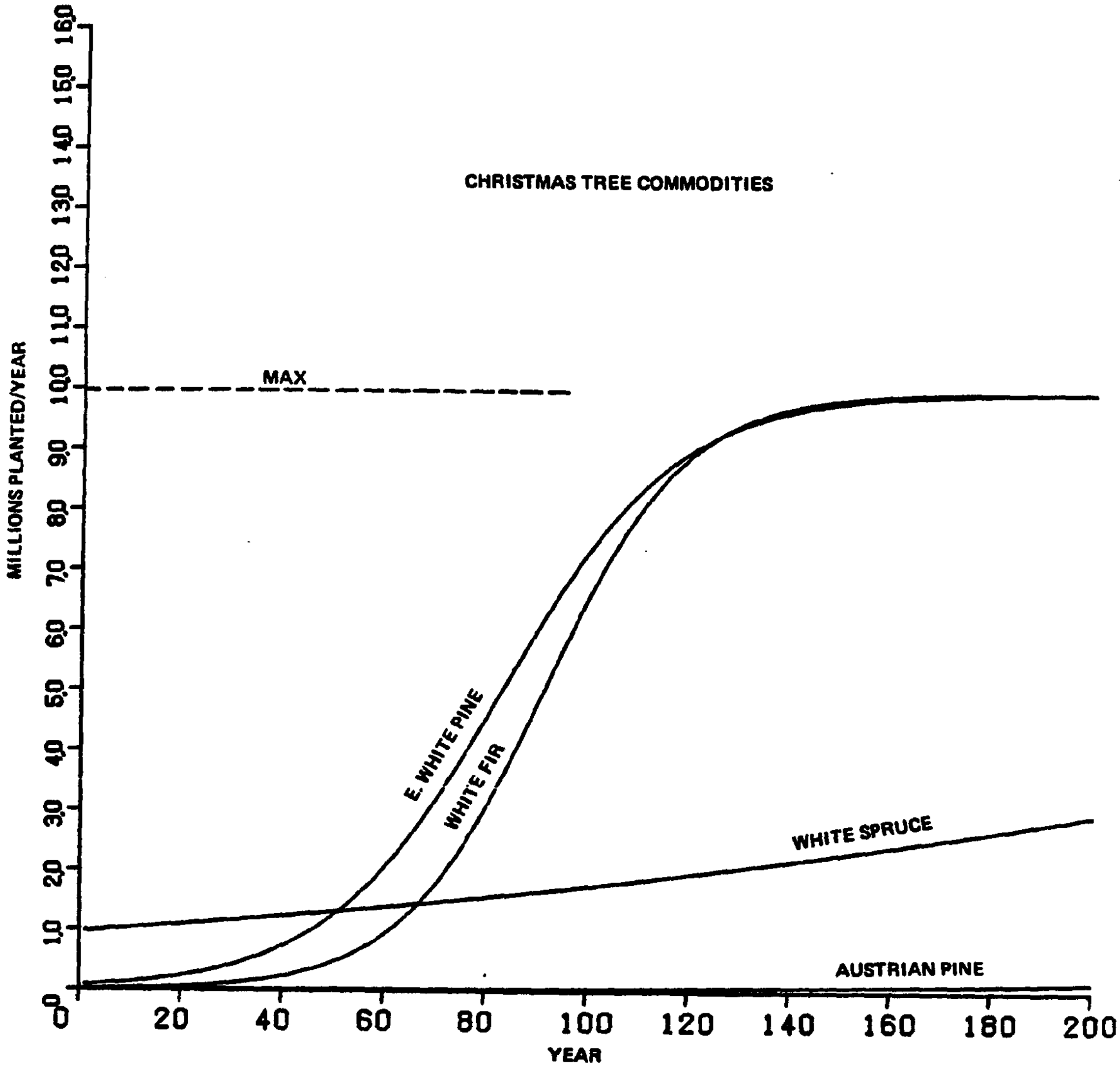

REFORESTATION COMMODITIES
MAX
JACK PINE
WHITE SPRUCE
BLACK WALNUT
HYBRID POPLAR
MILLIONS PLANTED/YEAR
YEAR
0
10
20
30
40
50
60
70
80
90
100
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0

Figure 4.4



CHRISTMAS TREE COMMODITIES
MILLIONS PLANTED/YEAR
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
MAX
E. WHITE PINE
WHITE FIR
WHITE SPRUCE
AUSTRIAN PINE
0
20
40
60
80
100
120
140
160
180
200
YEAR

Figure 4.5

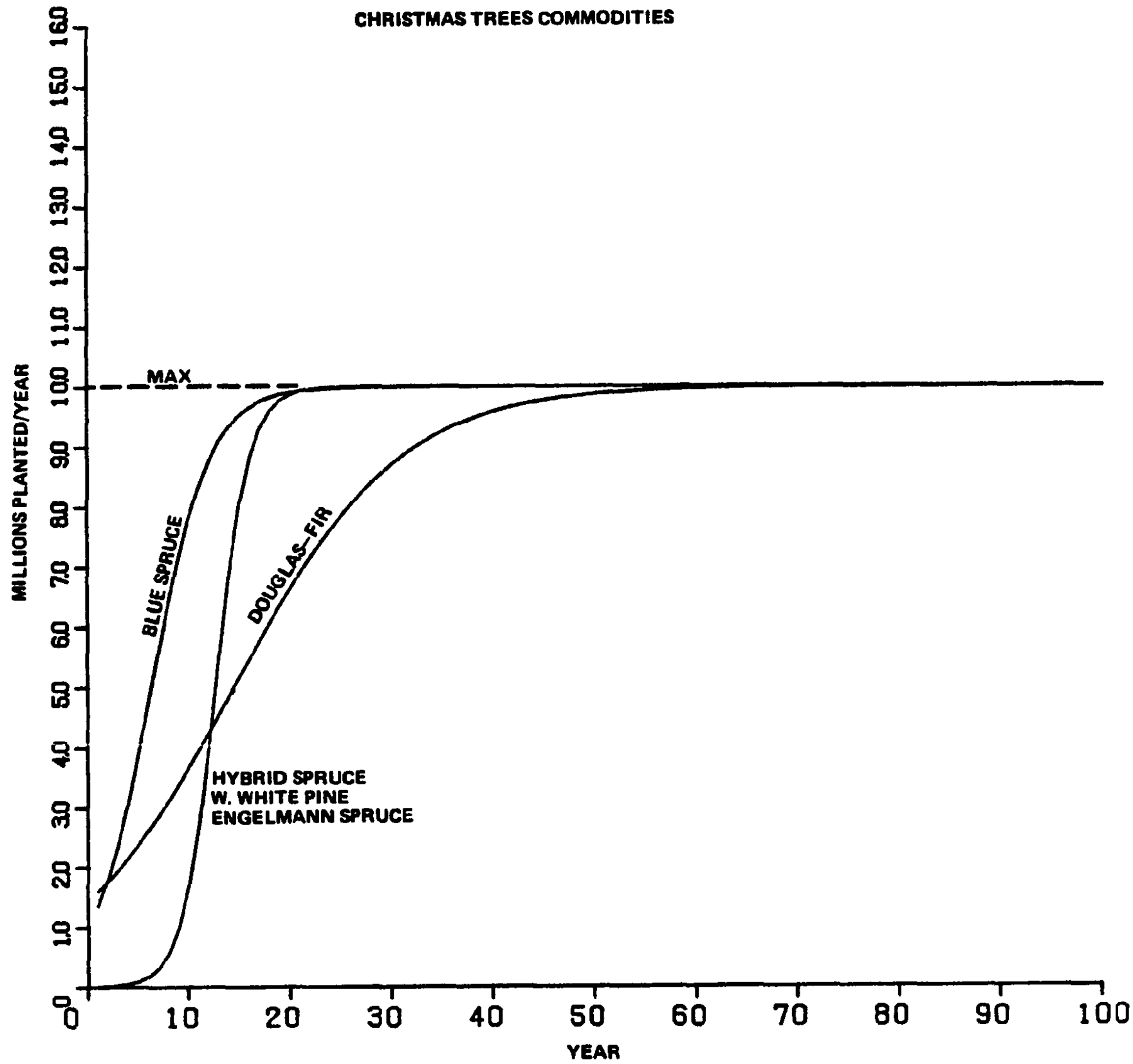

CHRISTMAS TREES COMMODITIES
MILLIONS PLANTED/YEAR
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
MAX
BLUE SPRUCE
DOUGLAS-FIR
HYBRID SPRUCE
W. WHITE PINE
ENGELMANN SPRUCE
0
10
20
30
40
50
60
70
80
90
100
YEAR

Figure 4.6

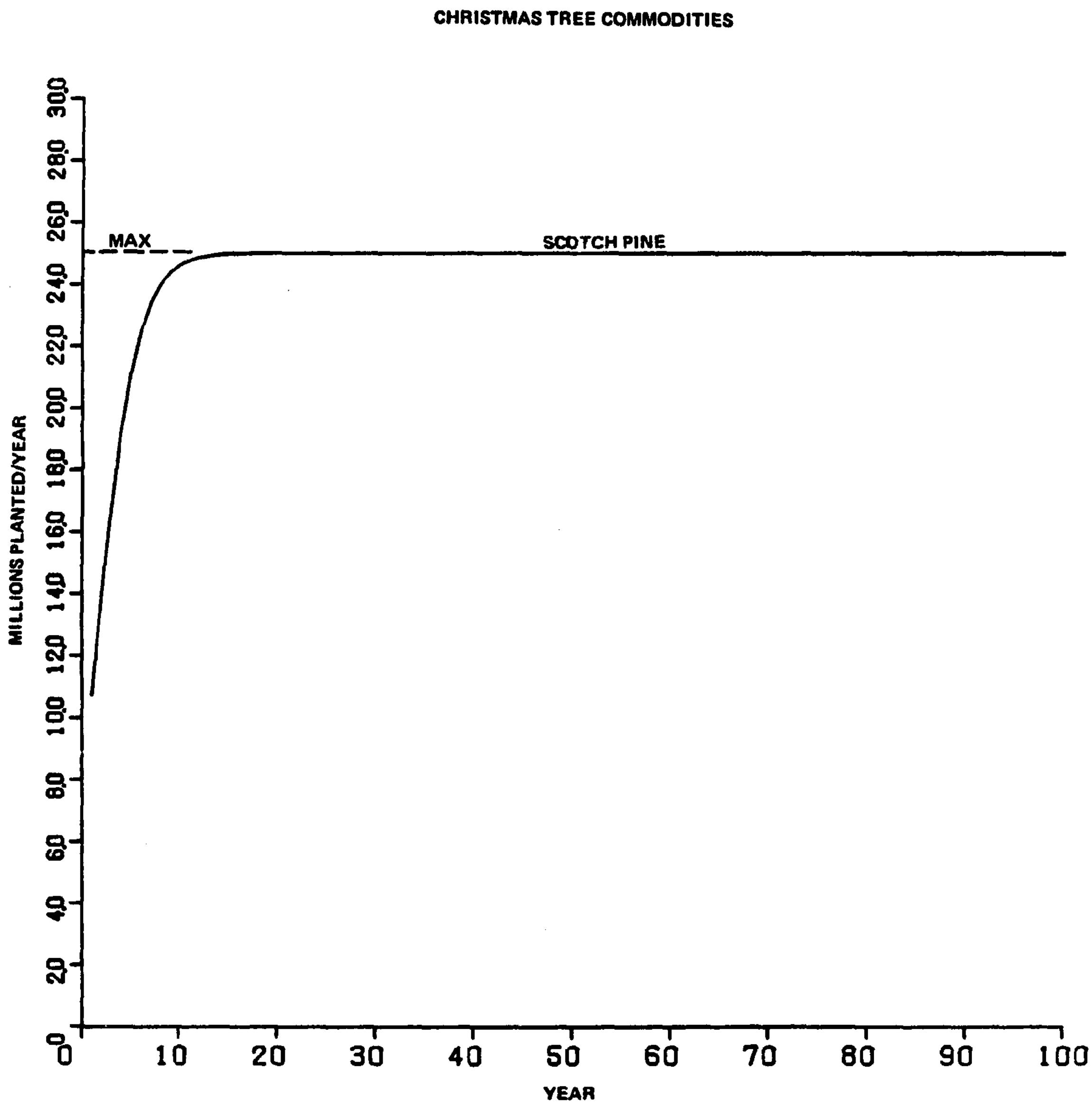

CHRISTMAS TREE COMMODITIES
MILLIONS PLANTED/YEAR
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
MAX
SCOTCH PINE
0
10
20
30
40
50
60
70
80
90
100
YEAR

Figure 4.7

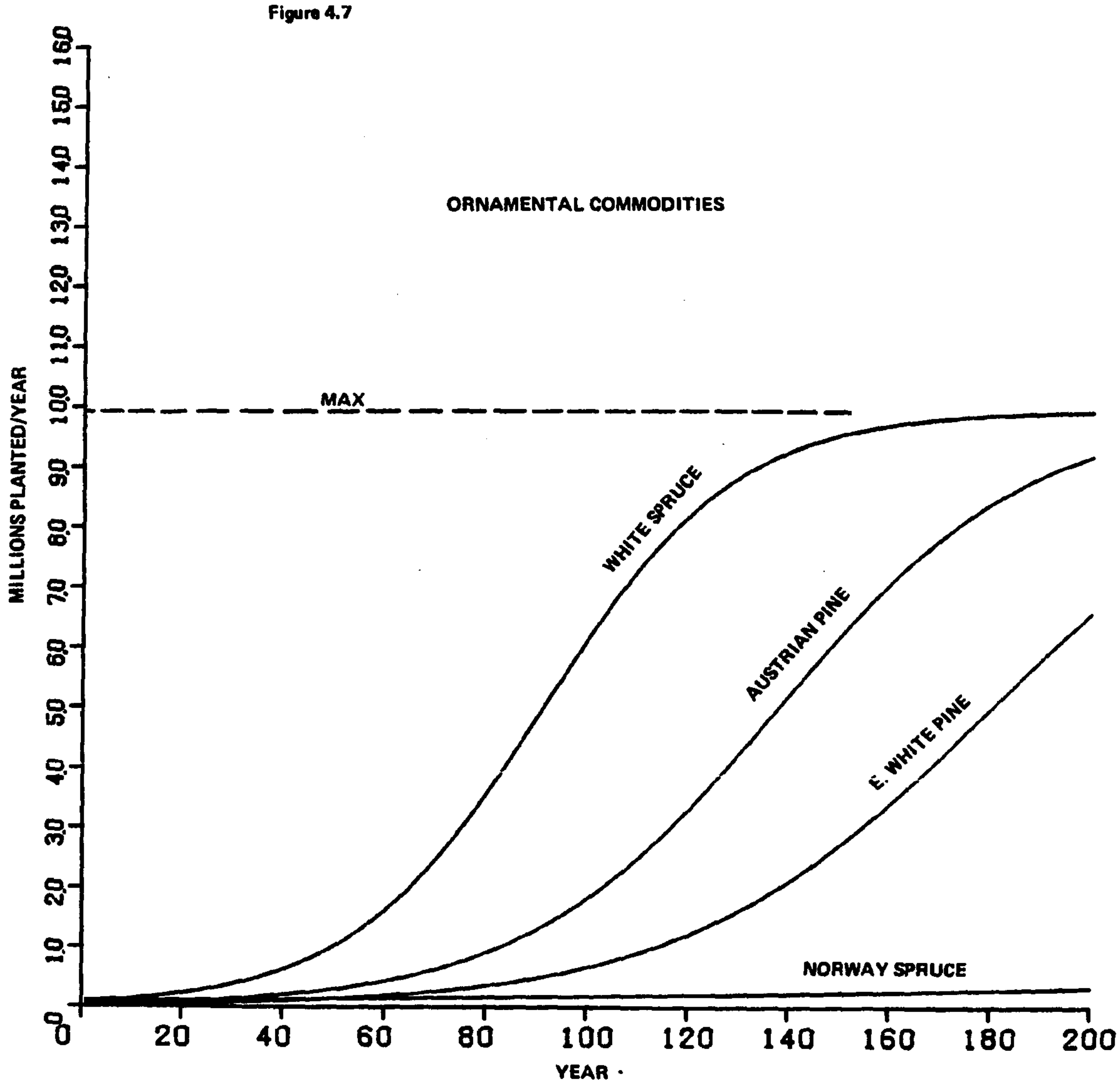
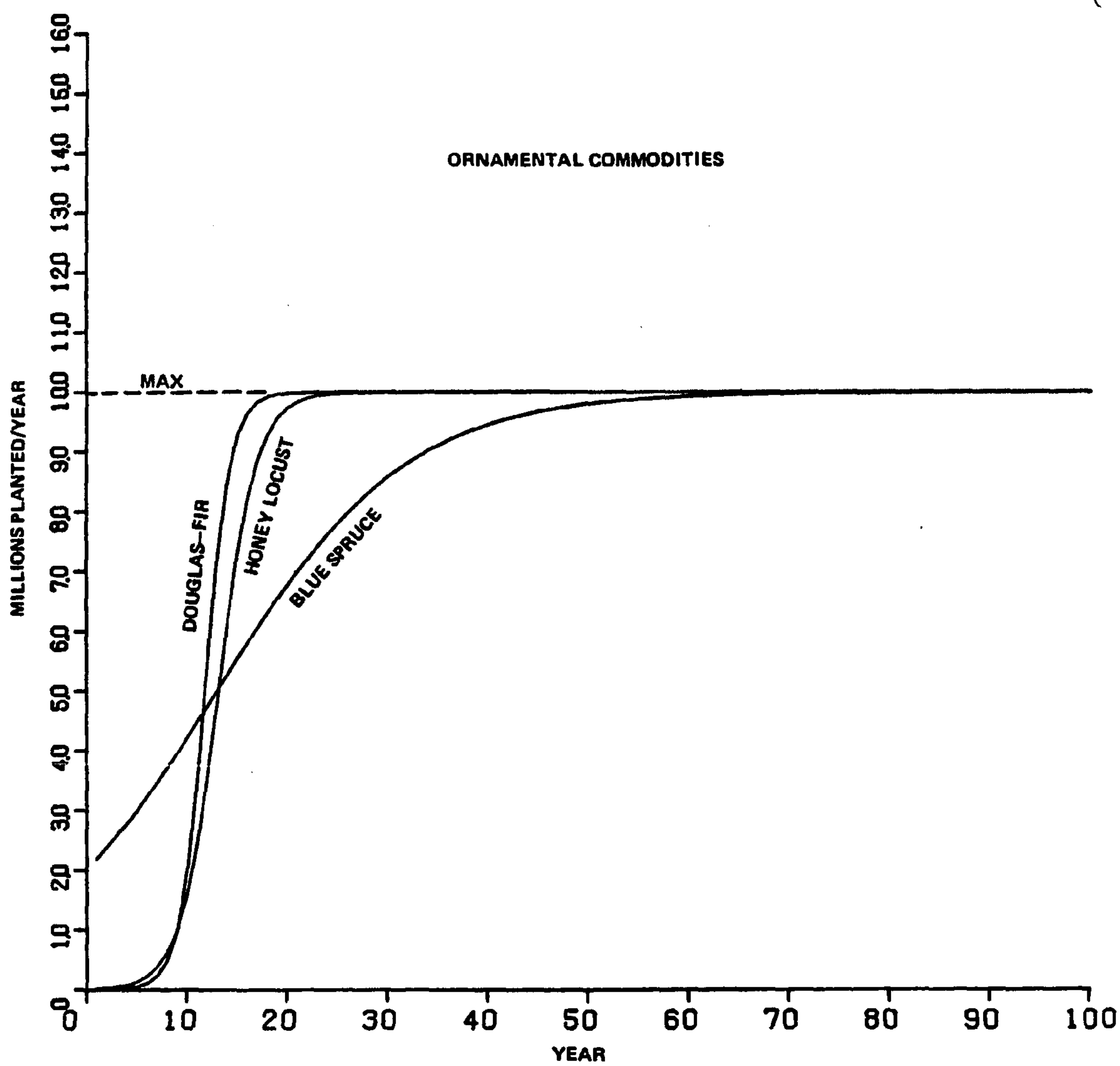

ORNAMENTAL COMMODITIES
MAX
WHITE SPRUCE
AUSTRIAN PINE
E. WHITE PINE
NORWAY SPRUCE
MILLIONS PLANTED/YEAR
YEAR
0
20
40
60
80
100
120
140
160
180
200
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0

Figure 4.8


ORNAMENTAL COMMODITIES
MILLIONS PLANTED/YEAR
YEAR
MAX
DOUGLAS-FIR
HONEY LOCUST
BLUE SPRUCE
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
0
10
20
30
40
50
60
70
80
90
100

Three estimates of genetic gain are used for the sensitivity analysis on genetic gain. Interest rates of 4%, 6%, 8%, 10%, 12%, and 14% (representing a range of both public and private discount rates) are used for the interest rate sensitivity analysis. The sensitivity analysis was performed on all combinations of changes in the variables resulting in 108 estimates of benefits to tree improvement research. All benefits and costs are expressed in present value terms (1983 dollars).

Costs are determined based on research salaries, direct, and indirect expenses to complete the research program specified. Although detailed cost information is available for the research program as a whole, allocation of costs at the commodity level is impossible. Costs are therefore calculated for the same six interest rates used in the benefit calculation. This procedure results in one cost estimate for every 18 benefit estimates.

NOTES - CHAPTER IV

1) This is not the case with many agricultural crop research programs. Hybrid corn, although yielding more, requires extra inputs such as more fertilizer and herbicides. Genetically superior trees at the F1 level (first round of breeding cycle), do not require a change in silvicultural practice, or additional inputs. Subsequent generations may require supportive inputs.

CHAPTER V

RESULTS OF THE MODEL

This chapter presents the results of the model using parameter values previously indicated. The sensitivity analysis on four key variables is examined and discussed.

Benefits

Gross potential benefits resulting from tree improvement programs in Michigan are substantial under all assumptions. The benefits range from \$52 million to \$25 billion (1983 dollars). The benefits are all in present value terms and have been valued at the first link in each of the commodities market chains. Trees to be used for pulp and timber are valued as stumpage. Christmas trees are valued as wholesale cut trees F.O.B. farm. Ornamentals are valued as wholesale trees F.O.B. nursery. The wide range of values shows the degree of uncertainty reflected in the sensitivity analysis. A complete range of estimates is found in Table 5.1.

Costs

The costs to produce the knowledge and physical breeding necessary to capture these benefits are relatively small, ranging from \$5.5 million to \$15.5 million (1983 dollars). The costs are shown in Table 5.2. Costs are not subject to the same sensitivity analysis which considers the economic uncertainty of future trends in the

Table 5.1

PRESENT VALUE BENEFITS - ALL COMMODITIES, INFINITE ROTATIONS

(THOUSANDS OF 1983 DOLLARS)

CONSTANT PRICE

BLOCK 1 ESTIMATES:
1981 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	395,493	791,387	1,188,704
6	213,512	427,284	641,184
8	130,870	262,224	395,636
10	87,695	178,917	274,277
12	64,921	133,196	210,257
14	52,274	111,108	177,468

BLOCK 2 ESTIMATES:
1986 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	512,191	1,025,067	1,541,788
6	269,122	538,689	810,320
8	160,766	322,610	489,521
10	107,049	223,303	350,327
12	83,805	176,451	281,154
14	67,633	144,790	233,095

BLOCK 3 ESTIMATES:
INCREASING PLANTING (1981)

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	3,497,160	7,048,066	10,734,536
6	1,430,880	2,877,539	4,376,628
8	717,534	1,441,648	2,198,633
10	413,101	840,537	1,297,087
12	266,906	547,526	862,316
14	188,687	397,417	632,163

INCREASING PRICE

BLOCK 4 ESTIMATES:
1981 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	657,666	1,316,330	1,978,153
6	308,972	618,507	929,586
8	177,425	355,644	537,044
10	114,572	233,914	358,902
12	82,818	170,035	268,539
14	65,526	139,312	222,599

BLOCK 5 ESTIMATES:
1986 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	868,056	1,737,822	2,616,477
6	396,508	793,980	1,195,617
8	221,692	445,087	676,272
10	142,156	296,648	465,775
12	108,467	228,455	364,215
14	85,960	184,059	296,436

BLOCK 6 ESTIMATES:
INCREASING PLANTING (1981)

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	7,901,849	16,030,800	24,596,830
6	2,509,349	5,074,969	7,777,343
8	1,109,247	2,236,182	3,429,830
10	595,778	1,216,770	1,884,035
12	370,148	759,709	1,198,906
14	254,240	535,446	852,763

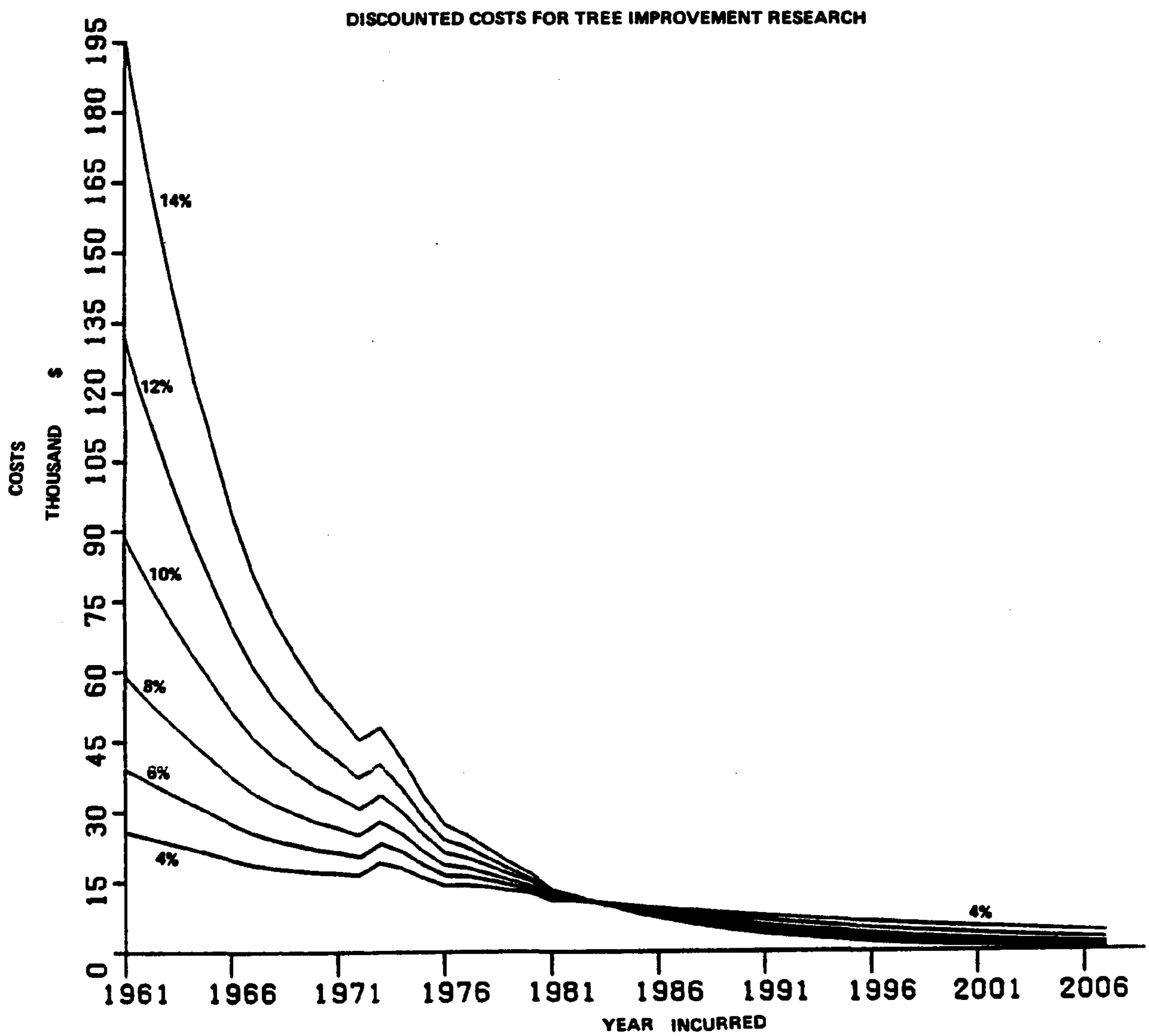
Table 5.2

PRESENT VALUE COSTS OF TREE IMPROVEMENT RESEARCH

Interest Rate (%)	Present Value Costs (thousand $)
4	5,568.3
6	6,393.8
8	7,664.2
10	9,489.8
12	12,032.4
14	15,518.7

forest products industry. The cost of the research is calculated for six interest rates. The analysis uses 1983 as a base year for present value calculations. Approximately half of the nominal costs occured before this date. Discounting expenditures which have occurred in the past has the opposite effect on the present value of discounting expenditures in the future. Higher interest rates applied to future expenditures result in a lower present value. (There is a larger interest charge which must be subtracted from the nominal value). Higher interest rates applied to past expenditures result in a higher present value. (The higher interest charge represents the forgone opportunity for using the money for other purposes.) The result of this is that higher interest rates result in higher present value costs, opposite to the benefit estimates. Higher interest rates for benefits result in lower present value benefits. Present value costs for the research program calculated with the six interest rates used are shown in Figure 5.1

Figure 5.1


DISCOUNTED COSTS FOR TREE IMPROVEMENT RESEARCH
COSTS
THOUSAND $
0
15
30
45
60
75
90
105
120
135
150
165
180
195
14%
12%
10%
8%
6%
4%
4%
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
YEAR INCURRED

Benefit-Cost Ratios

By dividing the benefits by the costs, benefit-cost ratios are derived. The benefit-cost ratios range from 3.37 to 469.[1] Together with the gross benefit figure, benefit-cost ratios are an excellent evaluation criterion for the worth of a research project. The lowest benefit-cost ratio estimate of 3.37 indicates that for every dollar invested in the tree improvement program research, a potential of $3.37 is returned. This value can be expressed two other ways. Similar to early consumer surplus studies by Griliches and Schmidtz and Seckler, an "extended" rate of return (ERR) can be calculated from the benefit-cost ratio.[2] The lowest benefit-cost estimate of 3.37 represents an ERR of 47.1% at a 14% discount rate. This figure represents an average annual rate of return. The ERR is not the same as the internal rate of return (IRR). Calculation of the IRR is generally done when a fixed number of periods of costs and benefits occur. The IRR is more commonly found as an evaluation criteria in financial analysis. The value of the research program can also be viewed from the perspective of a venture capitalist. An investor could underestimate costs, or overestimate benefits, by a factor of three without losing money. To view the analysis from this perspective gives some indication of the degree of risk involved. Lower benefit-cost ratios place more importance on the amount of error in estimation allowed for projects which involve uncertainty (such as research).

Sensitivity Analysis

The analyses of sensitivity to two economic parameters, price and number of trees planted, results in six blocks, each block composed of eighteen individual estimates. Two price assumptions and three tree quantity assumptions were used to create these six blocks. Each block then presents the results from the remaining two parameters in the sensitivity analysis resulting in a total of 108 estimates for all six blocks. Blocks one through six show a series of estimates covering a wide range of uncertainty in the economic environment. The first block of estimates represents a pessimistic outlook and is the most conservative from an economic perspective. Real price is assumed to remain constant, and the quantity planted is assumed to remain at the actual number of trees planted in 1981. This is a rather unrealistic outlook in terms of the number of trees planted. Only 20 of the 29 species/commodities used in the analysis were planted in 1981. There are indications that the artificial regeneration component in the forest product industry is in the midst of an explosive growth stage.[3] Estimates in block 1 represent the minimum potential benefit to accrue from tree improvement programs in Michigan. Within this block, estimates range from \$52 million for the lowest genetic gain estimate and 14% interest rate, to \$1.2 billion for the highest genetic gain estimate and a 4% interest rate. The medium estimate of gain using an 8% interest rate shows a potential benefit of \$262 million. This corresponds to a benefit-cost ratio of 34.2 and ERR of 273% (discounted at 8%).

The second block shows the results for constant price and 1986 levels of planting. All twenty nine commodities were included at some level of planting for the 1986 quantity estimate. Those commodities which did not appear in the survey were estimated to be planted at conservative numbers.[4] The benefits do not increase substantially using the higher planting estimates, even though the number of trees planted more than doubles. The lowest estimate in this block is \$67.6 million. The highest estimate is \$1.541 billion. There is approximately a 23% increase in the benefits using the 1986 planting level over the 1981 level.[5]

The third block of estimates represents the value of benefits under the constant price assumption, but with an expanding industry. The expansion of the artificial regeneration segment of the industry is expressed by logistic growth curves for each commodity. These curves are fitted to data from both historical production information and production projections derived from the Michigan Tree Seedling Industry Survey.[6] The maximum number of seedlings planted is 180 million reforestation seedlings, 115 million Christmas tree seedlings (or other short rotation crop of similar value such as agro-forestry or bio-mass crops), and 70 million ornamental seedlings. Using these assumptions, the gross benefit from tree improvement research climbs to \$188 million for the lowest estimate and \$10.7 billion for the highest estimate. The lowest estimate in this block is a 72% increase over the lowest estimate in block 1 while the highest is a 89% increase.

Changing the assumption of constant price to an increasing real price has a significant effect on the magnitude of gross benefits. The estimate of benefits in blocks 4, 5 and 6 are calculated under the assumption that the real price of all 29 commodities increases 1.2% annually. The last 100 years has shown forest products to be the only natural resource commodity group to show a real price increase. Potter and Christy (1962) show deflated prices of the forest resource sector increasing 1.26% yearly for the period 1870-1957.[7] A breakdown of the forest resource sector into component commodities shows the real price of lumber increasing at 1.86% yearly for the same period and softwood stumpage increasing at 2.5% yearly. The price of pulp shows a 1.61% increase for 1927-1957.[8] Barnett and Morse (1963) confirm the real price increase trends the Potter and Christy study found.[9] Manthy (1978) and later Smith (1979), both show the upward real price trend to be continuing into the 1970's.[10] The figure of 1.2% real price increase for a stumpage price composite is a revised number from Manthy (1981).[11] From the most conservative estimate in block 1, (1981 planting levels, 14% interest rate, and low genetic gain estimates), the assumption of increasing real price adds $13 million to the gross benefit, or a 20.2% increase in value. The benefit-cost ratio improves from 3.37 to 4.22, and the ERR moves up from 47.14% with constant prices to 59.1% under the increasing price assumption.

The price increase assumption also has a rather large effect when 1986 planting levels are used. The most conservative estimate from block 2 increases 21.3% to $86 million and the highest estimate increases 41.1%, to $2.6 billion. By far, the most dramatic effect of increasing price is under the expanding industry assumption. The results are shown in block 6. The most conservative estimate is $254 million and the highest estimate (high genetic gain and 4% interest rate) is $25 billion. This figure represents the maximum direct benefit that would result from tree improvement research. A medium estimate under increasing price and expanding industry assumptions, using an 8% interest rate and medium genetic gain estimates is $2.2 billion.

Sector Analysis

These results reflect the cumulative value or total sum of benefits of up to 29 species/commodities. A complete listing of the present value benefits of research each industry sector contributes to the the total is presented in Tables 5.3 and 5.4. The 1981 planting assumption uses 20 commodities, and 29 commodities are included in the analysis under the other two planting assumptions. It is revealing to investigate how the benefits are split between the industry sectors and also to see which species/commodities are responsible for the greatest percentage of benefits. Using the assumption of 1986 planting levels only six species/commodities are expected to be planted in excess of one million trees per year. Three species will be used in the reforestation industry sector; jack pine (4.7 million planted); red pine (12 million planted); and european larch (1.7 million planted). Three species will be produced for Christmas trees;

Table 5.3

PERCENTAGE CONTRIBUTION TO PRESENT VALUE BENEFITS BY INDUSTRY SECTOR

Constant Price - 1981 Planting Levels

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	1.2	40.1 *	58.7 *	1.3	40.1 *	58.6 *	1.4	40.0 *	58.6 *
6	1.0	38.6	60.4	1.0	38.6	60.4	1.2	38.6	60.3
8	0.7	37.4	61.9	0.7	37.5	61.8	0.9	37.6	61.5
10	0.5	37.2	62.3	0.5	38.4	61.1	0.6	39.6	59.8
12	0.3	40.4	59.3	0.3	41.9	57.8	0.4	42.3	57.3
14	0.2	40.6	59.2	0.2	41.0	58.8	0.3	41.4	58.3

Constant Price - 1986 Planting Levels

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	1.6	79.8 *	18.6 *	1.7	79.7 *	18.6 *	2.0	79.5 *	18.5 *
6	1.4	79.8	18.8	1.4	79.8	18.8	1.7	79.5	18.8
8	1.0	79.9	19.1	1.1	79.8	19.1	1.3	79.8	18.9
10	0.7	80.5	18.8	0.7	81.2	18.1	0.9	81.8	17.3
12	0.4	83.0	16.6	0.4	83.8	15.8	0.6	83.9	15.5
14	0.3	83.5	16.2	0.3	83.7	16.0	0.4	83.9	15.7

Constant Price - Expanding Industry

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	15.5	26.5 *	58.0 *	16.2	26.3 *	57.5 *	17.5	25.9 *	56.6 *
6	7.5	29.6	62.9	8.0	29.4	62.6	9.3	29.0	61.7
8	3.5	31.5	65.0	3.8	31.4	64.8	4.9	31.4	63.7
10	1.7	33.8	64.5	1.9	34.9	63.2	2.8	35.8	61.4
12	1.0	38.7	60.3	1.0	40.2	58.8	1.7	40.7	57.6
14	0.6	41.3	58.1	0.6	42.2	57.2	1.2	42.8	56.0

* These columns are not monotonic due to the valuation method switching between discounting time and discounting quantity.

Table 5.4

PERCENTAGE CONTRIBUTION TO PRESENT VALUE BENEFITS BY INDUSTRY SECTOR

Increasing Price - 1981 Planting Levels

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	1.8	40.9 *	57.3 *	1.9	40.9 *	57.2 *	2.1	40.8 *	57.1 *
6	1.4	39.4	59.2	1.5	39.4	59.1	1.7	39.3	59.0
8	1.0	38.1	60.9	1.1	38.2	60.7	1.3	38.4	60.3
10	0.7	38.0	61.3	0.8	39.2	60.0	0.9	40.4	58.7
12	0.4	41.2	58.4	0.5	42.6	56.9	0.6	43.1	56.5
14	0.3	41.3	58.4	0.3	41.7	58.0	0.4	42.1	57.5

Increasing Price - 1986 Planting Levels

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	2.4	79.2	18.4 *	2.5	79.2	18.3 *	2.8	78.9	18.3 *
6	1.9	79.5	18.6	2.1	79.4	18.5	2.5	79.1	18.4
8	1.4	79.7	18.9	1.6	79.6	18.8	1.9	79.5	18.6
10	1.0	80.5	18.5	1.1	81.2	17.7	1.3	81.7	17.0
12	0.6	83.1	16.3	0.6	83.9	15.5	0.8	84.0	15.2
14	0.4	83.7	15.9	0.4	83.9	15.7	0.6	84.0	15.4

Increasing Price - Expanding Industry

Interest Rate (%)	Low Genetic Gain REF	Low Genetic Gain X-MAS TREE	Low Genetic Gain ORN	Medium Genetic Gain REF	Medium Genetic Gain X-MAS TREE	Medium Genetic Gain ORN	High Genetic Gain REF	High Genetic Gain X-MAS TREE	High Genetic Gain ORN
4	28.5	21.9	49.6 *	29.6	21.6	48.8 *	31.1	21.1	47.8 *
6	14.9	26.9	58.2	15.8	26.6	57.6	17.6	26.1	56.3
8	6.7	30.1	63.2	7.4	29.9	62.7	8.9	29.8	61.3
10	3.1	33.1	63.8	3.3	34.1	62.6	4.5	34.9	60.6
12	1.5	38.2	60.2	1.7	39.6	58.7	2.6	40.1	57.3
14	0.8	41.0	58.2	0.9	41.8	57.3	1.6	42.4	56.0

* These columns are not monotonic due to the valuation method switching between discounting time and discounting quantity.

Scotch pine (21 million planted); blue spruce (3.8 million planted); and Douglas Fir (1.5 million planted). The contribution of the reforestation species to the gross benefit resulting from the tree improvement program is small. This is because the longer production spans (rotation periods) of reforestation species creates a higher interest charge, reducing present value benefits. The relatively long market chain causes a low price of the raw material product which then reduces benefits relative to the Christmas tree and ornamental sectors.

The contribution to gross present value by the reforestation group of commodities is highly sensitive to interest rate. The reforestation component (7 commodities) in the most conservative block of estimates (1981 planting and constant price) contributes only 1.2% of the total present value benefits at a 4% discount rate. At a 14% discount rate, the contribution to present value benefits is only 0.2%. This is a six fold drop in benefits resulting from a less than four fold increase in discount rate. The ornamental and Christmas tree sectors account for virtually all the gross present value under the static industry assumptions (1981 and 1986 planting levels). Reforestation species, at best, account for only 2.8% of the present value benefits (at a 4% discount rate, high genetic gain, 1986 planting levels, and the increasing price assumption). In real dollars, 2.8% of the gross present value represents $73.3 million. Under the 1981 planting levels (blocks 1 and 4) the Christmas tree sector accounts for between 37.2% and 43.1% of the present value benefits. Increasing price has little effect on the distribution of value between the reforestation, Christmas tree, and ornamental sectors under static industry assumption. Increasing the size of the industry to the 1986 projected level (using industry projections) increases the percentage of gross present value accounted for by the Christmas tree sector. (The Christmas tree sector also exhibits the greatest percentage increase in planting from 1981 to 1986). At the 1986 planting level, the gross present value accounted for by the Christmas tree sector ranges from 78.9% to 84.0% of present value benefits. The value of the reforestation sector ranges from 0.3% to 2.8% of present value benefits, and ornamentals account for the rest (15.2% to 19.1%).

One species in the Christmas tree sector, Scotch pine, accounts for approximately 60% of the value for the conservative block estimates. Table 5.5 shows the percent contribution to gross present value by each species/commodity under the assumptions of 1986 planting levels, medium gain, 8% discount rate, and, both constant and increasing real price assumptions. Jack pine and red pine contribute most of the value in the reforestation sector. Scotch pine, blue spruce, white pine, and Douglas-fir account for most of the value in the Christmas trees sector. Blue spruce, and white spruce are the major species contributing to value in the ornamental sector. Table 5.6 lists the rank order of each species' contribution to the total value of research benefits when all commodities are combined.

Table 5.5

CONTRIBUTION TO BENEFITS BY SPECIES

SPECIES	CONSTANT PRICE	INCREASING PRICE
Reforestation	(%)	(%)
Hyprid Pine	0.01	0.02
Jack Pine	0.33	0.49
Hybrid Poplar	0.04	0.04
E. White Pine	0.03	0.03
White Spruce	0.02	0.02
Red Pine	0.60	0.87
Hybrid Aspen	0.01	0.01
Black Spruce	0.00	0.00
Honeylocust	0.00	0.00
E. Larch	0.03	0.05
Hybrid Larch	0.00	0.00
Black Walnut	0.01	0.03
Christmas trees		
Scotch Pine	61.35	60.36
Blue Spruce	13.39	13.49
E. White Pine	0.20	0.20
White Spruce	2.18	2.25
Hybrid Spruce	0.34	0.34
W. White Pine	0.13	0.15
Austrian Pine	0.01	0.01
Englemann Spruce	0.09	0.11
Douglas-Fir	2.15	2.69
White Fir	0.01	0.01
Ornamental		
Blue Spruce	13.93	13.39
E. White Pine	0.67	0.65
White Spruce	2.07	2.04
Norway Spruce	0.88	0.99
Honeylocust	0.54	0.58
Austrian Pine	0.19	0.22
Douglas-Fir	0.79	0.94

Table 5.6

CONTRIBUTION TO PRESENT VALUE BENEFITS - RANKED BY SPECIES

SPECIES	PERCENT CONTRIBUTION	RANK
Scotch Pine	61.35	1
Blue Spruce	27.32	2
White Spruce	4.27	3
Douglas-Fir	2.94	4
E. White Pine	0.90	5
Norway Spruce	0.88	6
Red Pine	0.60	7
Honeylocust	0.54	8
Hybrid Spruce	0.34	9
Jack Pine	0.33	10
Austrian Pine	0.20	11
W. White Pine	0.15	12
Englemann Spruce	0.09	13
Hybrid Poplar	0.04	14
Black Walnut	0.01	15
Hybrid Aspen	0.01	15
White Fir	0.01	15
Hybrid Larch	0.00	16
Black Spruce	0.00	16

When the static industry assumption is dropped and the industry is allowed to grow (more trees are planted each year up to a maximum level in the distant future), the reforestation sector accounts for a much greater portion of the gross present value. This is especially evident at the lower discount rates. Assuming a 4% discount rate, high genetic gain estimate, constant price, and increasing industry size, the reforestation sector accounts for 17.5% of the gross present value, the Christmas tree sector 25.9%, and ornamental sector 56.6%. Under the increasing price assumption (using the same parameters otherwise) reforestation accounts for 31.1%, Christmas trees 21.1%, and ornamentals 47.8% of the gross present value. Reforestation sector production processes show a high degree of sensitivity to the discount rate. This sensitivity to discount rate is the result of long rotation periods. Using a higher discount rate reduces the economic value of reforestation sector products and accordingly the contribution to gross present value. When a discount rate of 14% is used, reforestation accounts for only 1.2% at a high genetic gain and constant price, and 1.6% at a high genetic gain estimate and increasing price. The reforestation sector contributes more to present value benefits under the expanding industry assumption relative to the static industry assumptions. This is due to a much larger potential for expansion in the reforestation sector relative to the Christmas tree and ornamental sectors. At the maximum expansion allowed in the model a total of 180 million trees are planted each year. This is an increase of nine times over the 1986 projected commercial planting level of 19.7 million seedlings (for those species included in the research program). The Christmas tree sector has an assumed expansion capacity of only four times the 1986 projected planting of 28.6 million seedlings. The ornamental sector has an allowed capacity for expansion of nearly 66 times its current projected level, but accounts for the same range of gross present value as under the static 1981 planting level industry assumptions. This is due, in part, to the relatively slow growth anticipated in this industry sector (relative to reforestation and Christmas trees).

To put the dollar value of the present value benefits in perspective, it is useful to express benefits as a percentage of the value of the forest products industry. An accurate figure for the value of the forest products raw resource (at the first level in the market chain) is difficult to determine. Most studies which do attempt an estimate are broad in scope (usually at the national level), and generally restrict the investigation to timber or reforestation products. The Christmas tree industry is rarely included in these studies, and the ornamental industry is often ignored altogether. National surveys often rely on state natural resource agencies to supply the raw data for the econometric models, which ultimately produce a resource value estimate. Many of the state agencies in turn, gather their raw data from previous national surveys. Interviews with officials in the United States Forest Service, Michigan Department of Natural Resources, and the Michigan Department of Agriculture indicate this practice is wide-spread.

Original data series created from economic surveys are rare in this field. The State of Michigan is fortunate in being one of the few states where an original data series is available. An on-going study on the timber products economy of Michigan has published preliminary estimates of the 1980 value of raw timber products. Several other previous assessments of the Michigan resource base have also presented estimates of the value of the forest products in the state.[12]

James (1982) estimated the 1980 value of raw timber products harvested in Michigan to be $265 million.[13] This value is inclusive of raw products from the reforestion and Christmas tree sectors, specifically including; pulpwood, timber sawlogs, Christmas trees, fuelwood, raw forest non-fiber products (primarily maple syrup) and wood residues. This is the most accurate and recent estimate of forest products production in Michigan. From this value of $265 million, an estimate of the 1983 value is derived for the three industrial sectors (reforestation, Christmas tree, and ornamental) in this analysis. The 1980 production level of pulpwood, sawlogs, fuelwood, raw forest non-fiber products and wood residues are assumed to be the same for 1983. There is no data to indicate these sectors have increased or decreased. The 1982-1983 Christmas tree harvest is estimated at 6 million, 2 million more than in 1980. The 1983 estimate of the value of raw timber products is $482 million, using 1983 prices and adding $100 million as the estimate of the states's ornamental nursery wholesale business.[14] The value is then expressed as the present value terms of an infinite series for the same interest

Table 5.7

1983 ESTIMATE OF THE VALUE FOR RAW TIMBER PRODUCTS IN MICHIGAN

	1980 $ (millions)		1983 $ (millions)
Reforestation	137		
Fuelwood	82		
Wood Residue	14	(add 10% inflation)	
	233	------>	310
Ornamental			100
Christmas tree			72
		Total	482

rates used in the analysis, similar to the gross present value of research. At a discount rate of 4% the total value is $12.050 billion, at 14 % the value is $3.44 billion. Assuming a real price increase of 1.2% the total value at a 4% discount rate is $17.421 billion.[15] Table 5.8 shows the estimated total value and percentage of value attributed to genetic research.

The value of the genetic research as a percentage of the total forest products industry value is small. At a 4 percent discount rate, low genetic gain estimate, 1981 planting levels and constant price, the value of the research is 3.3% of the total value of the industry. The highest estimate of genetic research value in block 1 is still only 9.8% of the total industry value. With a 1.2% real price increase in raw forest resources, the research value is 11% of the total value. The value of research as a percentage of the total value is estimated for only the 1981 planting level of estimates. It is not calculated for the assumptions of 1986 planting levels and

Table 5.8

VALUE OF GENETIC RESEARCH AS PERCENTAGE OF TOTAL FOREST PRODUCTS INDUSTRY **

Constant Price

Interest Rate	Present Value of Industry, Infinite Rotations (million $)	Research Value as Percent of Total Forest Products Industry * (Genetic Gain Estimates) [low (%)	med (%)	high] (%)
4	12,050	3.3	6.6	9.9
6	8,033	2.6	5.3	8.0
8	6,025	2.2	4.3	6.5
10	4,820	1.8	3.7	5.7
12	4,017	1.6	3.3	5.2
14	3,443	1.5	3.2	5.1

Increasing Price

Interest Rate	Present Value of Industry, Infinite Rotations (million $)	Research Value as Percent of Total Forest Products Industry (Genetic Gain Estimates) [low (%)	med (%)	high] (%)
4	17,420	3.8	7.5	11.5
6	10,162	3.0	6.1	9.1
8	7,173	2.5	4.9	7.5
10	5,543	2.1	4.2	6.5
12	4,516	1.8	3.8	5.9
14	3,811	1.7	3.6	5.8

* Value of Research Estimated for 1981 Planting Levels

** Forest products industry is valued at the primary raw material level. Products include: stumpage for pulp, timber, veneer, fuelwood, wood residues, maple syrup, Christmas trees, and woody ornamentals.

increasing growth in the forest products industry. Since estimation of the total value of the industry under these assumptions involve too many unknowns.

NOTES - CHAPTER V

1) Benefit-cost ratios are not calculated for blocks three and six (expanding industry assumptions) since substantial additional extension costs (sometimes referred to as "adoption costs") may be involved in applying the genetic gain to the expanded industry.

2) Willis L. Peterson. 1971. The returns to Investment in Agricultural Research in the United States. in, Research Allocation in Agricultural Research, 1971; Walter L. Fishel ed. p. 139-162.

3) Industrial growth in forest products industry is supported by Burt Levenson and J. Hanover 1983. Michigan Tree Seedling Industry Survey. (in press), 1982 Mead Corp. Annual Report, and personal communications with the woodland managers of Mead Corp. and Champion International Corp.

4) A minimum initial commercial level of planting was established to be 100,000 trees planted. This estimate was used for hybrid pine, hybrid spruce, hybrid aspen, hybrid larch, western white pine and Englemann spruce.

5) Value increases are presented here as a percentage increase over the base value. As an example, a doubling of the value from 100 to 200 is a 50% increase. A quadrupling of value from 100 to 400 is a 75% increase.

6) Burton Levenson and James W. Hanover. 1983. Michigan Tree Seedling Industry Survey. Michigan State Experiment Station Research Report, In press.

7) Neal Potter and Francis T. Christy. 1962. Trends in Natural Resource Commodities. Johns Hopkins Press, Forest statistics section; p. 3.

8) ibid; p. 30-31.

9) Harold Barnett and Chandler Morse. 1963. Scarcity and Growth. Johns Hopkins Press; p. 210-216.

10) Robert Manthy. 1978. Trends in Natural Resource Commodities. Johns Hopkins Press; Kerry Smith. 1979. Scaricity and Growth Reconsidered. Johns Hopkins Press. 368 p.

11) Robert Manthy. 1981. Notes to Natural Resource Economics. Michigan State University, Department of Forestry, Winter 1981.

12) Forest Statistics of the U.S., 1977. Washington D.C.; Research Report Lee James, Suzanne Heinen, David Olson, and Daniel Chappelle. 1982. Timber Products Economy of Michigan. Agricultural Experiment Station Research Report No. 446, Michigan State Unversity.; An

Assessment of the Forest and Rangeland Situation in the United States. USFS, FS-345, 1980.; Darius Adams et al. 1982. Private Investment in Forest Management and the Long-Term Supply of Timber. Amer. J. Agr. Econ. 64: 11, p. 232-241; USFS. 1982. Lake States Forest Inventory Survey - Preliminary Results. North Central Forest Experiment Station.

13) Lee James, S. Heinen, D. Olson, and D. Chappelle. 1982. Timber Products Economy of Michigan. Agricultural Experiment Station Research Report No. 446, Michigan State University; 23 p.

14) Unpublished figures obtained through the Michigan Department of Agriculture from a yearly survey by Walter Gammel Inc. (Miami), show the seedling portion of the nursery business to be worth $100 million at the wholesale level. Although this figure must be taken lightly since Gammel Inc. receives their data from the Michigan Department of Agriculture, (which in turn uses national estimates derived from state estimates), it appears to be a reasonable figure for the state-wide value of this industry.

15) The formula to calculate the present value of a perpetual annual series is from; Warren A. Flick. 1976. A Note On Forest Investments. For. Sci. 22: 1; p. 30-32.

CHAPTER VI

ANALYSIS OF RESEARCH GAINS TO INDIVIDUAL PRODUCERS

Introduction

This chapter investigates the benefits of tree improvement research from the economic perspective of different institutional users. A large pulp and paper company with a paper mill and extensive land holdings in Michigan will represent the private reforestation sector. A public agency modeling the Michigan Department of Natural Resources and the United States Forest Service is chosen to represent the public reforestation sector. A large commercial Christmas tree farm shows how tree improvement research will benefit the individual operator in the Christmas tree and ornamental sector. Figures for the sample institutional users are based on real but annonomous companies and public agencies.

Reforestation - Private Sector

Artificial forest regeneration for the production of wood fiber is an activity showing large economies of scale. Owners of small land parcels do plant a substantial number qf trees in Michigan; however, the economic motivation is a mixture of fiber production, enhanced recreation value, and esthetic motives. Two institutional groups engage in artificial regeneration strictly for fiber production: large pulp and paper companies (or other large land owners leasing holdings to these companies), and public natural resource agencies. In Michigan, these two public agencies are the Michigan Department of

Natural Resources (DNR) and the United States Forest Service (USFS). A recent survey estimated the 1980 population of wood-using mills to be 1,637. The majority of these are secondary manufacturing companies. The primary manufacturing companies include 276 sawmills and 8 integrated pulp and paper mills.[1] Only three pulp and paper companies actively engage in artificial regeneration of the forest, with a fourth company about to begin.

The sample pulp and paper company represented in this study is located in the Upper Peninsula of Michigan with a planting schedule of four million trees per year. The land holdings of the company exceed 200,000 acres, all of which are suitable for artificial regeneration of one or more species. The paper mill is operating at capacity on the yield from four million trees per year, and no mill expansion is planned or taken into account in this analysis. The planted trees all take 35 years to mature. The current price of stumpage in this area is $1.20 per tree.[2] Six diverse species are planted and grown, with genetically improved seedlings becoming available in 1987.

The purpose of this exercise is to see what a genetic tree breeding research program is worth to this hypothetical company. All benefits are expressed in present value dollars (base year=1983) on a per mill basis. The sensitivity analysis is performed as in the main analysis for all parameters. Only one level of industrial production is analyzed. The genetic gain estimates used are 5%, 10%, and 15% for all species planted. The genetic gain in this case is reflected by increased growth rate, resulting in shorter rotation times. For example, harvesting trees with a 10% genetic gain means the company will be able to meet its raw fiber requirements in 31.5 years as opposed to the "normal" 35 year rotation time. The method of valuation is discounting time (decreased interest charge).

The results of this analysis are presented in Table 6.1. The potential benefits are very sensitive to the interest rate. When an interest rate of 4% is used, the present value benefits range from $1.3 million at 5% genetic gain to $6.2 million for a 15% genetic gain. An interest rate of 14% reduces the benefits to $61,000 and $233,000 for 5% and 15% genetic gain respectively. Both these estimates are made under the assumption that real price is constant. Increasing real price at 1.2% per year has a large effect on the benefits the company will receive. The lowest estimate increases from $61 thousand to $105 thousand. The high estimate of benefits is increased by $7.8 million to $14 million. A third block of estimates is presented with a constant price set at $6.00 per tree. This price is used to illustrate potential benefits using a stumpage price actually predicted by a large pulp and paper company for the Upper Peninsula of Michigan.[3] At this stumpage price, the benefits to the company are substantial. The benefits are in excess of $1 million, even using the very high long-term interest rate of 14% and high genetic gain estimate.

The high potential benefits which can be realized by individual companies in the pulp and paper industry would appear to provide a strong incentive to fund tree improvement research. Although pulp and

Table 6.1

PRESENT VALUE BENEFITS OF TREE IMPROVEMENT RESEARCH
Infinite Sequence of Rotations
- PULP AND PAPER COMPANY (begin production 1987) -
(thousands 1983 $)

Constant price = $1.20/tree
Rotation = 35 years
4 million trees planted/year

Interest Rate (%)	Genetic Gain Estimate low	medium	high
4	1,291	3,978	6,181
6	938	1,977	3,127
8	468	956	1,604
10	233	508	833
12	118	262	438
14	61	137	233

Constant price = $6.00/tree
Rotation = 35 years
4 million trees planted/year

Interest Rate (%)	Genetic Gain Estimate low	medium	high
4	6,455	19,889	30,905
6	4,691	9,885	15,637
8	2,322	4,979	8,019
10	1,164	2,541	4,166
12	591	1,313	2,192
14	304	686	1,167

Increasing price @ 1.2%/year
Rotation = 35 years
4 million trees planted/year

Interest Rate (%)	Genetic Gain Estimate low	medium	high
4	4,368	9,046	14,057
6	1,876	3,935	6,225
8	870	1,866	3,005
10	421	919	1,508
12	209	464	776
14	105	239	406

paper companies are members of a competitive industry, products and prices are relatively standardized. From the long-term corporate perspective, a positive motive is apparent for corporate contributions to university research. The research product (genetic material to construct seed orchards) directly benefits the private companies. Whichever individual company first implements genetically improved populations will have a comparative advantage over other regional firms. The company with improved trees planted will have raw material available to them at a lower real cost. Conversely, the company which does not plant improved trees will surely be at a comparative disadvantage. This competitive edge will exist for as long as this company has the only genetically improved trees planted. It is suprising that more leverage is not placed on the university research system by these companies requesting genetic materials.

<u>Reforestation</u> - <u>Public Sector</u>

The second institutional group planting trees for fiber production is that of the two public natural resource agencies, the DNR and the USFS. The DNR controls over 3.635 million acres of commercial forest and the USFS 2.423 million acres in Michigan. Both agencies have extensive artificial regeneration programs. To investigate the benefits these agencies would receive, a hypothetical public agency, representative of both, is constructed.

The public agency plants on sites of poorer quality (or lower site index) than the private pulp and paper companies. The private companies are able to choose parcels of land for regeneration based on productive capacity. The public agencies are granted land and take what is given to them, often because no one else wants it. Due to the poorer quality of land for timber regeneration, the average rotation period is assumed to be 45 years to produce a tree yielding 15 cubic feet of chips. The price is assumed to be the same as in the private industy, $1.20 per tree. The genetic stock, mostly jack and red pine, will be available for planting in 1987. The public agency is also assumed to plant 20 million trees for fiber production, of which 15 million survive to harvest. The public natural resource agency is charged with the care, management, and "wise use" of the natural resources. Applied to forest lands in the lake states, this means multiple use. The agency not only manages forest land for fiber production, but also for recreational uses, wilderness, wildlife, and many other uses. Genetic tree improvement research directly effects only the fiber production part of the agencies' mandate. The research contributes indirectly to the other multiple use goals of the agencies.

The direct benefits to the public agency are shown in Table 6.2. Even with the longer rotations and poorer sites, the most conservative is $1 million using an 8% interest rate.[4] The highest estimate is $20.7 million, assuming constant prices, a 15% genetic gain and a 4% interest rate. Assuming that real prices increase 1.2% per year in the forest products sector, the estimates of benefits range from $2.2 million to over $53 million.

Table 6.2

PRESENT VALUE BENEFITS OF TREE IMRPOVEMENT RESEARCH
Infinite Sequence of Rotations
- STATE OF MICHIGAN DNR (begin production 1987) -
(thousands 1983 $)

Constant price = $1.20/tree
Rotation = 45 years (assumes poorer sites)
15 million trees planted/year

Interest Rate (%)	Genetic Gain Estimate low	medium	high
4	6,318	13,220	20,758
6	2,563	5,486	8,818
8	1,058	2,316	3,811
10	444	994	1,675
12	189	433	748
14	82	192	339

Increasing price @ 1.2%/year
Rotation = 45 years (assumes poorer sites)
15 million trees planted/year

Interest Rate (%)	Genetic Gain Estimate low	medium	high
4	16,189	33,873	53,188
6	5,749	12,303	19,775
8	2,233	4,888	8,045
10	905	2,026	3,415
12	377	863	1,491
14	160	376	666

Obviously, the people of Michigan, through the public natural resource agency, receive more than the direct benefits of raw resource production. The public feels the effects of the secondary benefits. There are increased jobs from higher productivity; a greater property tax base to support schools and other public programs, and more efficient production on the fiber producing commercial forest releases other public lands for alternative uses.

The direct and indirect benefits the public receives from the tree improvement research are large by any estimation. From the institutional perspective, public agencies should have a strong motive to promote and contribute to tree improvement research. Public natural resource agencies' primary function is one of management. Although research activities are conducted throughout public agencies, particularly in the USFS, the public agency research is centered around research of management practices. Genetic tree improvement research is partly management oriented but primarily biological in nature. Additionally, a tree improvement program requires a very long-term funding commitment (with respect to the yearly budget process). Few public agencies have sustained a steady direction of management goals and objectives for as long as a genetic tree improvement research program requires. Most public agencies see a change in priorities with each new administration. The relative autonomy and personnel stability at university research institutions is an attractive environment for parenting new research products. While public priorities are conducive for allocation of public funds to genetic research, direct support of the university research programs will enhance the continuity and potential the university research program offers.

High Value Commodity Industrial Sector

The forest products industry has two sectors which produce a high value commodity directly from planted trees: the Christmas tree grower; and the wholesale ornamental nursery. The economics of the two are sufficiently similar to be included in the same case study. Both production processes are highly labor and management intensive, and both produce a high value product directly from a planted seedling in 8 - 12 years. A Christmas tree operation is modeled representing the magnitude of benefits possible to a similar ornamental nursery. The Christmas tree farm is 1,000 acres of plantation on a 12 year rotation (83.3 acres planted per year). The operation plants 100,900 seedlings yearly at 1,210 trees per acre. Although some trees mature in fewer than 12 years, this analysis, for convenience and to be conservative, assumes that all tree are harvested and sold at 12 years from planting. The real price F.O.B. farm is $12.00 per tree.

Two methods are used to determine the value of genetic gain: discounting time, and discounting quantity. The first refers to the decrease in interest charges by shortening the rotations. The second refers to a genetic gain translated into a higher quality and, therefore, a higher priced tree. If all the genetic gain were to result in a faster growing tree, a 10% gain would mean that rotations could be produced in roughly 11 years. The decrease in interest charge from shorter rotations would value benefits according to discounting time. If all the genetic gain were to produce a Christmas tree which could sell for a 10% higher price ($13.20) the valuation method would be discounting quantity. In reality, both actions may be at work. For this analysis, the most lucrative valuation method alone is used, realizing that some degree of under valuation occurs.

The potential benefits to the grower are not as sensitive to interest rates as in the reforestation sector due to the shorter rotation period. This results in a higher value of benefits, $108,000, for the low genetic gain estimate and 14% interest rate. The greatest benefit estimate is $4.8 million. Increasing real price at 1.2% per year has less effect on benefits to Christmas tree growers than to the reforestation sector, again due to the shorter rotations. The range of estimates, assuming increasing real price, is from $242,000 to $8.5 million. A complete listing of the benefits is in Table 6.3.

The state-wide economic analysis shows the Christmas tree and ornamental sectors to be the greatest beneficiaries of genetic tree improvement research. The individual producer in these sectors is generally quite small compared with public agencies and pulp and paper companies. The yearly gross revenue of a pulp and paper mill is measured in the hundreds of millions of dollars. The gross revenue of the model Christmas tree farm (relatively large at 1,000 acres) is only $1.2 million. The problem of capturing the enormous potential

Table 6.3

PRESENT VALUE BENEFITS OF TREE IMPROVEMENT RESEARCH
Infinite Sequence of Rotations
- CHRISTMAS TREE COMPANY (begin production 1988) -
(thousands 1983 $)

Constant price = $12.00/tree
Rotation = 12 years
100,833 trees planted/year

Interest Rate (%)	Genetic Gain Estimate low		medium		high	
4	1,615*	q	3,230	q	4,845	q
6	794	q	1,587	q	2,381	q
8	441	q	895	t	1,409	t
10	319	t	677	t	1,077	t
12	239	t	514	t	829	t
14	108	t	392	t	640	t

Increasing price @ 1.2%/year
Rotation = 12 years
100,833 trees planted/year

Interest Rate (%)	Genetic Gain Estimate low		medium		high	
4	2,825	q	5,650	q	8,475	q
6	1,215	q	2,431	q	3,647	q
8	636	q	1,290	t	2,030	t
10	444	t	942	t	1,500	t
12	326	t	699	t	1,128	t
14	242	t	526	t	857	t

* q, and t, represent the highest value:
q = valuation by discount quantity
t = valuation by discount time

benefit to the industry is that no one individual can afford any extra costs. The short rotations, and large number of small producers (many of them part-time), create a highly competitive market where no single grower can afford the lag-time between the cost outlay for research (or contribution to university research) and the revenue from genetically improved trees. The usual economic solution in this situation is a tax. Several options are available for a tax structure. A direct tax on the producers (those groups who stand to benefit the most) is one feasible option. At the public regulation level, the state trade agencies may impose a tax, proceeds of which would go to genetic tree improvement research. A second alternative is self regulation through the trade association. This method of generating funds for mutually beneficial activities is common in many industrial areas. The plywood companies pay so many cents per thousand square feet of plywood produced. The paper companies pay a fee to several trade and lobby organizations based on paper output. At the retail level, automobile dealerships pay fees or dues to the local "greater area dealership association". This method of self-taxation works best when there are large numbers of individual units or products produced. If a small percentage of the value of each unit is taxed, a large amount of revenue is generated without noticeable effect on the cost of production. The Christmas tree and ornamental operations are ideally suited for this method of self-taxation.

The Christmas tree market is developing into several regional competitive areas. Species suited for Christmas tree production are specific to the lake States. Genetic research products in this area could not be transported to other regions. The potential gains in Michigan from costs saved, increased price, and larger nationwide market share are substantial. These gains translate into a competitive advantage, an advantage which may help sustain the projected growth and prosperity of the industry.

NOTES - CHAPTER VI

1) Lee James, S. Heinen, D. Olson, and D. Chappelle. 1982. Timber Products Economy of Michigan. Agricultural Experiment Station Research Report No. 446, Michigan State University; 23 p.

2) The analysis is conducted on an individual tree basis so prices are expressed as dollars per tree. This price is based on a tree 35 years old yielding 15 cubic feet of wood chips and a conversion factor of 100 cubic feet per cord.

3) This price is derived from the 1982 Mead Paper Company Annual Report. Mead reported purchasing future timber options valued at five times the current stumpage price. Mead Annual Report to the Stockholders, 1982. p. 34-35.

4) Public agencies rarely use an interest rate greater than 8%. The full range of estimates using higher interest rates are presented for comparison only.

CHAPTER VII

ANALYSIS OF RESEARCH GAINS AND POLICY IMPLICATIONS

Introduction

The goal of applied research in forestry is to increase the productive efficiency of the industry. Pursuant to this goal, the primary objective of the tree breeding program is to increase the genetic quality of stock material for the establishment of commercial seed orchards. These seed orchards, in turn, are used to increase the efficiency of producing the raw forest products. The purpose of this analysis is to estimate potential benefits to the industry which may result from the research program.

Begun in 1961, the research program has not yet been completed. The first commercial products are expected to be available in 1984. A continuing stream of products will follow through the year 2008, as research on more species is completed. The effective agent today of the genetic based tree improvement program in Michigan is the Michigan State Cooperative Tree Improvement Program (MICHCOTIP). MICHCOTIP, since it's organization in 1974, has at one time or another, conducted genetic research on over 45 species. These species are classified into three market categories: reforestation commodities, which includes trees grown for pulp or fiber, timber (lumber and veneer), and fuelwood or energy; species used for Christmas trees; and species used for ornamentals.

A review of the research status of each species coupled with the Michigan Tree Industry Survey has identified 21 species for which commercialization of the genetic research is feasible in the near future (specifically within the next 25 years). All benefits, as calculated by this analysis, will occur in the future. There is always some degree of uncertainty about the future economic environment, so several different economic assumptions are used to calculate a range of potential benefit estimates. The range of estimates represents a broad spectrum of outlooks on future economic trends.

Interpretation of Results

The results derived by the analysis clearly show that under all assumptions tested, even the most economically and biologically conservative, economic costs incurred by the research program are more than covered by the economic benefits. The lowest benefit-cost ratio is 3.37, reflecting economic benefits of $52 million.[1] The high estimate of economic benefits (using the most optimistic assumptions) is $24 billion.

The validity of these results depends on the validity of the assumptions made in defining the economic environment. The assumptions are made in a somewhat subjective manner. Economic assumptions are chosen to clarify economic behavior. The fundamental assumptions in this model are concerned with maintaining a competitive exchange market for "raw" tree resources. The phrase "raw tree resources" refers to tree products which are exchanged at the first level in the market chain. These assumptions neglect any market imperfections which may confound the analysis or cast doubt on the validity of the results. Said assumptions are not varied in the model. Other assumptions concern the uncertain future. These are varied and, due to the uncertainty attached to them, the results are open to interpretation.

The greatest degree of subjectivity in any returns-to-research analysis lies in setting the level at which research costs and benefits are determined. The model used here sets the cost and benefit level at the point where a minimum of outside factors contribute to either costs or benefits, and where analytical estimation of costs and benefits is feasible. The level of costs is defined as those research activities which uniquely contribute to increased production of the raw forest input. On the benefit side, the level is defined at the point where the raw forest resource first attains a market value and a competitive market exchange exists. To value either costs or benefits at higher levels would necessitate a far broader approach in the analysis, diluting the accuracy of estimates for any one research or benefit component. Research activities which are a precursor to the final product research stage (such as basic tree physiology research) potentially benefit not only the production of raw forest products, but also the production of other commodities. The question is one of allocation of costs to multiple different production systems. Theoretically, this question can be solved by a global general equilibrium economic model, but of course such a model is not practical.

Direct Benefits Not Included in the Model

Within the valuation constraints of this model, other costs and benefits do exist, which are not reflected in the estimates of potential benefits or costs. The unique structure, operation, and production characteristics of the Michigan tree seedling nursery industry accounts for a potentially large benefit not included in the model. The 1982 Michigan Tree Seedling Industry Survey found that approximately 30% of all seedlings sold were exported out of Michigan to surrounding states. An implicit assumption in the model is that the nursery industry in Michigan will assume the role for production of genetically improved seedlings. If the demand for seedlings in Michigan stays at the 1981 or projected 1986 levels, an expected 25 million seedlings of genetically superior stock will be shipped yearly to other states. The survey did not delineate by species the intended production use of the exported seedling stock, so it is difficult to assess an accurate value for these exported seedlings in the context of the model. The survey did show that 56% of the exported seedlings may be used for Christmas trees, 24% for ornamentals and 20% for reforestation production. To put the seedling export component in perspective, the export segment of production is compared with the numbers used in this analysis to calculate the benefits. The analysis of the 1981 planting level used in the model is based on a total number of 24.1 million seedlings planted, split 47.4% for Christmas trees, 43.2% for reforestation, and 9.4% for ornamentals. The export segment of nursery production has a higher percentage of seedlings to be used for the more valuable commodities. The total number of seedlings exported is approximately the same as the number used in the analysis for Michigan. The high percentage of more valuable production categories exported may indicate greater economic benefits going to other states than what was derived for Michigan alone. The estimate of economic benefits derived from tree breeding research might easily double if the benefits accrued by other states as a result of importing Michigan produced genetically superior seedlings were to be included.

A second major benefit not shown in the model is observed under the assumption of a fixed constant supply requirement. This benefit will be realized by the companies which derive most of their supply through artificial regeneration on lands which they own or lease. This situation applies to large pulp and paper companies, and to most Christmas tree growers. If the supply of raw material needed is constrained by factory capacity (pulp companies) or market saturation (Christmas tree growers), a fixed number of acres is needed to produce the supply. As each rotation of genetically improved trees is planted, less land is needed resulting in savings in the value of the land, lease payments, taxes, and/or economic rents paid. As an example, suppose that a paper company has annual requirements of 250,000 cords of wood chips met by a harvest on 5,000 acres of plantation stocked with "wild" unimproved trees. The unimproved stock is grown on a 40 year rotation, each acre producing 50 cords at the end of 40 years. To supply the company's mill, 200,000 acres are needed. The first plantation of 10% genetically improved stock in the series of rotations will mature in 36 years. The 10% improvement reflects an increased growth rate; the same amount of raw material as can be produced on 5,000 acres of unimproved stock in 40 years now takes only 36 years. This assumes a linear relationship between volume production and time. A full series of plantations in genetically improved stock will require a total land base of only 180,000 acres, a "savings" of 20,000 acres. The land savings will occur incrementally in 5,000 acre blocks four years before genetically improved stock is planted. Rotations numbered 37, 38, 39, and 40, each 5,000 acres large and normally needed under the 40 year rotation plan, are now unnecessary. When harvested, this land need not be replanted, and can be sold. As calculated in the model, the primary method of valuation is the time value in the reduced rotation length. The "savings" of 20,000 acres is a one-time benefit not included in the model. The same analysis can be applied to the Christmas tree grower desiring to sell a fixed number of trees each year. The reduced variation in the genetic base means the trees will mature more evenly. As an example, instead of four years required to "clear" a plantation, genetically improved trees require only three years. With a total land base of 2,000 acres, and assuming a 12 year rotation including clearing time, the rotation period of genetically improved stock is reduced to 11 years, including clearing time. For 11 years as a rotation time, only 1,833 acres are needed, creating a one-time savings of 166 acres (the land area of one rotation).

A third major potential benefit (not included in the model) is the possibility of more than one genetically controlled trait simultaneously being improved through a breeding program. For Christmas trees and ornamental commodities, improvement in multiple qualitative traits is assumed. For reforestation commodities, reduction of the reduced time required to produce the resource is the lone valuation method, with no assumed increase in qualitative characteristics of the resource. Recent work on the genetics of jack pine indicates that specific gravity is positively correlated with growth rate.[2] This implies that qualitative traits may indeed add additional value. Only one primary valuation method (reduced time or increased quality) was used for each commodity in constructing the gross present value benefit estimates. Obviously, in some commodities, more than one valuation method is at work. The valuation method used in the model calculates the greatest direct benefit for each commodity. The benefits reported by the model are those with the least amount of uncertainty and are most directly applicable to the individual production process and Michigan's economy. While additional direct benefits may indeed exist, they are not included in the reporting of results. It has been stressed that the nature of this analysis is conservative. Inclusion of additional benefits with a high degree of uncertainty, or benefits which are not quantifiable, will add little to the impact and nothing to the integrity of the analysis.

Secondary Benefits

There are further additional benefits which are not so easily quantifiable, but nevertheless deserve mention. These fall into the category of secondary benefits: economic or employment income multipliers, and induced indirect benefits.

Under the assumption of less than full employment in the economy, any rightward equilibrium shift of supply results in either greater local production or increased export of the product. This, in turn, creates a greater number of jobs with a result that more people are employed. These new jobs and income represent new money in someone's pocket. Given a positive marginal propensity to consume, an increase in the National Income will result.[3] This is called the multiplier effect. Multiplier effects can also be felt through the market chain from raw material resources to manufactured wood-based consumer products. Raw timber products harvested in Michigan in 1980 were worth $265 million. When value is added by the manufacturing, transportation, marketing, and construction activities, the portion of the economy dependent on raw timber products is worth $4.7 billion. A fundamental change in the economics of supply is felt at each level all the way up the market chain to the consumer.

In addition to multiplier effects, there are induced benefits, which effect sectors of the economy only indirectly tied to the forest products industry. Induced benefits are realized when economic activities outside the the forest products industry are able to make use of scarce resources freed up by the increased efficiency of growing wood resources. A prime example of this type of benefit is the value of production resulting from alternative uses of land saved by shortening the rotation period. This was discussed in the case of a company requiring a fixed supply of forest products. For instance, land used to produce wood fiber for pulp attracts only wood cutters. If this land is sold and used as a national lakeshore area, hotels, tourist stands, and other economic support activities are induced. The additional economic activities are the induced benefits. A second type of potential induced benefit may be the attraction of more wood based manufacturing and processing companies due to the availability of a cheaper source of raw wood resource supply. With respect to artificial regeneration of supply, the pulp and paper industry has traditionally located in the southern United States. The industry has also traditionally regarded the Lake States area as an unproductive and slow growing source of wood fiber. Decreasing the rotation period and increasing the quality of the wood resource will move toward reversing this plant location trend. As more plants locate in the state, more economic support activities are needed and more induced benefits realized.

In addition to indirect benefits, which theoretically are quantifiable, certain intangible benefits exist which are much more difficult to quantify. Two intangibles are related to the value of information or knowledge about a previously unknown or untested hypothesis of biological production functions. The value to the industrial user of the raw resource supply is enhanced by greater understanding of the production process. Greater understanding of how trees grow eliminates a degree of uncertainty in the supply of raw material.

This model assumes an infinite sequence of rotations of timber, Christmas trees and ornamental species. Under the assumption of increasing industry size certain constraints are reached with respect to land and market saturation. The primary constraint is land. Currently, 17.5 million acres are classified as commercial forest area in Michigan. Much of this land is unsuitable for artificial regeneration due to a low site productivity. The limit of artificial regeneration defined in the model is 9.3 million acres of reforestation (timber plantations) forest land and 1.1 million acres of Christmas trees. Ornamental species are insignificant with respect to the land constraint since those species are grown in nurseries that compete with agricultural land.[4] Of the commercial forest land, 2.4 million acres are in National Forest, 3.6 million acres are in State Forest, 4 million acres are owned or leased by the forest products industry (primarily pulp and paper companies), 3.5 million acres are owned by farmers in small woodlots and 4 million acres are in miscellaneous private ownership. The current institutional ownership patterns for commercial forest indicates that the maximum limit (as defined in the model) of artificial regeneration is feasible. Studies addressing future management possibilities also confirm the feasibility of these limits.[5] The primary constraint on the maximum limit of land for artificial regeneration supply is site productivity. A genetically derived increase in productivity, without additional silvicultural inputs or costs, will allow poorer sites to be artificially regenerated. This is an obvious benefit when the limit as constrained by the site productivity is reached. This benefit is not included in the formulation of estimates as calculated in the model.

Another intangible benefit of the research is the possibility of an unforeseen technological breakthrough. When engaged in research and development, the possibility exists of revoluntionary discovery. Obviously this is not quantifiable; nonetheless, it is still a benefit to the research and must be taken into account when deciding on the total worth of the research.

Secondary Costs

Indirect costs also exist which are not included in the model. For the most part, these are negligible compared with both direct and indirect benefits. One cost not included may have a limited effect on the economics of tree improvement research. With the increased efficiency of the supply function, particularly under the cost savings assumption, a certain amount of labor displacement may occur, particularly in the Christmas tree sector. A narrowing of variation in the stock planted for Christmas trees results from genetic breeding programs. This in turn, may result in cost savings through fewer labor inputs in the production process of growing the Christmas trees.

An accurate estimate of this cost reduction is not possible with today's information, thus was not included in the model. A rough estimate of the magnitude of labor displacement is possible with the available data. A 1979 state-wide survey found 711 Christmas tree growers in Michigan. The majority of these (83.5%) are non-commercial growers or part-time operators.[6] Labor requirements vary greatly from grower to grower, depending on size of operation, quality of growing stock, and degree of mechanization. A reasonable estimate of average labor requirements for the average grower would be 3 person-years per farm. Rounding to the high side, approximately 2,500 person-years of labor are engaged in the production of Christmas trees in Michigan. Further assuming that all the 30% genetic gain (using the high estimate), constitutes a direct labor savings, a labor displacement of 750 person-years would occur. If this displaced labor is compensated at 50% on a $15,000 yearly wage basis for two years (time to seek alternative employment), an additional cost of $11 million is incurred. The above labor displacement analysis is valid only under two unlikely assumptions: that there would be no expansion of the industry with respect to labor requirements; and that labor is not mobile. Recent surveys based on planting trends show the Christmas tree industry to be expanding, throwing some doubt on the validity of the first assumption. The majority of the labor inputs in the Christmas tree production process are filled by highly mobile temporary or seasonal labor, negating the second assumption.

A second indirect cost not accounted for by the model is the difference in yield between research plantations, of provenance and progeny tests, and commercial plantations. Both research plantations and commercial plantations yield a wood product. Because many research plantations are composed of both superior (some) and inferior (many) trees, as compared to the "wild planted" forest, the yield of research plantations when harvested is often less than what a plantation of commercially planted and managed trees would be. The data needed to estimate this cost is not available. The cost is again assumed to be minor. An upper bound for this cost would be the total commercial value of the area in research plantations; this assumes research plantations have zero salvage value. There are approximately 550 acres of land in research plantations in the state. If all 550 acres were in Christmas trees, the highest value wood crop possible, the total gross value would be almost $8 million. Assuming a high 20% profit margin, the net value, and therefore the cost to the research program, would be $1.6 million. Experience is proving that the salvage value of research plantations is not zero, further reducing this cost.[7]

The cost of adopting the new genetically improved species in the production process must also be addressed. A recent study evaluating the returns to agricultural research, segregating the extension program component as a separate input, found that the extension programs accounted for 25% to 60% of the return to the investment in experiment station research.[8] The logic behind the efforts of extension programs to assist in new technology transfer is clear. Researchers themselves are generally not in a position to distribute or demonstrate the new technological production possibilities. If the industry does not use the new technology, there are no benefits. For the specific case of tree improvement research in Michigan, the initial adoption costs of the "new technology" (meaning genetically improved stock) are negligible, if any. The structure of the tree seedling industry in Michigan and institutional structure of MICHCOTIP make adoption costs an unnecessary consideration. The majority of tree seedlings are produced by only a handful of nurseries; 54.5% of the total seedling production is accounted for by only 8.93% of the firms. The few large nursery operations are eager for genetically improved stock. There is no problem in getting the nursery industry to adopt genetically improved stock into their production processes. Once the nurseries are growing the genetic stock, the planters will buy the new genetic seedlings. In addition, MICHCOTIP (the state-wide tree improvement cooperative) is active not only in the final product research activities but also in disseminating information and genetically improved stock. At the 1981 or 1986 industry production levels, there appears to be little extra cost involved with adopting genetically improved stock. Under the expanding industry assumption, it is reasonable to expect that a portion of gross benefits would be due to cooperative extension programs. These extension program costs would then be germane to the model.

Analysis of Benefits

It is clear that there is some room for interpretation in the results and conclusions of the study. The model presents the user with a wide range of estimates, the estimates indicating the direct or primary benefits which are felt in the state. It is also clear that when the total social welfare of the state or region is considered (including direct, primary and indirect induced, and secondary benefits), the estimates derived from the model are conservative. The order of magnitude of secondary benefits is much greater than secondary costs. To state quantitatively how much the model underestimates the total value of research is not possible. There simply is inadequate information and data on the various economic components to conduct such an investigation.

When all factors and economic trends are considered, a reliable but still conservative figure for the value of tree improvement research in Michigan is $539 million. This estimate uses the 1986 projected planting level, constant prices, medium genetic gain estimates, and a long term interest rate of 6%. The costs involved are only $6.4 million, a small amount compared to the benefits. The benefit-cost ratio is 84.2. This estimate is based on real projected planting levels and a widely used government institutional discount rate (6%). Due to discount factors and the long time spans experienced in forestry, most of the $539 million value is realized in the first 50 years. At very low discount rates, the present value of a revenue realized 400 years in the future is close to zero. Even though the model calculates the value based on infinitely many rotations, the estimate approximates the short-term (less than 50 years) returns to the research program. Estimates of gross benefits do not differ greatly when the model is run within a time span equal to the productive life of the F_1 seed orchards. The average F_1 seed orchard life is 35 years for the species used in the analysis. For this time span, the conservative estimates (constant price, 1981 planting levels) are only 2% to 30% less than when the model is run for infinite rotations. The most conservative estimate under these assumptions is reduced from $52 million (with infinite rotations) to $51 million for only those rotations resulting from the F_1 seed orchards. The high estimate is reduced from $1.188 billion to $830 million. A greater percentage of the benefit occurs in the earlier years with lower discount rates. The present value benefits calculated for only the rotations resulting from one cycle of F_1 seed orchards are shown in Table 7.1.

The greatest potential for benefits from tree improvement research, as estimated by the model, is realized by the higher priced and shorter market chain Christmas tree and ornamental sectors of the industry. When secondary benefits are included in the analysis, the longer market chain reforestation industry sector will contribute proportionally more. This is true particularly under the assumption of an expanding industry and when multiplier effects are included. The longer the market chain, the greater effect multiplier effects

Table 7.1

PRESENT VALUE BENEFITS - ALL COMMODITIES, ROTATIONS FROM F1 SEED ORCHARDS ONLY, APPROXIMATELY 50 YEARS

(THOUSANDS OF 1983 DOLLARS)

CONSTANT PRICE

BLOCK 1 ESTIMATES:
1981 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	276,190	552,701	830,137
6	177,161	354,557	532,571
8	118,127	236,697	357,098
10	82,759	168,848	258,816
12	62,785	128,815	203,326
14	51,259	108,953	174,015

BLOCK 2 ESTIMATES:
1986 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	358,398	717,357	1,079,010
6	223,538	447,481	673,135
8	145,186	291,359	442,086
10	101,047	210,782	330,652
12	81,054	170,657	271,903
14	66,323	141,986	228,566

BLOCK 3 ESTIMATES:
INCREASING PLANTING (1981)

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	691,173	1,383,522	2,078,811
6	398,711	798,112	1,199,205
8	243,647	488,431	737,839
10	159,309	325,247	498,898
12	113,777	233,572	368,794
14	88,217	187,553	299,617

INCREASING PRICE

BLOCK 4 ESTIMATES:
1981 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	373,550	747,779	1,123,754
6	233,829	468,133	703,579
8	152,768	306,239	426,418
10	105,370	215,131	330,049
12	78,930	162,055	255,911
14	63,712	135,455	216,419

BLOCK 5 ESTIMATES:
1986 PLANTING

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	494,735	990,677	1,491,857
6	300,617	602,064	906,737
8	191,052	383,609	582,875
10	130,792	272,933	428,495
12	103,388	217,756	347,129
14	83,583	178,971	288,221

BLOCK 6 ESTIMATES:
INCREASING PLANTING (1981)

INTEREST RATE %	LOW GAIN	MEDIUM GAIN	HIGH GAIN
4	1,013,440	2,029,819	3,052,678
6	561,927	1,125,455	1,692,534
8	332,714	667,397	1,009,531
10	212,535	434,306	666,923
12	148,864	305,868	483,223
14	113,545	241,284	385,616

will have on total social benefits.

Research Policy Implications

The results presented with the analysis have definite policy implications both on the direction of scientific research, and on the institutional structure of the tree improvement program. The research program in Michigan is at a pivotal stage. The main emphasis up to present has been on establishment of provenance and progeny tests for a wide variety of commercial tree species. The direction and thrust of research in establishment of these tests has been toward the reforestation sector of the forest products industry. The Michigan Tree Seedling Industry Survey identified three distinct industry sectors which could potentially benefit from tree improvement. Recent developments in Michigan point to a fourth sector of agro-forestry/biomass as being a beneficiary of tree improvement efforts in the future. In light of the immediate great potential in the Christmas tree and ornamental industry sectors, the future direction of tree improvement should be reviewed. Activities to be completed in the research program (measurement of progeny tests, and thinning for seed orchards or distribution of genetic stock for other commercial seed orchard establishment), are focused more toward a specific industry sector and a specific product. A research program geared toward accomodating the high potential returns in the Christmas tree and ornamental sectors would experience a greater rate of return than one looking only at reforestation commodities/species.

A definite research direction toward blue spruce Christmas tree/ornamental, Scotch pine Christmas tree/ornamental, and Douglas-fir Christmas tree/ornamental commodities would prove to be highly beneficial to these industries. This is based on the potential economic returns, and research stage each species is currently at.

<u>Institutional Analysis</u>

Why has not more funding been allocated to tree improvement research? With potential returns apparently very high, this question is germane. The answer to this question is complex and embedded in the nature of the research product, and in the institutional framework of the research institution and forest products industry.

The research product, (information about which individual trees in a progeny test will yield the best off-spring and how to construct seed orchards from these parents), has many characteristics of a joint-impact good.[9] By definition, the maintenance costs for the research product are zero. After the product is produced, (the information obtained), the marginal cost of an additional user of that research product is zero. The exclusion costs of tree improvement products is extremely high. The information is of a public nature, coming from the university system. Widely planted genetic stock from commercial seed orchards would be equally difficult to exclude unwanted users or "free-riders." Benefits to users are only attained with wide-spread use of genetically superior stock. Once dispersed on a large scale, to exlude others from gathering seeds or snipping cuttings would be virtually impossible. The private producer of a product will attempt to maximize profits by selecting the level of production at which marginal cost equals marginal revenue. Despite a demand for the product, the problem from the private producers' point of view, is that with the optimal price at zero, there is no way to pay for total costs (which are positive).

From the income perspective, research is counted against income without contributing to immediate profits. Many executives and company managers with fund allocating responsibilities, receive income bonuses based on profitability. Research expenses lowers corporate profit. Consequently, there is a strong incentive for managers to allocate funds to capital expansion, an expenditure which can be capitalized and depreciated over a number of years. (Capital expenditures also usually generate income.)

From the strategic planning perspective, there are two strategies for obtaining information which can increase productive efficiency: develop it through expensive research and development programs (R&D); or acquire it from some other company which conducts the R&D. Abundant examples of both strategies exist at the firm level as well as at the national level. Information espionage is an industry in itself. As has already been pointed out, exclusion costs for tree improvement research products are high enough to dissuade any company from choosing the R&D strategy.

Conclusions

Tree improvement research appears to be a highly profitable economic activity for the economy of the State of Michigan. Immediate potential direct benefits which may be realized over the next half century are enormous. The costs of the program relative to the size of the benefits are insignificant.

The analysis calculates only the direct benefits which are realized by the primary producers in the forest products industry. When secondary benefits are added to the direct benefits, the total worth of the research program may grow tremendously. Surrounding states in the Lake States area are potentially large beneficiaries of the research program in Michigan. Secondary costs appear to be small or non-existent.

The unique joint-impact characteristics of the research product present severe barriers to the private sector for engaging in tree improvement research, at least at the development stage. The joint-impact nature of the research product would indicate that the university setting may be a proper place for this kind of research.

The research program is at a mid-stage of completion. A research direction aimed at providing genetically improved material to the Christmas tree and ornamental sectors of the forest products industry would yield the highest economic return. Emphasis on developing the potential in Scotch pine, blue spruce, Douglas-fir, and white spruce for Christmas tree and ornamental stock will account for over half of the present value benefits.

The policy implications of these conclusions are many. A policy goal can be generated for each conclusion. A policy dialog between researchers, private industry, and public administrators could be an initial step in utilizing these conclusions.

The next step in the economic analysis of tree improvement research will be to investigate more accurately the specific micro-economic aspects of the problem. Specifically, at what level should private industry now enter into the research process to optimize the research gains created so far? On a somewhat broader level, what are the gains to other nearby states resulting from tree improvement research? Finally, on the macro-economic scale, the investigation into suitable methods for analysis of gains to society (the question of consumer surplus) should be considered.

NOTES - CHAPTER VII

1) All costs and benefits are expressed in present value terms (1983 dollars).

2) Unpublished measurement data generated by MICHCOTIP personnel on the Pickford jack pine progeny test in the Upper Peninsula of Michigan has a statistically significant positive correlation between specific gravity and growth rate. When rogued on the basis of volume, one to two percent gain is shown in specific gravity.

3) National Income is equal to Net National Product minus indirect business taxes. Net National Product is considered to be a true measure of the output of the economy and reflects "how well off we are." When Net National Product increases, on the average, people are better off.

4) The individual species limit for reforestation is 15 million trees planted per year. At 600 trees/acre and an average 31 year rotation, the 12 species planted for reforestation requires 9.3 million acres for continuous rotations. Christmas trees at the production limit will need 1.1 million acres for the 115 million trees planted at 1,210 trees/acre on a 12 year rotation.

5) Michigan Forest Resources 1979: An Assessment, by Michigan Department of Natural Resources; Adams, Haynes, and Dutrow's Private Investment in Forest Management and the Long-Term Supply of Timber, Am. J. Ag. Econ. 1982; and the USFS North Central Forest Survey, Preliminary Results, 1982; all show the possibility that roughly half the current commercial forest area in Michigan could ultimately be artificially regenerated.

6) Production and Marketing of Christmas trees in Michigan, James, Rudolf, and Koelling; Research Report No. 412. 1979.

7) Sales of a White pine stand for lumber and a blue spruce provenance test at Kellogg Research Forest in Kalamazoo County, Michigan have shown that the salvage value of research plantations can be substantial.

8) Araji, Sim and Gardner in their 1978 study on research and extension programs in sheep, fruits and vegetables, potatoes, cotton and rice in the western region conclude: "Depending on the commodity and nature of the research program, 25% to 60% of the expected returns to public investment in agricultural research will not be realized without extension involvement."

9) Allan Schmid explains the terminology of joint-impact goods with respect to other authors definitions in Political Economy of Public Investment, 1982, and in Property, Power, and Public Choice: An Inquiry into Law and Economics, 1978. Frequently, other literature

refers to joint-impact goods as "public goods" or as Samuelson's definition of "consumption externality".

APPENDIX

Program ECON
Program ANALYS
Program ECNCOST

```
      PROGRAM ECON
C
C  THIS IS THE MAIN DRIVER PROGRAM FOR CALCULATING GROSS
C     **** REVISED 8/15/83 ****
C     **** CALCULATION OF GPV FOR INFINITE SERIES ****
C     **** APPROXIMATED WITH 300+ YEARS
C     **** INCLUDES LOGISTIC CURVES CALCULATED FOR EACH SPECIES ****
C
C   PRESENT VALUE BENEFITS FOR ALL SPECIES
C
      CHARACTER*80 TITLE,YES,SPECIE,DISTT,DISQQ
      DIMENSION SPECIE(29)
C
      INTEGER ROTAT,GENER,YEAR,I,K,J,INITY,JK,J3,FLAG1,RROTAT,TFLAG,QFLA
     *   G,III,IIJ,II,JJ,JJI,PFLAG,SFLAG
C
      REAL PRICE,QUANT,GAIN,INT,PVTK,PVTJ,PVK,PVJ,PVY1K,PVY2K,PVY1J,PVY2
     *   J,DISC,GAN,INT1,PRICET,TEMP2,TEMP3,PLANT,GPV,PRICC,ABTGPV,PERGP
     *   V
C
      COMMON /MAIN/ PVK(500),PVJ(500),PVTK,PVTJ,INT,GAIN,QUANT,PRICE(29)
     *   ,I,K,ROTAT,PVY1K(500),PVY2K(500),PVY1J(500),PVY2J(500),SFLAG,GA
     *   N(29,3),PLANT(29,2),DISC,INT1,PRICET(29),TEMP2,J3(29),TEMP3,GEN
     *   ER(29),RROTAT(29),GPV(29,3,6,3,2),INITY(29),YEAR(500)
C
      OPEN (6,FILE='TABLE')
      OPEN (7,FILE='ARRAY')
      OPEN (8,FILE='SUMTAB')
C
C   VARIABLE LISTING
C
C  **********INTEGERS*********
C RROTAT = ROTATION PERIOD OF THE CROP OR SPECIES
C ROTAT = ROTATION PERIOD ADJUSTED FOR DISCOUNTING BACK TO 1983
C GENER = GENERATION OF GENETIC VIABILITY (YEARS) (F1 USEFULNESS)
C YEAR = PRESENT YEAR OF DISCOUNTING
C I, K, COUNTERS
C QFLAG = QUANTITY OPTION FLAG
C TFLAG = THINNING FLAG FOR REFORESTATION OR CHRISTMAS TREE THINNING
C SFLAG = FLAG FOR SHORT CUTTING PRINTING OPTION
C PFLAG = FLAG FOR PRINTING DETAILED TABLE (WARNING, THIS IS EXPENSIVE)
C FLAG1 = FLAG FOR PRICE INCREASE OPTION
C J3(I) = DIFFERENCE BETWEEN 1983 AND BEGINNING YEAR OF F1 SEED ORCHARD
C INITY = BEGINNING YEAR OF F1 SEED ORCHARD
C ***********REALS***********
C PLANT(I,1) = AMOUNT PLANTED IN 1981 FOR EACH SPECIES
C PLANT(I,2) = AMOUNT PLANTED IN 1986 FOR EACH SPECIES
C PRICE = PRICE OF THE PRODUCT AT HARVEST (TO THE GROWER)
C QUANT = QUANTITY OF PRODUCT STATEWIDE
C GAIN = GENETIC GAIN EXPECTED FOR THE PRODUCT OR SPECIES
C INT = INTEREST RATE NET OF RISK AND INFLATION
C PVTK = PRESENT VALUE TOTAL FOR 'K' OPTION (DISCOUNT TIME)
C PVTJ = PRESENT VALUE TOTAL FOR 'J' OPTION (DISCOUNT QUANTITY)
C ABTGPV = PRESENT VALUE OF THE TOTAL CROP
C PERGPV = GENETIC GAIN VALUE AS PERCENTAGE OF TOTAL VALUE
C PVY1K = IS THE TEMPORARY STORAGE FOR EACH PV
C PVY2K = "    "    "    "    "    "    "
C PVY1J = "   "   "   "   "    "    "    "
C PVY2J = "   "    "    " "    "    "    "
C DISCT = GAIN RELATED DISCOUNT FACTOR FOR TIME IN OPTION 1 (K)
C INT1 = INPUT VARIABLE FOR INTEREST RATE
C PRICET(I) = TEMPORARY PRICE STORAGE FOR RE-SETTING PRICE TO BASE YEAR
C TEMP2, TEMP3 = TEMPORARY STORAGE FOR YEARLY PV SUMS
C GPV(SPECIES,GAIN,INTEREST,QUANTITY,PRICE)= STORAGE ARRAY FOR SUMS
C PRICC = TEMPORARY PRICE VARIABLE FOR CALCULATING PV
C
C  *********CHARACTER********
C YES = PROMPT TO GO AGAIN (FOR INTERACTIVE VERSION)
C TITLE = IS THE TITLE OF THE PARTICULAR RUN
C SPECIE = THE NAME OF EACH SPECIES
C DISTT = TITLE FOR DISCOUNTING TIME
C DISQQ = TITLE FOR DISCOUNTING QUANTITY
C
C  READ IN DATA FOR 20 SPECIES:
C
      DATA (SPECIE(I),I=1,29) / 'HYBRID PINE REFORESTATION','JACK PINE R
     *EFORESTATION','HYBRID POPLAR REFORESTATION','EASTERN WHITE PINE RE
     *FORESTATION','WHITE SPRUCE REFORESTATION','RED PINE REFORESTATION'
     *,'HYBRID ASPEN REFORESTATION','BLACK SPRUCE REFORESTATION','HONEYL
     *OCUST REFORESTATION','EUROPEAN LARCH REFORESTATION','HYBRID LARCH
     *REFORESTATION','BLACK WALNUT REFORESTATION','SCOTCH PINE CHRISTMAS
```

```
     * TREE','BLUE SPRUCE CHRISTMAS TREE','EASTERN WHITE PINE CHRISTMAS
     *TREE','WHITE SPRUCE CHRISTMAS TREE','HYBRID SPRUCE CHRISTMAS TREE'
     *,'WESTERN WHITE PINE CHRISTMAS TREE','AUSTRIAN PINE
     *  CHRISTMAS TREE','ENGLEMANN SPRUCE CHRISTMAS TREE','DOUGLAS FIR C
     *HRISTMAS TREE','WHITE FIR CHRISTMAS TREE','BLUE SPRUCE ORNAMENTAL'
     *,'EASTERN WHITE PINE ORNAMENTAL','WHITE SPRUCE ORNAMENTAL','NORWAY
     * SPRUCE ORNAMENTAL','HONEYLOCUST ORNAMENTAL','AUSTRIAN PINE ORNAME
     *NTAL','DOUGLAS FIR ORNAMENTAL'/
C
C  READ IN DATA FOR AMOUNT PLANTED IN 1981 AND 1986
C
      DATA  (PLANT(1,J),J=1,2)  / 0,100 /
      DATA  (PLANT(2,J),J=1,2)  / 3748,4692 /
      DATA  (PLANT(3,J),J=1,2)  / 200,230 /
      DATA  (PLANT(4,J),J=1,2)  / 58.3,306 /
      DATA  (PLANT(5,J),J=1,2)  / 154,309 /
      DATA  (PLANT(6,J),J=1,2)  / 6000,12000 /
      DATA  (PLANT(7,J),J=1,2)  / 0,100 /
      DATA  (PLANT(8,J),J=1,2)  / 0,42 /
      DATA  (PLANT(9,J),J=1,2)  / 0,50 /
      DATA  (PLANT(10,J),J=1,2)  / 250,1743 /
      DATA  (PLANT(11,J),J=1,2)  / 0,100 /
      DATA  (PLANT(12,J),J=1,2)  / 1,3 /
C
C  REM THIS IS THE END OF REFORESTATION DATA I=12
C
      DATA  (PLANT(13,J),J=1,2)  / 7892,21095 /
      DATA  (PLANT(14,J),J=1,2)  / 1004,3861 /
      DATA  (PLANT(15,J),J=1,2)  / 74.7,60 /
      DATA  (PLANT(16,J),J=1,2)  / 970,880 /
      DATA  (PLANT(17,J),J=1,2)  / 0,100 /
      DATA  (PLANT(18,J),J=1,2)  / 0,100 /
      DATA  (PLANT(19,J),J=1,2)  / 12.2,8 /
      DATA  (PLANT(20,J),J=1,2)  / 0,100 /
      DATA  (PLANT(21,J),J=1,2)  / 1450,2380 /
      DATA  (PLANT(22,J),J=1,2)  / 13,30 /
C
C  REM THIS IS THE END OF CHRISTMAS TREE DATA I=22
C
      DATA  (PLANT(23,J),J=1,2)  / 2018,599 /
      DATA  (PLANT(24,J),J=1,2)  / 26.3,31 /
      DATA  (PLANT(25,J),J=1,2)  / 80,104 /
      DATA  (PLANT(26,J),J=1,2)  / 100,103 /
      DATA  (PLANT(27,J),J=1,2)  / 0,50 /
      DATA  (PLANT(28,J),J=1,2)  / 41,32 /
      DATA  (PLANT(29,J),J=1,2)  / 10,136 /
C
C  READ IN DATA FOR GAIN ESTIMATES, 20 SPECIES
C
      DATA  (GAN(1,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(2,J),J=1,3)  / .05,.1,.15 /
      DATA  (GAN(3,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(4,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(5,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(6,J),J=1,3)  / .05,.1,.15 /
      DATA  (GAN(7,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(8,J),J=1,3)  / .05,.1,.15 /
      DATA  (GAN(9,J),J=1,3)  / .05,.1,.15 /
      DATA  (GAN(10,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(11,J),J=1,3)  / .05,.1,.30 /
      DATA  (GAN(12,J),J=1,3)  / .05,.1,.15 /
C
C  REM THIS IS THE END OF REFORESTATION DATA
C
      DATA  (GAN(13,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(14,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(15,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(16,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(17,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(18,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(19,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(20,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(21,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(22,J),J=1,3)  / .1,.2,.3 /
C
C  REM THIS IS THE END OF CHRISTMAS TREE DATA
C
      DATA  (GAN(23,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(24,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(25,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(26,J),J=1,3)  / .1,.2,.3 /
```

```
      DATA  (GAN(27,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(28,J),J=1,3)  / .1,.2,.3 /
      DATA  (GAN(29,J),J=1,3)  / .1,.2,.3 /
C
C   READ IN DATA FOR PRICE 20 SPECIES (29 VALUES)
C
      DATA  (PRICE(I),I=1,29) / 1.05,1.5,1.2,1.2,.975,1.05,.75,.975,1.2,.
     *   75,.75,480,
C
C   REM THIS IS THE END OF THE REFORESTATION PRICE DATA
C
     +8.75,12,11,10,12,11,12,12,12.5,7,
C
C   REM THIS IS THE END OF THE CHRISTMAS TREE PRICE DATA
C
     +60,60,60,60,60,60,60/
C
C   READ IN DATA FOR INITIAL YEAR OF SEED ORCHARD PRODUCTION 20 SPECIES
C      (29 VALUES)
C
      DATA  (INITY(I),I=1,29) / 1984,1985,1985,1986,1987,1988,1988,1988,1
     *   998,2003,2003,2003,1985,1985,1986,1987,1987,1998,2003,2003,2003
     *   ,2008,1985,1986,1987,1998,1998,2003,2003 /
C
C   READ IN DATA FOR LIFE OF F1 SEED ORCHARD 20 SPECIES
C
      DATA  (GENER(I),I=1,29) / 30,30,15,35,30,60,20,35,30,35,35,60,30,30
     *   ,35,30,30,35,45,40,35,40,30,35,30,45,30,45,35 /
C
C   READ IN DATA FOR NORMAL ROTATION LENGTH OF SPECIES USE (29)
C
      DATA  (RROTAT(I),I=1,29) / 20,45,15,35,40,40,15,45,20,30,25,50,10,1
     *   2,10,12,10,10,10,12,12,12,8,8,8,8,5,8,8 /
C
C   DATA TO BE OUTPUTED IN THE FOLLOWING FORMAT:
C
C   SPECIES(I)  ;A80
C   PLANT(1)  ;F20.2
C   PLANT(2)  ;F20.2
C   GAN(1)  ;F3.2
C   GAN(2)  ;F3.2
C   GAN(3)  ;F3.2
C   PRICE ;F8.2
C   INITY ;I4
C   GENER ;I3
C   RROTAT ;I3
C
C    **** INITIALIZE VARIABLES ****
C
C   LOAD J3(I)
C
      DO 10 I = 1,29
         J3(I) = INITY(I)-1983
   10 CONTINUE
C
      PVTK = 0.0
      PVTJ = 0.0
      ABTGPV = 0.0
      PERGPV = 0.0
      GAIN = 0.0
      FLAG1 = 0
C
C   SET SFLAG TO A VALUE GREATER THAN 0 FOR SHORTEST OUTPUT
C
      SFLAG = 1
      TFLAG = 0
      PFLAG = 0
      QFLAG = 0
      DISTT = 'DISCOUNT TIME'
      DISQQ = 'DISCOUNT QUANTITY'
C
C   DO LOOP FOR THE TWO PRICE OPTIONS
C
      DO 180 III = 1,2
         IF (III.EQ.2) THEN
            FLAG1 = 1
      TITLE = 'F1 BREEDING CYCLE GROSS PRESENT VALUE W/ INCREASING PRICE
     *'
C
C   BRING PRICE UP TO LEVEL OF F1 FIRST YEAR
C   LOAD STORAGE ARRAY FOR PRICE
```

```
C
            DO 20 I = 1,29
               PRICET(I) = PRICE(I)*1.012**(J3(I)+RROTAT(I)-1)
   20       CONTINUE
C
         ELSE
      TITLE = 'F1 BREEDING CYCLE GROSS PRESENT VALUE WO/PRICE OPTION'
         ENDIF
C
C  DO LOOP FOR QUANTITY OPTIONS
C
         QFLAG = 0.0
C
         DO 170 IIJ = 1,3
            QFLAG = QFLAG+1
C
C  DO LOOP FOR SPECIES 1,...,29
C
            DO 160 I = 1,29
C
C  INTEREST RATE LOOP
C
               INT = .02
               DO 150 J = 1,6
                  INT = INT+.02
C
C  SET THE YEAR ADJUSTMENT TO ACCOUNT FOR DISCOUNTING BACK TO 1983
C
                  IF (INITY(I).LT.1983) THEN
      PRINT *,'THIS PROGRAM CANNOT HANDLE CALCULATIONS OF PAST PRODUCTIO
     *N'
      PRINT *,'FOR F1 SEED ORCHARDS.  YEAR MUST BE GREATER THAN 1983'
                     STOP
                  ENDIF
                  ROTAT = RROTAT(I)+J3(I)
C
C   DO LOOP FOR GENETIC GAIN ESTIMATES
C
                  DO 140 JJ = 1,3
                     IF (JJ.EQ.1) GAIN = GAN(I,1)
                     IF (JJ.EQ.2) GAIN = GAN(I,2)
                     IF (JJ.EQ.3) GAIN = GAN(I,3)
C
                     DISCT = RROTAT(I)*GAIN
C
                     PVTJ = 0.0
                     PVTK = 0.0
                     ABTGPV = 0.0
                     PERGPV = 0.0
C
C SET PRICE TO BASE LEVEL FOR THE NEXT ROUND IF INCREASE PRICE OPTION
C
                     IF (FLAG1.EQ.1) THEN
                        PRICC = PRICET(I)
                     ELSE
                        PRICC = PRICE(I)
                     ENDIF
C
C  CHECK FOR QUANTITY OPTION
C
                     IF (QFLAG.EQ.3) THEN
                        CONTINUE
                     ELSEIF (QFLAG.EQ.2) THEN
                        QUANT = PLANT(I,2)
                     ELSE
                        QUANT = PLANT(I,1)
                     ENDIF
C
C  DO LOOP FOR F1 LIFE OF SEED ORCHARD TO CALCULATE GAINS FROM HARVEST
C
                     DO 30 II = ROTAT,(GENER(I)+300)
                        K = II+1-ROTAT
                        TEMP2 = 0
                        TEMP3 = 0
C
C  CHECK FOR QUANTITY OPTION
C
                        IF (QFLAG.EQ.3) THEN
                           IF (I.EQ.1) QUANT = (15000/(1+(2999*(2.718281
     *                        828**(-.6004175747*(II-RROTAT(I)))))))
                           IF (I.EQ.2) QUANT = (15000/(1+(3.0021345*(2.7
```

```
     *                  18281828**(-.062452433*(II-RROTAT(I)))))))
                     IF (I.EQ.3) QUANT = (15000/(1+(74*(2.71828182
     *                  8**(-.028358205*(II-RROTAT(I)))))))
                     IF (I.EQ.4) QUANT = (15000/(1+(256.28987*(2.7
     *                  18281828**(-.334939944*(II-RROTAT(I)))))))
                     IF (I.EQ.5) QUANT = (15000/(1+(96.402597*(2.7
     *                  18281828**(-.141376818*(II-RROTAT(I)))))))
                     IF (I.EQ.6) QUANT = (15000/(1+(1.5*(2.7182818
     *                  28**(-.358351893*(II-RROTAT(I)))))))
                     IF (I.EQ.7) QUANT = (15000/(1+(2999*(2.718281
     *                  828**(-.600417574*(II-RROTAT(I)))))))
                     IF (I.EQ.8) QUANT = (15000/(1+(2999*(2.718281
     *                  828**(-.426140448*(II-RROTAT(I)))))))
                     IF (I.EQ.9) QUANT = (15000/(1+(2999*(2.718281
     *                  828**(-.461118121*(II-RROTAT(I)))))))
                     IF (I.EQ.10) QUANT = (15000/(1+(59*(2.7182818
     *                  28**(-.409723899*(II-RROTAT(I)))))))
                     IF (I.EQ.11) QUANT = (15000/(1+(2999*(2.71828
     *                  1828**(-.600417574*(II-RROTAT(I)))))))
                     IF (I.EQ.12) QUANT = (15000/(1+(14999*(2.7182
     *                  81828**(-.219749128*(II-RROTAT(I)))))))
                     IF (I.EQ.13) QUANT = (25000/(1+(2.167764825*(
     *                  2.718281828**(-.492094972*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.14) QUANT = (10000/(1+(8.960159363*(
     *                  2.718281828**(-.345810465*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.15) QUANT = (10000/(1+(132.8688086*(
     *                  2.718281828**(-.058848465*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.16) QUANT = (10000/(1+(9.309278351*(
     *                  2.718281828**(-.006757396*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.17) QUANT = (10000/(1+(1999*(2.71828
     *                  1828**(-.601056496*(II-RROTAT(I)))))))
                     IF (I.EQ.18) QUANT = (10000/(1+(1999*(2.71828
     *                  1828**(-.601056496*(II-RROTAT(I)))))))
                     IF (I.EQ.19) QUANT = (10000/(1+(818.6721312*(
     *                  2.718281828**(-.012718701*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.20) QUANT = (10000/(1+(1999*(2.71828
     *                  1828**(-.601056496*(II-RROTAT(I)))))))
                     IF (I.EQ.21) QUANT = (10000/(1+(5.896551724*(
     *                  2.718281828**(-.122469066*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.22) QUANT = (10000/(1+(768.2307692*(
     *                  2.718281828**(-.072783558*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.23) QUANT = (10000/(1+(3.955401388*(
     *                  2.718281828**(-.105556844*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.24) QUANT = (10000/(1+(379.2281369*(
     *                  2.718281828**(-.032977923*(II-RROTAT(I))))
     *                  )))
                     IF (I.EQ.25) QUANT = (10000/(1+(124*(2.718281
     *                  828**(-.052957731*(II-RROTAT(I)))))))
                     IF (I.EQ.26) QUANT = (10000/(1+(99*(2.7182818
     *                  28**(-.005972375*(II-RROTAT(I)))))))
                     IF (I.EQ.27) QUANT = (10000/(1+(9999*(2.71828
     *                  1828**(-.783387108*(II-RROTAT(I)))))))
                     IF (I.EQ.28) QUANT = (10000/(1+(242.902439*(2
     *                  .718281828**(-.03987101*(II-RROTAT(I)))))
     *                  )
                     IF (I.EQ.29) QUANT = (10000/(1+(999*(2.718281
     *                  828**(-.524552523*(II-RROTAT(I)))))))
C
                  ELSE
                     CONTINUE
                  ENDIF
C
C   DISCOUNT TIME
C
C    CHECK FOR PRICE INCREASE OPTION
C
                  IF (FLAG1.EQ.1) PRICC = PRICC*1.012
C
                  PVY1K(K) = PRICC*QUANT*(1/((1+INT)**(II-DISCT)))
                  PVY2K(K) = (PRICC*QUANT*(1/((1+INT)**II)))
                  PVK(K) = PVY1K(K)-PVY2K(K)
                  TEMP2 = PVK(K)
                  PVTK = PVTK+TEMP2
```

```
C
                        YEAR(K) = INITY(I)+K-1
C
C  NOW TO THE OTHER OPTION - DISCOUNTING VOLUME
C
                        PVY1J(K) = (PRICC*QUANT*(1+GAIN)*(1/((1+INT)**II
     *                     )))
                        PVY2J(K) = (PRICC*QUANT*(1/((1+INT)**II)))
                        PVJ(K) = PVY1J(K)-PVY2J(K)
                        TEMP3 = PVJ(K)
                        PVTJ = PVTJ+TEMP3
C
C  WRITE OUT THE ABSOLUTE VALUE OF THE CROP INTO ABTGPV
C
                        ABTGPV = ABTGPV+PVY2J(K)
C
   30                CONTINUE
C
C  CALCULATE THE VALUE OF GAIN AS PERCENTAGE OF TOTAL VALUE
C
C  WRITE TO FILES
C
                     IF (PVTJ.GE.PVTK) THEN
                        IF (ABTGPV.LE.0) THEN
                           PERGPV = 0.0
                        ELSE
                           PERGPV = (PVTJ/ABTGPV)*100
                        ENDIF
                        GPV(I,JJ,J,IIJ,III) = PVTJ
                        IF (SFLAG.EQ.0) THEN
                           WRITE (7,40) SPECIE(I),GAIN,INT,QUANT,PRICE(I
     *                        ),PRICC,DISQQ,GPV(I,JJ,J,IIJ,III),ABTGPV,P
     *                        ERGPV
   40 FORMAT (/4X,A,2X/,4X,'GENETIC GAIN = ',F3.2,4X,'INTEREST RATE =',F
     *3.2/,4X,'QUANTITY =',F15.2/,4X,'PRICE =',F8.2,4X,'FINAL PRICE IS =
     *',F8.2,2X/,10X,'OPTION IS ',A/,4X,'GROSS PRESENT VALUE=',15X,F20.2
     */,4X,'TOTAL GROSS PRESENT VALUE OF THE CROP IS',5X,F20.2,/4X,'GENE
     *TIC VALUE AS PERCENTAGE OF TOTAL IS',10X,F10.4)
                        ENDIF
                        WRITE (8,50) GPV(I,JJ,J,IIJ,III),ABTGPV
C
                     ELSE
                        IF (ABTGPV.LE.0) THEN
                           PERGPV = 0.0
                        ELSE
                           PERGPV = (PVTJ/ABTGPV)*100
                        ENDIF
                        GPV(I,JJ,J,IIJ,III) = PVTK
                        IF (SFLAG.EQ.0) THEN
                           WRITE (7,40) SPECIE(I),GAIN,INT,QUANT,PRICE(I
     *                        ),PRICC,DISTT,GPV(I,JJ,J,IIJ,III),ABTGPV,P
     *                        ERGPV
                        ENDIF
                        WRITE (8,50) GPV(I,JJ,J,IIJ,III),ABTGPV
   50                   FORMAT (F20.2,4X,F20.2)
                     ENDIF
C
C  SKIP AROUND THE LONG DETAILED FILE
C
                     IF (PFLAG.GT.0) THEN
                        WRITE (6,60) TITLE
   60                   FORMAT (8X,A)
                        WRITE (6,60) SPECIE(I)
C
C  PRINT PARAMETERS
C
                        WRITE (6,70) PRICE(I),QUANT,INT,GAIN,GENER(I),RR
     *                     OTAT(I)
   70 FORMAT (4X,'PRICE= ',F8.2,4X,'QUANTITY= ',F15.2,2X/,4X,'INTEREST R
     *ATE= ',F3.2,4X,'GENETIC GAIN= ',F3.2,2X/,4X,'GENERATION PERIOD = '
     *,I3,6X,'ROTATION PERIOD= ',I3)
                        WRITE (6,80)
   80 FORMAT (7X,'*****ALL VALUES ARE IN 1983 DOLLARS*****')
                        WRITE (6,90)
   90 FORMAT (3X,'YEAR',6X,'DISCOUNT TIME',10X,'DISCOUNT QUANT.')
                        WRITE (6,100)  (YEAR(JJ1),PVK(JJ1),PVJ(JJ1),JJ1=1
     *                     ,GENER(I))
  100                   FORMAT (3X,I4,4X,F14.2,6X,F14.2)
                        WRITE (6,110)
                        WRITE (6,120)
  110 FORMAT ('----------------------------------------')
```

```
 120                    FORMAT ()
                        WRITE (6,130) PVTK,PVTJ
 130                    FORMAT (4X,F20.2,4X,F20.2)
C
                     ELSE
                        CONTINUE
C
                     ENDIF
C
 140              CONTINUE
 150           CONTINUE
 160        CONTINUE
 170     CONTINUE
 180  CONTINUE
      END
```

```
      PROGRAM ANALYS
C
C    **** VERSION 8/18/83 ****
C THIS IS THE PROGRAM TO MANIPULATE THE OUTPUT FILES FOR
C ECONTHESIS MODEL.
C
      CHARACTER*80 TITLE,SPECIE,GAIN,PRICE,QUAN,INTER
      DIMENSION SPECIE(29),TITLE(20),GAIN(3),PRICE(2),QUAN(3),INTER(6)
C
      INTEGER I,JJ,J,IIJ,III
C
      REAL GPV,GPVSUM,TEMP1,TEMP2,TEMP3,TGPV,GPVSUT,REFPER,CHTPER,ORNPER
     *    ,REFGPV,CHTGPV,ORNGPV,SPPCT,RATE,ABT
C
      COMMON /MAIN/ GPV(29,3,6,3,2),GPVSUM,TEMP1,TEMP2,TEMP3,TGPV(3,6,3,
     *    2)
C
      OPEN (5,FILE='SUMTAB')
      OPEN (6,FILE='TAB1')
      OPEN (7,FILE='TAB2')
      OPEN (8,FILE='TAB3')
      OPEN (9,FILE='TAB4')
      OPEN (10,FILE='TAB5')
C
C  READ IN TITLES AND GAIN HEADERS
C
      DATA (TITLE(I),I=1,5) / 'TABLE-TOTAL GPV FOR ALL SPECIES WITH OUT
     *   THINNING','SPECIES PERCENTAGE OF GPV FOR TWO CASES','TOTAL GPV
     *FOR 50 PERCENT THIN OF REFORESTATION SPECIES','TOTAL GPV FOR EACH
     *USE CATAGORY AND PERCENTAGES WITHOUT          THINNING','TOTAL GPV
     *-INTEREST RATE SENSITIVITY'/
C
      DATA (GAIN(I),I=1,3) / 'LOW ESTIMATE GENETIC GAIN','MEDIUM ESTIMAT
     *E OF GENETIC GAIN','HIGH ESTIMATE OF GENETIC GAIN'/
C
      DATA (PRICE(I),I=1,2) / 'CONSTANT PRICE OPTION','INCREASING PRICE'
     *    /
C
      DATA (QUAN(I),I=1,3) / '1981 PLANTING LEVELS','1986 PLANTING
     *   LEVELS','INCREASING PLANTING LEVELS USING LOGISTIC EQ.'/
C
      DATA (INTER(I),I=1,6) / '4 PER','6 PER','8 PER','10 PER','12 PER',
     *    '14 PER'/
C
C  READ IN DATA FOR 20 SPECIES:
C
      DATA (SPECIE(I),I=1,29) / 'HYBRID PINE REFORESTATION','JACK PINE R
     *EFORESTATION','HYBRID POPLAR REFORESTATION','EASTERN WHITE PINE RE
     *FORESTATION','WHITE SPRUCE REFORESTATION','RED PINE REFORESTATION'
     *,'HYBRID ASPEN REFORESTATION','BLACK SPRUCE REFORESTATION','HONEYL
     *OCUST REFORESTATION','EUROPEAN LARCH REFORESTATION','HYBRID LARCH
     *REFORESTATION','BLACK WALNUT REFORESTATION','SCOTCH PINE CHRISTMAS
     * TREE','BLUE SPRUCE CHRISTMAS TREE','EASTERN WHITE PINE CHRISTMAS
     *TREE','WHITE SPRUCE CHRISTMAS TREE','HYBRID SPRUCE CHRISTMAS TREE'
     *,'WESTERN WHITE PINE CHRISTMAS TREE','AUSTRIAN PINE
     *  CHRISTMAS TREE','ENGLEMANN SPRUCE CHRISTMAS TREE','DOUGLAS FIR C
     *HRISTMAS TREE','WHITE FIR CHRISTMAS TREE','BLUE SPRUCE ORNAMENTAL'
     *,'EASTERN WHITE PINE ORNAMENTAL','WHITE SPRUCE ORNAMENTAL','NORWAY
     * SPRUCE ORNAMENTAL','HONEYLOCUST ORNAMENTAL','AUSTRIAN PINE ORNAME
     *NTAL','DOUGLAS FIR ORNAMENTAL'/
C
C  LOAD IN THE ARRAY
C
      DO 60 III = 1,2
         DO 50 IIJ = 1,3
            DO 40 I = 1,29
               DO 30 J = 1,6
                  DO 20 JJ = 1,3
C
                     READ (5,10) GPV(I,JJ,J,IIJ,III),ABT
  10                 FORMAT (F20.2,4X,F20.2)
C
  20              CONTINUE
  30           CONTINUE
  40        CONTINUE
  50     CONTINUE
  60  CONTINUE
C
C  INITIALIZE TEMPORARIES FOR THE FIRST MANIPULATION
C
      GPVSUM = 0.0
```

```
C
C  WRITE TITLE TO THE FILES
C
      WRITE  (6,70)  TITLE(1)
   70 FORMAT  (4X,A)
      WRITE  (7,70)  TITLE(4)
      WRITE  (8,70)  TITLE(3)
      WRITE  (9,70)  TITLE(2)
C
      DO 170 III = 1,2
         DO 160 IIJ = 1,3
            DO 150 J = 1,6
               DO 140 JJ = 1,3
C
C  RESET GPVSUM FOR NEXT CASE
C
                  GPVSUM = 0.0
                  REFGPV = 0.0
                  CHTGPV = 0.0
                  ORNGPV = 0.0
                  GPVSUT = 0.0
C
                  DO 80 I = 1,29
C
C  FIRST DO THE THINNING OPTION FOR REFORESTATION SPECIES
C
                     IF  (I.LE.12) THEN
                        GPVSUT = GPV(I,JJ,J,IIJ,III)/2+GPVSUT
                     ELSE
                        GPVSUT = GPV(I,JJ,J,IIJ,III)+GPVSUT
                     ENDIF
C
C  NOW FOR THE SUM TOTAL, PERCENTAGES WON'T CHANGE
C
                     GPVSUM = GPV(I,JJ,J,IIJ,III)+GPVSUM
                     IF  (I.EQ.12)  REFGPV = GPVSUM
                     IF  ((I.GT.12).AND.(I.LE.22))  CHTGPV = GPV(I,JJ,J,II
     *                  J,III)+CHTGPV
                     IF  (I.GT.22)  ORNGPV = GPV(I,JJ,J,IIJ,III)+ORNGPV
C
   80             CONTINUE
                  WRITE  (6,90)  PRICE(III),QUAN(IIJ),INTER(J),GAIN(JJ),GP
     *               VSUM
   90             FORMAT  (/4(4X,A/),4X,'GROSS PRESENT VALUE =',F20.2)
C
                  WRITE  (8,90)  PRICE(III),QUAN(IIJ),INTER(J),GAIN(JJ),GP
     *               VSUT
C
C WRITE OUT THE USE CATAGORY FILES
C
                  WRITE  (7,100)  PRICE(III),QUAN(IIJ),INTER(J),GAIN(JJ),R
     *               EFGPV
  100             FORMAT  (/4(4X,A/),4X,'REFORESTATION SPECIES GPV =',F20
     *               .2)
                  WRITE  (7,110)  PRICE(III),QUAN(IIJ),INTER(J),GAIN(JJ),C
     *               HTGPV
  110             FORMAT  (4(4X,A/),4X,'CHRISTMAS TREE SPECIES GPV =',F20
     *               .2)
                  WRITE  (7,120)  PRICE(III),QUAN(IIJ),INTER(J),GAIN(JJ),O
     *               RNGPV
  120             FORMAT  (4(4X,A/),4X,'ORNAMENTAL SPECIES GPV =',F20.2)
C
                  REFPER =  (REFGPV/GPVSUM)*100
                  CHTPER =  (CHTGPV/GPVSUM)*100
                  ORNPER =  (ORNGPV/GPVSUM)*100
C
                  WRITE  (7,130)  REFPER,CHTPER,ORNPER
  130 FORMAT  (4X,'REFORESTATION SPECIES PERCENTAGE OF GPV  =',F7.2/,4X,'
     *CHRISTMAS TREE SPECIES PERCENTAGE OF GPV =',F7.2/,4X,'ORNAMENTAL S
     *PECIES PERCENTAGE OF GPV      =',F7.2)
                  TGPV(JJ,J,IIJ,III)  = GPVSUM
  140          CONTINUE
  150       CONTINUE
  160    CONTINUE
  170 CONTINUE
C
C  WRITE OUT SPECIES BREAKDOWN FILE - PERCENTAGE OF GPV
C
      DO 210 III = 1,2
         GPVSUM = 0.0
         DO 180 I = 1,29
```

```
            GPVSUM = GPV(I,2,3,2,III)+GPVSUM
  180     CONTINUE
C
          DO 200 K = 1,29
            SPPCT = (GPV(K,2,3,2,III)/GPVSUM)*100
            WRITE (9,190) SPECIE(K),SPPCT
  190       FORMAT (4X,A/,4X,'PERCENTAGE OF TOTAL =',F7.2)
  200     CONTINUE
  210 CONTINUE
C
C  WRITE OUT INTEREST RATE SENSITIVITY FILE
C
      WRITE (10,220) TITLE(5)
  220 FORMAT (/4X,A/,4X,'INTEREST RATE',4X,'TOTAL GPV')
C
      RATE = .02
C
      DO 240 J = 1,6
        RATE = RATE+.02
        WRITE (10,230) RATE,TGPV(2,J,2,1)
  230   FORMAT (8X,F3.2,8X,F20.2)
  240 CONTINUE
      WRITE (10,250) PRICE(1),GAIN(2),QUAN(2)
  250 FORMAT (3(A/))
      REWIND 5
      REWIND 6
      REWIND 7
      REWIND 8
      REWIND 9
      REWIND 10
      END
```

```
      PROGRAM ECNCOST
C
C  THIS IS THE PROGRAM TO CALCULATE PRESENT VALUE COSTS
C
      CHARACTER*80 TITLE
C
      INTEGER J,I,YEAR
      REAL INT,COST,PCOST,TCOST,SALAR,OPER,TEMP
C
      COMMON /MAIN/ INT(6),COST(47),PCOST(47),SALAR(47),OPER(47)
      OPEN (7,FILE='DATA')
      OPEN (8,FILE='COST')
      OPEN (9,FILE='OUT')
      REWIND 7
C
C  FILE DATA IS THE INPUT FILE, FILE COST IS THE OUTPUT FILE.
C
      DO 20 I = 1,22
         READ (7,10) YEAR,SALAR(I)
 10      FORMAT (I4,F8.3)
 20   CONTINUE
C
      DO 30 I = 23,47
         SALAR(I) = SALAR(22)
 30   CONTINUE
      K = 1960
      DO 50 I = 1,47
         K = K+1
         WRITE (9,40) K,SALAR(I)
 40      FORMAT (I4,2X,F18.2)
 50   CONTINUE
C
C  READ IN THE DATA FOR OPERATING COSTS
C
      K = 1960
      DO 70 I = 1,47
         IF (I.LE.11) THEN
            OPER(I) = 25.0
         ELSE
            OPER(I) = 50.0
         ENDIF
C
         K = K+1
         COST(I) = SALAR(I)+OPER(I)
         WRITE (9,60) K,COST(I)
 60      FORMAT (I4,2X,F18.2)
 70   CONTINUE
C
C READ IN THE VALUES FOR INTEREST
C
      DATA (INT(I),I=1,6) / .04,.06,.08,.10,.12,.14 /
      WRITE (8,80)
 80   FORMAT (2X,'NET PRESENT VALUE COST    INTEREST RATE')
C
      DO 120 J = 1,6
         K = 1960
         DO 100 I = 1,47
            IF (I.LE.22) THEN
               PCOST(I) = COST(I)*((1+INT(J))**(23-I))
            ELSEIF (I.GE.24) THEN
               PCOST(I) = COST(I)*((1+INT(J))**(23-I))
            ELSEIF (I.EQ.23) THEN
               PCOST(I) = COST(22)
            ENDIF
            K = K+1
            WRITE (9,90) K,PCOST(I)
 90         FORMAT (I4,2X,F18.2)
C
 100     CONTINUE
C
         TCOST = 0
C
         DO 110 I = 1,47
            TCOST = PCOST(I)+TCOST
 110     CONTINUE
C
         WRITE (8,130) TCOST,INT(J)
 120  CONTINUE
 130  FORMAT (4X,F20.2,4X,F4.2)
      REWIND 8
      END
```

REFERENCES

<u>REFERENCES</u>

Abbott, Herschel G. and Stanley D. Fitch. 1977. Forest Nursery Practices in the United States. J. For. 75: 3; p. 141-145.

Adams, Darius M., Richard W. Haynes, George R. Dutrow, Richard L. Barber, and Joseph M. Vasievich. 1982. Private Investment in Forest Management and the Long-Term Supply of Timber. Amer. J. Agr. Econ. 64: 5; p. 232-241.

Ames, Edward. 1961. Research, Invention, Development and Innovation. Amer. Econ. Rev. 51: 3; p. 370-381.

Araji, A. A., R. J. Sim, and R. L. Gardner. 1978. Returns to Agricultural Research and Extension Programs: An Ex-Ante Approach. Amer. J. Agr. Econ. 60: 11; p. 964-968.

Arndt, Thomas M., Dana G. Dalrymple and Vernon W. Ruttan. 1976. Resource Allocation and Productivity in National and International Agricultural Research. University of Minnesota Press, Minneapolis; 617 p.

Baily, M. N. 1972. Research and Development Costs and Returns: The U.S. Pharmaceutical Industry. J. Pol. Econ. 80: 1; p. 70-85.

Baker, N. R. and W. H. Pound. 1964. R and D Project Selection: Where We Stand. IEEE Trans. Eng. Mgt. Vol EM-11: p. 124-134.

Barnett, Harold J. and Chandler Morse. 1963. Scarcity and Growth. Johns Hopkins Press, Second Printing 1967; 288 p.

Benzie, John W. 1977. Managers Handbook for Red Pine in the North Central States. General Technical Report NC-33; 22 p.

Bey, Calvin F. 1973. Growth of Black Walnut Trees in Eight Midwestern States - A Provenance Test. USDA Forest Service North Central Exp. Station Research Paper No. NC-91; 7 p.

Binswanger, Hans P. and Vernon W. Ruttan. 1978. Induced Innovation. Johns Hopkins Press; 423 p.

Bongarten, Bruce C. and James W. Hanover. 1982. Hybridization Among White, Red, Blue and White X Blue Spruce. For. Sci. 28: 1; p. 129-134.

Bredahl, Maury and Willis Peterson. 1976. The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations. Amer. J. Agr. Econ. 58: 11; p. 684-692.

Business Week. 1982. The Battered Fortunes of the Forest Products Industry. Business Week: September 13, 1982; p. 70-76.

Callahan, John C. and Robert P. Smith. 1974. An Economic Analysis of Black Walnut Plantation Enterprises. Purdue Univeristy Research Bulletin No. 912, August, 1974; 20 p.

Calvert, R. F. and R. Marie Rauter. 1979. Status of Larch Improvement. Proc. 15th LSTIC; p. 145-152.

Cannell, Melvin G. R. 1977. Improving Per Hectare Forest Productivity. Proc. 13th LSTIC; p. 120-147.

Carlisle A. and A. H. Teich. 1970. The Costs and Benefits of Tree Improvement Programs. Petawawa Forest Experiment Station Information Report PS-X-20, June, 1970; 28 p.

----, 1971. The Costs and Benefits of Tree Improvement Programs. Canadian Forestry Service Publication No. 1302; 34 p.

----, 1975. The Economics of Tree Improvement. Proc. 15th Canadian Tree Improvement Association; p. 45-56.

Cartwright, R. W. 1971. Research Management in A Department of Agricultural Economics. Ph.D. Thesis, Purdue University.

Cochran, William G. 1977. Sampling Techniques. Wiley Press; 428 p.

Cramer, Robert H. and Barnard E. Smith. 1964. Decision Models for the Selection of Research Projects. The Eng. Econ. 9: 2; p. 1-20.

Davis, Jeffrey S. 1979. Stability of the Research Coefficient for U.S. Agricultural. Ph.D. Thesis, University of Minnesota; 168 p.

Davis, Lawrence S. 1967. Cost-Return Relationships of Tree Improvement Programs. Working Paper from Virginia PolyTechnic Institute, Blacksburg Virginia. 6 p.

Dawson, David H. and John A. Pitcher. 1970. Tree Improvement Opportunities in the North Central States as Related to Economic Trends, A Problem Analysis. USDA Forest Service Research Paper NC-40; 30 p.

Dutrow, George F. 1977. Improved Trees: Economic Promises and Pitfalls. Proceedings 13th LSTIC; p. 72-80.

Easter, K. W. and G. W. Norton. 1977. Potential Returns from Increased Research Budgets for the Land Grant Universities. Agr. Econ. Res. 29: p. 127-33

Economic Report of the President. 1982. United States Government Printing Office.

Evenson, Robert, E. 1967. The Contribution of Agricultural Research to Production. J. Farm Econ. 49: 12; p. 1415-1425.

Evenson, Robert E. and Yoav Kislev. 1976. A Stochastic Model of Applied Research. J. Pol. Econ. 82: 2; p. 265-281.

Evenson, Robert E., Paul E. Waggoner, and Vernon W. Ruttan. 1979. Economic Benefits from Research: An Example from Agriculture. Science. 205: 14 September 1979; p. 1101-1107.

Fishel, Walter L. 1971. Ed. Resource Allocation in Agricultural Research. University of Minnesota Press; 391 p.

Flick, Warren A. 1976. A Note on Inflation and Forest Investments. For. Sci. 22: 1; p. 30-32.

Fowler, D. P. 1975. Tree Breeding and the Forest Manager. Forest Chronicle, Vol 51: p. 233-235.

Gregory, G. Robinson. 1972. Forest Resource Economics. John Wiley Press; 548 p.

Giamatti, Bartlett A. 1983. The University, Industry, and Cooperative Research. Science, 218: 24 December, 1982. p. 1278-1280.

Griliches, Z. 1957. Hybrid Corn: An Exploration in the Economics of Technical Change. Econometrica, 25: 4; p. 501-522.

----, 1958. Research Costs and Social Returns: Hybrid Corn and Related Innovations. J. Pol. Econ. 66: 4; p. 419-431

----, 1964. Research Expenditures, Education, and the Aggregate Agricultural Production Function. Amer. Econ. Rev. 54: 9; p. 961-974.

Grover, Stephen. 1980. Forest Companies Develop Superior Trees that Grow Faster and Can Resist Disease. Wall Street Journal, Oct. 2, 1980.

Gunter, John E. 1983. Financial Analysis of Hybrid Poplar Management Regimes. Draft for Publication, Department of Forestry, Michigan State University; 33 p.

Guries, R. and A. Ager. 1980. Red Pine Seedling Seed Orchard: 10 Year Results. University of Wisconsin-Madison Department of Forestry Research Notes No. 242, Dec. 1980. 4 p.

Hanover, James W. 1983. Short Rotation Woody Crops Program, Renewal Proposal. Report Submitted to Union Carbide, March 1, 1983; 32 p.

----, 1983. Short Rotation Woody Crops Program, Annual Technical Report, 1983. Report Submitted to Union Carbide, March 15, 1983. 81 p.

----, 1983. A Directory of Forest Genetic Plantings in Michigan: MICHCOTIP Update. Taken Originally from Michigan State University Agr. Exp. Station Research Report 395, June 1980; 16 p.

----, 1980. Michigan State Cooperative Tree Improvement Program. Presented at the 16th North American Quantitative Forest Genetics Group Meeting, Coeur D'Alene, Idaho, August 6-8, 1980; 17 p.

Hanover, James W., and Bruce Bongarten. 1977. Accelerated-Optimal-Growth: Applications in Tree Improvement. Proc. 25th Northeastern Forest Tree Improvement Conference, July 27-29, 1977, Orono, Maine; 15 p.

Heiner, Ronald A. 1983. The Origin of Predictable Behavior. Amer. Econ. Rev. 73: 4; p. 560-595.

Hirshleifer, Jack. 1980. Price Theory and Applications, Second Edition. Prentice-Hall; 620 p.

Hotvedt, James E. 1982. Inflation and the Capital Budgeting Process. S. J. Appl. For. 6: p. 195-200.

Howe, Charles W. 1979. Natural Resources Economics. John Wiley & Sons; 350 p.

Huffman, Wallace E. and John A. Miranowski. 1981. An Economic Analysis of Expenditures on Agricultural Experiment Station Research. Amer. J. Agr. Econ. 63: 1; p. 104-118.

James, Lee M., Victor J. Rudolph and Melvin R. Koelling. Production and Marketing of Christmas Trees in Michigan. Michigan State University Agr. Exp. Station Research Report 412; 8 p.

James, Lee M., Suzanne E. Heinen, David D. Olson and Daniel E. Chappelle. 1982. Timber Products Economy of Michigan. Agricultural Experiment Station Research Report No. 446, Michigan State University; 23 p.

Jensen, H. 1975. Tree Improvement - A Company Viewpoint. Forest Chronicle. Vol 51: p. 242-243.

Keefer, Donald L. 1978. Allocation Planning for R&D with Uncertainty and Multiple Objectives. IEEE Transactions on Engineering Management, Vol EM-25, No. 1; p. 8-14.

Knutson, Marlys and Luther G. Tweeten. 1979. Toward an Optimal Rate of Growth in Agricultural Production Research and Extension. Amer. J. Agr. Econ. 61: 2; p. 70-76.

Kudray, George M. and James W. Hanover. 1980. A Preliminary Evaluation of the Spartan Spruce (Picea Glauca X P. Pungens). Michigan State University Agr. Exp. Station Research Report 405; 16 p.

Ledig, F. T. and Richard L. Porterfield. 1981. West Coast Tree Improvement Programs: A Break-Even, Cost-Benefit Analysis. Pacific Southwest Forest and Range Experiment Station Research Paper PSW-156; 8 p.

Lee, Tom K. 1982. A Nonsequential R&D Search Model. Mgt. Sci. 28: 8; p. 900-909.

Lester, D. T., R. M. Jeffers, and J. W. Wright. 1976. Provenance and Family Variating in Balsam Fir from Michigan and Wisconsin. Proceedings from 12th LSTIC; p. 74-79.

Linder, R. K., and F. G. Jarrett. 1978. Supply Shifts and the Size of Research Benefits. Amer. J. Agr. Econ. 60: 1; p. 48-56.

Lothner, David C. and Dennis P. Bradley. 1982. Financial Returns from Growing Red Pine in the Lake States Using New Yield Evidence, Also Some Red Pine Versus Loblolly Pine Comparisons. Draft for Publication, North Central Forest Experiment Station, Sept. 17, 1982. 28 p.

Lundgren, Allen L. and James P. King. 1965. Estimating Financial Returns from Forest Tree Improvement Programs. Working Paper from Lake States Forest Experiment Station, St. Paul, Minnesota; 17 p.

----, 1981. Research Productivity from an Economic Viewpoint. Proc. SAF, September 1981; p. 256-262.

----, 1981. Methods for Evaluating Forestry Research; A Problem Analysis for Problem No. 3. USFS North Central Forest Experiment Station internal Memo, November 1981; 35 p.

----, 1982. Methods for Evaluating Forestry Research: Where Are We? And Where Should We Go From Here? North Central Forest Experiment Station, Paper presented at a seminar on Evaluating Returns to Southern Forestry Research, Duke University, August 19, 1982. 17 p.

Mahlstede, J. P. 1971. Long-Range Planning at the Iowa Agricultural and Home Economics Experiment Station. in: Resource Allocation in Agricultural Research. ed. W. L. Fishel, Minneapolis: University of Minnesota Press.

Manthy, Robert. 1981. Notes to Natural Resource Economics. Department of Forestry, Michigan State University, Winter, 1981. 150 p.

----, 1978. Natural Resource Commodities--A Century of Statistics: Prices, Output, Consumption, Foreign Trade, and Employment in the United States, 1870-1973. RFF by Johns Hopkins Press; 240 p.

Marquis, David A. 1973. Factors Affecting Financial Returns From Hardwood Tree Improvement. J. Forestry 71: 2; p. 79-83.

Mead Paper Company. 1982. Annual Report to the Stockholders.

Michigan Department of Natural Resources. 1979. Michigan Forest Resources 1979: An Assessment. 134 p.

Mills, Thomas J. 1972. An Econometric Analysis of Market Factors Determining Supply and Demand for Softwood Lumber. PhD Thesis Michigan State University, Department of Forestry; 182 p.

Namkoong, Gene, R. C. Biesterfeldt, and J. C. Barber. 1971. Tree Breeding and Management Decisions. J. For. 69: 3; p. 138-142.

Nelson, Richard R. 1962. The Rate and Direction of Inventive Activity: Economic and Social Factors, A Report of the National Bureau of Economic Research, New York. Princeton University Press; 635 p.

Norton, George W., and Jeffrey S. Davis. 1981. Evaluating Returns to Agricultural Research: A Review. Amer. J. Agr. Econ. 63: 10; p. 685-699.

Pappas, James L. and Eugene F. Brigham. 1979. Managerial Economics, Third Edition. Dryden Press; 656 p.

Perala, Donald A. 1978. Thinning Strategies for Aspen: A Prediction Model. USDA Forest Service Research Report NC-161; 16 p.

Perry, Thomas O. and Chi-Wu Wang. 1958. The Value of Genetically Superior Seed. J. For. 56: 11; p. 843-845.

Peterson, Willis L. 1980. Principles of Economics - Macro. Irwin Inc. Fourth Edition, 1980; 401 p.

Phillips, Bruce D. 1968. Scientific Research Innovation and Economic Growth a Possible Relationship. Institute of Social and Economic Research, Rhodes Univerity; 178 p.

Porterfield, Richard L. 1974. Predicted and Potential Gains from Tree Improvement Programs--A Goal Programming Analysis of Program Efficiency. North Carolina State University School of Forest Resources Technical Report No. 52; 112 p.

Porterfield, Richard L., Bruce J. Zobel and F. T. Ledig. 1975. Evaluating the Efficiency of Tree Improvement Programs. Silvae Genetica 24: 2-3; p 33-44.

Potter, Neal and Francis T. Christy Jr. 1962. Trends in Natural Resource Commodities. Johns Hopkins Press; 568 p.

Ramalho de Castro, J. P., and G. E. Schuh. 1977. An Empirical Test of an Economic Model for Establishing Research Priorities: A Brazil Case Study. in, Resource Allocation and Productivity in National and International Agricultural Research. ed T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

Read, Ralph A. 1976. Austrian (European Black) Pine in Eastern Nebraska: A Provenance Study. USDA Forest Service Rocky Mountain Forest and Range Experiment Station Research Paper RM-180; 8 p.

Rehfeldt, Gerald E. 1980. Genetic Gains from Tree Improvement of Ponderosa Pine in Southern Idaho. USDA Forest Service Intermountain Forest and Range Experiment Station Research Paper INT-263; 9 p.

Reilly, J. J. and D. G. Nikles. 1977. Analyzing Benefits and Costs of Tree Improvement: Pinus Caribaea. Proc. Third World Consultation on Forest Tree Breeding, FAO/IUFRO March, 1977 Canberra, Australia; p. 1099-1121.

Rosegger, Gerhard. 1980. The Economics of Production and Innovation. Pergamon Press; 404 p.

Russell, D. G. 1977. Resource Allocation in Agricultural Research Using Socio-Economic Evaluation and Mathematical Models. Can. J. Agr. Econ. 23: 2; p. 29-52.

Ruttan, Vernon W. 1982. Agricultural Research Policy. Minneapolis: University of Minnesota Press. p. 237-261.

Schmid, Allan A. 1978. Property, Power, and Public Choice: An Inquiry into Law and Economics. Praeger Press; 316 p.

Schmid, Allan A. 1982. Political Economy of Public Investment. Course Material for Public Program Analysis, Michigan State University; 386 p.

Schmitz, Andrew and David Seckler. 1970. Mechanized Agriculture and Social Welfare: The Case of the Tomatoe Harvester. Amer. J. Agr. Econ. 52: 10; p. 569-576.

Scherer, F. M. 1965. Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions. Amer. Econ. Rev. 55: 5; p. 1097-1125.

Schreuder, Gerald F. 1971. The Economics of Tree Improvement. WFGA Short Course Handout; 11 p.

Schultz, T. W. 1958. The Economic Organization of Agriculture. New York McGraw-Hill Book Co.; 374 p.

Shumway, C. R. 1973. Allocation Scarce Resources to Agricultural Research: Review of Methodology. Amer. J. Agr. Econ. 55: 3; p. 557-566.

Shumway, C. R. and R. J. McCracken. 1975. Use of Scoring Models in Evaluating Research Programs. Amer J. Agr. Econ. 57: 10; p. 714-718.

Silen, Roy R. and Ivan Doig. 1976. The Care and Handling of the Forest Gene Pool. Pacific Search, 10: 8 June 1076; p. 7-9.

Smith, V. Kerry (ed.) 1979. Scarcity and Growth Reconsidered. Johns Hopkins Press. 368 p.

Sprackling, John A. and Ralph A. Read. 1975. Red Pine Provenance Study in Eastern Nebraska. USDA Forest Service Rocky Mountain Forest and Range Experiment Station Research Paper RM-144; 7 p.

Taylor, Bernard W., Laurence J. Moore and Edward Clayton. 1982. R&D Project Selection and Manpower Allocation with Integer Non-linear Programming. Mgt. Sci. 28: 10; p. 1149-1158.

Timber Mart-North. 1983. A Report of the Market for Raw Forest Products of the North Central. 1st Quarter, 1983. 4 p.

United States Department of Agriculture, Forest Service. 1983. Timber Resource Inventory - Preliminary Results.

----, 1980. An Assessment of the Forest and Range Land Situation in the United States. FS-345; 631 p.

United States General Accounting Office. 1981. A Glossary of Terms Used in the Federal Budget Process. March 1981, PAD-81-27; 136 p.

Van Buijtenen, J. P. and W. W. Saitta. 1972. Linear Programming Applied to the Economic Analysis of Forest Tree Improvement. J. Forestry 70: 3; p. 164-167.

Wheeler, N. C., H. B. Kriebel, C. H. Lee, R. A. Read and J. W. Wright. 1976. 15-Year Performance of European Black Pine in Provenance Tests in North Central United States. Silvae Genetica, 25: 1; p. 1-5.

White, Fred C. and Joseph Havlicek, Jr. 1982. Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding. Amer. J. Agr. Econ. 63: 2; p. 48-55.

Winkofsky, E. P., N. R. Baker and D. J. Sweeney. 1981. A Decision Process Model of R&D Resource Allocation in Hierarchical Organizations. Mgt. Sci. 27: 3; p. 268-283.

Wright, Jonathan W., and L. F. Wilson. 1972. Genetic Differences in Scotch Pine Resistance to Pine Root Collar Weevil. Michigan State University Agr. Exp. Station Research Report 159; 5 p.

Wright, Jonathan W. 1976. Introduction to Forest Genetics. Academic Press; 463 p.

Zobel, Bruce J. 1974. Increasing Productivity of Forest Lands Through Better Trees. S. J. Hall Lectureship in Industrial Forestry, April 18, 1974; 19 p.

Zobel, Bruce J., John Barber, Claud L. Brown, and Thomas O. Perry. 1958. Seed Orchards-Their Concept and Management. J. For. 56: 11; p. 815-825.

Zusffa, L. 1979. A Breeding Program for Short Rotation Poplar Biomass Production in Ontario, Canada. IUFRO Working Paper on Poplar Breeding and Provenances, Belgium and France, Sept. 17-22, 1979. 12 p.

Zsuffa, L., and H. Anderson. 1979. The Potential of Poplar Plantations. Paper from International Symposium on Forest Sciences and Their Contribution to the Development of Tropical America, San Jose, Costa Rica, Oct. 11-17, 1979.; 12 p.